Wetland classification in western Canada

by J. B. Millar


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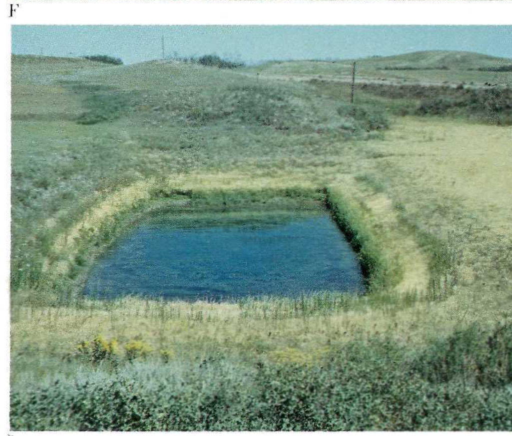
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Wetland classification in western Canada: A guide to marshes and shallow open water wetlands in the grasslands and parklands of the Prairie Provinces

by J. B. Millar

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The author sampling submergent vegetation in a Shallow Open Water Wetland near Floral, Sask.

The author

John B. Millar is a wildlife biologist with the Canadian Wildlife Service (CWS) in Saskatoon, Saskatchewan. A graduate of the University of Alberta (B.Sc., M.Sc.) and the University of Wisconsin (Ph.D.), he joined the CWS in 1960. Since completing his studies on wetland classification in 1972, he has been involved in environmental assessment work in Saskatchewan and is currently developing a wetland habitat monitoring program for the Prairie Provinces.

Acknowledgements

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Perspective

As our industrial society continues to demand more space and more resources for technological purposes, the need for planned use of land grows urgent. Land-use planning is essential if we hope to guide future developments in a way which minimizes further unnecessary and irreversible destruction of our dwindling natural resources.

The first step in planning land use is to classify the kinds of natural habitats which still exist. These classifications make it possible to interpret the potential of different types of habitat for producing such valuable renewable resources as wildlife and water. Sometimes, the most helpful classifications for the land-use planner are general ones as, for example, the broad categories of the Canada Land Inventory. However, when individual land units, such as a marsh, are being evaluated, we need more detailed and specific ways of describing their values.

This paper attempts to improve upon existing systems of classifying some important natural habitats characteristic of western Canada: the marshes, ponds, and sloughs of the grassland and parkland regions — landscape features which may collectively be termed wetlands. My objective is to provide a convenient guide for the land-use investigator which will aid him in classifying these wetlands. The classification system described here is both flexible and thorough enough to allow those responsible for evaluating habitat to assess wetlands efficiently and accurately, using as many refinements as are appropriate to the particular task at hand.

Abstract

The system of classifying marshes and shallow open waters described in this paper is based on data obtained during a 10-year study of 103 wetlands at three locations in the grassland and aspen parkland regions of Saskatchewan. The features I have used in this system fall into two groups, those related to a wetland's vegetation and those based on its physical characteristics.

Wetland vegetation is divided according to species composition, stability, and gross appearance into seven categories or zones as follows: Wet Meadow, Shallow Marsh, Emergent Deep Marsh, Transitional Open Water, Shallow Open Water, Open Alkali, and Disturbed. The first five zones form a gradient indicative of increasing

depth and duration of flooding, while the last two reflect extreme salinity and disturbance respectively.

I have defined and, with one exception, have named the basic types of wetlands in terms of the vegetation zone which occupies the central or lowest portion of the depression. Wetlands having a central Shallow Open Water Zone are divided into two types, Open Water Marshes and Shallow Open Water Wetlands, according to the proportion of the wetland occupied by the Shallow Open Water Zone.

The proportion of the wetland occupied by the central vegetation zone, the density of emergent vegetation at its centre, the extent of and reason for that density value, and the pattern or sequence of vegetation zones all contribute additional information about a wetland's moisture regime and relative stability.

Vegetation can also be used to interpret a wetland's salinity and hence something of its moisture regime and attractiveness to waterfowl. Furthermore, within any vegetation zone the particular species which dominate provide further clues about its moisture regime and recent history. Finally, regional variations in plant behaviour can influence the interpretation of moisture regime.

The physical features of a wetland have particular value as classification criteria because, unlike vegetation, they usually change little over a span of years and hence provide a more reliable indication of a wetland's long-term potential value. Three of these features — size, basin depth, and position in a watershed — are included in my classification system. Wetland size affects water regime because the rate of water loss is directly related to the length of shoreline per hectare of area, which in turn is inversely related to pond size. Basin depth can limit water regime by restricting the amount of water that a wetland can hold. The nature of a wetland's watershed determines the amount of water it can receive from spring runoff or heavy rains and hence affects its water regime.

Although this classification system may, at first glance, seem rather complex, it is important to remember that the various criteria are intended to be used individually or in whatever combinations are best suited to a particular project. All categories have been given code numbers as well as names to facilitate direct input of data into a computer for analysis.

Résumé

Le système de classification des marais et des nappes d'eau superficielles à découvert décrit dans cet exposé se fonde sur les données recueillies en dix ans d'étude de 103 terres mouillées situées dans trois régions de prés et de peupleraies de la Saskatchewan. Les caractéristiques utilisées dans la présente classification se regroupent en deux catégories en fonction soit de la végétation des terres mouillées, soit de leurs éléments physiques.

La composition, la stabilité et l'apparence générale des espèces ont servi à diviser la végétation des terres mouillées en sept catégories ou secteurs: prés humides, marais superficiels, marais profonds à végétation émergente, eaux libres de transition, eaux libres superficielles, eaux libres alcalines et eaux perturbées. L'ordre d'énumération des cinq premiers secteurs nommés ci-haut manifeste une augmentation progressive de la profondeur et de la durée d'inondation tandis que les deux derniers dénotent respectivement des conditions extrêmes de salinité et de bouleversement.

J'ai défini et, à une exception près, désigné les types fondamentaux de terres mouillées en fonction de la catégorie dont relève la végétation retrouvée dans la partie inférieure ou centrale de la dépression. Celles des terres mouillées qui comportent un secteur central d'eaux libres superficielles ont été réparties en deux types, marais d'eaux libres et terres mouillées d'eaux libres superficielles, selon la proportion de la terre que comprend le secteur en cause.

La proportion de la mouillère constituée d'un secteur central de végétation, la densité de la végétation émergente au centre, l'importance et les raisons de cette valeur de densité, ainsi que la structure ou l'ordre séquentiel des secteurs de végétation, autant d'apports supplémentaires à notre savoir sur le régime hygrométrique et la stabilité relative d'une terre mouillée.

La végétation peut aussi servir à interpréter la salinité d'une mouillère, donc à nous en apprendre sur son régime hygrométrique et l'attrait qu'elle peut exercer sur les oiseaux aquatiques. En outre, de connaître l'espèce dominante au sein d'un secteur de végétation apporte des indices supplémentaires sur le régime hygrométrique et le passé récent d'une terre mouillée. Enfin, l'interprétation de ce type de régime peut varier en fonction des variations régionales en matière de physiologie des plantes.

Les caractéristiques physiques d'une terre mouillée possèdent une valeur particulière en tant que critère de classification car, au contraire de la végétation, elles demeurent généralement stables pendant un certain nombre d'années et donnent donc une idée plus fiable du potentiel à long terme d'une terre mouillée. La présente classification comporte trois de ces caractéristiques: dimensions, profondeur du bassin et emplacement dans le bassin versant. La dimension d'une terre mouillée influence son régime hydrologique car le taux de perte d'eau est directement proportionnel à la longueur de la rive par hectare de terrain et cette dernière inversement proportionnelle aux dimensions de l'étang. La profondeur d'une dépression peut limiter le régime hydrologique en réduisant la quantité d'eau qu'une mouillère peut contenir. La nature du bassin versant détermine la quantité d'eau que peut recevoir une terre mouillée tant du ruissellement printanier que de fortes pluies, en influençant ainsi le régime hydrologique.

Bien qu'à première vue, cette classification puisse sembler assez complexe, il importe de se rappeler qu'il faut recourir aux critères invoqués, soit isolément, soit en les combinant de la façon qui convienne

le mieux aux fins d'un projet donné. Toutes les catégories ont reçu un numéro de code et un nom afin de faciliter l'entrée directe des données dans l'ordinateur pour analyse.

Резюме

Классификационная система болот и мелких открытых водоемов, описываемая в настоящей статье, основана на данных, полученных в результате 10-летнего изучения 103 затопленных участков в трех местностях пастбищных угодий и осиновых рощ в озелененных районах Саскачевана. Характеристики, использованные мною в настоящей системе, подразделяются на две группы, а именно: характеристики, связанные с растительностью затопленных участков и с их физическими чертами.

Растительность затопленных участков подразделяется на 7 категорий или же зон, согласно составу, устойчивости и общему виду, а именно на: мокрые луга, мелкие болота, возникающие глубокие болота, промежуточные открытые воды, мелкие открытые воды, открытые и прерванные солончаки. Первые пять зон соответствуют шкале показателей по мере увеличения глубины и продолжительности затопления, в то время как последние две зоны отражают соответственно предельную соленость и прерванность местности.

Мною дается определение и, за исключением одного, названия основных типов затопленных участков с учетом растительности зоны в центре или нижайшем месте углублений. Затопленные участки, относящиеся к категории мелких открытых вод, подразделяются на два типа: болота с открытой водой и затопленные участки с мелкой водой, в соответствии с пропорцией поверхностей заводненного участка и покрывающей его зоны мелкой открытой воды.

Соотношение поверхности затопленного участка и поверхности, покрытой центральной растительной зоной, плотность надводной растительности в его центре, степень и причина этого значения плотности, а также узор и последовательность растительных зон дают совокупно дополнительные сведения о режиме влажности и относительной устойчивости затопленных участков.

По растительности можно также определить соленость затопленных участков и, следовательно, получить некоторые сведения о их влажностном режиме и их привлекательности для водной птицы. Далее, в рамках каждой зоны растительности, наличие преобладающих видов даст дальнейшие сведения о ее влажностном режиме и недавнем прошлом. И, наконец, областные вариации в поведении растительности могут повлиять на толкование влажностного режима.

Физические характеристики затопленных участков имеют особое значение в качестве классификационных критериев, так как в отличие от растительности они подвергаются обычно незначительным изменениям в течение ряда лет и дают, поэтому, более надежные сведения о долгосрочной возможности использования затопленных участков. Три из числа этих параметров — размер, глубина бассейна и его расположение относительно водораздела — включены в мою классификационную систему. Размер затопленных участков влияет на водный режим, так как степень обезвоживания прямо пропорциональна длине береговой линии на акр местности, т. е. величине, которая обратно пропорциональна размеру водоема. Глубина бассейна может ограничить водный режим путем ограничения количества воды, которое может содержаться на затопленном участке. Природные условия водораздела затопленной местности определяют количество воды, которое местность может получать от весенних стоков воды или сильных ливней и, таким образом, влияет на ее водный режим.

Хоть и предложенная классификационная система может показаться на первый взгляд сложной, необходимо отметить, что отдельные критерии можно применять в отдельности или любой комбинации, в соответствии с требованиями данного проекта. Кроме названий все категории обозначены номерным кодом с целью обеспечения непосредственного ввода данных в счетную машину для анализа.

Introduction

In the past four decades several systems for classifying wetlands have been developed in the United States and Canada. The impetus for this work has come largely from waterfowl ecologists and managers seeking to understand the relation between waterfowl production and various kinds of habitat. Most of these classification systems have dealt specifically with wetlands in the glaciated prairie regions of western Canada and the adjacent United States. Three systems, however, are continental in their scope.

The earliest of the continent-wide systems, that devised by Martin *et al.* (1953), is perhaps the one most widely used. They classified wetlands according to the depth and duration of flooding, and the composition and distribution of their vegetation. Martin's classification system has been officially adopted by the U.S. Fish and Wildlife Service, and used in the Service's wetland acquisition program as well as in several large-scale wetland inventory programs. Among the latter have been inventories conducted by state and federal agencies in the United States (Shaw and Fredine, 1956), the Canada Land Inventory conducted by the Agricultural Rehabilitation and Development Administration (ARDA) (Benson, unpublished, 1965), and the U.S. National Wildlife Federation's wetlands priority rating program on the Canadian prairies (Rose and Morgan, 1964).

Still working in the continental context, Mason (1957) has drawn up a rather generalized list of classes for all types of water bodies and associated wetlands. He based his categories on the movement of water, its permanence and salinity, and the amount of vegetative cover, but did not define them quantitatively. Finally, in the course of a biophysical land classification program for Canadian forest lands and associated wildlands, Adams and Zoltai (1969) have developed a comprehensive system for classifying open water bodies and wetlands. Because their scheme is designed to serve the needs of many scientific disciplines, their classes are necessarily very general. Moreover, the criteria they use for subdivisions, including the depth, permanence and chemistry of the water, the characteristics of the drainage system, and the sources of water and vegetation, tend to vary from class to class. Recently, Zoltai *et al.* (1975) have modified some minor details of the system.

Among systems designed specifically for classifying wetlands of the glaciated prairie region, Metcalf's (1931) is the earliest on record. He classified lakes and large sloughs in North Dakota according to their salinity and the composition of their vegetation. Metcalf is unique in that he disregards the permanence of the slough or lake. Hayden's (1943) classification system, which arranged Iowa wetlands in an evolutionary gradient from early hydroseres to prairie climax, recognizes the occurrence of wetland vegetation in zones. Bach's system (1950), designed for air surveys, classifies North Dakota wetlands according to their relative permanence, emphasizing vegetation as an index of permanence and other water conditions. Although he distinguished subclasses of wetlands according to their vegetation in his own surveys, he did not describe those categories in his report. To Bach's permanency factor, Nord, Evans, and Mann (1951), working in North and South Dakota and in Minnesota, added several factors, including wetland area and the interspersion, density, and composition of vegetation as criteria for classifying wetlands. Thus, they first employed the concept of selecting a *chain* of factors to meet the needs of a particular project. The flexibility of this approach to wetland classification contributes to the rationale of the system proposed here.

Although the classification system of Martin *et al.* (1953) has generally been accepted for survey and inventory work, the broad and often overlapping nature of its categories renders it inadequate for the precise evaluation of individual wetlands demanded in waterfowl research and management. Consequently, many investigators in the prairies have either modified Martin's system to provide more detail or have developed their own classifications. For example, Evans and Black (1956) redefined water depth limits for various wetland categories and divided seasonally flooded wetlands into two types. They also subdivided their pothole classes according to size, but did not formally introduce these new distinctions as part of their system. Lynch, Evans, and Conover (1963) used a system in their aerial survey of wetlands in the Prairie Provinces which, although they described it as "generally following Martin *et al.*" appears to be their own unique creation. They distinguished several classes of wetlands as follows: puddles (cultivated depressions), potholes (as defined by Evans and Black), sloughs (in glacial drains and valleys), lakes, reservoirs, streams, and man-made waters. They further differentiated these wetlands according to their size and the extent to which they were filled with emergent vegetation. However, they did not consider the composition of the vegetation in their evaluations.

The classification system which Ducks Unlimited uses to inventory large wetlands in the Canadian prairies and parklands (Leitch, 1966) has no basis in Martin's system at all. Instead, it involves (1) a rating for permanence adapted from Bach (1950), but emphasizing historical records rather than the occurrence of vegetation; (2) a rating for waterfowl production drawn from analyses of physical and biological factors, including those used by Nord *et al.* (1951); and (3) an assessment of the soil zone in which the wetland occurs.

Both Smith (1971) and Stoudt (1971) used Martin's system in their extended studies of waterfowl production in western Canada, but they additionally classified wetlands by size, and by the extent of the emergent cover in the wetland and the woody vegetation along its margins. Stoudt also redefined Martin's Types 6 and 7 wetlands to describe man-made water areas.

The most recent effort to classify prairie wetlands, and the most highly refined, is Stewart and Kantrud's (1971) treatment of potholes and lakes in North Dakota. They base their evaluations entirely on vegetation, classifying wetlands according to zonal patterns of plant forms, the interspersion of emergent cover, and the species composition of the vegetation: all factors which reflect relative permanence, salinity, and attractiveness to waterfowl.

Although each of the classification systems described above has unique features, most have two concepts in common: (1) water permanence is a key factor in classifying the wetlands, and (2) vegetation is used as an index of water permanence. Thus, numerous investigations have established the value of interpreting the permanence of water, in a short-term context, by analyzing wetland vegetation. At the same time, however, others (Evans and Black, 1956; Gollop, 1965) have recognized the instability of plant life as water levels fluctuate over a period of many years. Hence, vegetation alone is not acceptable as a wholly reliable index of water permanence, nor as the sole basis for evaluating a wetland. To increase the accuracy of assessments of wetlands and predictions of their permanence we need additional criteria which can account for long-term changes in water levels.

The wetland classification system presented in this paper incorporates many of the vegetation criteria used in earlier classifications, with modifications to improve the interpretation of current water regime. It also contains several important features not found in those systems, including (1) guidelines for interpreting vegetation dynamics as they relate to wetland classification, and (2) the use of physical features of wetlands to improve predictions of long-term water regime.

I have developed my system for classifying wetlands especially for marshes, including wet meadows, and for shallow open water wetlands as Adams (pers. comm.) has most recently defined them: "Marshes are grassy wet areas, periodically inundated up to a depth of 2.00 m (78.70 in.) or less with standing or slowly moving water. Surface water levels may fluctuate seasonally... Shallow open waters... are relatively small nonfluvial bodies of standing water occupying a transitional stage between lakes and marshes. In contrast to marshes, these waters impart a characteristic open aspect, with proportionately large expanses of permanent surface water that lack emergent cover, except for relatively narrow zones adjoining shorelines...". Adams' current definitions have been modified somewhat from those in his original classification (Adams and Zoltai, 1969). A number of Canadian government agencies are likely to adopt some form of Adams and Zoltai's system for general use. Consequently, I have attempted to make my system formally compatible with comparable portions of theirs. I have, however, incorporated into mine those additional details which I consider useful in evaluating wetlands according to their potential as waterfowl habitat. My system still has to be tested on other types of wetlands besides marshes and shallow open waters.

Because so many environmental factors influence the plant life of a wetland, my discussion of the classification of wetlands by their vegetation is necessarily more elaborate than that of their physical features. Appendix 1 is a check-list of the principal criteria set forth in the text, together with references to the illustrative plates (on the front and back covers). The figures which diagram features of wetlands and their relationships are, like the plates, intended to assist investigators in their field work.

Methods

I evolved the system of classifying marshes and shallow open waters described in this paper from data obtained during a 10-year study of 103 wetlands in the grassland and aspen parkland regions of Saskatchewan. Observations of other wetlands elsewhere in the province have provided additional information about wetland types which were not part of the study proper.

Of the wetlands under intensive study, 32 were near Melfort in the northern fringe of the aspen parkland, 36 were east of Saskatoon in the southern portion of the parkland, and 35 were in the vicinity of Swift Current in the southwestern part of Saskatchewan's grasslands (Fig. 1). Individual wetlands were chosen to include a representative selection of wetland sizes and examples of the Shallow Marsh to Shallow Open Water vegetation types (Classes III and IV of Stewart and Kantrud, 1971) common to each locality. Saline wetlands were, however, inadequately represented, a deficiency somewhat rectified by supplementary observations.

Between late April or early May and the end of October of each year from 1962 to 1971, with the exception of the Melfort study site where observations ended in 1970, Canadian Wildlife Service personnel visited each wetland at intervals of four weeks or less. During these visits, we routinely recorded maximum pond depth, changes in vegetation, and evidence of disturbance. Our first visit each year was timed to follow as closely as possible after the wetlands had been refilled from spring runoff, usually in late April, but occasionally as late as the first part of May. Annually, in mid July, we assessed the species dominance and the density of the vegetation in each basin. In 1967, as part of studies of rate of water loss in the wetlands, we obtained comparative data on the surface area of ponds and on the lengths of their shorelines at intervals which represented approximately 15-cm (6-in.) changes in water depth.

Plant nomenclature here follows Fernald (1950), except for *Salix petiolaris* and *Aster hesperius*, which are according to Moss (1959).

The major wetland types and each category of every wetland characteristic in my classification system are identified with both a descriptive name and a code number. The numbers are intended to facilitate coding of data for computer analysis, a procedure explained more fully at the end of this paper.

Some terms used in this paper can be interpreted in a variety of ways and to avoid misunderstandings I have defined them below:

Basin — a depression in the land, the lowest part of which is often occupied by a wetland or lake.

Wetland — that portion of a basin which is normally covered with shallow water for at least a portion of each year and, in an undisturbed state, supports wetland vegetation as defined in Section 1. (Vegetation zones).

Pond — the water contained in a wetland. This term is applied to a wetland only when it contains water.

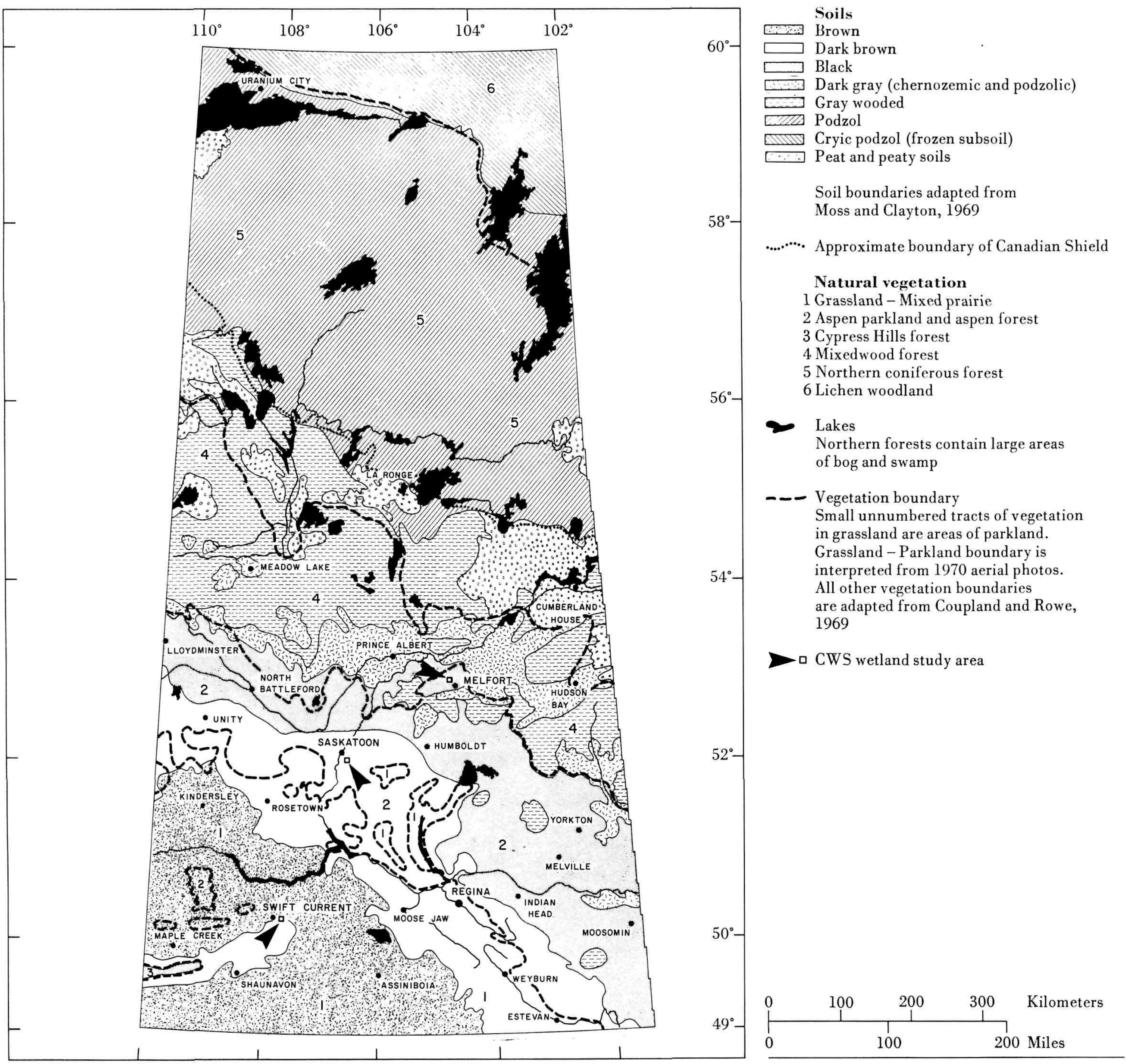
Flooding — covering with water; also immersion or inundation.

Moisture regime or water regime — the depth and duration of flooding experienced by a wetland from year to year.

Other terms are defined as they are used in the text.

Figure 1
Location of wetland study areas in Saskatchewan

Figure 1



Classifying wetlands by their vegetation

A plant's abundance, robustness, and location in a wetland are dictated to a considerable extent by its tolerance of the depth and duration of periodic flooding. This fact allows us, within limits, to use the distribution of plant life in a wetland to interpret the significance of water as a regular but variable feature of that site.

In each wetland there is a progressive change in the composition of its vegetation, frequently referred to as a vegetation continuum, from its lowest portions, where flooding is greatest, to the outer edge, where flooding is least. Often the continuum is a gradual one, with the overlapping of species which tolerate slightly different depths and durations of immersion. Sometimes, however, the changes in vegetation are abrupt, especially in wetlands supporting few species — or in those with steeply sloping sides. In general, the continuum is more complex in wetlands which hold water year-round than it is in those which dry up annually.

Within this vegetation continuum there are distinct differences in the physical forms of the species which are dominant at various elevations. These differences in the stature or relative coarseness of various species are associated with the depth and duration of periodic flooding. Hence, we can use these visible differences in plant form to divide wetland vegetation into zones, each having a characteristic species composition which indicates a particular moisture regime. Definitions of these vegetation zones vary considerably in different classification systems. My own definitions follow most closely those of Stewart and Kantrud (1971).

1. Vegetation zones

In order to simplify the classification of marshes and shallow open waters, I arbitrarily consider as *wetland vegetation* only that which occurs within the outer, or shoreward, margin of an undisturbed wetland's Wet Meadow Zone (Fig. 2), the driest of the seven vegetation types described below. When stable natural vegetation has been disrupted or destroyed, the outer limit of wetland vegetation may be defined in terms of the Disturbed Zone rather than the Wet Meadow Zone. In adopting this definition of wetland vegetation, I am excluding Stewart and Kantrud's (1971) drier Low Prairie Zone, a vegetation type which is usually under water so briefly that its value to ducks or other aquatic vertebrates as feeding or resting habitat is extremely limited. Also, in cropland the Low Prairie Zone is normally destroyed by annual cultivation and its position in relation to the Wet Meadow Zone, which is also usually cultivated, is difficult to assess. Furthermore, in the northern and eastern portions of the grassland and in the parkland this zone is dominated by trees and shrubs which also grow on moist uplands, a situation that makes it difficult to identify water-holding depressions from a distance or from the air if they contain only this type of vegetation. Omitting the Low Prairie Zone, therefore, seems to be a reasonable simplification, the first of a number proposed here. This definition of wetland vegetation is also the basis of my earlier definition of a wetland.

Within my definition of wetland vegetation, I recognize seven vegetation types or zones. Each vegetation type is recognizable by its gross physical appearance — four of them by their distinctive emergent vegetation and the other three by the presence of open water. Each vegetation zone can also be characterized according to its relative stability. *Stable* zones are those which normally persist for many years unless subjected to abnormal water levels or man-made disturbance.

Below is a general description of each vegetation type, with remarks on its stability. To facilitate discussion I have, for the moment, grouped these zones according to their gross appearance. The principal dominant rooted plant species for each zone are discussed in Section 5. and examples of the zones are illustrated in Plates A–R (on front and back covers). Further details are given in Appendices 1 and 3.

1.1. Zones having emergent vegetation

Three of the four zones in this group — the Wet Meadow, Shallow Marsh, and Emergent Deep Marsh zones — are considered to be stable and form a gradient reflecting increasingly longer periods of seasonal inundation. The Disturbed Zone is transitory in nature and develops when soil has been exposed.

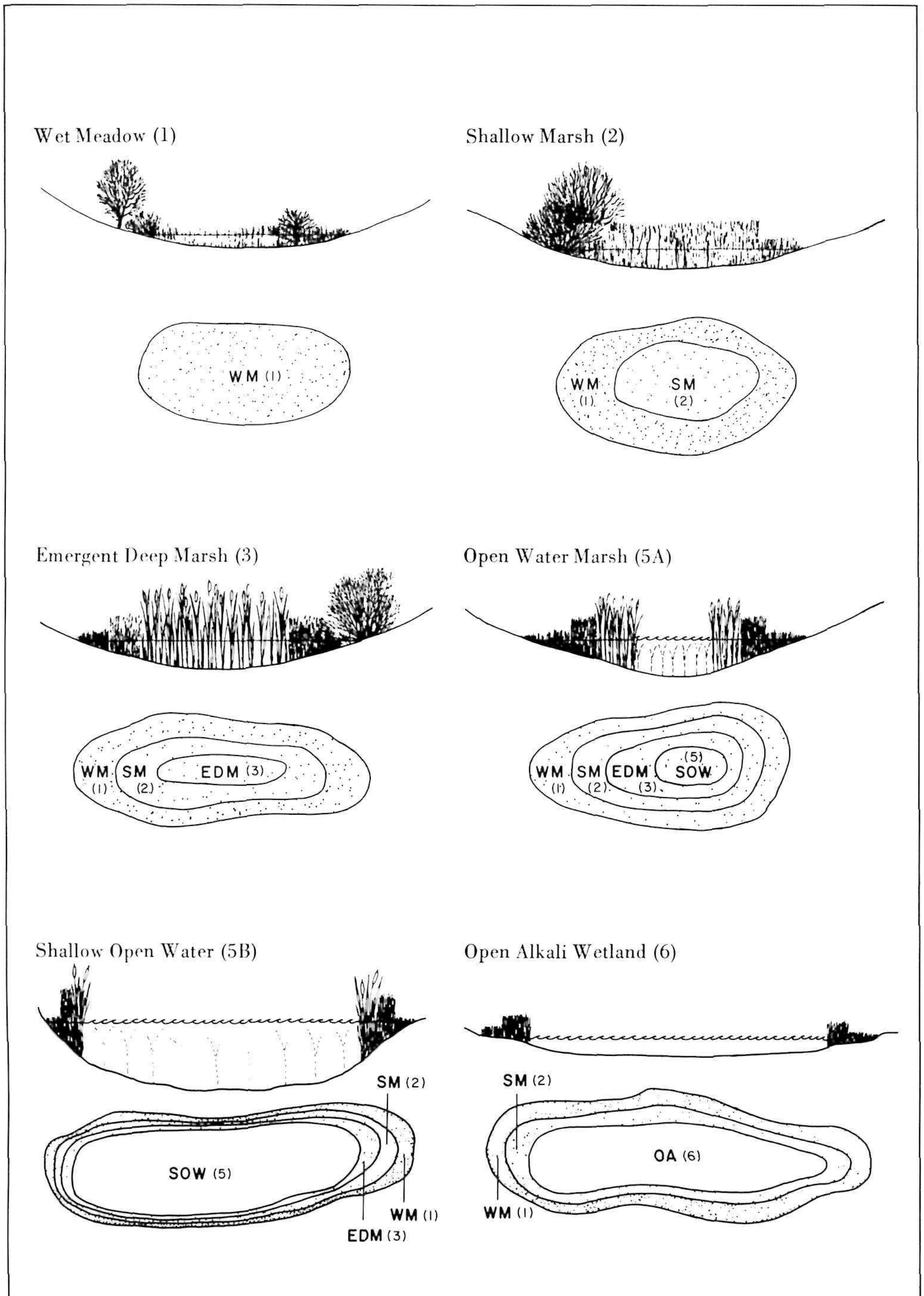
Wet Meadow Zone (Plate A on front cover): Normally the Wet Meadow Zone is flooded only for three or four weeks in the spring, and the depressions in which this type occupies the lowest levels are usually dry by late May. Under natural conditions in the grassland, fine-textured grasses and sedges of low stature generally predominate, intermixed with a wide variety of forbs. Occasionally, willow shrubs (*Salix* spp.) may partially dominate. In the parkland, where willows characteristically dominate, the Wet Meadow Zone is technically a *shrub-carr* (Curtis, 1959). In cropland, cultivation destroys the Wet Meadow Zone and it is replaced by the Disturbed Zone.

Shallow Marsh Zone (Plates B–D on front cover): In basins where flooding normally lasts until July or early August, the Shallow Marsh Zone develops with grasses, sedges, and forbs of intermediate height — 0.46 to 1.22 m (1.5 to 4 ft) — as its dominant plant species. Floristically it is much simpler than the Wet Meadow Zone, with 33 species compared to the 75 species we found in Wet Meadows (Millar, 1967). The species composition of Shallow Marsh Zones varies little throughout the grassland and parkland regions. Such zones are rarely cultivated continuously except in the drier parts of the prairies or during periods of drought. Even when intermittently cultivated, the Shallow Marsh Zone is still fairly easy to identify and delineate from the regenerating remnants of its original vegetation or from characteristic disturbance species.

Emergent Deep Marsh Zone (Plates E, F on front cover): Inundation of the Emergent Deep Marsh Zone ordinarily persists from spring to late summer or fall, and

Figure 2
Normal vegetation patterns in stable wetlands shown in vertical and profile diagrams. With one exception, the Open Water Marsh (5A), each wetland type is given the name of the vegetation zone which occupies its centre. Open Water Marshes have a small central Shallow Open Water Zone. The number following the name of each wetland type is its code number. Letter abbreviations and numbers in each vertical diagram identify the individual vegetation zones

Figure 2



occasionally throughout the winter. It is rarely cultivated except during droughts. The vegetation is very simple — five species recorded during our studies. Coarse, grass-like plants dominate, and, with one exception, *Scirpus paludosus*, they are distinctly taller than those in the Shallow Marsh Zone.

Disturbed Zone (Plates G–I on front cover): Pioneering vegetation which characteristically develops in a wetland after the original vegetation zone(s) have been destroyed forms a Disturbed Zone. This vegetation type commonly originates after cultivation (Plate G) or with overgrazing (Plate I) of the three emergent vegetation zones described above, but it can also develop in former open water zones (described below) when mud flats are exposed by drawdown or declining water levels (Plate H). The origin of this vegetation type is an essential element in interpreting its significance and should be recorded, for example, as "Disturbed (Drawdown)".

A Disturbed Zone is, by definition, transitory and once repeated exposure of the soil ends it is normally soon transformed into one or more of the stable vegetation zones. During this transition a few pioneering species may continue to dominate for a long time as part of the stabilizing vegetation.

My single, broad category of Disturbed Zone simplifies the multiplicity of tillage, cropland, and natural drawdown categories of unstable vegetation types which Stewart and Kantrud (1971) distinguish. I have treated pioneering vegetation in this manner because it is so highly variable, both in composition and sequence of appearance, that particular combinations of species cannot be reliably associated with a certain habitat situation. As Stewart and Kantrud suggest, individual pioneering species can be readily identified with the particular stable vegetation zones in which they regularly occur as minor elements. However, when they achieve dominance following disturbance, it is usually as the result of fortuitous events which are not necessarily normal — for instance, plentiful moisture at the time of germination or during early growth. Consequently, the vegetation of a Disturbed Zone does not always accurately reflect the moisture conditions of the wetland over the longer term, conditions which eventually stabilize wetland vegetation and so determine the ultimate character of the wetland. I have, for example, seen many repeatedly cultivated wetlands in the Saskatchewan parklands undergo successive colonization by pioneering species associated with, respectively, the Low Prairie, Wet Meadow, Shallow Marsh, and even Emergent Deep Marsh vegetation zones, depending upon the relative wetness of each season. However, in spite of such variability in the occurrence of pioneering vegetation, it is helpful to record the apparent affinities of a Disturbed Zone to stable zones.

Although variable as to species, the vegetation of a Disturbed Zone is primarily forbs, mixed with a few grasses of low or mid stature. As already noted, I do not consider as natural wetlands those depressions which contain only Low Prairie vegetation. In cropland, however, many such sites become indistinguishable from Wet Meadow depressions when cultivated and may be classed as Disturbed (Cultivated) Wetlands.

1.2. Zones associated with open water

Open water is particularly helpful in evaluating wetlands because its presence under natural conditions, other than those of extremely high salinity, is a reliable indicator of at least some year-round flooding (Millar, 1973b). Two of the three zones in this group, the Shallow Open Water and Open Alkali Zones, are stable while the third, the Transitional Open Water Zone, is transitory.

Shallow Open Water Zone (Plates J–O on back cover): This zone develops where flooding is permanent or occurs for several years at a time and where the water is shallow enough to permit growth of most rooted aquatic plants. All plant species in a Shallow Open Water Zone are either submergent or floating, and the species composition and gross appearance of the zone is similar wherever it is found throughout the grassland and parkland regions. Shallow Open Water Zones are rarely cultivated except during extreme drought, and then primarily in the grasslands.

Open Alkali Zone (Plate P on back cover): The Open Alkali Zone is devoid of all rooted vegetation except one submergent species, *Ruppia maritima*. It owes its stability to a high concentration of alkali salts (chlorides and sulphates of sodium and magnesium) rather than to prolonged flooding. The flooding of Open Alkali Zones is, in fact, highly variable: it may occur for only a few weeks or months, or persist for an entire season. When the zone is dry, alkali salts encrust its surface. Because there may also be salt deposits on exposed portions of the Shallow Open Water Zones of Saline Wetlands (described in Section 4.), the investigator should not rely on these deposits alone to distinguish between these two zones. The soils of Open Alkali Zones are so unsuitable for agriculture that they are almost never disturbed.

Transitional Open Water (Plates Q, R on back cover): As the name implies, the Transitional Open Water Zone is unstable. It may develop from any of the three stable emergent vegetation zones described above, but most often replaces a Shallow Marsh Zone. Transitional Open Water vegetation develops following the natural destruction of one of the emergent vegetation types as a result of high water levels, and it is ultimately replaced either by one of the emergent vegetation zones, if conditions become drier, or by the Shallow Open Water Zone, if continuous flooding persists. The Transitional Open Water Zone may develop in a single season as a result of the sudden die-off of the original emergent vegetation or gradually over two or three years by progressive thinning-out of the old plants. The life of a Transitional Open Water Zone depends only in part upon the duration of the new moisture regime. Sometimes rooted Shallow Open Water vegetation fails to develop, for reasons unknown, despite continuous flooding. Two wetlands under observation in this study still have the characteristics of Transitional Open Water Zones although they have been flooded continuously for nine years.

The vegetation of the Transitional Open Water Zone is quite variable. Sometimes its rooted submergent species fail to develop for several years and the only plants present are floating duckweeds (*Lemna* spp.), and aquatic mosses and liverworts. Within the group of submergent species that is characteristic of the Transitional Open Water Zone it is possible to distinguish some that are indicative of longer periods of flooding than others (see Section 5.). Isolated stems of emergent species may persist as well. However, the gross appearance of the zone, whether viewed from the air or at a distance, is that of open water.

Although applicable to a variety of situations, the term Transitional Open Water should in practice be used only for those open water sites originating from natural changes in moisture regimes, and where flooding persists during most of the summer season. Open water resulting from cultivation of a wetland usually disappears by midsummer, either because of evaporation or because emergent vegetation soon carpets the site. Likewise, the transitory open water condition that exists in most wetlands following the early spring thaw and prior to the regrowth of plants will disappear as vegetation develops. The investigator should not confuse these very temporary conditions with the more persistent open water typical of a true Transitional Open Water Zone.

In Table 1, which compares the wetland zones just described with those devised by Stewart and Kantrud (1971), I have rearranged five of these zones in a gradient from the driest to the wettest, according to the depth and duration of their flooding. The two zones associated

Table 1
Comparison of wetland vegetation zones described in this report with those of Stewart and Kantrud (1971)

Code no.	Zone	Stewart & Kantrud's equivalent
1	Wet Meadow	Wet Meadow
2	Shallow Marsh	Shallow Marsh
3	Emergent Deep Marsh	Emergent phase of Deep Marsh
4	Transitional Open Water	Primarily the open water phase of Shallow Marsh
5	Shallow Open Water	Open Water phase of Deep Marsh; perhaps part of their Permanent Open Water Zone
6	Open Alkali	Intermittent Alkali
7	Disturbed	
	• Cultivated	Cropland tillage and cropland drawdown phases of various zones.
	• Grazed	No specific equivalent; included in the normal emergent phases of various zones
	• Drawdown	Natural drawdown phase of various zones

with other environmental factors, i.e., disturbance and extreme salinity, are placed last. The number assigned to each zone is its code number in my classification system.

Stewart and Kantrud's distinctions between the species compositions of the various cropland and drawdown phases of their vegetation zones do not apply to my simpler system of treating Disturbed Zones according to their origins.

I have omitted two of Stewart and Kantrud's zones, the Low Prairie and Fen (alkaline bog) Zones, from my classification. The Low Prairie Zone has been left out because, as mentioned earlier, I have arbitrarily limited the definition of wetland vegetation to those zones lying within the outer edge of the Wet Meadow Zone. I have not included their Fen Zone because I have also limited my classification to marshes and shallow open waters as defined by Adams and Zoltai, who consider bogs or fens to be distinctly different entities.

2. Vegetation in centre of wetland

When an investigator sets out to evaluate a wetland, usually one of the first things he wants to determine is its moisture regime, that is, the depth and duration of flooding it experiences each year. Since the vegetation zones described in the preceding section each reflect a different moisture regime, they provide an effective means of interpreting current water conditions in a wetland. The greatest depth and duration of flooding naturally occurs in the lowest part of the depression, which is usually also the centre, and the vegetation zone occupying this area is, therefore, the key to interpreting a wetland's moisture regime.

2.1. Identification of basic wetland types

Because of its importance in the process of interpreting wetland moisture regimes, I consider that the central or innermost vegetation zone in a wetland is also the most suitable factor to use in identifying basic wetland types. Therefore, in this paper I have recognized eight wetland types, one for each of six of the vegetation zones discussed earlier and two associated with the Shallow Open Water Zone. Wetlands having a central Shallow Open Water Zone are divided into two types on the basis of whether that zone occupies more or less than 75% of the wetland's diameter (56% of its area). This distinction maintains the general compatibility between my classification and that of Adams and Zoltai (1969), as most recently modified by Adams (pers. comm.), although the percentages of area values are not precisely the same.

The descriptive name I have applied to each wetland type is, with the exception of one of the Shallow Open Water types, the same as that of its central vegetation zone. In order to distinguish between the Shallow Open Water types I use the term Shallow Open Water Wetland only for those wetlands in which the Shallow Open Water Zone occupies more than 75% of the wetland's diameter, and in which emergent vegetation is confined to a clearly defined narrow marginal band. Wetlands having a smaller Shallow Open Water Zone are given the name Open Water Marsh to indicate that emergent marsh vegetation is a dominant feature. It is important to remember that this term has been introduced to describe a wetland type and that there is no corresponding vegetation zone of the same name.

Table 2
Basic wetland types

Code no.	Name of wetland type	Vegetation in wetland's centre
1	Wet Meadow	Wet Meadow Zone
2	Shallow Marsh	Shallow Marsh Zone
3	Emergent Deep Marsh	Emergent Deep Marsh Zone
4	Transitional Open Water Wetland	Transitional Open Water Zone
5A	Open Water Marsh	Shallow Open Water Zone (<75% of wetland's diameter)
5B	Shallow Open Water Wetland	Shallow Open Water Zone (>75% of wetland's diameter)
6	Open Alkali Wetland	Open Alkali Zone
7	Disturbed Wetland • Cultivated • Grazed • Drawdown	Disturbed Zone

Each wetland is given the same code number as the vegetation zone for which it is named. Since the Shallow Open Water Zone occupies the centre of the depression in both Open Water Marshes and Shallow Open Water Wetlands these types are coded 5A and 5B respectively. Code numbers and descriptive terminology relating to wetland types are summarized in Table 2.

I have deliberately avoided using terms indicative of relative permanence, such as those employed by Stewart and Kantrud (1971), to identify wetland types because they tend to lose their significance in the face of the annual and regional variations in water conditions experienced by the various vegetation types. For example, a Shallow Marsh is called a seasonal pond by those authors, but during drought in arid southwestern Saskatchewan the survival time of ponds in such wetlands may be no longer than they describe for their ephemeral ponds. Similarly, Open Water Marshes and Shallow Open Water Wetlands are commonly permanent in the northern parklands, but usually go dry every few years in the grassland region.

While the identity of the vegetation occupying the centre of a wetland provides the basis for determining its general character and moisture regime, additional details about that regime can also be interpreted from the proportion of the wetland occupied by the central vegetation zone and the relative density of its vegetation.

2.2. Extent of central vegetation zone

The size of the central vegetation zone in relation to the entire wetland is a good indicator of whether the current moisture regime is marginal or favourable for the innermost flora. In other words, a Type 3 wetland with a central Emergent Deep Marsh Zone which occupies only 5% of its total area probably experiences shorter periods of flooding than a wetland which has 75% of its area in a central Emergent Deep Marsh Zone.

To help investigators evaluate the extent of the central vegetation zone I have established five arbitrary categories based on easily estimated wetland diameters. Wetland diameter is used to define the categories because it can be visually estimated in the field with less difficulty than area. Code numbers and diameter and area limits of the five categories are summarized below.

Code no.	% of wetland diameter	% of wetland area
1	10 to 25	1 to 6
2	26 to 50	7 to 25
3	51 to 75	26 to 56
4	76 to 95	57 to 90
5	Over 95	Over 90

The diagrams in Figure 3 are guides to the general appearance of each category. The dividing point between categories 3 and 4 (75% of wetland diameter) is also the separation point for distinguishing between the two types (Open Water Marshes–5A and Shallow Open Waters–5B) of wetlands having a central Shallow Open Water Zone.

It is important to note that the minimal values for category 1 in the table above are 10% of the wetland's diameter and 1% of its area. A vegetation zone which occupies a smaller proportion of the wetland than this is not recognized as its central vegetation zone. Stewart and Kantrud (1971) use 5% of the wetland area as the minimal value for the central vegetation zone, but I consider that vegetation stands occupying 1 to 5% of the area are too obvious to discount, particularly since they may occupy 10 to 22.5% of the wetland's diameter.

When the shape of a wetland is so irregular that its diameter is difficult to establish, the areas of the wetland and its central vegetation zone can be estimated from their length and width measurements by using the formula for the area of an ellipse (Millar, 1973a). A wetland's length and width are normally, of course, the distances between the outer edges of the Wet Meadow Zone. However, when a wetland lies in a cultivated field the measurements are limited to the extremities of the uncultivated area or, if taken in early spring, the extremities of the flooded area.

2.3. Density of emergent vegetation in centre of wetland

The relative stability of the current moisture regime can be interpreted from the density of the emergent plant cover in the lowest part of the wetland. This is possible because abnormally long or deep flooding of emergent vegetation reduces the vitality and density of the plants. If flooding is extreme, the vegetation may die off rapidly. More often, however, vegetation changes associated with changes in mois-

Figure 3

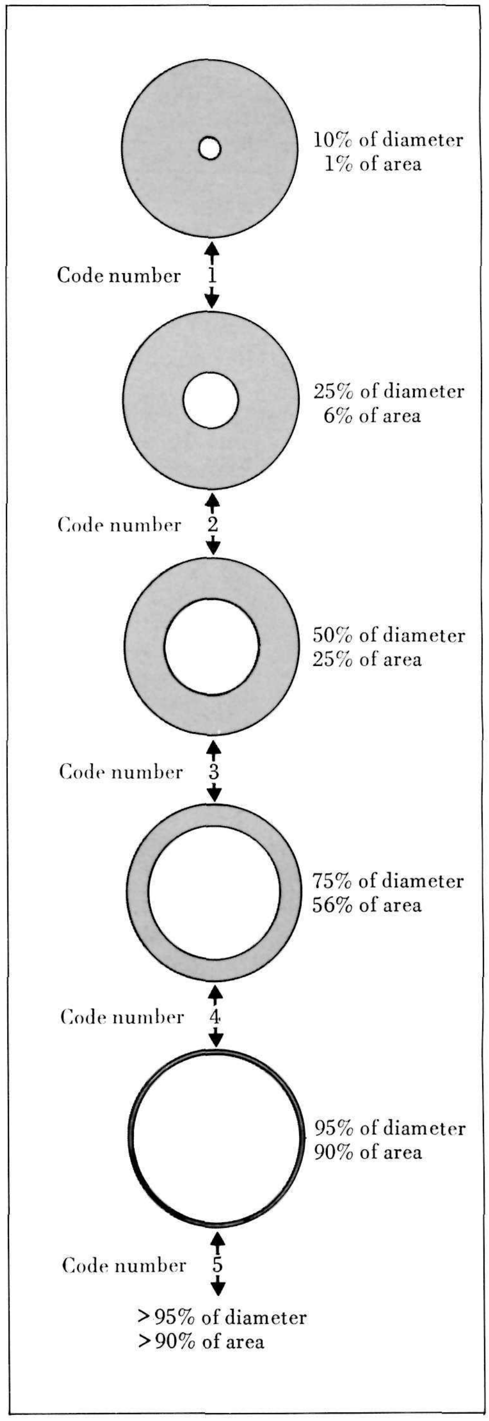


Figure 3
Categories used in assessing the proportionate size of a wetland's central vegetation zone and the extent of its central cover density: a guide to their appearance in the field

ture regime are gradual. When abnormal conditions persist, the vegetation usually thins out progressively though some species tend to survive in small isolated patches. Where sparse or patchy stands of emergent species occur without evidence of gross disturbance, they usually indicate a period of flooding more extreme than that experienced by dense closed stands of the same species.

Patchy or thinned-out cover may also result from muskrat activity, grazing, or cultivation, but these sources of disturbance are usually easy to identify. Furthermore, seasonal changes in density of plant cover occur each year in the normal cycle of growth and decay. For that reason, it is frequently difficult to interpret accurately the wetland's moisture regime from the condition of its central vegetation until after the peak of the growing season in July.

Four categories of cover density seem adequate for general use. A wetland is classed as Closed when total open water or exposed soil occupies less than 1% of its whole area. At the other extreme, the term Barren is applied to dry Disturbed Wetlands without vegetation. Two intermediate cover conditions require more detailed explanation.

A Semi-closed Wetland is one in which the emergent cover in its centre has either uniformly thinned to the point where water is visible throughout, or the vegetation has become sufficiently patchy that there are scattered small areas of open water, each occupying less than 1% of the total area of the wetland. The visual effect of a Semi-closed Wetland is that of water occurring in a matrix of emergent vegetation, that is to say, the vegetation exceeds the visible water.

A Semi-open Wetland is one in which open water in the centre has increased to the point where the vegetation appears as sparsely distributed plants or clumps in a matrix of water, yet patches of open water do not individually exceed 1% of the total area. When emergent vegetation is reduced to only occasional isolated stems, the wetland is usually classed as Transitional Open Water because the vegetation is too sparse to be visible on aerial photos or when viewed from a distance.

Table 3
Emergent wetland vegetation cover categories

Code no.	Category name	Description
1	Closed	Total open water or exposed soil is less than 1% of wetland area
2	Semi-closed	Vegetation and water intermixed, vegetation dominates, individual patches of open water are each less than 1% of wetland area
3	Semi-open	Vegetation and water intermixed, water dominates, individual patches of open water are each less than 1% of wetland area
4	Barren	No vegetation present; applies to Disturbed Wetlands.

Table 3 gives the code numbers and descriptive terminology of the four categories of plant cover density just described. It is important to remember that the ratings of plant cover density used in evaluating moisture regimes apply only to the central or lowest portions and not to the wetland as a whole. As with the central vegetation zone, cover density values are recognized only when they involve at least 10% of the wetland's diameter or 1% of its area. The open water wetland types described earlier are, of course, not rated for their central vegetation. Cover density evaluations are influenced by the extent to which the investigator can clearly see the entire wetland. It is important, therefore, that these observations be made from the highest possible elevation adjacent to the wetland.

Occasionally it may be helpful to record the cover density of peripheral emergent vegetation zones in open water wetlands, particularly in situations where sparse, semi-open growth makes it difficult to determine the limits of the open water zone.

Variations in cover density can be due to factors other than moisture regime and it is necessary to recognize these when evaluating a wetland. The most common factors affecting vegetation density are listed below with the code numbers assigned to them.

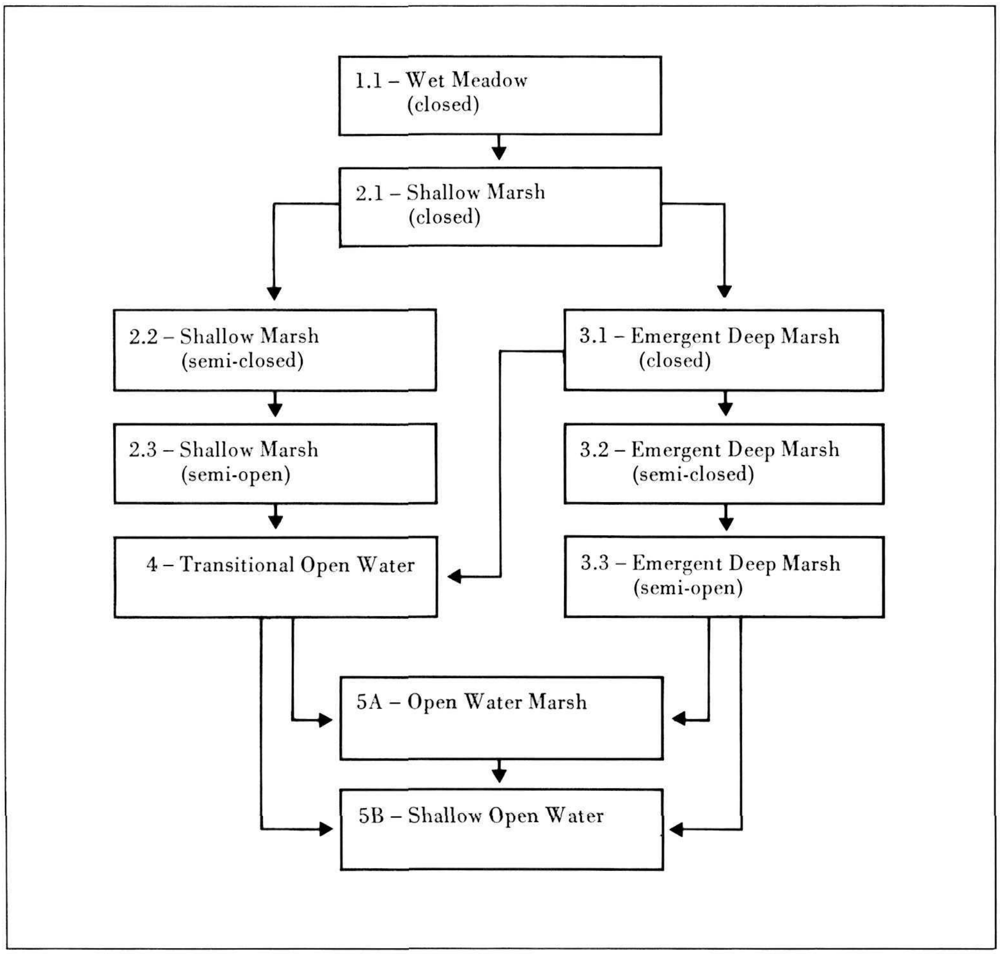
Code no.	Factor
1	Natural causes, i.e., moisture regime
2	Cultivation
3	Grazing, including activities of wild animals, e.g., muskrats
4	Mowing
5	Artificial alteration of wetland depth, e.g., partial drainage and damming

Some general observations on the dynamics of changes in vegetation density may also help in assessing wetland moisture regimes. My studies in Saskatchewan show that Semi-closed and Semi-open cover conditions are not common in Wet Meadow Wetlands, and that when they do occur they normally do not last for more than one season. In Shallow Marsh Wetlands these same conditions develop frequently when the moisture regime improves, but seldom remain constant for more than two or three years. Continued improvement in the moisture regime causes the wetland to convert to Transitional Open Water, while drier seasons cause it to revert to denser emergent cover. In Emergent Deep Marsh Zones, Semi-closed and Semi-open vegetation is often more stable and may survive for a number of years, particularly when *Scirpus acutus* is the species present. Because such wetlands tend to have more permanent water, submergent species typical of the Shallow Open Water Zone commonly develop in the open water areas.

Figure 4 shows normal sequences of change in cover conditions and in wetland

Figure 4
Normal sequences of change in cover density and wetland type in Fresh to Saline Wetlands experiencing improving moisture regime. The numbers prefixing the name of each wetland type are combinations of the code numbers assigned, first to that wetland type, and second to the category of cover density

Figure 4



vegetation type under improving moisture regime. The numbers prefixed to the name of each wetland type demonstrate the coding combination for wetland type and cover density.

2.4. Extent of central cover density

In most cases, a simple rating of the density of the central vegetation, together with the identity and extent of the central vegetation zone, are all that an investigator needs to interpret adequately a wetland's current moisture regime. When necessary, however, moisture regime can be evaluated somewhat more precisely by determining the extent of the density category recorded for the central vegetation. This indicates whether conditions causing the thinning of vegetation are of major or minor importance in the wetland. For example, if the central vegetation zone covers 51 to 75% of the wetland diameter and Semi-open cover conditions extend over 10 to 25% of the diameter, only part of the central vegetation zone is being affected and the degree of instability is probably minor. Conversely, if Semi-open conditions extend over 76 to 95% of the wetland diameter the changes in moisture regime are likely to be major because the entire central vegetation zone plus one or more adjoining zones are affected. Categories for the extent of central cover density are the same as those used for the extent of the central vegetation zone (Subsection 2.2.).

3. Variations in vegetation patterns

Thus far I have used only the central vegetation zone of a wetland to interpret its moisture regime and general character. While this is sufficient for most purposes, additional information can be obtained by studying the pattern or sequential arrangement of vegetation zones throughout the entire wetland.

Wetland vegetation zones characteristically occur as a series of concentric rings which follow basin contours and reflect the relative depth and duration of flooding. When wetlands experience several years of relatively stable environmental conditions, including flooding, they usually develop a particular sequence of vegetation zones which may be considered *normal*. If, however, the moisture regime fluctuates too widely or human disturbance occurs, a variety of abnormal or deviant zonal patterns may develop. Furthermore, when the bottom of a wetland is very uneven, vegetation zones may be distributed in a patchy pattern rather than the classic concentric ring arrangement. Unless the observer is aware of their causes and what they signify, the anomalies created by zonal irregularities may be confusing and lead to a misinterpretation of wetland type. The *normal* vegetation patterns and the more common zonal deviations are described below.

3.1. Normal vegetation patterns

Two vegetation patterns can be considered *normal* — those which develop in Fresh to Saline Wetlands (see Section 4. for salinity categories) under relatively stable environmental conditions and the unique pattern found in Hypersaline or Open Alkali Wetlands. In Fresh to Saline Wetlands the stable vegetation zones described in Section 1. are distributed from the outer edge to the centre of the wetland in the order of their increasing tolerance to flooding. The complexity of this pattern increases, of course, with the depth and duration of flooding. Open Alkali Wetlands have a special vegetation pattern that is stable, normal for that wetland type, and is related to extreme salinity rather than moisture regime. The Emergent Deep Marsh Zone is absent and the vegetation sequence is Wet Meadow Zone – Shallow Marsh Zone – Open Alkali Zone. The normal vegetation patterns in stable wetland types, including the special pattern of Open Alkali Wetlands, are illustrated in Figure 2.

3.2. Deviant vegetation patterns related to fluctuations in water regime

Under prolonged drought conditions plant species of the various emergent zones tend to die out in their original location and invade the lower and moister levels of the wetland. This produces a shift in the actual location of the zones, but no deviation from the normal pattern. Frequently it is possible to interpret previous water conditions from surviving remnants of the original vegetation. Once normal moisture conditions return, the original vegetation may re-establish itself rather rapidly from these same remnants.

A significant deviation occurs in the vegetation pattern of Open Marsh and Shallow Open Water wetlands during drought, when declining water levels create exposed mudflats in portions of the Shallow Open Water Zone. Pioneering forbs or grasses appear on the exposed soils to form a Disturbed (Drawdown) Zone inside the Emergent Deep Marsh Zone. If the drawdown lasts for only a single season, the Disturbed Zone is eliminated during the first year of reflooding and the original zonal pattern is restored. However, if lowered water levels persist for two or more years, a stable Shallow Marsh Zone may replace the pioneering forbs inside the Emergent Deep Marsh Zone. The result is a sandwiching of the Emergent Deep Marsh Zone between two Shallow Marsh Zones. This situation may persist for several years, if there is sufficient moisture to keep the Emergent Deep Marsh species alive and not enough year-long flooding to kill out the newly-established Shallow Marsh Zone.

Most deviations in vegetation patterns, however, arise from longer and deeper flooding rather than drought. Water level fluctuations in Wet Meadows are usually not extreme enough to affect the vegetation seriously. Shallow Marshes, however, are more susceptible to prolonged flooding and consequently experience frequent vegetation die-offs (Millar, 1973b). When the central Shallow Marsh vegetation dies out completely it is replaced by a Transitional Open Water Zone and the wetland assumes the appearance of a Shallow Open Water Wetland with its Emergent Deep Marsh Zone missing. Should flooding be prolonged, the Transitional Open Water Zone is usually replaced by a true Shallow Open Water Zone. However, unless there is a temporary drawdown to expose suitable seed-beds for species associated with the Emergent Deep Marsh Zone, the wetland will continue to lack that particular zone. I observed this vegetation pattern frequently during my 10-year study. Unless submergent species have grown enough to be observed from the shore or the air, the true status of such a wetland cannot be determined except by detailed examination of the open water area.

Another deceptive wetland situation occurs when an Emergent Deep Marsh is subjected to extreme flooding. Usually the Wet Meadow and Shallow Marsh Zones are eliminated sooner than the Emergent Deep Marsh Zone, resulting in an inversion of the normal zonal sequence with a Transitional Open Water Zone outside the Emergent Deep Marsh Zone. A similar situation may develop in Open Water Marshes or Shallow Open Water Wetlands except that the Emergent Deep Marsh Zone becomes isolated between two zones of open water. Occasionally a second Emergent Deep Marsh Zone may develop on the outer periphery of the Transitional Open Water Zone. Prolonged deep flooding will ultimately destroy the isolated Emergent Deep Marsh Zone in the various situations just described, leaving the wetland with the appearance of a Shallow Open Water Wetland that may or may not have a new peripheral Emergent Deep Marsh Zone. Again, only a close examination of the open water area can establish the true character of such a wetland.

A remarkable wetland anomaly near Saskatoon involved a central semi-open stand of Shallow Marsh vegetation (*Scolochloa*) surrounded by a wide peripheral Shallow Open Water Zone (*Myriophyllum*). This wetland experienced several years of continuous flooding and the survival of the *Scolochloa* is difficult to explain.

Occasionally a patchwork pattern of two vegetation zones replaces the characteristic concentric-ring pattern in the centre of the wetland. This situation may originate as a result of fluctuating water levels, human disturbance, or topographical irregularities. Unless the contributing factors can be clearly identified the wetland should simply be classified according to the vegetation zone which appears to be dominant.

3.3. Deviant vegetation patterns related to human disturbance

Cultivation of the Wet Meadow and Shallow Marsh Zones, as explained earlier, usually results in the development of vegetation characteristic of the Disturbed Zone. Occasionally, however, ideal germination conditions permit Emergent Deep Marsh vegetation, particularly *Typha*, to take hold in cultivated depressions (Millar, 1973b). If above-average water conditions persist for several years, these cattail stands may survive in what are normally very temporary wetlands. This situation is more likely to occur in the moister parkland regions than elsewhere and can usually be correctly interpreted from the size and depth of the wetland.

Drainage activities often produce the same types of deviations in the wetland vegetation patterns as do natural droughts. Thus, partial drainage of an Open Water Marsh or Shallow Open Water Wetland may expose mudflats which then develop into a Shallow Marsh Zone lying within the surviving band of Emergent Deep Marsh vegetation. On the other hand, when a wetland is flooded with abnormal amounts of runoff water drained from other wetlands, the existing vegetation may be partially or entirely destroyed. Usually, the causes of such changes — drainage ditches — are easily recognized, but tiled drains and portable pumps may bring about the same results less obviously.

Grazing reduces the plant cover of a wetland, of course, and in the extreme will totally eradicate the flora. Where livestock have destroyed the vegetation, the wetland may appear as Transitional Open Water when flooded. After grazing ceases and pioneering vegetation appears, the same depression may be classed as a Disturbed Wetland. Grazing of Emergent Deep Marshes, Open Water Marshes, or Shallow Open Water Wetlands suppresses or eliminates the more palatable Wet Meadow and Shallow Marsh species, while the Emergent Deep Marsh Zone survives surrounded by open water. This apparent inversion of vegetation zones resembles that produced by excessive flooding of the same types of wetland. Grazing, however, is so obvious a factor that interpretation of the vegetation changes associated with it should present no problem.

Mowing undoubtedly produces subtle changes in the flora of wetlands by removing annual species before they produce seed, yet it causes no apparent changes in the existing pattern of vegetation zones. Quasi-deviations in vegetation patterns sometimes appear when heavy rains reflood the wetland after mowing. The central or peripheral areas of open water so produced superficially resemble Transitional Open Water, but they are only temporary phenomena. Mowed portions of the wetland beyond the water's edge should be a sufficient indication of the true situation to allow the observer to make a correct interpretation.

No doubt some deviations in wetland vegetation patterns are related to environmental factors not mentioned here. However, I believe that most of the wetland vegetation anomalies encountered in the prairie and parkland regions can be explained in terms of the factors just described.

In classifying a marsh or shallow open water, the investigator can reduce information about the sequence of vegetation zones and vegetation anomalies to a compact numerical formula by listing the code numbers of the various vegetation zones, in the order in which they occur from the centre of the wetland to its outer edge. For example, the formula for a Transitional Open Water Wetland with the Emergent Deep Marsh Zone absent would be 4-2-1. The only information which needs to be recorded separately is the nature of the factor or factors which produced the anomaly.

4. Vegetation and salinity

Many of the wetland classification systems described earlier in this paper have used salinity of surface waters as one of their criteria. Salinity is of particular value in that, first, it influences a wetland's attractiveness to waterfowl, and secondly, it often reflects the involvement of groundwater in the moisture regime of a wetland. For these reasons, salinity studies should be part of any thorough wetland assessment.

One can determine quite precisely the salinity of water by measuring its total dissolved solids in ppm, or alternatively, by measuring its specific conductivity in micromhos per cc at 25°C. Either of these methods is time-consuming. Moreover, unless samples are taken repeatedly throughout the year, such measurements can only approximately reflect the seasonal fluctuations in the salinity of wetland waters, which occur as a result of dilution by runoff in the spring and of progressive concentration due to evapotranspiration during the summer. A simpler method of assessing water salinity, and one which is sufficiently accurate for most field studies, relates the composition of a wetland's vegetation to the salinity of its waters.

The definition of wetland salinity by plant associations tends to be somewhat arbitrary. Most plant species tolerate some variation in salinity, and their presence or absence indicates average conditions in the wetland rather than the seasonal extremes of salinity. Some plant species can survive for brief periods under very abnormal salinity induced by extreme flooding or drought. In such cases, the wetland's salinity should be interpreted with considerable caution. As one might expect, the response of plants to increasingly saline conditions is in the nature of a continuum, with individual species gradually dropping out or appearing as the level of salinity rises.

My studies of the vegetation in Saskatchewan wetlands indicate that four salinity categories are adequate for most purposes of wetland evaluation. I have tentatively given these the same salinity limits as Stewart and Kantrud's (1971) classes, or combinations thereof, and they coincide precisely with the broader categories secondarily suggested by those authors. Possible modification of these salinity limits is discussed later in this section. In naming the salinity categories, I have avoided the term *brackish*, which should be restricted to its proper use in connection with mixtures of fresh and marine waters (Bayly, 1967). The four salinity categories, then, with their normal ranges, and with Stewart and Kantrud's equivalents, appear in Table 4.

I have chosen to combine Stewart and Kantrud's (1971) first four salinity classes (A, B, C, and D) into two categories (Code nos. 1 and 2) for two reasons. First, most of the species which I have found to be commonly or occasionally dominant in my Fresh category achieve this dominance over most or all of the salinity range covered by Stewart and Kantrud's classes A and B. This is true, for example, of all but

Table 4
Wetland salinity categories with Stewart and Kantrud's (1971) equivalents

Salinity category		Salinity range		
Code no.	Name	Dissolved solids (ppm)*	Specific conductivity ($\mu s/cm^3$ at 25°C.)	Stewart and Kantrud's salinity class
1	Fresh	< 28–1,400	< 40–2,000	A. Fresh B. Slightly Brackish
2	Moderately Saline	1,400–10,500	2,000–15,000	C. Moderately Brackish D. Brackish
3	Saline	10,500–31,500	15,000–45,000	E. Subsaline
4	Hypersaline	> 31,500	> 45,000	F. Saline

* Parts/million values are derived by multiplying conductance values by 0.7, the maximum ratio suggested by Thomas (1953).

one of the 13 Wet Meadow species listed in Table 5 as flourishing in Fresh Wetlands. This situation also applies, to a lesser extent, to their Classes C and D, which I include in my Moderately Saline category. Second, many plant species exhibit differences in their environmental requirements from one part of the grassland and parkland regions to another (see Section 6.) and these variations largely overshadow the finer distinctions in salinity tolerance suggested by Stewart and Kantrud.

The salinity relationships of plant species which do not display a uniform response over the entire range of one of my broader categories can be interpreted by examining their status in adjacent categories. For example, a pond dominated by *Phragmites communis* or *Scirpus acutus* is unlikely to be extremely fresh because those species also dominate in the Moderately Saline category. On the other hand, the total absence of *Potamogeton gramineus* from Moderately Saline water suggests that it is unlikely to dominate at the upper limit of my Fresh category.

A number of different salinity classifications have been developed for a wide variety of biological and non-biological purposes. Their relationships to the system I propose are illustrated in Figure 5. The complexity of these other systems varies from as few as two categories (Northcote and Larkin, 1963; Williams, 1967) to as many as eight in a system designed especially for studies of marine waters (International Limnological Society, 1959). What is more, definitions of fresh water vary considerably. Most biologically oriented classification systems consider fresh water as having less than 300 to 500 ppm of dissolved solids, whereas those concerned with potability use an upper limit of 1,000 ppm. Williams (1967), in his studies of Australian lakes, uses an extreme of 3,000 ppm, a definition of fresh water which corresponds to the U.S. Geological Survey's limit on slightly saline water (Robinove *et al.*, 1958), and to the limits on β-Oligohaline water set by the International Limnological Society (1959).

The level of 1,400 ppm, which is the upper limit of my definition of the Fresh water category, has no precedent, therefore, except in Stewart and Kantrud (1971) from whom I derived it. I am not convinced that 1,400 ppm is necessarily the best point at which to distinguish Fresh from Moderately Saline waters, but at the same time I do not feel that the differences in wetland vegetation at the 350 to 500 ppm level are sufficient to justify a division there. It is possible that further study will reveal that significant changes in vegetation are associated with the changes in water chemistry which Różkowska and Różkowski (1969) observed at 700 and 2,000 ppm.

Of the classification systems which recognize other categories of salinity beyond 3,500 ppm, all but one have a division at 10,000 to 10,500 ppm, and all but one have another division at 30,000 to 35,000 ppm — the approximate salinity of sea water. This agreement about the definition of high salinity supports my decision to adopt those distinctions for the more saline levels in western Canadian wetlands.

Only one classification system, that of Gorrell (1958), has a salinity category in excess of 100,000 ppm. Unfortunately, recent references to this system (Davis and DeWiest, 1966; and Todd, 1970) obscure the fact that it was developed for the very specialized purpose of classifying the subterranean waters encountered during oil-drilling operations.

Table 5 presents the relationships of dominant plant species to the salinity categories in which each species achieves normal growth, i.e., vegetative stature and seed production. In a few cases, I have supplemented my observations of certain species with data from Rawson and Moore (1944) and Stewart and Kantrud (1971). I discuss regional variation in the response of plant species to salinity in a later section.

Several general observations regarding vegetation and salinity are relevant. First, the number of dominant species in each vegetation zone decreases as the salinity of the wetland's waters increases, until only a single species, *Ruppia maritima*, occurs in Hypersaline conditions. Secondly, when Hypersaline conditions prevail at the lowest levels in a wetland, the Emergent Deep Marsh Zone is usually absent, and the salinity at the higher peripheral elevations is low enough that the Wet Meadow and Shallow Marsh Zones are dominated by species characteristic of the Saline category.

Certain generalizations can also be made in regard to the relationship between water regime and salinity. Wet Meadow and Shallow Marsh Wetlands are characteristically Fresh or occasionally Moderately Saline, and normally they dry up each year. It is usually only in the semi-permanent to permanent Emergent Deep

Marsh, Open Water Marsh and Shallow Open Water Wetlands that the full range of conditions from Fresh to Saline occur. Open Alkali or Hypersaline Wetlands are extremely variable in terms of their water regime. Higher levels of salinity may also indicate that a wetland's water regime is being supplemented by groundwater inflow (Meyboom, 1967).

5. Dominant plant species

The dominant plant species in each vegetation zone not only indicate the level of salinity in a wetland, but also provide a guide to its recent moisture regime and disturbances. This information permits more accurate assessment of a wetland's potential as waterfowl habitat.

The discussion of wetland plants in this paper is limited to those rooted vascular species which I have found to be most useful for assessing wetlands. Table 5 lists the species which contribute most significantly to the gross appearance of each wetland zone and which occur, at least occasionally, as the principal dominant plant in wetlands in the grasslands and parklands of western Canada. Stewart and Kantrud (1971) provide extensive plant lists which are useful for more detailed wetland vegetation studies. Some 80% of their primary species occur throughout the grasslands and parklands of the Prairie Provinces, according to Breitung (1957), Budd (1957), Fraser and Russell (1954), Moss (1959), and Scoggan (1957).

Dominant plant species should be recorded as part of any wetland assessment and I have provided for the inclusion of this information in the data coding scheme presented in Appendix 2. Each investigator may assign code numbers to individual plant species according to his own particular needs.

Certain of the dominant species listed in Table 5 are useful as indicators of particular events or conditions which are important for wetland evaluation. These species are discussed below by vegetation zone.

Table 5
Principal dominant rooted wetland plant species — their vegetation zone, salinity, and frequency of dominance relationships

Vegetation zone, (code no.) and species	Salinity categories with code no. in which species occurs[1]: Fresh (1)	Mod. Saline (2)	Saline (3)	Hyper-saline (4)	Relative frequency with which species dominates in its normal salinity range: Common	Occasional
Wet Meadow (1)						
Agrostis scabra	X					*
Calamagrostis canadensis	X				*	
Deschampsia caespitosa	X					*
Poa palustris	X	o			*	
Salix bebbiana	X	o			*[2]	
Salix discolour	X	o			*[2]	
Salix petiolaris	X	o			*[2]	
Aster hesperius	X	o				*[2]
Cirsium arvense[3]	X	o				*
Sonchus arvensis[3]	X	o			*	
Calamagrostis inexpansa	X	X			*	
Juncus balticus	X	X	o		*	
Hordeum jubatum	X	X	o		*	
Distichlis stricta	o	X	X		*	
Shallow Marsh (2)						
Phalaris arundinacea	X					*[2]
Polygonum coccineum[3]	X	o			*	
Carex atherodes	X	o			*	
Alisma triviale[3]	X	o				*[2]
Sparganium eurycarpum	X	o				*
Sium suave	X	o				*[2]
Sagittaria cuneata	X	o				*
Scolochloa festucacea	X	X			*	
Eleocharis palustris	X	X			*	
Puccinellia nuttalliana		o	X		*	
Salicornia rubra		o	X		*	
Suaeda depressa		o	X			*
Emergent Deep Marsh (3)						
Scirpus validus	X				*[2]	
Typha latifolia	X	o			*[2]	
Phragmites communis	X	X				*[2]
Scirpus acutus	X	X			*	
Scirpus paludosus	o	X	X		*	

cont'd on page 23

Table 5, cont'd
Principal dominant rooted wetland plant species — their vegetation zone, salinity, and frequency of dominance relationships

Vegetation zone, (code no.) and species	Salinity categories with code no. in which species occurs[1]				Relative frequency with which species dominates in its normal salinity range	
	Fresh (1)	Mod. Saline (2)	Saline (3)	Hyper-saline (4)	Common	Occasional
Disturbed[4] (7)						
Glyceria grandis (2)	X				*	
Chenopodium album (1)	X					*
Potentilla norvegica (1)	X					*
Rorippa islandica (1)	X					*
Thlaspi arvense (1)	X					*
Agropyron repens[3] (1)	X	o			*	
Beckmannia syzigachne (2)	X	o			*	
Alisma triviale[3] (1)	X	o				*
Alopecurus aequalis (2)	X	o				*
Polygonum coccineum[3] (2)	X	o			*	
Polygonum lapathifolium (1)	X	o				*
Cirsium arvense[3] (1)	X	o				*
Sonchus arvensis[3] (1)	X	o				*
Senecio congestus (2)	X	o			*[2]	
Artemisia biennis (1)	X	X				*
Chenopodium rubrum (1)	X	X				*
Rumex maritimus (1)	X	X				*
Hordeum jubatum[3] (1)	X	X	o		*	
Aster brachyactis	o	X				*
Transitional Open Water (4)						
Potamogeton gramineus	X				*[2]	
Utricularia vulgaris	X	o			*[2]	
Potamogeton pusillus	X	o			*	
Ranunculus subrigidus	X	o				*
Shallow Open Water (5)						
Myriophyllum exalbescens	X	o			*	
Potamogeton richardsonii	X	o				*
Ceratophyllum demersum	X	o				*
Potamogeton pectinatus	o	X	o		*	
Open Alkali (6)						
Ruppia maritima			X	X	*	

[1] X and o indicate normal and sub-normal development respectively.
[2] Dominance of species is associated with factors explained in the text.
[3] Commonly a pioneer species, but also capable of maintaining dominance for long periods, hence it is listed for both stable and disturbed zones.
[4] 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. The Disturbed Zone is usually dominated by a mixture of two or more species; hence, most species in this zone are listed here as occasional dominants.

Wet Meadow Zone: The presence of three Wet Meadow dominants, *Hordeum jubatum*, *Cirsium arvense*, and *Sonchus arvensis*, must be interpreted with care as they occur both as pioneering species and as long-term members of relatively stable vegetation. The absence of willows (*Salix* spp.) from Wet Meadow Zones of wetlands in the parkland region is a reliable indication that these depressions have at one time been partially or entirely cultivated.

Shallow Marsh Zone: Four species — *Polygonum coccineum*, *Carex atherodes*, *Scolochloa festucacea*, and *Eleocharis palustris* — are the most frequent dominants in this zone. Within this group there are consistent differences related to moisture regime. *Polygonum coccineum* and *Carex atherodes* generally dominate in drier situations where the pond regularly dries up by midsummer. *Scolochloa festucacea* and *Eleocharis palustris*, on the other hand, frequently occur where there is a longer period of flooding. Shallow Marshes dominated by these latter two species are usually the first to change into Transitional Open Water or Shallow Open Water Wetlands when the moisture regime improves in an area (Millar, 1973b).

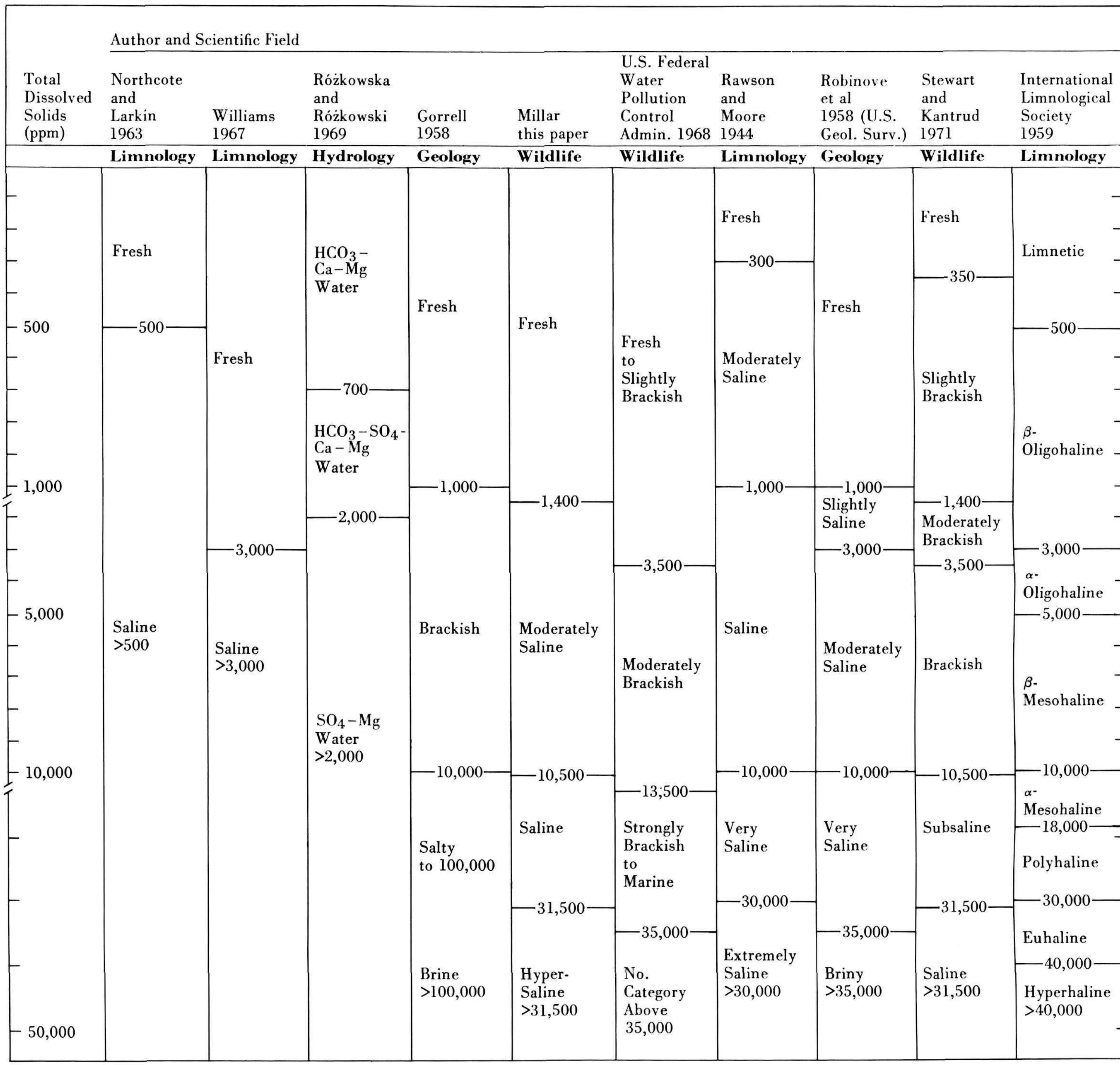
Carex atherodes is also indicative of stable, undisturbed conditions. *Polygonum coccineum* is less useful in this regard because it develops quickly after cultivation and can persist for many years afterwards if undisturbed. *Scolochloa festucacea* is erratic in its behaviour, exhibiting a wide amplitude in its response to changing moisture regime; sometimes it dies out as a result of minor changes, and sometimes it survives drastic changes for two or three years. *Eleocharis palustris* often replaces *Carex atherodes* and other species when they are heavily grazed, and in such situations its presence may lead to the interpretation of a wetter moisture regime than actually exists.

Phalaris arundinacea is difficult to interpret because it is frequently planted as a forage crop in wetlands. Wherever it becomes dominant, either naturally or with

Figure 5
A comparison of some definitions of water salinity

* The definitions of salinity in each system, except that of Stewart and Kantrud, were originally in parts per million, or in values directly convertible to those units. Specific conductivity values of Stewart and Kantrud have been converted to ppm by multiplying them by 0.7 (Thomas, 1953).

Figure 5



the farmer's help, removal of existing vegetation and exposure of the soil appears to have been a prerequisite. *Alisma triviale* is considered to be a disturbance species, but is also capable of maintaining itself for several years after disturbance ends.

Several Shallow Marsh species, notably *Sium suave* and, to a lesser extent, *Alisma triviale*, are *seasonal* dominants in that they tend to become inconspicuous after they have matured. A wetland in which these species are dominant will, therefore, change its appearance as the season progresses. Hence, it is advisable to record the co-dominant and sub-dominant species associated with these two plants.

Emergent Deep Marsh Zone: The presence of *Typha latifolia* in wetlands requires careful interpretation because of its flexibility in responding to environmental changes. The fact that its seed is windborne allows *Typha* to achieve rapid and widespread dominance in a variety of habitats provided that it has the right seedbed and moisture conditions for germination. Thus, *Typha* may establish itself in very temporary water bodies and survive for a few years if the moisture regime is not too dry. On the other hand, relatively stable stands of cattails may persist for years in semi-permanent Fresh ponds.

Dominant stands of *Scirpus validus* were not present in my study samples, and my interpretation of this species is based largely upon the work of others. Dabbs (1971) found *S. validus* in shallower water sites than *S. acutus;* McCauley (pers. comm.) associates *S. validus* with unstable conditions; and Stewart and Kantrud (1972) refer to it as a pioneering species which appears after disturbance by grazing. These observations suggest that the presence of *S. validus* indicates environmental instability. *Scirpus acutus*, on the other hand, is a good indicator of relatively stable, semi-permanent water conditions in the Fresh (upper end) to Moderately Saline categories.

Scirpus paludosus indicates not only Saline conditions, but also a lower level of water permanence than do other deep marsh emergents. Ponds dominated by this species typically go dry from midsummer onwards but, because groundwater discharge is usually associated with such sites, the wetland is likely to be reflooded again when the water table rises after heavy rains. My observations support those of Stewart and Kantrud (1972) who found that, as Emergent Deep Marsh Zones become more saline, their waters become less permanent.

Phragmites communis has a very limited distribution in the wetlands of the grassland and southern parkland, but it becomes more common northward and eastward where, according to my few observations, it does not seem to be restricted to fen situations as Stewart and Kantrud (1971) have suggested.

Transitional Open Water Zone: Submergent species characteristic of this zone define a gradient in water permanence. *Potamogeton gramineus* occurs either as an understory in the Shallow Marsh Zone or as a dominant species in Transitional Open Water, and it commonly thrives without any year-long flooding (Millar, 1973b). *Utricularia vulgaris* has similar habits, but is more closely associated with occasional year-long flooding. Finally, *Potamogeton pusillus* and *Ranunculus subrigidus* do not usually appear until after two or more consecutive years of continuous flooding. In the northern parkland *P. pusillus* may persist as a dominant for several years.

Shallow Open Water Zone: Except for the salinity relationships which appear in Table 5, I have not observed any distinctive habits of the dominant Shallow Open Water species which might serve as indicators of wetland values. I have previously discussed the problems involved in interpreting past moisture regime from the drought-induced vegetation sequences in Shallow Open Water and Transitional Open Water Zones, but one further observation of species behaviour deserves mention here. When normal water levels return in the year after pioneer vegetation develops on an exposed mudflat, that vegetation is usually destroyed and the former open water zone is re-established. *Senecio congestus*, however, is a biennial which tolerates considerable flooding in its second year, and, when found next to open water, it is a reliable indicator of previous low water levels.

Open Alkali Zone: Since this zone supports only one plant, *Ruppia maritima*, there is no problem in interpreting the significance of its species composition.

Disturbed Zone: As mentioned earlier, most disturbance species are associated with stable vegetation zones in which they regularly occur as minor elements. These relationships can be used to predict the probable nature of the stable vegetation which will develop in a wetland once disturbance stops but, because disturbance vegetation responds so readily to the existing water conditions, this type of interpretation should be made with caution. Affinities of disturbance species with stable vegetation zones are indicated in Table 5. *Hordeum jubatum*, *Sonchus arvensis*, *Cirsium arvense* and *Alisma triviale* have already been discussed in connection with the stable zones with which they are associated. *Beckmannia syzigachne* and *Glyceria grandis* are probably the most common species to achieve dominance in moderately moist situations following disturbance and normally give way to Shallow Marsh vegetation. *Alopecurus aequalis* is frequently their associate, and, although too short in stature to be a normal dominant, it does dominate on exposed mudflats when it occurs in pure stands. Contrary to the views of some authors, including Stewart and Kantrud (1972), I have not found these three species to be restricted as to the specific types of disturbance situations in which they will dominate (Millar, 1973b). A few pioneer species do, however, seem to favour particular habitat conditions. *Senecio congestus*, for example, develops primarily on mudflats created by natural drawdown, but also occurs in grazed wetlands.

6. Regional variations in plant behaviour

Observations during this study suggest that many plants respond quite differently to moisture regime, salinity, and other environmental factors, depending upon whether they are in the grassland or parkland. These regional differences in behaviour can affect our interpretation of moisture regimes. *Scholochloa festucacea*, for example, thrives under shorter periods of flooding at Melfort than it does further to the south and west. In the grassland and adjacent parts of the parkland, *Salix bebbiana* confines itself to slough edges, but in the northern and eastern portions of the parkland it also grows on the low uplands. Similarly, the shrubs and trees associated with the Low Prairie Zone also occur on higher ground in the parkland. It was this behaviour of Low Prairie species which led me to omit that vegetation zone from my wetland classification.

The ability of plant species to grow under apparently drier conditions further north and east than they do in the southwest is undoubtedly related to the combination of higher precipitation and humidity, reduced wind speeds due to the sheltering effect of trees and shrubs, and lower temperatures. These factors all affect the processes of evaporation and transpiration and reduce a plant's requirements for free water at the upper levels of its root system.

Stewart and Kantrud (1972) list a number of species as occurring less abundantly in wetlands whose surface waters had a specific conductivity of less than 500 micromhos per cc at 25°C. Yet I found these same plants flourishing under such conditions in the northern and eastern parts of the parkland. The species in question are *Juncus balticus*, *Calamagrostis inexpansa*, *Hordeum jubatum*, *Scolochloa festucacea*, *Eleocharis palustris*, *Sagittaria cuneata*, *Myriophyllum exalbescens*, and *Potamogeton richardsonii*. Moreover, several species which Stewart and Kantrud (1972) restricted to fen ponds occur in normal marsh situations throughout the parkland. These include *Phragmites communis*, *Deschampsia caespitosa*, *Salix interior*, *Carex rostrata*, *Ranunculus gmelini*, and *Hippurus vulgaris*. The environmental basis for these differences in salinity and fen pond relationships has yet to be determined.

Table 6
Expected combinations of wetland vegetation factors, identified in terms of code numbers

Code no.	Wetland type (central veg. zone)	Code nos. of other vegetation-based factors: Extent of central veg. zone	Density of central emergent cover: Category	Extent	Origin	Salinity
1	Wet Meadow	1 to 5	1 to 3	1 to 5	1 to 5	1 to 2
2	Shallow Marsh	1 to 5	1 to 3	1 to 5	1 to 5	1 to 2
3	Emergent Deep Marsh	1 to 5	1 to 3	1 to 5	1 to 5	1 to 3
4	Transitional Open Water Wetland	1 to 5	NA*	NA	NA	1 to 3
5A	Open Water Marsh†	1 to 3	NA	NA	NA	1 to 3
5B	Shallow Open Water Wetland†	4 to 5	NA	NA	NA	1 to 3
6	Open Alkali Wetland	1 to 5	NA	NA	NA	4
7	Disturbed Wetland‡	1 to 5	1 to 4	1 to 5	1 to 5	1 to 3

* NA = Not Applicable.
† Open Water Marshes (5A) and Shallow Open Waters (5B) both have the same vegetation zone (Shallow Open Water) in the wetland centre, but the proportion of open water to emergent vegetation is different.
‡ The origin of the central cover category in Disturbed Wetlands also identifies the origin of the disturbance.

7. Summary

In the preceding sections I have described a variety of ways in which vegetation can be used to evaluate a wetland's water regime and salinity. This discussion has, of necessity, been rather complex and detailed and a brief review of its main points is needed before moving on to consider the classification of wetlands by their physical features.

I began by describing the vegetation zones which can be recognized in wetlands and identifying the type of moisture regime under which each normally develops. Wetland types are defined according to the vegetation zone occupying the centre of the depression and are, with one exception, given the name of that central zone. The exception to this procedure involves wetlands with a central Shallow Open Water Zone, which are divided into two types, Open Water Marshes and Shallow Open Waters, according to the proportion of the wetland which the Shallow Open Water Zone occupies. I then discussed the use of the proportional size of the central vegetation zone, the density of its vegetation, and variations in the pattern of vegetation zones to interpret details of water regime. Finally, I described how vegetation indicates the wetland's varying salinity and its history of disturbance, and also how regional variations in plant behaviour may influence the interpretation of moisture regimes.

Every category of each criterion in my classification is not necessarily found in every wetland type. For example, Hypersaline conditions do not occur in Wet Meadow or Shallow Marsh Wetlands. A summary of the combinations of categories that may be expected in common wetland situations is given in Table 6, and some are illustrated in the colour plates. I have not attempted to tabulate the multitude of possibilities for anomalies in arranging vegetation zones.

The vegetation-based factors I have described provide a variety of detailed in-

Classifying wetlands by physical features

formation from which to evaluate the short-term water regime of wetlands. However, because vegetation is a dynamic characteristic, it is less useful in interpreting the status of a wetland over periods of many years. In the next section I will discuss the use of a wetland's physical features to aid in the assessment of its long-term potential.

A wetland's physical features, including its size, the depth of the basin in which it lies, and the nature of its watershed, limit its potential water regime by interacting to control the amount of water it can receive from runoff, the depth of water it can hold, and the rate at which it will lose water throughout the season. Except for alterations produced by human activity or catastrophic natural events, these features, unlike vegetation, are usually quite stable. For that reason, they are particularly helpful in assessing a wetland's long-term potential, which may be different from the level of water regime apparent at the time the investigator makes his observation. Together, a wetland's vegetation and its physical features make possible the most comprehensive evaluation of its present and potential value.

1. Wetland size

Several of the existing classification systems make reference to wetland size, but in every case it is considered simply as a factor which influences waterfowl use. Only Evans and Black (1956) refer in passing to the relation of wetland size to water permanence.

Data collected over 10 years in Saskatchewan show that the rate of water loss is directly related to the ratio of length of shoreline to water area, and hence is inversely related to pond size (Millar, 1971). This relationship is explained, in part, by the fact that as the pond becomes smaller, the amount of shoreline available for lateral seepage becomes proportionately greater in relation to the volume of water remaining. All ponds experience an accelerated rate of water loss as they become smaller through the season, but those which are small to begin with start the season with a high rate of water loss and hence go dry very quickly.

Earlier, I defined a wetland as that portion of a basin lying within the outer edge of the Wet Meadow Zone. The limits of this zone can be used without difficulty to determine the size of most wetlands because the long-term fluctuations in water depth they experience are not extreme enough to cause significant shifts in the shoreward margin of the Wet Meadow vegetation. There are, however, several situations in which size determination can present special problems. First, large wetlands lying in deep, steep-sided depressions often experience variations of several feet in the depth of waters that flood them. In such cases maximum size can usually be interpreted from previous high-water marks such as wave-cut banks, old beachlines and water marks on trees. Second, the size of a wetland located in cropland is difficult to measure because the Wet Meadow Zone is almost always cultivated and frequently the entire depression is ploughed up. In such cases the most practical solution is to use aerial photos or to make ground surveys to measure the outer limits of spring flooding. Finally, the most difficult situation is presented by large wetlands in shallow, saucer-shaped depressions or flats which can fluctuate wildly in size between periods of drought and high water. These fluctuations are most extreme in the arid grassland region and such wetlands are commonly converted to cropland during dry periods. When this happens, it is almost impossible to recognize some of the depressions as potential wetlands, let alone interpret their former size. In such cases one is forced to rely on the historical record of old aerial photos.

Once the limits of a wetland have been defined, its area can be readily measured either by planimetering or digitizing its image on an aerial photo, or measuring its length and width in the field and calculating the area by means of the formula for the area of an ellipse (Millar, 1973a).

My observations of the relationship between rate of water loss and the size of the wetland indicate that nine size categories are convenient for most purposes in classifying wetlands in the western Canadian grasslands and parklands. The table below gives the code numbers and size ranges for these categories.

Code no.	Hectares	Acres*
1	0.00 to 0.10	0.00 to 0.25
2	0.11 to 0.20	0.26 to 0.50
3	0.21 to 0.40	0.51 to 1.00
4	0.41 to 1.00	1.01 to 2.50
5	1.01 to 2.00	2.51 to 5.00
6	2.01 to 4.00	5.01 to 10.00
7	4.01 to 8.00	10.01 to 20.00
8	8.01 to 16.00	20.01 to 40.00
9	> 16.00	> 40.00

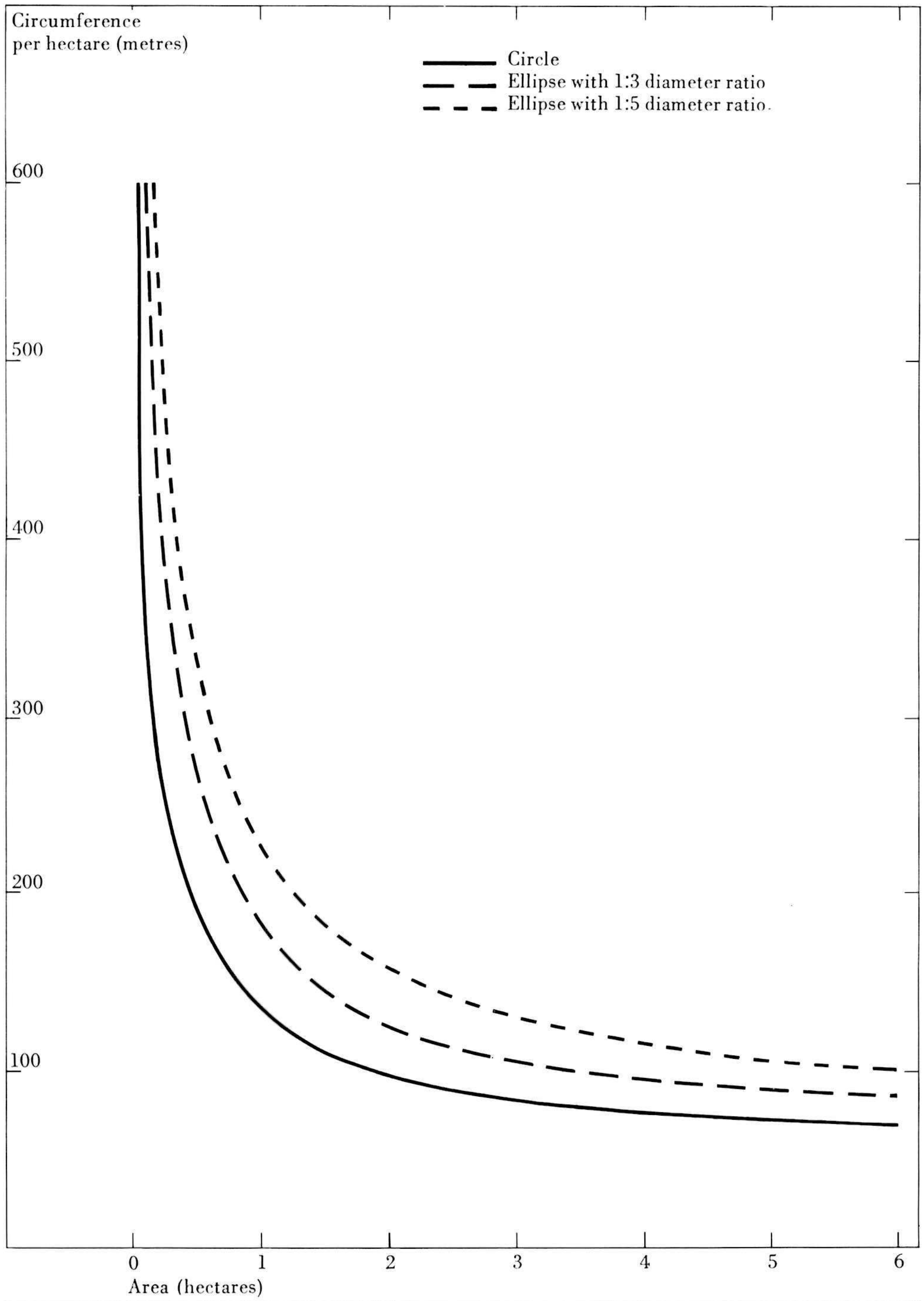
*Values in categories 4 to 9 have been rounded to the nearest acre.

As mentioned earlier, rate of water loss is directly related to the length of shoreline per hectare of pond area which, in turn, is inversely related to pond size. With this in mind, I have established the limits of the wetland size categories to coincide in part with changes in the relationship between the area and length of shoreline per unit area of the wetland. This latter relationship is plotted for circular and elliptical shapes in Figure 6. Marked changes in the slopes of the curves are evident at 0.40 and 2.00 hectares (1 and 5 acres), thus warranting separation at these points. In wetlands smaller than 0.40 hectare, the length of the shoreline in proportion to the flooded area increases sharply, producing large changes in rate of water loss with small changes in pond area. For that reason, I have created three size categories for wetlands of less than 0.40 hectare (1 acre). The separation at 1 hectare (2.5 acres) is an arbitrary one to subdivide the large change in length of shoreline per hectare which occurs between 0.41 and 2.00 hectares (1 and 5 acres). In wetlands larger than 2 hectares (5 acres) the length of shoreline per hectare changes more slowly in relation to the size of the wetland. Changes in the rate of water loss are, therefore, smaller and the categories are correspondingly larger. I have placed all wetlands over 16 hectares (40 acres) in a single category, but recognize that further subdivisions might be useful for special purposes.

In my studies I rarely found wetlands of 0.40 hectare (1 acre) or less which held

Figure 6
Relationship between length of shoreline per hectare and area of wetlands illustrated in terms of circumference and area of circles and ellipses

Figure 6



water throughout the season, either in the grasslands or parklands. Those which did not dry up each year usually had abnormally large sources of water, either inflow of groundwater or surface runoff. Furthermore, large wetlands had more variable water regimes than small ones, especially in the more arid grasslands and in areas of low topographic relief.

2. Basin and wetland depth

Although the depth of the basin in which a wetland lies clearly may affect the relative permanence of its waters, this factor does not seem to have been considered in any system of classifying wetlands. A few authors, notably Martin *et al.* (1953) and Adams and Zoltai (1969), include certain ranges of water depth in their descriptions of wetlands, but they make no reference to the physical limitations that a basin's depth places upon the wetland's potential.

Maximum basin depth can be used by itself as a measure of the greatest potential depth a wetland can attain, given an unlimited supply of water. However, the extent to which it effectively influences the water regime of a particular wetland can best be interpreted when the maximum depth of the basin and the maximum depth of the wetland itself are compared. As the difference between these two values decreases, the potential influence of basin depth increases and it becomes most active as a limiting factor in wetland water regime when its overflow level is at the same elevation as the outer edge of the wetland's Wet Meadow Zone.

Three depth categories which can be used to describe either basin or wetland depths are proposed as follows:

Code no.	Depth category		
1	<0.91 m	or	<36.00 in.
2	0.92 to 2.00 m	or	36.10 to 78.70 in.
3	>2.00 m	or	>78.70 in.

The dividing point at 0.91 m (36.00 in.) was selected because data from my studies on the stability of wetland vegetation have demonstrated that Shallow Marshes which have less than this depth of water on May 1 are normally stable and will not undergo conversion to Transitional Open Water (Millar, 1973b). This limit seems to apply regardless of the size or geographic location of the wetland. Exceptions to this are usually wetlands with groundwater inflow or artificially enlarged watersheds. Vegetation in Shallow Marsh Zones tends to become unstable when the maximum depth of water on May 1 ranges between 0.76 and 0.91 m (30.00 and 36.00 in.), but even at this point the marsh rarely progresses to the Transitional Open Water stage. My division at 0.91 m (36.00 in.) approximates the one-metre limit which Adams and Zoltai (1969) assign to their shallow marsh category.

The 2.00 m (78.70 in.) level is an arbitrary division which I use to separate the Shallow Open Water Zone from what might be called a deep open water zone – i.e., deeper waters which support little or no rooted vegetation. Wetlands with a maximum basin depth of less than 2.00 m will not develop a deep open water zone because they can never become too deep to support a maximum growth of rooted submergent vegetation. Some submergent species can, of course, grow at greater depths and the 2.00 m level should not be interpreted as the absolute maximum depth at which a Shallow Open Water situation can exist. Zoltai *et al.* (1975) use the same depth as the arbitrary limit of the littoral zone and the dividing line between their shallow and deep open waters.

3. Position in watershed

The size and character of the watershed from which a wetland basin receives its spring runoff water significantly influences its water regime. Because the measurement of a watershed is costly and time-consuming, this feature of wetland physiography has never been used systematically in assessing wetland values. Nevertheless, the position a wetland holds in a watershed and the drainage patterns associated with it can usually be deduced in the field, and from their description it is possible to refine the assessment of a wetland's potential water regime.

Four kinds of wetlands, based on characteristics of their watersheds and topographic position, are worth considering for purposes of wetland classification. These are coded below according to their positions in the watershed, which are diagrammed in Figure 7.

Code no.	Position in watershed
1	Isolated Wetland
2	Overflow Wetland
3	Channel Wetland
4	Terminal Wetland

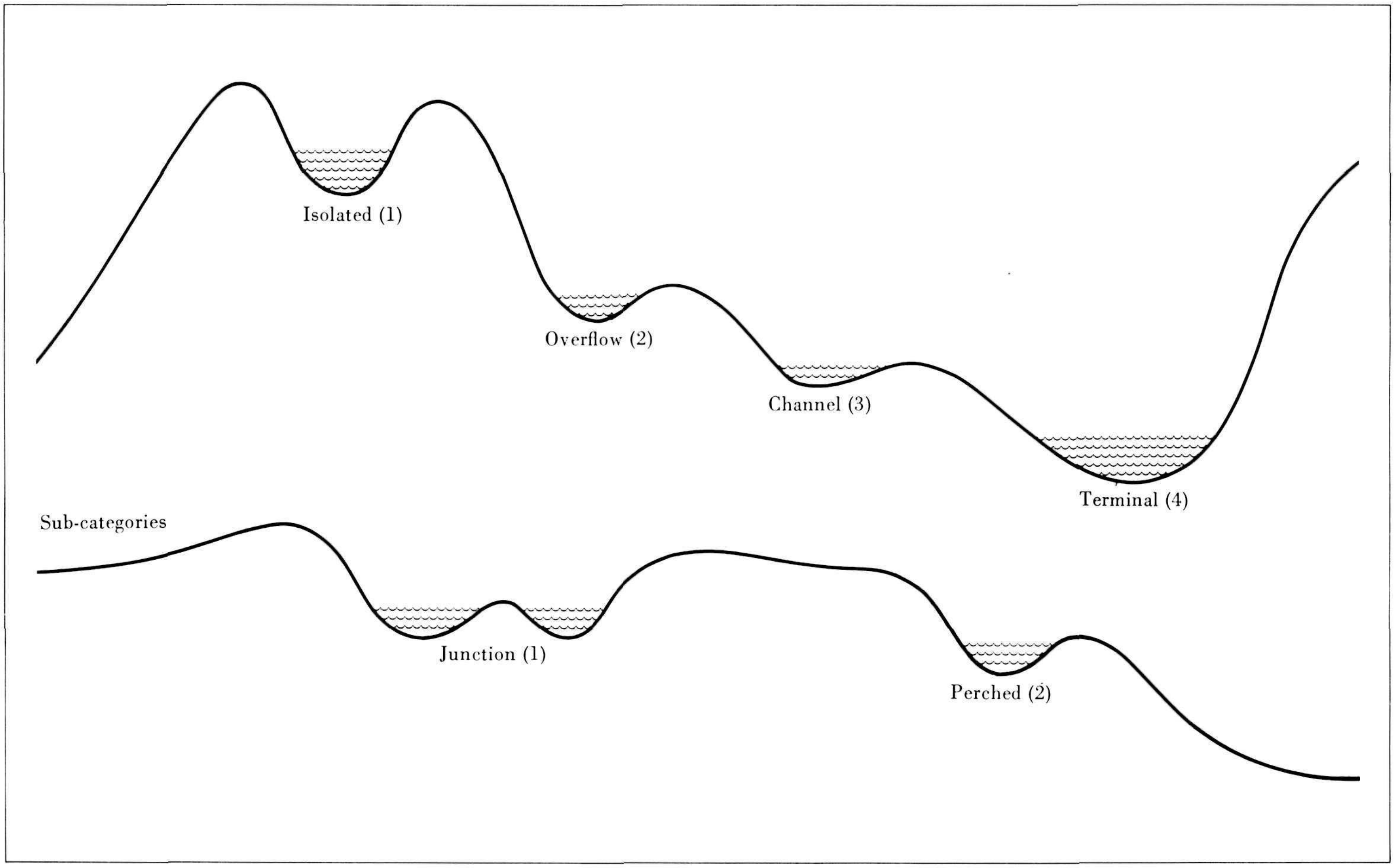
An Isolated Wetland, which receives runoff waters only from the surrounding upland, never overflows and its pond is almost always temporary. Small kettleholes in glacial moraines are typical of this type.

An Overflow Wetland also receives runoff waters only from the surrounding upland, but its depth is limited, and it will overflow when it receives sufficient water. Its potential for overflowing is greatest if the overflow channel is level with the Wet Meadow Zone. Overflow Wetlands, too, are characteristic of topographically high areas, and their ponds are usually temporary.

A Channel Wetland is one which receives runoff from both the surrounding uplands and from Overflow or Channel Wetlands higher in the watershed, and will overflow itself when full. Again, the Channel Wetland whose overflow channel is level with its Wet Meadow Zone is most susceptible to overflow. This type of wetland occurs in a wide variety of topographic situations, ranging from upland sites to glacial meltwater channels. Its moisture regime is highly variable because it depends for water upon other wetlands further up the watershed. Thus, overflow can be high in a wet year and non-existent during drought. At low elevations, the Channel Wetland may receive groundwater inflow. Wetlands in the flood plain of river valleys

Figure 7
Types of wetlands according to their positions in a watershed. Lower portion of figure illustrates two sub-categories. Figures in parentheses are code numbers assigned to each type

Figure 7



can be included in this category, although their source of water is different.

Terminal Wetlands are found in topographically low areas and represent the endpoint of internal drainage systems. They receive runoff from surrounding uplands and Overflow and Channel Wetlands, but cannot overflow themselves. Open Alkali Wetlands are characteristically Terminal Wetlands, but not all Terminal Wetlands are Open Alkali Wetlands. The moisture regime of the Terminal Wetland may be as variable as that of the Channel Wetland, and for the same reasons.

Two special sub-categories (Figure 7) need to be recognized in connection with the classification of wetlands according to the physical features of the watershed. These sub-category designations are always associated with one of the four previously described categories and for that reason I have assigned them a separate series of code numbers:

Code no.	Sub-category
1	Junction Wetland
2	Perched Wetland

Two or more adjoining wetlands at about the same elevation are termed Junction Wetlands if spring runoff or abnormally high water during the season floods the ground between them so that their waters flow together. Under ordinary conditions, a Wet Meadow Zone or more xeric vegetation separates Junction Wetlands. If the plant life between the depressions is characteristic of a wetter vegetation zone, the depressions are considered to be lobes of the same wetland. A wetland's status can change from Junction to lobed and vice versa if extremely wet or dry conditions induce changes in the vegetation. Artificial Junction Wetlands are created when a basin is divided by a road or railroad grade and the two parts are joined by a culvert.

A Perched Wetland is one which is elevated well above the adjacent terrain. The limits of this category are difficult to define precisely, but as a rule a wetland is considered to be Perched when the land surface falls sharply away from its edge to a level lower than the basin. Because of its peculiar situation, a Perched Wetland is particularly susceptible to high rates of natural seepage or drainage through human activities.

4. Origin and alteration of wetlands

To be complete, a system of classifying wetlands should provide for information about the origin of individual depressions. Three categories are adequate for this purpose:

Code no.	Origin
1	Natural wetland
2	Dugout, borrow pit, or road or railroad ditch
3	Dam or reservoir

Some indication of man-made alterations to the wetland or its watershed which may affect the wetland's water regime is also relevant to the assessment of its value. Seven categories of alteration will cover most situations:

Code no.	Nature of alteration
1	No alteration; wetland in original condition
2	Wetland area and depth reduced by partial drainage
3	Wetland area and depth increased by damming of overflow channel
4	Wetland depth increased with a dugout
5	Wetland area reduced by construction of a road or railroad grade, earth fill, or other man-made structure
6	Watershed area reduced by human activities
7	Watershed area increased by human activities

Application of classification system

The system for classifying wetlands described here covers a range of environmental factors sufficiently broad to assist those who must evaluate marshes and shallow open waters for a variety of purposes, whether they are oriented to plant ecology, agriculture, forestry, hydrology or engineering. The chief use of this system, however, will undoubtedly be for waterfowl management and land-use planning. Evaluation of wetlands is an essential component of both kinds of programs if they are to serve social and resource needs wisely.

The limitations of my system relate to its origin, which was an extended and specialized study of wetlands in the grassland and parkland regions of western Canada. Its usefulness is yet to be tested in assessing other kinds of wetlands and those in other regions. Because many of my criteria are closely co-ordinated with those of Stewart and Kantrud (1971), this system probably will be suitable for studies of similar wetlands in adjacent areas of the United States.

An important factor in achieving accuracy in wetland classification is the timing of surveys and measurements. Because the nature of vegetation is often difficult to assess early in the season, the best time for vegetation studies is July or later. In particular, the true character of open water becomes most apparent toward the end of the season, in September or October, when submergent plants have reached the surface. On the other hand, the physical features of a wetland are most clearly visible in the spring, when flooding is at its peak and the patterns of runoff and overflow are most distinct. Of course, many studies are such that repeated field trips are out of the question, and compromises are necessary to make the most of a single trip to a wetland site.

As shown earlier, I have given a code number as well as a name to each of the individual categories in my classification system. These numbers make it possible to code data in the field in a form that can be punched directly onto computer cards for analysis. Appendix 2 gives a sample format for this procedure. In general, the smallest, most xeric, freshest, shallowest, and least disturbed wetlands have the lowest numbers.

While numerical ratings are necessary for data recording and computer analyses, descriptive accounts of wetlands also have particular value, especially for communicating information to persons without technical training. The term "1.1.1.1 wetland", for example, may be concise, but to anyone other than a specialist the expression "a one-quarter acre, isolated wet meadow less than 0.91 m deep" is more easily understood.

Taken in its entirety, my classification system would provide far more information than most wetland studies ordinarily require, and I do not intend it to be treated as a packaged unit that must be used as a whole or not at all. Rather, I hope that those who use the system will regard the wide variety of factors I have described as a series of individual units which can be used or rejected according to the needs of a particular project.

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Appendices

Appendix 1
A check-list of the principal criteria for classifying wetlands with references to the illustrative plates (on front and back covers)

1. Vegetation features		
a. Basic wetland type (central vegetation zone)	Code no.	Plate
Wet Meadow	1	A
Shallow Marsh	2	B-D
Emergent Deep Marsh	3	E, F
Transitional Open Water Wetland	4	Q, R
Open Water Marsh	5A	J, K
Shallow Open Water Wetland	5B	L-O
Open Alkali Wetland	6	P
Disturbed Wetland	7	G-I
Cultivated		G
Drawdown		H
Grazed		I
b. Vegetation patterns		
Normal zonation	—	A-K, O, Q, R
Anomalies	—	L-N, P
c. Extent of central vegetation zone (% of wetland diameter)		
10 to 25	1	K
26 to 50	2	—
51 to 75	3	H, J
76 to 95	4	B-F, I, L, O, Q
Over 95	5	A, G, M, N, P, R
d. Density of central cover		
Closed	1	A, B, D*, E, I
Semi-closed	2	F
Semi-open	3	C
Barren	4	G, H
e. Extent of central cover density (% of wetland diameter)		
10 to 25	1	—
26 to 50	2	C, H
51 to 75	3	—
76 to 95	4	B, D-F, I
Over 95	5	A, G
f. Origin of cover density		
Natural	1	A-F, H, J-R
Cultivation	2	G

cont'd on page 34

Appendix 1, cont'd

	Code No.	Plate
Grazing	3	—
Mowing	4	—
Artificial alteration of wetland depth	5	I
g. Salinity		
Fresh	1	A-E, G-L, N, O, Q, R
Moderately Saline	2	F
Saline	3	M
Hypersaline	4	P

2. Physical features

a. Wetland size	Code no.	Plate
0.10 hectare or less (0.25 acre or less)	1	A, G
0.11 to 0.20 hectare (0.26 to 0.50 acre)	2	Q
0.21 to 0.40 hectare (0.51 to 1.00 acre)	3	B, D
0.41 to 1.00 hectare (1.01 to 2.50 acres)	4	I, L
1.01 to 2.00 hectares (2.51 to 5.00 acres)	5	C, F, J, K, O (right)
2.01 to 4.00 hectares (5.01 to 10.00 acres)	6	E, H, M, O (left)
4.01 to 8.00 hectares (10.01 to 20.00 acres)	7	N
8.01 to 16.00 hectares (20.01 to 40.00 acres)	8	R
Over 16.00 hectares (over 40 acres)	9	P
b. Basin depth (use also for wetland depth)		
Less than 0.91 m (Less than 36.00 in.)	1	A, G
0.92 to 2.00 m (36.10 to 78.70 in.)	2	B, J
Over 2.00 m (Over 78.70 in.)	3	C-F, H, I, K-R
c. Position in watershed		
Isolated Wetland	1	A, B, I, L, Q
Overflow Wetland	2	G
Channel Wetland	3	J, R
Terminal Wetland	4	C-F, H, K, M-P
Special wetland sub-types:		
Junction Wetland	1	
natural		O
artificial		I, Q

	Code No.	Plate
Perched Wetland	2	B, R (background)
d. Origin of wetland		
Only natural wetlands illustrated		
e. Wetland and watershed alterations		
No alterations	1	A-F, H, J, K, N, P
Partial drainage	2	G, O
Depth increased by dam	3	L
Depth increased by dugout	4	I
Area reduced by man-made structures	5	I, Q, R
Watershed area reduced	6	G
Watershed area increased	7	I, M, O

* Illustrates problem of assessing vegetation cover in early spring.

Appendix 2
Sample format for computer coding of wetland assessment data

Details of the coding sequence are given below, with italicized titles indicating those features to which I have assigned code numbers in this paper. In the field, data may be recorded in coded form onto sheets of the type shown in Figure 8 and later be punched directly onto computer cards.

Columns	Data
1–4	Study identification: study area no., etc.
5–14	Location: wetland no., quarter-section, etc.
15–20	Date of observation.
21–24	Nature of wetland: 21 is the *Origin;* 22–24 provide for a maximum of three different kinds of *Basin Alterations.*
25–30	*Size of Wetland:* 25 is the *Size Category*; 26–29, the area to the nearest 1/10 hectare (or acre equivalent); 30 is for an indication of potentially larger size (coding may indicate yes or no, or the code number for the maximum *Size Category*).
31–35	*Depth of Basin and Wetland:* 31 is *Basin Depth Category*; 32–34 is the actual depth of wetland to the nearest centimetre (or inch equivalent); 35 is the *Wetland Depth Category.*
36–37	*Position in Watershed:* 36 is *Position in Watershed*; 37 is *Sub-category.*
38–49	Peripheral Upland Uses: Each in percent of the basin's periphery (99% equals 100%). Note: this is not one of the classification factors described in this paper, but is included as additional habitat information.
50–52	Maximum water depth: to the nearest centimetre (or inch equivalent) on date of observation.
53–54	Blank
55	*Wetland Type:* based on the vegetation zone at the centre of the wetland, e.g., Wet Meadow (1). Types 5A and 5B are identified from the *Extent of Central Vegetation Zone* value in column 59.
56–57	*Density of Central Cover.*
58	*Extent of the Density of Central Cover.*
59	*Extent of Central Vegetation Zone.*
60	*Salinity Category.*
61–65	*Vegetation pattern:* sequence of vegetation zones from the wetland centre outwards.

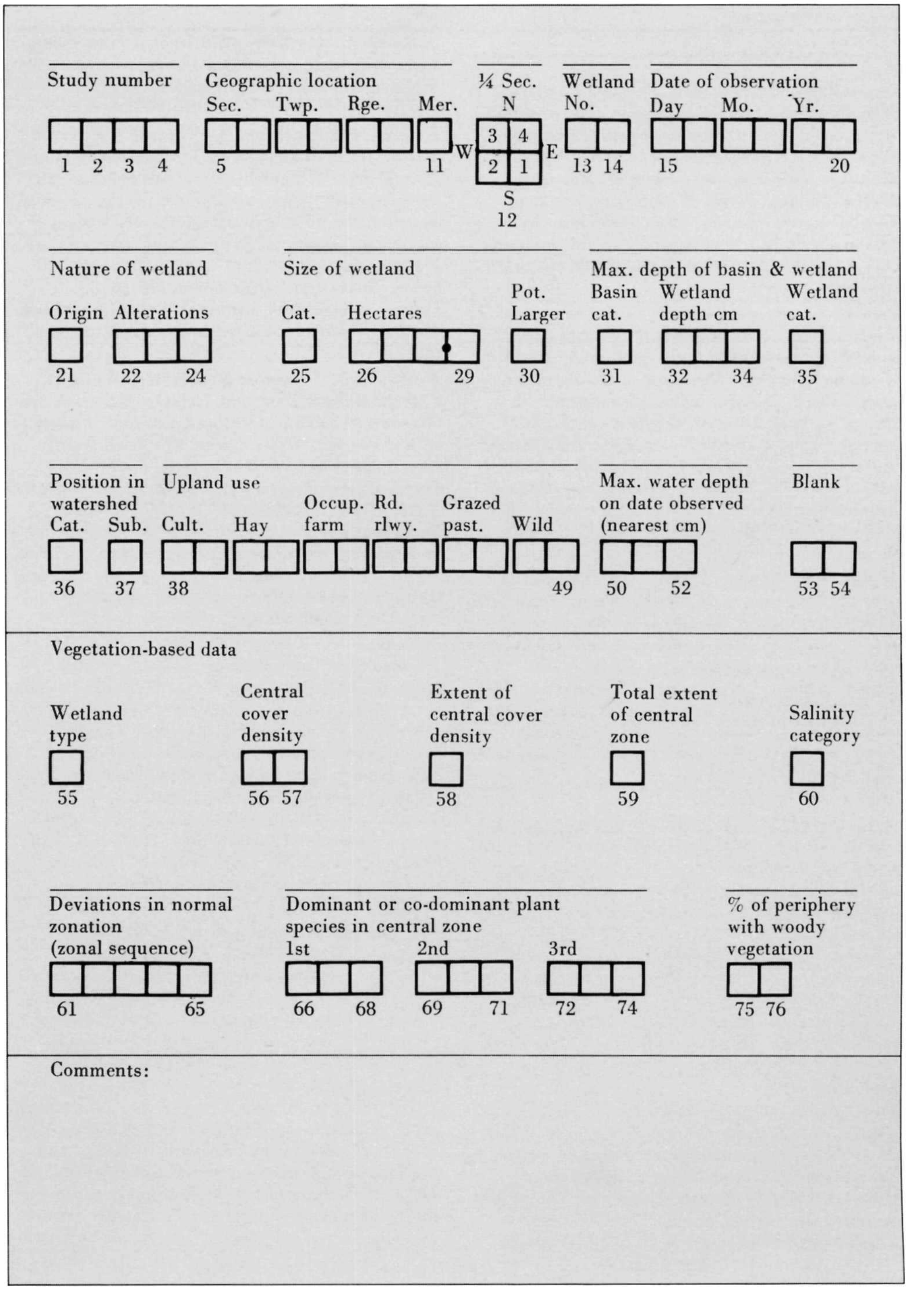
cont'd on page 35

Figure 8
Sample form for recording wetland assessment data in the field. This form is designed so that data can be easily transferred to computer punch cards

Appendix 2, cont'd

Columns	Data
66–74	Dominant or co-dominant plant species in the central vegetation zone: these columns provide for a maximum of three species to be coded according to the requirements of the project.
75–76	Peripheral shrub and tree growth (99% equals 100%). Note: this is added habitat data, not part of the classification system.

Figure 8



Appendix 3
Details of wetlands illustrated on front and back covers of this report

1. Front cover

Plate A.
Wetland type: Wet Meadow. *Vegetation pattern:* normal. *Extent of central vegetation zone:* over 95% of wetland diameter. *Density of central emergent cover:* Closed. *Extent of central cover density:* over 95% of wetland diameter. *Origin of cover density:* normal. *Salinity:* Fresh. *Wetland size:* less than 0.10 hectare (0.25 acre). *Basin depth:* less than 0.91 m (36.00 in.). *Position in watershed:* Isolated. *Origin of wetland:* natural. *Wetland and watershed alterations:* none.

Plate B.
Wetland type: Shallow Marsh. *Vegetation pattern:* normal. *Extent of central vegetation zone:* 76 to 95% of wetland diameter. *Density of central emergent cover:* Closed. *Extent of central cover density:* 76 to 95% of wetland diameter. *Origin of cover density:* normal. *Salinity:* Fresh. *Wetland size:* 0.21 to 0.40 hectare (0.51 to 1.00 acre). *Basin depth:* 0.91 to 2.00 m (36.00 to 78.70 in.). *Position in watershed:* Isolated-Perched. *Origin of wetland:* natural. *Wetland and watershed alterations:* none.

Plate C.
Wetland type: Shallow Marsh. *Vegetation pattern:* normal. *Extent of central vegetation zone:* 76 to 95% of wetland diameter. *Density of central emergent cover:* Semi-open. *Extent of central cover density:* 26 to 50% of wetland diameter. *Origin of cover density:* normal. *Salinity:* Fresh. *Wetland size:* 1.01 to 2.00 hectares (2.51 to 5.00 acres). *Basin depth:* over 2.00 m (78.70 in.). *Position in watershed:* Terminal. *Origin of wetland:* natural. *Wetland and watershed alterations:* none.

Plate D.
Wetland type: Shallow Marsh. *Vegetation pattern:* normal. *Extent of central vegetation zone:* 76 to 95% of wetland diameter. *Density of central emergent cover:* Closed (Semi-open condition shown exists only in early spring; this illustrates the problem of assessing cover before new growth develops). *Extent of central cover density:* 76 to 95% of wetland diameter. *Origin of cover density:* normal. *Salinity:* Fresh. *Wetland size:* 0.21 to 0.40 hectare (0.51 to 1.00 acre). *Basin depth:* over 2.00 m (78.70 in.). *Position in watershed:* Terminal. *Origin of wetland:* natural. *Wetland and watershed alterations:* none.

Plate E.
Wetland type: Emergent Deep Marsh. *Vegetation pattern:* normal. *Extent of central vegetation zone:* 76 to 95% of wetland diameter. *Density of central emergent cover:* Closed. *Extent of central cover density:* 76 to 95% of wetland diameter. *Origin of cover density:* normal. *Salinity:* Fresh. *Wetland size:* 2.01 to 4.00 hectares (5.01 to 10.00 acres). *Basin depth:* over 2.00 m (78.70 in.). *Position in watershed:* Terminal. *Origin of wetland:* natural. *Wetland and watershed alterations:* none.

Plate F.
Wetland type: Emergent Deep Marsh. *Vegetation pattern:* normal. *Extent of central vegetation zone:* 76 to 95% of wetland diameter. *Density of central emergent cover:* Semi-closed. *Extent of central cover density:* 76 to 95% of wetland diameter. *Origin of cover density:* normal. *Salinity:* Moderately Saline. *Wetland size:* 1.01 to 2.00 hectares (2.51 to 5.00 acres). *Basin depth:* over 2.00 m (78.70 in.). *Position in watershed:* Terminal. *Origin of wetland:* natural. *Wetland and watershed alterations:* none.

Plate G.
Wetland type: Disturbed (Cultivated) Wetland. *Vegetation pattern:* normal. *Extent of central vegetation zone:* over 95% of wetland diameter. *Density of central emergent cover:* Barren. *Extent of central cover density:* over 95% of wetland diameter. *Origin of cover density:* cultivation. *Salinity:* Fresh. *Wetland size:* less than 0.10 hectare (0.25 acre). *Basin depth:* less than 0.91 m (36.00 in.). *Position in watershed:* Overflow. *Origin of wetland:* natural. *Wetland and watershed alterations:* partial drainage through road ditch in foreground; watershed reduced by road ditch.

Plate H.
Wetland type: Disturbed (Drawdown) Wetland — normally a Shallow Open Water Wetland. *Vegetation pattern:* normal. *Extent of central vegetation zone:* 51 to 75% of wetland diameter. *Density of central emergent cover:* Barren. *Extent of central cover density:* 26 to 50% of wetland diameter. *Origin of cover density:* normal. *Salinity:* Fresh. *Wetland size:* 2.01 to 4.00 hectares (5.01 to 10.00 acres). *Basin depth:* over 2.00 m (78.70 in.). *Position in watershed:* Terminal. *Origin of wetland:* natural. *Wetland and watershed alterations:* none.

Plate I.
Wetland type: Disturbed (Grazed) Wetland — normally a Shallow Marsh. *Vegetation pattern:* normal (other than alterations). *Extent of central vegetation zone:* 76 to 95% of wetland diameter. *Density of central emergent cover:* Closed (disregarding dugout). *Extent of central cover density:* 76 to 95% of wetland diameter. *Origin of cover density:* artificial alteration of wetland depth. *Salinity:* Fresh. *Wetland size:* 0.41 to 1.00 hectare (1.01 to 2.50 acres). *Basin depth:* over 2.00 m (78.70 in.). *Position in watershed:* Isolated-Artificial Junction. *Origin of wetland:* natural. *Wetland and watershed alterations:* wetland area reduced by road grade; wetland depth increased with dugout; watershed area increased slightly by road ditches.

2. Back cover

Plate J.
Wetland type: Open Water Marsh. *Vegetation pattern:* normal. *Extent of central vegetation zone:* 51 to 75% of wetland diameter. *Density of central emergent cover:* not applicable. *Extent of central cover density:* not applicable. *Origin of cover density:* normal. *Salinity:* Fresh. *Wetland size:* 1.01 to 2.00 hectares (2.51 to 5.00 acres). *Basin depth:* 0.92 to 2.00 m (36.10 to 78.70 in.). *Position in watershed:* Channel. *Origin of wetland:* natural. *Wetland and watershed alterations:* none.

Plate K.
Wetland type: Open Water Marsh. *Vegetation pattern:* normal. *Extent of central vegetation zone:* 10 to 25% of wetland diameter. *Density of central cover:* not applicable. *Extent of central cover density:* not applicable. *Origin of cover density:* normal. *Salinity:* Fresh. *Wetland size:* 1.01 to 2.00 hectares (2.51 to 5.00 acres). *Basin depth:* over 2.00 m (78.70 in.). *Position in watershed:* Terminal. *Origin of wetland:* natural. *Wetland and watershed alterations:* none.
Note: The Shallow Open Water Zone is represented by a small central area of floating submergent vegetation. The rest of the visible water is a Semi-open Emergent Deep Marsh Zone.

Plate L.
Wetland type: Shallow Open Water Wetland. *Vegetation pattern:* Shallow Marsh Zone is missing. *Extent of central vegetation zone:* 76 to 95% of wetland diameter. *Density of central emergent cover:* not applicable. *Extent of central cover density:* not applicable. *Origin of cover density:* normal. *Salinity:* Fresh. *Wetland size:* 0.41 to 1.00 hectare (1.01 to 2.50 acres). *Basin depth:* over 2.00 m (78.70 in.). *Position in watershed:* Isolated — isolation artificially created through damming by road grade at photo site. *Origin of wetland:* natural. *Wetland and watershed alterations:* depth increased by road grade acting as a dam.

Plate M.
Wetland type: Shallow Open Water Wetland. *Vegetation pattern:* partial development of two Emergent Deep Marsh Zones. *Extent of central vegetation zone:* over 95% of wetland diameter. *Density of central emergent cover:* not applicable. *Extent of central cover density:* not applicable. *Origin of cover density:* normal. *Salinity:* Saline. *Wetland size:* 2.01 to 4.00 hectares (5.01 to 10.00 acres). *Basin depth:* over 2.00 m (78.70 in.). *Position in watershed:* Terminal. *Origin of wetland:* natural. *Wetland and watershed alterations:* watershed enlarged slightly by road ditches.

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Plate N.
Wetland type: Shallow Open Water Wetland. *Vegetation pattern:* Emergent Deep Marsh Zone absent probably because of grazing. *Extent of central vegetation zone:* over 95% of wetland diameter. *Density of central emergent cover:* not applicable. *Extent of central cover density:* not applicable. *Origin of cover density:* normal. *Salinity:* Fresh. *Wetland size:* 4.01 to 8.00 hectares (10.01 to 20.00 acres). *Basin depth:* over 2.00 m (78.70 in.). *Position in watershed:* Terminal. *Origin of wetland:* natural. *Wetland and watershed alterations:* none.

Plate O.
Wetland type: Shallow Open Water Wetland. *Vegetation pattern:* normal. *Extent of central vegetation zone:* 76 to 95% of wetland diameter (both basins). *Density of central emergent cover:* not applicable. *Extent of central cover density:* not applicable. *Origin of cover density:* normal. *Salinity:* Fresh. *Wetland size:* left, 2.01 to 4.00 hectares (5.01 to 10.00 acres); right, 1.01 to 2.00 hectares (2.51 to 5.00 acres). *Basin depth:* over 2.00 m (78.70 in.). *Position in watershed:* Terminal – Natural Junction. *Origin of wetland:* natural. *Wetland and watershed alterations:* Watershed has been enlarged through partial drainage of the wetland in the willow aspen grove (centre right) by the road ditch.

Plate P.
Wetland type: Open Alkali Wetland. *Vegetation pattern:* Emergent Deep Marsh Zone absent because of high salinity. *Extent of central vegetation zone:* over 95% of wetland diameter. *Density of central emergent cover:* not applicable. *Extent of central cover density:* not applicable. *Origin of cover density:* normal. *Salinity:* Hypersaline. *Wetland size:* over 16.00 hectares (40.00 acres). *Basin depth:* over 2.00 m (78.70 in.). *Position in watershed:* Terminal. *Origin of wetland:* natural. *Wetland and watershed alterations:* none.

Plate Q.
Wetland type: Transitional Open Water Wetland. *Vegetation pattern:* normal. *Extent of central vegetation zone:* 76 to 95% of wetland diameter. *Density of central emergent cover:* not applicable. *Extent of central cover density:* not applicable. *Origin of cover density:* normal. *Salinity:* Fresh. *Wetland size:* 0.11 to 0.20 hectare (0.26 to 0.50 acre). *Basin depth:* over 2.00 m (78.70 in.). *Position in watershed:* Isolated – Artificial Junction. *Origin of wetland:* natural. *Wetland and watershed alterations:* area reduced by road grade.

Plate R.
Wetland type: Transitional Open Water Wetland. *Vegetation pattern:* normal. *Extent of central vegetation zone:* over 95% of wetland diameter. *Density of central emergent cover:* not applicable. *Extent of central cover density:* not applicable. *Origin of cover density:* normal. *Salinity:* Fresh. *Wetland size:* 8.01 to 16.00 hectares (20.01 to 40.00 acres). *Basin depth:* over 2.00 m (78.70 in.). *Position in watershed:* Channel. *Origin of wetland:* natural. *Wetland and watershed alterations:* area reduced by road grade.
Note: This plate also illustrates a Perched Wetland (willow grove on horizon).

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