WETLAND REHABILITATION OF SURFACE COAL-MINED LANDS FOR WILDLIFE

by

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CHAPTER ONE

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INTRODUCTION

The Problem Area

In any mining operation, especially surface coal-mining, there is a great need for rehabilitation of the wetland zone for wildlife. All forms of wildlife require food, cover, water, and adequate territory within their habitat to survive and reproduce. Wetland zones provide some or all of these requirements to a diverse wildlife population. Wetland zones are important habitat to 80 of the 276 species (29%) currently on the Federal Threatened or Endangered Species List (Brinson et. al., 1981).

In spite of their ecological significance, many of our wetlands have been directly destroyed or converted to urban and agricultural land uses. When compared to all other habitat types in the United States, conversion of wetlands to other land uses represents some of the most severe altering of landforms (Kuchler, 1964). A review of wetland communities from information documented by federal and state agencies indicate that between the mid-1950's and the mid-1970's about 11 million acres of wetlands were lost (Tiner, 1984).

Surface coal mining has been an expanding form of mineral extraction for decades. With greater demands for non-renewable resources, surface mining for coal in wetland areas has been increasing. This trend will continue in the future since many of the most accessible coal seams are often located near wetland areas.

As the competition for land increases and our nation continues a quest for energy self-sufficiency, it is essential that land planners and decision makers develop and evaluate alternative approaches and innovative techniques to rehabilitate land. Land must be treated as a precious resource and rehabilitation must return it to a form and level of productivity that conforms with the premine land use (Law, 1984). Rehabilitation should provide a stable ecological state that does not contribute to environmental degradation and that is consistent with surrounding aesthetic values.

While rehabilitation of surface coal-mined lands has come a long way since the enactment of federal legislation regulating the reclamation and mining standards in the United States, very little attention has been given to the reconstruction of wetland ecosystems. The major emphasis of most research has involved slope stabilization and revegetation, while little has combined these to concentrate on the rehabilitation of a complete biological system. What is badly needed is a set of realistic recommendations that will allow mining companies the latitude necessary to remove the resource, but with enough control to ensure proper rehabilitation of the ecological communities.

Statement of the Problem

A great deal of multi-disciplinary information including groundwater and surface water hydrology, glacial geology, wetland botany, waterfowl biology, and soils have been incorporated into the designs and plans currently approved by State and Federal regulating agencies for rehabilitating wetlands. The first rehabilitated wetlands utilizing these plans are in place, but their success has not been documented in detail. There exists, therefore, a tremendous potential for rehabilitating wetland areas for wildlife benefit on surface coal-mined lands.

Our knowledge of rehabilitated wetland ecosystems and wildlife species requirements, when applied to the desired management priorities, should lead to feasible and cost-effective rehabilitation technology in rehabilitating these vital wetland areas. Improved wetland success standards may result from this application of information, resulting in the conservation of wetland habitat values and floral and faunal gene pools associated with wetlands.

Hypothesis

The major hypothesis is: There are differences existing between current results of rehabilitation of wetland habitat on surface coal-mined lands and unmined, natural wetlands as they affect wildlife.

A corollary hypothesis is: Surface-mined and rehabilitated wetlands can undergo a vegetational and associated habitat succession similar to the vegetational succession on relatively undisturbed natural wetlands, ultimately resulting in a wetland community closely resembling that of seasonal and semipermanent natural wetlands.

Scope of the Study

The study of wetland rehabilitation of surface coal-mined lands for wildlife benefit focuses on a comparison of rehabilitated surface coal-mined wetland habitat with an unmined natural wetland area in the same region of the United States. Important characteristics of wetland ecosystems will be measured and compared between the rehabilitated and unmined wetland conditions. The result will be a set of recommendations to further increase wildlife benefits on surface coal-mined lands.

Objectives

The primary objectives of this study are as follows:

1. To evaluate the appropriateness and practicality of rehabilitation of surface coal-mined lands for wildlife as a primary land use.

2. To study the site conditions of rehabilitated surface coal-mined wetlands and compare them to unmined natural wetlands to identify important wetland wildlife values and measure the wildlife habitat suitability of rehabilitated wetlands.

3. To analyze the Gleasonian model of vegetational succession in wetlands developed by Van der Valk (1981) to determine its application to rehabilitated wetland vegetation succession.

4. To evaluate the integration of various remote sensing techniques with ground data collection techniques used on the research sites to measure the important wildlife parameters of the wetlands.

5. To make recommendations to improve wetland rehabilitation for wildlife value.

CHAPTER TWO

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LITERATURE REVIEW

DESCRIPTION OF WETLAND HABITAT

DEFINITION

Through the years a great number of definitions have appeared in the literature describing the term "wetland". Wetlands are known by such common names as: swamps, marshes, sloughs, potholes, bogs, mudflats, beaches, and shores. Since these common names have different meanings in different regions of the United States, the term wetland is used to cover all of them.

Common in most definitions is that wetlands are transitional areas between terrestrial and aquatic systems where saturation with water is the dominant factor determining the types of soil development and plant and animal communities living in the soil and on its surface (Cowardin et. al., 1979).

The Fish and Wildlife Service (Cowardin et. al., 1979) defines a wetland as "land where the water table is at, near or above the surface long enough each year to promote the formation of wetland (hydric) soils and to support the growth of wetland plants (hydrophytes). In certain types of wetlands, vegetation is lacking and soils are poorly developed or absent as a result of frequent and drastic fluctuations of surface-water levels, wave action, water, flows, turbidity or high concentrations of salts or other substances in the water substrate. Such wetlands can be recognized by the presence of surface water or saturated substrate at some time during each year and their location within, or adjacent to, vegetated wetlands or deep-water habitats." The U.S. Fish and Wildlife Service uses this presence or absence of hydric soils, hydrophytes, and change from land that is flooded or saturated for some period of time during normal years to land that is not to define the upper limit of a wetland. The lower limit of the wetland in fresh water is set at a depth of two meters below low water or to the limit of growth into the water of emergents, shrubs, or trees (Cowardin et. al., 1979).

The Executive Order on the Protection of Wetlands issued by President Carter on May 24, 1977, defined wetlands as "those areas that are inundated by surface or groundwater with a frequency sufficient to support and under normal circumstances does or would support a prevalence of vegetative or aquatic life that requires saturated or seasonally saturated soil conditions for growth and reproduction," (Reppert et. al., 1979).

GENERAL CHARACTERISTICS

Wetlands may be sandy, intertidal marshes with little vegetation, others may have high water tables with grasses and shrubs dominating, while others may have little water present and be dominated by tall trees. Regardless of the wetland type or appearance all wetlands have important unifying characteristics that distinguish them from other types of landscapes.

Wetland habitats are distinguished by the degree of exposure to the water. Plant and animal communities found in wetlands differ from those of surrounding areas because the ground is more moist and suited to plant and animal species that succeed in wet conditions. Yet wetlands vary a great deal, depending in part on the pattern of saturation at individual sites. Different plant species are adapted to water tolerances at different depths such as species that are found during a season of the year when there is no standing water visible. Coastal wetlands may be inundated by tides each day. Other wetland areas may be wet only seasonally. Characteristics such as water temperature, water depth, and water chemistry may also influence the nature of wetlands.

Wetlands are the interface area that separates water habitats from upland habitats and are greatly influenced by inputs from both environments. Runoff from upland habitats flows into wetlands, carrying sediments and pollutants. When water habitats flood, the wetland community is stressed by rising water elevations.

While all wetlands serve as interface areas between water and upland habitats, they differ greatly from site to site. Wetlands can be further distinguished by the characteristics of size, location, and condition.

Wetlands vary greatly in size, from broad tidal marshes along the Southeast and Gulf Coast to small pockets in arid areas of the West and the once glaciated prairie potholes of the Northern Plains. Size does not affect the ability of wetlands to perform important functions associated with the wetland type. Some of the smallest wetlands serve important biological and economic functions as well as larger wetlands.

The location of a wetland area in relation to its adjacent ecosystems and human activities has a great influence on the functions it can perform. Human activities that alter land adjacent to wetlands, such as land development for building sites or clearing for agriculture, alter key natural inputs sustaining wetlands, including the rate and pattern of water flow and the rate, pattern, and composition of sediments. A second aspect of wetland location is the relationship among types. In many areas wetlands of different types are found in close proximity where they exchange materials and chemicals and increase the ecological diversity and productivity of the regional wetland ecosystem.

The condition of a wetland is an important variable for the assessment of its functional potential. The most productive wetlands, those that support large and diverse populations, usually have minimal human modification. Wetlands are dynamic and transitory systems that respond rapidly to external change. Wetlands can be manipulated to provide a desired function, but often the diversity of the system's productivity is reduced.

FUNCTIONS AND VALUES OF WETLANDS

Wetlands in their natural condition provide a wealth of values to society. Wetland benefits can be divided into three categories: 1) Environmental Quality Values, 2) Socio-economic Values, and 3) Fish and Wildlife Values (Tiner, 1984).

Environmental Quality Values. Wetlands play an important role in maintaining high environmental quality standards, particularly in aquatic habitats. They are able to do this in several ways, including purifying natural waters by removing nutrients, chemical and organic pollutants, and sediments, and producing food for support of aquatic organisms (Tiner, 1984).

Wetlands are good water filters because of their location between land and water habitats, allowing them to intercept runoff from land before it reaches the water. This allows wetlands to remove some nutrients, especially nitrogen and phosphorus which are essential for plant growth, from flooding waters, yet helps to prevent overenrichment of natural waters.

Wetlands serve an important function in removing waste products from water. Some wetland plants are so efficient at this task that some artificial waste treatment systems are using them as part of the purifying procedure. For example, 96 wastewater treatment facilities in the Great Lakes States were utilizing cattail marshes as purifying agents (Radtke, 1984). Bottomland forested wetlands along the Alcovy River in Georgia filter impurities from flooding waters. Human and chicken wastes grossly pollute the river upstream, but after passing through less than three miles of swamp, the water quality of the river is greatly improved. The value of the 2,300 acre Alcovy River Swamp for water pollution control was estimated at $1 million per year (Wharton, 1970).

The ability of wetlands to treat wastes varies with the wetland's condition. Stressed wetlands usually have diminished capacities, and further introduction of wastes increasingly stresses the overall system. Waste absorption reduces other functional values, especially for wildlife.

Wetlands play an invaluable role in reducing the turbidity of flooding waters. Reduction of turbidity is important for aquatic life and in reducing siltation of harbors, rivers, and reservoirs. Reduction of the sediment load is valuable because sediments often transport absorbed nutrients, pesticides, heavy metals, and other toxins which pollute wetlands (Tiner, 1984).

Wetlands are among the most productive ecosystems in the world. Wetland plants are very efficient converters of solar energy. Through photosynthesis, plants convert sunlight into plant material or biomass, with oxygen produced as a by-product. The biomass serves as food for a great number of animals, both aquatic and terrestrial. When the plants die they fragment to form detritus. Detritus forms the base of an aquatic food web fed on by animals like shrimp, snails, and worms. Many of these animals are the primary food for commercial and recreational fishes, such as salmon. Thus, wetlands can be thought of as farmlands of the aquatic environment produbcing great amounts of food annually. The majority of non-marine aquatic animals are either directly or indirectly dependent on this food resource.

Socio-Economic Values. The more tangible benefits of wetlands to mankind are considered to be socio-economic values. Socio-economic functions and values can usually be separated into one of two categories, consumptive and nonconsumptive. The consumptive category includes those products, such as food, fuel, or fiber, or processes, such flood control, and erosion control that are dependent on wetlands and provide physical benefits to mankind. The nonconsumptive category includes scenic, recreational, educational, and historical values experienced by individuals, while preserving the natural qualities of the wetland.

One of the most important consumptive benefits of wetlands is flood control. Wetlands provide a natural means of flood control by retaining water during periods of high runoff, thereby protecting property owners from flood damage. The flood retention function also helps to slow the velocity of water and lower wave heights, reducing the erosive potential of the water. Rather than all flood waters flowing rapidly downstream and destroying private property and crops, wetlands slow the water flow, store it for some time, and slowly release stored water downstream. Studies have shown wetlands can retain 50 to 80% of the total runoff (Radtke, 1984). A study of Wisconsin watersheds concluded that flood flows are 80% lower and sediment yields are 90% lower in basins consisting of 40% lake and wetland areas than in basins with no lakes and wetlands (Radtke, 1984).

Another consumptive benefit derived from wetlands is erosion control. The location of wetlands between watercourses and uplands helps protect uplands from erosion. According to Tiner (1984), wetland vegetation helps reduce shoreline erosion in several ways, including: 1) increasing sediment durability through binding with its roots, 2) dampening waves through friction, and 3) reducing current velocity through friction and trapping sediment.

The effectiveness of shoreline vegetation in erosion control depends on the flood tolerance of the plant species involved, the width of the vegetated shoreline band, the vegetation band efficiency in trapping sediments, the bank or shore soil composition, the bank or shore height or slope, and the bank elevation with respect to the mean storm high water (Sather and Smith, 1984). Silberhorn et al. (1974) stated that any marsh vegetation two feet or more in average width has significant value as an erosion deterrent. Garbisch (1977) concurred about the erosion control value of wetland vegetation specifying ten feet as the minimum width required to reduce erosion.

Most wetlands are areas of groundwater recharge and some provide usable quantities of water for the public. At least 60 municipalities in Massachusetts have public wells used for drinking in or very near wetlands (Tiner, 1984).

The role that wetlands play in groundwater recharge is still not well understood. The recharge potential of wetlands varies according to many factors, including wetland type, geographic location, season, soil type, water table location, and precipitation (Tiner, 1984). Depressional wetlands like cypress domes in Florida and prairie potholes in the Dakotas may contribute to groundwater recharge (Odum, et al., 1975; Stewart and Kantrud, 1972; Winter and Carr, 1980).

There is a variety of consumptive products produced by wetlands, including timber, fish and shellfish, wildlife, peat, cranberries, blueberries, and wild rice (Tiner, 1984). Livestock graze in many wetlands across the country and wetland grasses are used for their winter feed in many places. These and other products are harvested for the use and livelihood of many people.

There are an estimated 82 million acres of commercial forested wetlands in the 49 continental states (Tiner, 1984). Most of these forests, which provide timber for a multitude of uses, are located east of the Rockies. The standing value of southern wetland forests alone is $8 billion (Tiner, 1984).

Wetlands also produce fish and wildlife for our use. Commercial fishermen and trappers make a living from such species as salmon, shrimp, catfish, muskrat, mink, and beaver.

Many wetlands produce peat used for horticulture and agriculture in the United States. Over 52 million acres of peat deposits are found in our nation (Tiner, 1984).

There are many nonconsumptive uses and values of wetlands such as recreational activities. In 1980, 5.3 million people spent $638 million on hunting waterfowl and other migratory birds (Tiner, 1984). Saltwater fishing has increased greatly over the last 20 years, with half of the total catch represented by wetland species. All freshwater fishing is dependent on wetlands and in 1975 alone, sportfishermen spent $13.1 billion on this activity (Tiner, 1984).

Other nonconsumptive activites of wetlands include hiking, nature observation, photography, swimming, boating, and ice-skating. Many people enjoy the beauty and sounds of nature and spend a good deal of their leisure time hiking or boating in or near wetlands observing plant and animal life. It is extremely difficult to evaluate the aesthetic value or place a dollar value on wetlands for nonconsumptive uses.

<u>Fish and Wildlife Values</u>. The variety of wetlands across the country provides many values important for fish and wildlife. Since these values are vital to the background of the study they will be discussed as a separate section.

VALUES OF WETLANDS TO FISH AND WILDLIFE

Wetlands provide unique environments in which a variety of natural functions are carried out. In many cases, the aquatic ecosystem is extremely productive and supports numerous, complex food chains representing important sources of energy to plants and animals. In addition to energy production wetlands provide valuable habitat for a wide diversity of aquatic and terrestrial organisms. Many of these areas are vital as spawning, rearing, and feeding grounds for economically important fish and shellfish. Since wetlands provide the basis for so many food chains and habitats, it is convenient to separate the discussion of these two interdependent values into: 1.) food chain production; and 2.) habitat for aquatic and terrestrial species.

FOOD CHAIN PRODUCTION

The transfer of food energy from the source in producing plants through a series of consumers is referred to as the food chain. The food chain in wetlands, as in all ecosystems, is based on primary productivity.

Primary productivity is a basic measure of energy flow and is defined as the rate at which producers (chiefly green plants) assimilate the energy of sunlight and store it as potential food resources for consumers (wildlife) (Reppert et. al., 1979). A portion of the plant tissue produced through photosynthesis is consumed by animals while the plants are living and another portion is consumed after the plants die.

The primary productivity determines the growth of vegetation in the wetland and influences the populations and secondary productivity of animals that feed on the plants, or that feed at higher trophic levels in the ecosystem. Net primary productivity is then a measure of the stored food potential of the vegetation in excess of the energy used by the plants in metabolism.

Productivity is an important factor in evaluating a wetland ecosystem. The range of productivity values is extremely variable and depends on a number of local conditions, both within and between particular wetland habitats. The regional variations are environmentally dependent and reflect latitudinal differences in solar radiation, mean annual temperature, and precipitation (Reppert et. al., 1979).

Wetlands are among the most productive ecosystems in the world. Wetlands along the East Coast produce about five to ten tons of organic matter per acre annually (Teal, 1969). The total energy input of primary production of wetlands comes from three sources: 1) macrophytes (marsh grasses, sea grasses, macroalgae, and terrestrial plants); 2) benthic or bottom microalgae; and 3) phytoplankton

(Reppert et al., 1979).

Wetland vegetation provides nutrients to the food chains of consumer species through two main pathways. The grazing food chain is the direct consumption of live vegetation by herbivore species (insects, fish, waterfowl, and mammals). The grazing food chain is very important in freshwater habitats as many species of waterfowl and fish are largely dependent on aquatic plants for food. Ducks, geese, and muskrats, to name a few species, are dependent upon a variety of wetland plants for most of their nutritional intake.

The second pathway, the detrital food chain, represents the largest source of potential energy available to consumer species. The detritus pathway involves the consumption of dead plant materials in various stages of decomposition by low level herbivores. During decomposition, plants undergo a series of physical and biochemical changes which result in a continuous particle size reduction and changes in composition. The plant tissue particles provide a substrate for bacteria, fungi, and other microorganisms, which add to the nutritive value of the detritus (Sather and Smith, 1984). A large number and variety of heterotrophic consumers utilize the dissolved nutrients and detritus particles produced by the decomposition process and in turn supply the nutrient requirements of higher trophic level consumers. In freshwater wetlands the detrital food chain supplies food to aquatic consumers from three major sources: 1) marsh detritus; 2) phytoplankton; 3) detritus from terrestrial sources introduced by upland drainage (Reppert et. al., 1979).

HABITAT FOR AQUATIC AND TERRESTRIAL SPECIES

Wetlands occupy the transitional zone between aquatic and terrestrial environments and provide important habitats for a wide diversity of wildlife species. Habitat is generally defined as the place where a particular plant or animal lives. The concept of a habitat involves more than just locale, such as the consideration of the ranges and seasonal variations in the environment through evolutionary time, and the definition of the ecological niche of the organism in the trophic structure of the community (Reppert et. al., 1979). Wetlands act as a type of habitat that fulfills a specific function whether it is as a feeding area, breeding site, resting area, moulting grounds, or provides nesting materials or protection from weather or predators. Some animals depend on wetlands for all these functions and spend their entire life cycle within a particular wetland. Other animal species use wetlands for only part of their life functions and are wetland residents only during a particular portion of their life cycle or season of the year.

Many factors are important in determining the value of wetlands as habitat for wildlife. The structure and species diversity of the vegetation, spatial patterns within and between wetlands, vertical and horizontal zonation, size, water chemistry, and surrounding land uses are important factors affecting wetland habitat values for wildlife.

The variety of wetlands across the country create habitats for many forms of wildlife. Fish and shellfish, waterfowl and other birds, mammals, and other forms of wildlife are dependent upon wetlands for important habitat.

Fish and Shellfish Habitat. Inland, estuarine, and coastal wetlands are essential in maintaining valuable fish populations, and in producing shrimp, crab, oysters, and clams for our consumption.

About two-thirds of the major commercial fishes in the nation depend on estuaries and salt marshes for spawning or nursery grounds (Tiner, 1984). Coastal marshes along the Atlantic, Gulf Coast, and Pacific Northwest are also important for spawning and rearing. Commercial species such as bluefish, mullet, striped bass, and drum are all wetland dependent.

Coastal wetlands provide important habitat for shellfish like shrimp, blue crabs, oysters, and clams. The areas serve as the primary nursery grounds and scientific studies have demonstrated a direct correlation between the amount of coastal marsh and shrimp production (Tiner, 1984).

Freshwater fishes also depend on wetlands for survival. Most freshwater fishes can be considered dependent on wetland because: 1) many species feed in wetlands or upon wetland produced food, 2) many fishes use wetlands as nursery grounds, and 3) most important recreational fishes spawn in aquatic portions of wetlands (Tiner, 1984). The marshes along Lake Michigan are spawning grounds for northern pike, yellow perch, smallmouth bass, largemouth bass, bullhead, bluegill, and other fishes (Tiner, 1984). Bottomland hardwood forests of the Southern U.S. serve as feeding and nursery grounds for young warmouth and largemouth bass, and adult bass feed and spawn in these wetlands (Tiner, 1984). Wetland vegetation along western rivers is important to fishes in several ways, providing cover, shade for regulation of water temperatures, and food.

Birds. Wetlands are not only important in providing year- round habitat for resident birds, but are especially valuable as breeding grounds, overwintering areas, and feeding grounds for migratory waterfowl and other birds.

Throughout the nation the importance of riparian forested wetlands along rivers for nesting and migration stopovers has been well documented. Avian breeding densities in riparian habitats are greater than in associated upland areas (Brinson et al., 1981). In a study of four woodland habitats, the riparian area was found to possess not only the most diverse bird population during the breeding season, but also during the winter and spring migrations (Svedarsky et al., 1982). In the West, riparian areas have been known to have as many as 94 species nesting in riparian vegetation. These areas are important due to availability of food, cover, and water during the migration season as well as during nesting.

Freshwater wetlands provide important habitat for a diverse variety of nongame birds. Bottomland forested wetlands of the South are the primary wintering grounds for herons, egrets, barred owls, downy and red-bellied woodpeckers, cardinals, and wood thrushes (Tiner, 1984).

In the Northeast, where red maple swamps are among the most common wetland types, a study of breeding birds in eight Massachusetts swamps revealed a total of 46 species breeding in these areas (Tiner, 1984). The most common species were yellowthroat, veery, Canada warbler, ovenbird, northern waterthrush, and gray catbird (Tiner, 1984).

Atlantic coastal marshes are also important feeding and resting areas for shorebirds, wading birds, and others.

These marshes provide nesting habitat for species as laughing gulls, Forster's terns, sharp-tailed sparrows, willets, and marsh hawks. Wading birds like herons and egrets also feed and nest in these wetland. The intertidal mudflats along the coasts are important feeding grounds for migratory shorebirds such as plovers, and oystercatchers, as well as chimney swifts and swallows which feed on insects as they fly over the marshes (Tiner, 1984).

A wide variety of gamebirds depend on wetlands for survival. The most important type of gamebird dependent on wetlands is waterfowl (ducks and geese).

Salt marshes along the Atlantic are used for nesting by black ducks and are prime wintering grounds for black ducks, snow geese, and others. Nearly the entire Pacific Flyway populations of Canada geese and white-fronted geese nest in Alaska's Yukon-Kuskokwim Delta and rely in migration on the coastal marshes.

Freshwater wetlands provide the most important nesting, migrating, and winter habitat for the most species of waterfowl (Reppert et al., 1979). The Prairie Pothole Region of the Great Plains is the most important breeding ground for ducks in North America and is thus referred to as the "duck factory" (Reppert et al., 1979). Pothole nesters include 15 species with mallard, pintail, and blue-winged teal as the most abundant (Tiner, 1984). Many of these species use different types of wetlands for mating and for rearing their young (Tiner, 1984). Individual mallard hens may use more than 20 different wetlands during the nesting season (Tiner, 1984).

Freshwater wetlands in southern states, especially those along migratory corridors, provide important nesting, wintering and resting habitats for large populations of ducks and geese. More than two-thirds of the waterfowl of the Mississippi Flyway winter in wetlands in Louisiana.

Wetlands provide important habitat for other types of gamebirds as well as waterfowl. The prairie potholes and other inland emergent wetlands provide important winter cover and nesting habitat for ring-necked pheasant. The pheasant population in east-central Wisconsin is directly related to the distribution and amount of wetlands present (Tiner, 1984). Playa lakes in the Texas Panhandle are important nesting habitats for pheasants and mourning doves. In Southern bottomland forests wild turkey are common nesters.

Mammals. A large number of mammals are wetland dependent for a variety of reasons. Large mammals, such as bear, deer, and moose, rely on wetlands for a great proportion of their habitat requirements, especially food and cover.

To furbearing mammals like muskrats, beavers, otters, mink, and nutria wetlands are critical habitat. Muskrats, the most wide-ranging of the group, are found in both coastal and inland wetlands. Muskrats are widely distributed in North America and range from subtropical rivers and coastal marshes of the Southeast to the Arctic tundra. Throughout their range, muskrats adapt to a variety of habitat conditions. In general they require water deep enough to allow them to remain active under the ice during the winter in their northern latitudes and to support the growth of emergent plants for food and cover. Large water level flucuations cause serious problems for muskrats, either flooding their houses in high water or causing them to be more vulnerable to predators during low water periods.

The habitat requirements of nutria and beaver are similar to those of muskrats. Nutria, found in Southeastern coastal marshes, prefer fresh over brackish water (Sather and Smith, 1984). Beaver, although they sometimes use the same habitat as muskrats, are more dependent on the presence of woody vegetation (Sather and Smith, 1984).

Although mink and otter depend on wetland for food and cover, there is surprisingly little information on the life history and ecology of these two economically important species (Sather and Smith, 1984).

Other mammals also frequent wetlands such as marsh and swamp rabbits, raccoons, skunks, weasels, bog lemmings, shrews, wood rats, and numerous mouse species. Most populations of these species live in wetland, as well as the adjoining upland habitats, utilizing the habitat for food and cover.

<u>Other Wildlife.</u> Other wildlife forms which make their homes in wetlands are invertebrates, turtles, snakes, and amphibians.

Wetlands are habitat for many invertebrates like insects and spiders. A tremendous variety of these types of organisms occur in wetlands, and there is a great variation in the kinds and numbers that different wetland types will support.

Turtles are most common in freshwater wetlands. Some of the more important are the painted, spotted, Blanding's, mud, map, musk, and snapping turtles (Tiner, 1984).

Many snakes inhabit wetlands like water snakes, cottonmouth or water moccasin, pygmy rattlesnake, queen, mud, and swamp snakes. Copperheads, rough green, and rat snakes are inhabitants of southern bottomland wetlands (Tiner, 1984). The San Francisco garter snake, an endangered species, requires wetlands for its survival

(Tiner, 1984).

The largest reptiles found in the U.S., the American alligator and the American crocodile live in wetlands. The crocodile, an endangered species, inhabits mangroves and coastal waters of Florida Bay (Tiner, 1984). The alligator lives in brackish and freshwater wetlands of Florida north to North Carolina and west to Texas (Tiner, 1984).

Almost all of the 190 species of amphibians in North America are dependent on wetlands, at least for breeding (Tiner, 1984). Every freshwater wetland in the U.S., except the tundra, has some amphibians. Frogs such as the bull, green, leopard, pickerel, wood, chorus, and spring peeper live their entire lives in wetlands. Many salamanders use wetlands for breeding, although they spend most of their lives in uplands. The numbers of amphibians, even in the smallest wetlands, can be surprising. In a small gum pond (less than 100 feet wide) in Georgia, 1,600 salamanders and 3,800 frogs and toads were found (Tiner, 1984).

CURRENT STATUS AND TRENDS OF U.S. WETLANDS

CURRENT STATUS

Wetlands are found in every state in our nation. Their abundance is variable due to the differences in climate, soils, geology, land uses, and other regional differences (Tiner, 1984). Alaska, Florida, and Louisiana contain the greatest amounts of wetland acreage. Alabama, Arkansas, Georgia, Maine, Michigan, Minnesota, Mississippi, North Carolina, North Dakota, South Carolina, South Dakota, and Wisconsin all have large amounts of wetland acreage. Smaller states like Connecticutt, Delaware, Maryland, Massachusetts, New Jersey, and Rhode Island also have conbiderable wetland acres. (Figure 2.1 shows the estimated wetland extent within each of the fifty states).

In the mid-1970's, an estimated 99 million acres of wetlands remained in the conterminous United States, occupying only 5% of the land surface of the lower 48 states (Frayer et al., 1982). This amounts to an area equal in size to the state of California (Tiner, 1984). Alaska and Hawaii are not included in these figures, but the estimated extent of Alaska's wetlands is approximately 200 million acres (Tiner, 1984).

The most abundant wetland types in the conterminous U.S. are palustrine (freshwater) and estuarine (brackish) wetlands. Palustrine wetlands, including freshwater marshes and swamps, make up 94% of the wetlands of the lower 48 states (Tiner, 1984). In the mid-1970's palustrine wetlands accounted for 93.7 million acres, with over half of this acreage being forested wetland and about a third consisting of emergent wetland (Tiner, 1984). The remaining palustrine wetland acreage, mostly shrub

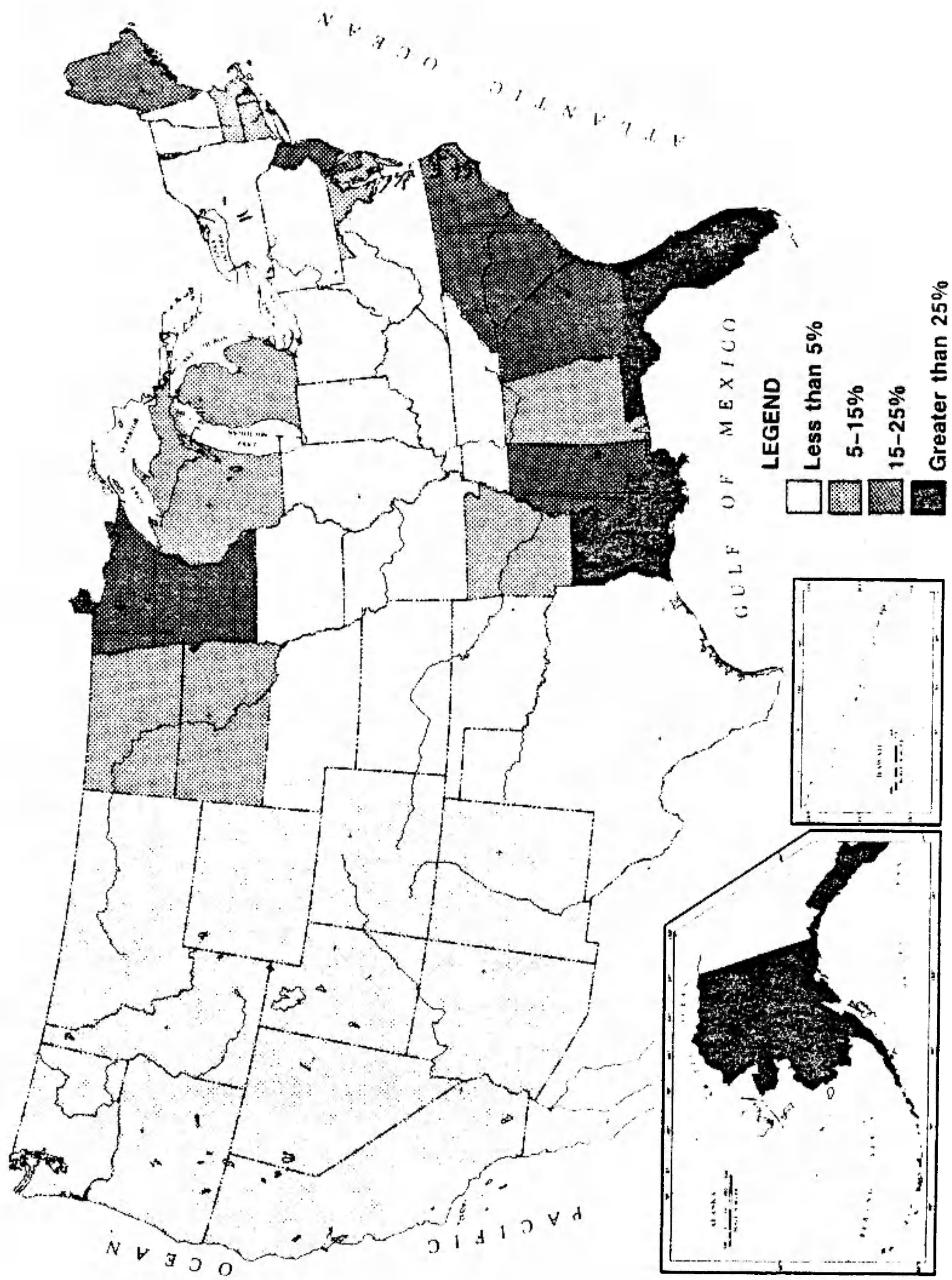

FIGURE 2.1 RELATIVE ABUNDANCE OF WETLANDS IN THE U.S.
(Source: Tiner, 1984)

wetlands, make up the other 15% (Tiner, 1984). In contrast, only 5.2 million acres of estuarine wetlands existed by the mid-1970's, amounting to about 0.3% of the land surface of the lower 48 states (Tiner, 1984).

WETLAND LOSSES

Since the available information is largely incomplete, estimates of the original wetland acreage present at the time of this country's settlement vary. However, a very reliable account estimates this acreage at 215 million acres for the conterminous United States (Tiner, 1984). Thus, today's wetlands in the lower 48 states represent approximately 46% or less of our original wetlands (Tiner, 1984).

Wetland losses have been enormous in the last 20 years. In the mid-1950's, wetland acreage in the lower 48 states was estimated to be 108.1 million acres (Frayer et al., 1982). By the mid-1970's these wetlands had been reduced to 99 million acres, despite some gains in wetlands due to reservoir and pond construction, irrigation, and by creating new marsh areas (Frayer et al., 1982). The 9 million acre difference equates into a loss of wetland area equal to twice the size of New Jersey (Tiner, 1984). From the mid-1950's to the mid-1970's the average annual loss was 458,000 acres per year: 439,000 acres of palustrine losses and 19,000 acres of estuarine losses (Frayer et al., 1982).

The largest percentage of wetland losses in individual states have occurred in Louisiana, Mississippi, Arkansas, North Carolina, North Dakota, South Dakota, Nebraska, Florida, and Texas (Tiner, 1984). Iowa, Illinois, and Missouri have lost at least 25% of their wetlands in the last 25 years (Radtke, 1984). (Table 2.1 gives examples of wetland losses in various states).

The greatest losses of forested wetlands were in the Lower Mississippi Valley with the conversion of bottomland forests to farmland. Bottomland hardwoods have declined from 12 million to 5.2 million acres in this region (Radtke, 1984).

Shrub wetlands have suffered the greatest losses in North Carolina where upland coastal plain swamps are being converted to farmland, pine plantations, or mined for peat.

Inland marsh drainage was most significant in the Prairie Pothole Region occurring at the rate of 1-2% per year, some 15,000 to 20,000 acres per year in Minnesota, North Dakota, and South Dakota (Radtke, 1984). Nebraska's Sandhill Region and Florida's Everglades also suffered large losses due to drainage.

Between the mid-1950's and the mid-1970's estuarine wetland losses were greatest in the Gulf states of Louisiana, Florida, and Texas (Tiner, 1984). The losses of coastal marshes in Louisiana were due mostly to submergence by coastal waters.

TABLE 2.1 HIGHEST WETLAND LOSSES IN INDIVIDUAL STATES

STATE AND/OR REGION	ORIGINAL WETLANDS (acres)	TODAY'S WETLANDS (acres)	% WETLANDS LOST
Iowa (prairie potholes)	2,333,000	26,470	99%
California	5,000,000	450,000	91%
Nebraska (rainwater basin)	94,000	8,460	91%
Mississippi (alluvial plain)	24,000,000	5,200,000	78%
Michigan	11,200,000	3,200,000	71%
North Dakota (prairie potholes)	5,000,000	2,000,000	60%
Minnesota	18,400,000	8,700,000	53%
Louisiana (forested wetlands)	11,300,000	5,635,000	50%
Connecticut (coastal marshes)	30,000	15,000	50%
North Carolina (pocosins)	2,500,000	1,503,000	40%
South Dakota (prairie potholes)	2,000,000	1,300,000	35%
Wisconsin	10,000,000	6,750,000	32%

Source: Tiner, 1984.

ACTIVITIES WHICH IMPACT WETLANDS

Wetlands are dynamic natural environments which are subjected to both human and natural activities that result in wetland losses or gains and affect the wetland quality. (Table 2.2 outlines major causes of wetland loss and degradation).

Natural Activities. Natural occurences influencing wetlands include the hydrologic cycle, natural succession, sedimentation, erosion, beaver dam construction, seasonal changes in sea level, and fire (Tiner, 1984). The hydrologic cycle is the natural cycle of wet and dry periods over time. Prairie Pothole water levels, for example, flucuate greatly on an approximate 5-10 year cycle. This adds an important dimension to wetlands, making them susceptible to drainage during dry periods. Natural succession and fire typically change or influence the change in vegetation of a wetland. The activities of beaver create or alter wetlands by damming stream channels. In summary natural forces act in a variety of ways to create, destroy, or modify wetlands.

Human Activities. Wetlands are altered by human activities in many ways. Unfortunately, many activities are destructive to wetlands, converting them to agriculture or other land uses or degrading their quality. Wetlands may be directly altered by filling, dredging, draining or creating impoundments. Indirectly, alteration of waterflow patterns at other locations and changes in the adjacent land use can change the functions and values of the wetland.

TABLE 2.2 MAJOR CAUSES OF WETLAND LOSS AND DEGRADATION

DIRECT HUMAN THREATS:

1. Direct removal of vegetation.

2. Direct removal of topsoil.

3. Habitat destruction of dumping and surfacing.
   - Landfill from construction projects.
   - Hard-topping for roads and factories, etc.
   - Grading and concreting for drainage ditches.
   - Dumping of mine overburden, spoil, & tailings.
   - Dumping of dredged material.
   - Discharges of materials (pesticides, herbicides, sewage, other pollutants & sediment runoff).
   - Levee and dike construction for flood control, irrigation, water supply, & storm runoff.
   - Construction of access, logging, and mining roads.

4. Habitat destruction by digging.
   - Ditching.
   - Mining of wetland soils for peat, coal, sand, gravel, phosphate and other materials.
   - Dredging and stream channelization for navigation channels, flood protection, etc.

5. Habitat modification by water level manipulation.
   - Permanent flooding.
   - Alternate flooding.
   - Protection from normal flooding.
   - Drainage for crop & timber production & mosquito control.
   - Lowering of the soil water table.

TABLE 2.2 CONT'D.

INDIRECT HUMAN THREATS:

1. Habitat modification by erosion and loss of nutrients.

2. Habitat modification by chemical changes in wetlands.
   - By leaching of acids, metals, & sulfides from soil.
   - By leaching of chemicals from pavement.
   - By addition of salts (sodium & calcium chloride).
   - By motor vehicle wastes (petrolem products).

3. Sediment diversion by dams & other structures.

4. Hydrologic alterations from canals, spoil banks, & roads.

5. Subsidence due to extraction of groundwater, oil, gas, coal, and other minerals.

6. Introduction of exotic species.

NATURAL THREATS

1. Subsidence from natural causes such as sea level changes.

2. Droughts.

3. Hurricanes and other storms.

4. Erosion.

5. Biotic effects, such as heavy feeding by muskrats, geese, and other wetland wildlife.

Source: Zinn and Copeland,1982.

Filling of wetlands is done for a variety of purposes, ranging from construction of industrial plants to building of causeways for transportation corridors. Wetlands next to river channels have often been the most cost effective sites for fill from disposal of dredged material.

Filling destroys wetlands by smothering the habitat and raising the surface elevation. This activity develops a less productive habitat which is not subject to saturation or periodic inundation. Sediment is washed into the adjacent wetland and streams if the fill edges are not stabilized. In short, filling alters the functions of the wetland and can lead to drier or wetter conditions on the adjacent wetland.

Dredging is often done in wetlands or in adjacent stream channels as the first step in building a firm base for fill. The wetland soils, high in organic matter, are not stable enough for structure support and are often removed by dredging and replaced with rock or other material to provide a good base for construction.

Dredging is often an activity associated with navigational improvements to stream channels or harbors. Along the Gulf Coast dredging is done to lay oil and gas pipelines and to site drill rigs and production platforms.

In the dredging process the wetland is impacted in several ways. The alteration of the river channel affects the river flow patterns, velocity and water movement, changing the river-wetland relationship. When navigation is possible waves from the ships cause erosion of the adjacent streambank. Disposal of the dredged material in or adjacent to wetlands can also have an adverse affect on the environment.

Draining of wetlands to convert them to other land uses is a common activity and the greatest threat to the remaining inland wetlands. In the Great Plains the prairie potholes have been extensively drained for agricultural uses. The Lower Mississippi River drainage, North Carolina coast, and marshes along the Great Lakes have been largely converted to agriculture by draining wetlands.

Draining has permanent effects on wetlands and like dredging, upsets functions in adjacent wetlands by altering water flow velocities and patterns.

Farm ponds and low dams, common types of impoundments to catch water, also have an effect on wetland functions. Impoundments usually reduce the overall functions of wetlands. If ponds are constructed in natural wetland areas many natural functions of the area are lost.

Large impoundments like reservoirs drown wetland areas adjacent to former stream channels. In some cases these areas have been replaced with new wetland areas along the reservoir banks, but the new wetlands are usually of reduced functional value because reservoir water elevations may be seasonally altered for other needs.

Wetlands can also be affected by activities occurring at some distance away from the wetland. Any actions such as damming or polluted discharges that alter the water flow or quality can affect the wetland area.

Modification to lands adjacent to the wetland, as in agriculture, residential areas, or commercial structures can affect wetlands. The runoff may contain contaminants and sediments that reduce wetland functions. Indirect activities are usually more difficult to control both because their impacts on wetlands are often not anticipated, and since these activities have other economic and social values many believe should not be restricted due to uncertain effects on wetlands.

IMPACTS OF SURFACE COAL-MINING ON WETLAND HABITAT

Surface mining for coal has been an expanding form of mineral extraction for decades with the increasing demands for non-renewable resources. Stripping for coal will continue to increase as our national energy policy moves from an oil and gas to a coal-based economy. Of the millions of acres in the U.S. which have been surface mined over half are still considered non-reclaimed (Mason, 1978). This kind of ecosystem alteration contributes to the increasing number of endangered species and can lead to the extinction of wildlife species by altering wildlife niches and forcing animals to move to adjacent areas and adapt to adjacent habitats or die. Habitat destruction, such as from surface coal mining, is responsible for 30% of the present endangered species (Brinson et al., 1981). (Figure 2.2 shows a factor analysis of the major physical and chemical effects of mineral extraction on wetlands, Kusler, 1983).

Since most large scale surface mining activities are water intensive ventures, wetlands are often included as criteria in site selection for potential strip mine operations. As a result surface mining has potentially the most hazardous man-made or induced effect on wetland habitats (Young, 1983).

MAJOR IMPACTS OF MINING ON WETLANDS

Mining has primary and secondary impacts on the wetlands.

Primary Impacts. The primary impacts can be felt through the three phases of the mining process: exploratory, production, and post-production. In the exploratory phase, where sites are surveyed for their coal producing potential, wildlife and vegetation are disturbed, soil is compacted and erosion increased from the passage of personnel and vehicles. Ground water and aquifers are penetrated and potentially disturbed.

The production phase or mining extraction phase causes extensive loss of surface soils and vegetation resulting in major erosion, stream diversion, siltation, and chemical pollution. Large scale activity disturbs most wildlife through dispersion or destruction.

The post-mining or post-production phase results in

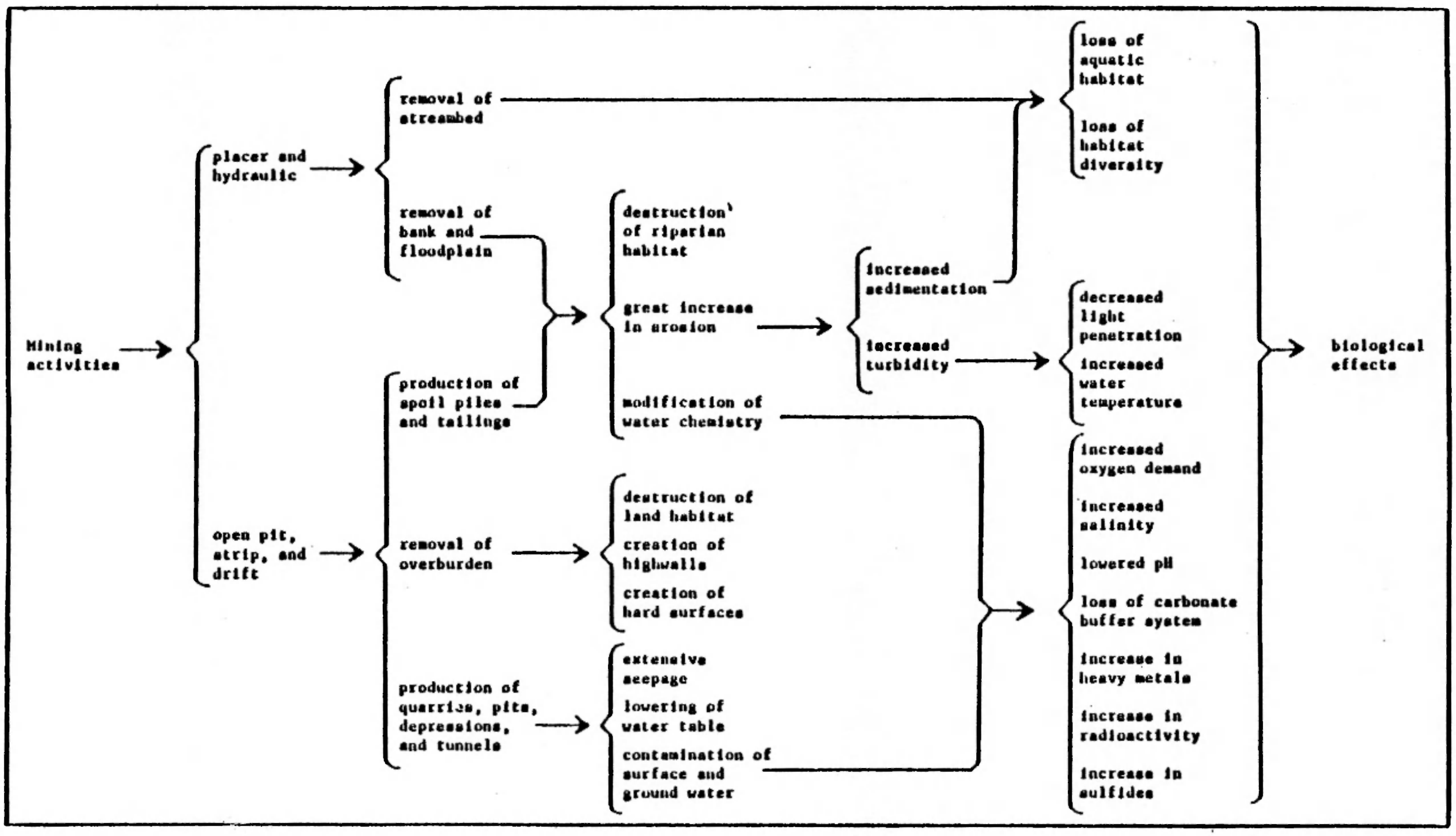

FIGURE 2.2 FACTOR ANALYSIS OF MINING IMPACTS ON WETLANDS (Source: Kusler, 1983)

permanent excavation, vegetative loss, modified hydrology, and extensive wildlife disruption.

Secondary Impacts. The secondary impacts of mining are those outside the area of actual digging or stripping. The land adjacent to the mining site and its wildlife may be adversely affected by the degradation of the mined area, especially if the area being mined includes wetland habitat since there is such an intricate relationship between wetland areas and the adjacent land. Secondary impacts may occur from noise associated with mining (blasting and from equipment and haul trucks), deposition of airborne dirt particles from blasting and hauling, and the surge in growth of towns near mines.

MAJOR IMPACTS AFFECTING WETLAND WILDLIFE

The effects of surface mining results in two major impacts on wetland habitats which, in turn, have destructive consequences for wildlife: change in the land form (including soils and vegetation) and change in water quality and quantity.

During strip mining, the topography is altered as the vegetation is stripped and the overburden removed to expose the seams of coal. This process destroys not only the vegetation and topographic features but destroys the soil structure as well, causing increased erosion.

The water quality and quantity of the wetland is also greatly affected by surface mining. The detailed set of conclusions which follow is representative of the potential effects associated with wetland alterations, such as surface coal-mining (Zinn and Copeland, 1982). These effects can be divided into two categories, physical impacts and biological impacts. The physical impacts are:

1. Change in mean water level-- levels can be decreased through drainage, altering wetland functions.

2. Change in periodicity--many wetland species require a predictably varied water regime. The extent and seasonal timing of these fluctuations are important.

3. Change in wetland circulatory patterns--wetland species have different tolerances for nutrients and dissolved gases whose distribution is based on the circulatory patterns.

4. Alterations of local water table levels--changes in water table levels often occur simultaneously with surface water alterations.

5. Drainage of surface water--resident and migratory species are affected when surface water is removed; restoration may be slow and difficult.

6. Elimination of periodic flooding and fertilization--stabilization of water levels or elimination of periodic flooding reduces productivity.

7. Change in retention storage--increase or decrease

of flow downstream is caused since wetlands regulate the local hydrology by diminishing peak flows.

8. Damping of tidal variation--wetland plants are adapted to tidal patterns, which influence water level periodicity and salinity gradients.

9. Alteration of salinity patterns--distribution of species in coastal wetlands is dependent on the salinity gradient. These gradient changes can cause major shifts in species composition and affect the estuarine food chains.

10. Turbidity--excess suspended solid, inorganic and organic byproducts of almost all phases of mining adversely affect wildlife.

11. Sedimentation--sediments deposited on the bottom plants and animals can greatly reduce their productivity.

12. Chemical pollution--the potential for chemical pollution exists during the mining process.

13. Change in temperature patterns--some impoundments can increase the surface temperature of water due to changes in water quality and quantity.

The biological impacts are:

1. Change in wetland size--changes in mean levels and periodicity of water well elevate or lower water levels, causing the wetland to grow or shrink as measured by shifts that indicate the edge of the wetland.

2. Change in wetland species composition--almost any

change in hydrologic or water quality conditions alter the vegetative community affecting the wetland composition, wetland primary productivity and plant species diversity.

3. Changes in wetland class composition--altered water levels may affect the distribution and abundance of wetland classes, which are a major determinant of wildlife values.

4. Change in wetland primary productivity--energy primary productivity is reduced by mining phases affecting secondary productivity and rate of plant succession.

5. Mortality of wetland species--creation of temporary but extreme environmental conditions can affect existing flora and fauna.

6. Barrier to animal movement--barriers can inhibit the normal periodic movement of animal populations, essential for their survival and productivity.

7. Rare and endangered species--mining destroys or alters critical habitat of some endangered or rare biota.

In summary, when human intrusion alters the natural and temporal patterns of water flow, as in surface coal-mining, the most important feature of wetland systems are threatened or destroyed. The alteration of these ecosystems temporarily removes the habitat for wildlife or degrades it to such a point that both diversity and and productivity are decreased as water quality and quantity and soil quality declines.

According to Kusler (1983) the impacts from mining can be reduced by: A.) avoiding the high value wetland areas, B.) rigorous enforcement of pollution controls, C.) using settling and water treatment facilities to reduce sediment runoff and other pollutants from mining activities, D.) using buffer strips between mining areas and adjacent wetlands to reduce runoff of sediment, chemicals, and other pollution, and E.) rehabilitating damaged wetland areas.

REHABILITATION OF WETLAND HABITATS FOR WILDLIFE

Tremendous potential exists for rehabilitating wetland areas for the benefit of wildlife. Surface coal-mining presents an excellent opportunity to refine wetland rehabilitation techniques so critical to many forms of wildlife.

To more fully understand the process of rehabilitation of wetlands for wildlife on surface coal-mined lands it is necessary to look at the criteria for any rehabilitation activity and the current rehabilitation practices of surface coal-mined lands for wildlife.

CRITERIA FOR REHABILITATION ACTIVITIES

Bauer (1965) states that three criteria are important for any rehabilitation program of mined lands. The three criteria are: 1) public pressure, 2) regulations, and 3) direct or indirect land values. These criteria are also applicable to rehabilitation of wetlands for wildlife benefit.

Public Pressure. The need for development and protection of wetlands for wildlife is well established. Public pressure to enhance our wetlands or create new ones may come from many private organizations. Private special interest groups such as Ducks Unlimited, The Wildlife Society, Audubon Society, Nature Conservancy, Sierra Club, The National Wildlife Society, and the Izaak Walton League have designated wetlands as vital wildlife habitats. Their enormous memberships and political clout have put pressure on governmental agencies to better deal with wetland losses. Smaller private conservation organizations as state or local conservation clubs, hunting clubs, and wildlife groups have interest in wetland status. Public agencies like the U.S. Fish and Wildlife Service, U.S. Forest Service, and various state natural resources divisions have identified wetlands as areas of primary concern.

Regulations. Regulations should define the performance standards aimed at eliminating objectionable operational characteristics and undesirable land forms. The standards may range from a detailed restoration plan to only revegetation and slope stabilization. These standards may include topsoil stockpiling methods, planting plans, topsoil handling and respreading, and limitations on the depth of excavation.

In the U.S., the National Environmental Policy Act of 1969 (NEPA) institutionalized the use of ecological parameters in planning federal resource development. One purpose of the Act is to protect nationally important natural resources and ecological systems, such as wetlands. NEPA requires an analysis of the existing environment, an assessment of environmental impacts, and their effects on long and short term land productivity, and an analysis of alternatives to the proposed action (Comer, 1981). The Environmental Impact Statement (EIS) is the tool used to ensure compliance with NEPA, in protecting our air, water, and land.

The Surface Mining Control and Reclamation Act of 1977 (SMCRA) is a land use law that regulates the extraction and reclamation of coal-mined lands. The main idea and authority of the SMCRA are parallel with that of the NEPA, except that the SMCRA deals only with coal resources. To achieve its goals the SMCRA requires compliance with the NEPA, the Clean Air Act, the Clean Water Act, and other federal environmental legislation (Comer, 1981).

The Mining and Reclamation Plan (MRP) is the document used to evaluate compliance with SMCRA. A comprehensive planning and decision making document, the MRP is used in the permitting process. Before an operator can be issued a permit to mine, the MRP must adequately address all the environmental protection standards and the reclamation plan must be approved.

The rehabilitation plan should address the following subjects (Law, 1984):

A. Identification of lands to be mined

B. Premining site conditions

C. Proposed postmining land uses

D. Description of how postmining land use will be accomplished

E. Engineering techniques to be used in mining and rehabilitation

F. Minimizing future disturbances on mining sites

G. Estimated timetables

H. Compliance with nonfederal regulatlions

I. Compliance with air and water quality laws

J. Physical, environmental, and climatological constraints

K. Interests and options on contiguous sites

L. Results of test borings

M. Protection of water resources

In addition to the Federal regulations there are State regulations governing the surfacing mining of coal. Although these regulations vary from state to state they control surface coal-mining much the same as the Federal regulations.

Direct or Indirect Land Value. Wetlands provide many values to our society. They provide environmental quality, socio-economic, and fish and wildlife values that have both direct and indirect influences on the land value. Improved wetland rehabilitation success standards result in increased habitat values and protection of floral and faunal gene pools associated with wetlands.

CURRENT REHABILITATION PRACTICES OF SURFACE COAL-MINED LANDS FOR WILDLIFE

Although federal and many state regulations indicate wildlife should be given consideration in the rehabilitation of surface coal-mined land, this aspect has not been given prime consideration in the United States (Brenner, 1984). The authority that the Surface Mining Control and Reclamation Act of 1977 provides is limited to the requirements for the development of wildlife protection programs and for compliance with federal legislation such as the Endangered Species Act and Bald Eagle Protection Act. However, it states that reclamation should "using the best technology currently available, minimize disturbances and adverse impacts of the operation on fish, wildlife, and related environmental features, and achieve enhancement of such resources where practicable," (Law, 1984). The lack of definition in the federal regulations leaves the integrity of wildlife reclamation requirements to state guidelines and regulatory policies. Thus, due to the lack of federal criteria, the wildlife rehabilitation program is developed in the negotiation process whereby the operator must satisfy site specific information requests of state/federal agencies and land management agencies (Comer, 1981). Unfortunately the inconsistencies in regulations from state to state or site to site negotiations and the specific nature of rehabilitation goals often do not include wildlife as high priority items.

Bauer (1983) states that a major concern is that most reclamation from an aesthetic and technological point of view yields poor wildlife productivity and diversity. Wildlife development on mined lands, however, can be supported for the following reasons (Bauer, 1983):

1.) Natural revegetation of plants and repopulation by native animals can occur and be stimulated with good management techniques during mining.

2.) Mine sites are usually located away from most other human activities and lend themselves to natural revegetation.

3.) Mine operations by earth moving can create more diverse environments than in adjacent areas.

A number of studies in the eastern United States (Pennsylvania, Indiana, Illinois, Ohio, Virginia, and West Virginia) have demonstrated that surface coal mines can support diverse and abundant wildlife populations (Brenner, 1984). In most of these cases the wildlife populations tend to have a greater degree of association with the volunteer vegetative species than they do with those in the initial reclamation.

There is currently very little information dealing with the processes to rehabilitate surface coal-mined wetlands. Little research has been done that identifies how the most important natural characteristics of wetland systems can be rehabilitated. There is almost no information on artificially created wetlands.

Olson and Barker (1979) and Bjugstad et al. (1983) in studies done in the Northern Great Plains found several differences in the wetland plant community development on strip-mine ponds. First, strip-mine ponds lack wet meadow and shallow marsh plant communities with such species as foxtail barley (*Hordeum jubatum*), prairie cordgrass (*Spartina pectinata*), sedges (*Carex spp.*), and rushes (*Juncus spp.*). Second, strip-mine ponds have extremely narrow bands of emergent vegetation, cattails (*Typha spp.*) and bulrushes (*Scirpus spp.*), as compared to natural wetland emergent vegetation. Third, submerged plant communities, with pondweeds (*Potamogeton spp.*) and water milfoil (*Myriophyllum exalbescens*), are restricted to a narrow band close to the shoreline on strip-mine ponds. Finally, strip-mine ponds exhibit fewer wetland plant communities, less species diversity within each community, and a more concentric pattern of community development around the pond margin than stockponds or natural wetlands.

These wetland plant community differences found by Olson and Barker (1979) and Bjugstad et al. (1983) have direct impact on wildlife. Waterfowl rely on wet meadow and shallow marsh vegetation as nesting cover. The retarded development of emergent vegetation reduces the brood rearing cover important for good waterfowl habitat. Reduced area of submerged vegetation limits the production of plant dependent aquatic invertebrates which are important preferred food required by ducklings for growth. Reduction of wetland vegetation variability is less attractive to waterfowl, and means lower waterfowl utilization of strip-mine ponds.

Olson and Barker (1979) found the major factor determining the development of wetland vegetation on the Northern Great Plains strip-mine ponds is the basin slope, which is normally much steeper than on natural wetlands. Since wetland plant development is closely linked with moisture conditions, the basin slope often limits the amount of shoreline area having favorable moisture conditions under fluctuating water levels. The basin slope influences wetland plant development by regulating water depth and permanence within zones of wetland vegetation. Rapidly changing water levels on steeply sloped strip-mine ponds produce extreme variations in moisture conditions to which many wetland plants are unable to adapt. As a result, plant species composition and density are limited.

The wetland plant composition on strip-mine ponds is affected by several other factors. Strip-mine ponds possess unique water chemistry as a result of runoff from exposed materials in the surrounding spoil banks. The build-up of these pollutants limits nontolerant wetland plant species and decreases the diversity and value as wildlife habitat. Water temperature can be different on strip-mine ponds and is known to influence the time of spring germination (Olson, 1981). Light penetration is another factor that affects aquatic plant growth by regulating photosynthesis. Olson (1981) found penetration to be greatest in slightly acid strip-mine ponds but reduced in highly acidic and alkaline ponds. Soil chemistry is also an important factor in plant growth affected by strip mining. Olson (1981) reported that spoil materials were found to be low in nitrogen and organic matter, major nutrients for growing vegetation, but rich in potassium, phosphorus, and potash.

IMPORTANT CRITERIA FOR PROPER WETLAND REHABILITATION FOR WILDLIFE

A great amount of research has been conducted to determine what wetland attributes are the most important to wildlife. A number of studies have found wildlife habitat utilization closely correlated with vegetative structure, diversity, and conditions (Beecher, 1942 and Hunt and Naylor, 1955). Weller and Spatcher (1965) found bird diversity and numbers closely correlated with spatial ratios of open water to vegetated area. Williams (1984) found size, juxtaposition, plant community richness, water permanence, water chemistry, and water-cover ratio as important to wildlife and their wetland habitats. Edge has long been known as a vital element to wildlife habitats.

Size. In general, the larger the wetland the greater the number of species it can support. The size has a direct relationship to the ecological value of the wetland area, but presently there is no clear consensus of the minimum size of a wetland needed to accomodate wildlife (Johnson and Jones, 1977). Studies by Williams (1984) and Probst (1979) indicate the number of avian species increased sharply with increased wetland size but began to level out once wetland size exceeded four hectares (about ten acres).

Edge. Leopold (1933) stated that "game (wildlife) is a phenomenon of edges and occurs where the types of food and cover which it needs come together, i.e., where their edges meet." An edge is that area where two or more plant communities or successional stages within plant communities meet (Thomas et al., 1977). Along with the size of the wetland the amount of edge in the wetland is important. Increasing the edge may be done by convoluting the shoreline. Irregular shorelines allow the development of narrow strips of vegetation important to species such as mink, raccoons, and numerous birds which utilize these areas for food and cover, especially in bad weather (Svedarsky, 1982). These buffer zones reduce erosion, preserve wetland shoreline stability, and help to maintain suitable water temperatures for aquatic life.

Edges can be increased by creating islands within the wetland. Creating islands in rehabilitated wetland landscapes have been found to be of great value to wildlife (Svedarsky, 1982). Giroux (1981) in a study of the use of artificial islands by nesting waterfowl (ducks and geese) in Alberta, Canada, found created islands to have significant habitat attributes. A comparison of island characteristics and productivity showed smaller islands located farther from shore with greater vegetative cover as the most productive for nesting waterfowl. Rectangular islands were the most appropriate because they had greater perimeter area than circular, elliptical, or square islands. The greater the ratio of water-land edge to land mass the more attractive the island was as habitat.

Juxtaposition. Juxtaposition is closely associated with size, and refers to the proximity of a single wetland to other wetland(s). Wetlands when in close proximity to each other can be thought of as one large wetland complex. Wetland complexes or clusters support more bird species than isolated wetlands (Williams, 1984). Wetland clusters may be more attractive to birds because of increased vegetative diversity, or greater variation in the vegetative structure. Two to three different wetland types close by each other seem to create the heterogeneity in avian breeding and feeding areas needed to maintain high species diversity (Weller, 1978).

Topographic Features. Topographic rehabilitation is the first step in the development of long term habitat rehabilitation for wildlife since it will affect the hydrology patterns and soil for establishing vegetation. The goal should be to rehabilitate the original topography as much as possible. Natural resource managers should rehabilitate surface coal-mined wetlands by contouring surrounding spoil banks to develop more gradual slopes, creating a more suitable habitat for wetland plant communities (Bjugstad, 1983). The gradual sloping of spoil banks on the wetland perimeter has been found to be vital to many shorebirds such as the long-billed curlew for feeding and cover (Armbruster, 1983).

Plant Community Richness. The plant community richness (i.e. the total number of plant communities occurring within or immediately adjacent to the wetland) has a great influence on wildlife (Williams, 1984).

Hydrological control, or the ability to manipulate the water levels in the wetland, is a major factors in managing vegetation diversity on rehabilitated surface coal-mined wetlands. Drawdowns result in mudflat exposure offering several advantages for improving vegetation diversity for waterfowl habitat. Exposed mudflats encourage the establishment of many wetland plant species from seed. Once germination and establishment occur on the mudflat, many wetland plant species continue to grow and reproduce by root sprouting, even when flooded. These mudflats exposed from drawdown quickly develop more favorable growing conditions for wetland plants than submerged soils. Decomposition of plant materials proceeds rapidly under aerobic conditions of exposed mudflats, releasing essential growth nutrients for future plant utilization. The study of drawdowns compared to flooded conditions can lead to the prediction of the successional community development and species richness (Van der Valk, 1981).

Plant community richness can also be increased by using native plant materials in the rehabilitation seeding process. The use of native plants develops a more heterogenous vegetative community that has higher diversity and productivity. Native species promote natural succession that is not only important in providing more diverse and stable plant communities on mined lands, but these species have also been shown to have greater food and cover value. Armbruster (1983) reported that establishment of native plant species on rehabilitated surface coal-mined lands was of great importance to 25 migratory bird species of high federal interest. The Surface Mining Control and Reclamation Act of 1977 requires the use of some native plants in the revegetation process because of their value to wildlife (Young, 1983).

<u>Water Permanence</u>. Water permanence is another criteria that can be important in rehabilitating mined wetlands for wildlife. Williams (1984) found that waterfowl displayed strong preferences for those wetlands that were seasonally flooded, presumably the result of higher aquatic invertebrate populations. As previously stated, fluctuating water regimes create a variety of

environmental conditions favorable to a wider number of wetland plant species. This condition is a major reason for the mosaic pattern of wetland plant community distribution on natural wetlands. Fluctuating water regimes prevent an accumulation of organic debris while contributing to soil fertility.

Water Chemistry. Water chemistry may have an important effect on the wetland condition. Richardson et al. (1978) found that incoming water is transformed within the wetland, particularly by microbial transformation of nitrogen species and nutrient uptake by vascular plants. Their data suggests sediments form the major nutrient pool, that low vascular plant productivity was associated with low nitrogen and phorphorus availability, and that Calcium was not limiting. Besides effecting the wetland vegetation biomass production so important to wildlife for food and cover, the water chemistry can greatly affect microorganisms vital in wetland food chains. The pH and the electrical conductivity of the water are important measures of the water chemistry.

Water-Cover Ratio. Some investigators (Williams, 1984) suggest that the ratio of open water to vegetated surface area influences wetland wildlife. Those cover types with 25-75% of the wetland occupied with cover plants were found to be most utilized (Williams, 1984).

CHAPTER THREE

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METHODOLOGY

RESEARCH CONCEPT AND DESIGN

OVERVIEW

The concept of the methodology was to develop a procedure to assess the success of the rehabilitation of wetland habitat for wildlife. The procedure was designed to be: 1) adaptable, to be implemented over regional areas using existing or easily acquired information; 2) transferable, with suitable recalibration, to other geographical regions; 3) able to provide data to the researcher and mining decision makers that can be used to determine the quality of the rehabilitated wetland for wildlife; and 4) able to integrate information about as many different wildlife species as listed on the pre-mine inventory as possible. It was anticipated that the results of this methodology of the rehabilitation of wetland habitats for wildlife can serve as an example for surface coal-mined lands and recommend improvements in the rehabilitation process of wetlands to further benefit wildlife.

The methodology of the study was achieved by the following processes:

A. Site Selection

B. Data Collection

C. Analysis of Data

Table 3.1 shows a chart of the processes and methods used in the study. Table 3.1 has also been included on page 109 of the methodology (last page) to allow the processes to be reviewed while reading the chapter.

CRITERIA FOR THE SELECTION OF A REGIONAL AREA

The first step in proceeding with the research was to select a regional area for the study. The regional area was to be within the boundaries of one of the six mining provinces (Law, 1984): A.) Eastern Province, B.) Interior Province, C.) Gulf Province, D.) Northern Great Plains Province, E.) Rocky Mountains Province, or F.) Pacific Province. (Figure 3.1 illustrates the six mining provinces within the continental U.S.).

The regional selection was based on two major factors: 1) The potential coal deposits that can be surface mined was an important factor. The amount of coal able to be surfaced mined gives an indication of the total land disturbance that will occur within that region and thus, the amount of wetlands to be impacted by surface mining. 2) The total amount of wetland acreage within a region

TABLE 3.1 PROCESSES AND METHODS USED IN STUDY

SITE SELECTION

A. Regional Selection Criteria

1. Coal resources present
2. Wetland acres present

B. Study Site Selection Criteria

1. Location within region selected
2. Presence of rehabilitated surface coal-mined wetlands
3. Presence of unmined wetlands of the same type as rehabilitated wetlands
4. Cooperation of a mining company

DATA COLLECTION

Physical Factors

A. Physiography
1. Elevation
2. Slope
3. Aspect
4. Bedrock type & condition
5. Landform dissection

B. Hydrology
1. Water quality & quantity
2. Watershed stability

C. Soils
1. Composition
2. pH
3. Texture
4. Topsoil thickness
5. Organic matter content
6. Water holding capacity

D. Microclimate
1. Site temperatures
2. Site precipitation
3. Solar radiation
4. Wind speed
5. Surrounding landforms

Biological Factors

E. Vegetation
1. Species composition
2. Species diversity
3. Spatial community variation
4. Successional pattern
5. Cover & nutrition wildlife values

F. Wildlife
1. Species composition
2. Species diversity

DATA ANALYSIS

A. Assessment Matrix
(physical factors)

B. Remote Sensing Techniques
1. Landsat-5 Thematic Mapper
2. Brightness Response of B&W
3. Color-Infrared Photos
4. Natural Color Photos

(physiography, hydrology, and vegetation)

C. Wetland Vegetation Succession Model
(vegetation)

D. Plant Information Network Database
(vegetation)

E. Waterfowl Pair Counts
(wildlife)

F. Waterfowl Brood Counts
(wildlife)

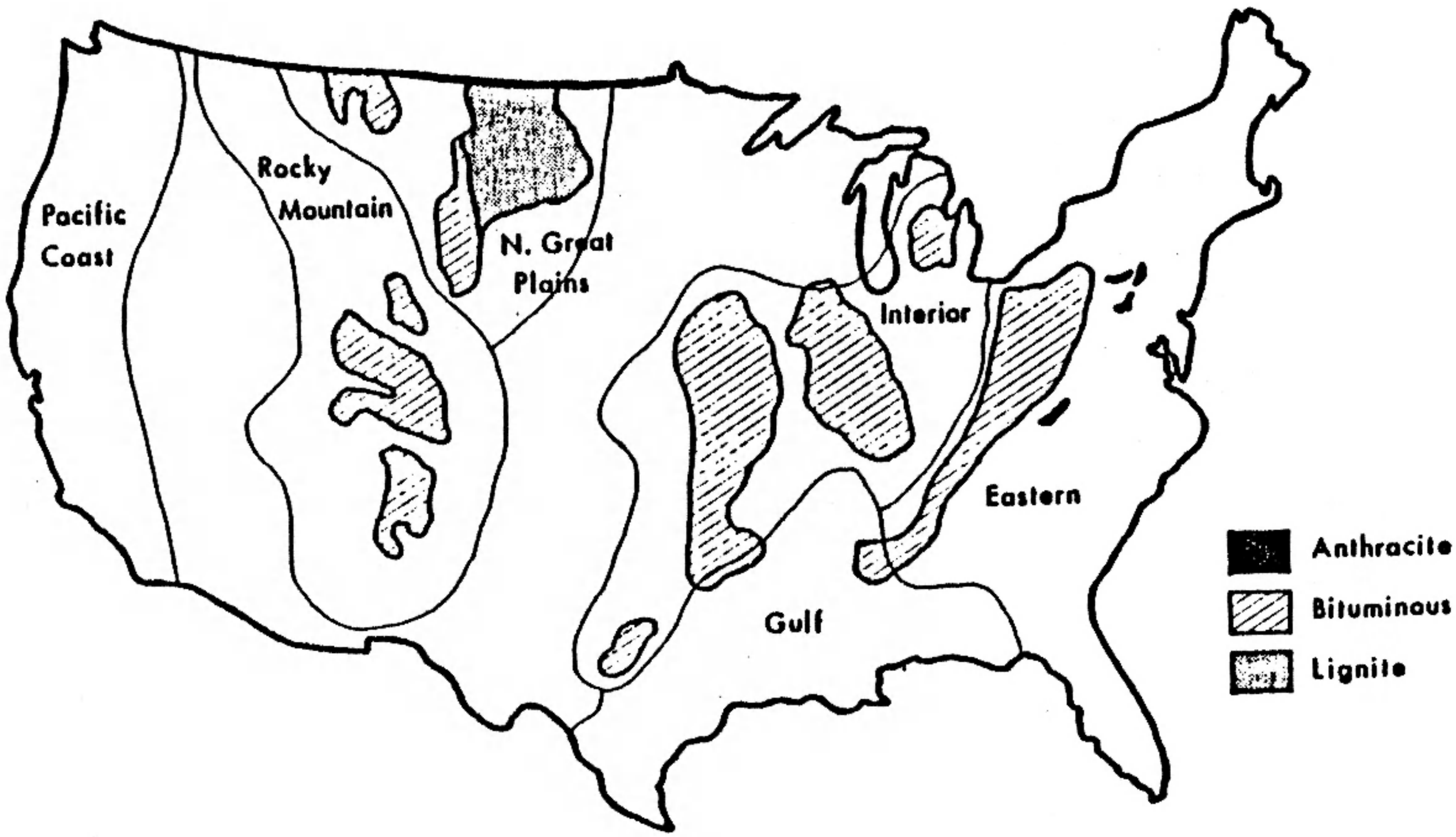


FIGURE 3.1 THE SIX COAL MINING PROVINCES IN THE UNITED STATES

(Source: Law, 1984)

and the region's current wetland losses was also an important factor. By knowing the total wetland acreage and the rate of wetland depletion within a region the area with the most critical need for the research can be assessed.

CRITERIA FOR THE SELECTION OF A STUDY SITE

The selection of a study area within the region was based on:

1) Location within the regional area or mining province chosen.

2) The presence of rehabilitated areas of wetland habitat resulting from surface coal-mining.

3) The presence of unmined, natural wetland habitat of the same wetland class as the rehabilitated wetland habitat.

4) Willingness by a mining company to work with the researcher on the project.

SITE SELECTION

REGIONAL AREA CHOSEN FOR THE STUDY

The regional area chosen was in the Northern Great Plains Mining Province. Figure 3.2 shows the location of the Northern Great Plains Mining Province. This mining province, which includes North Dakota, South Dakota,

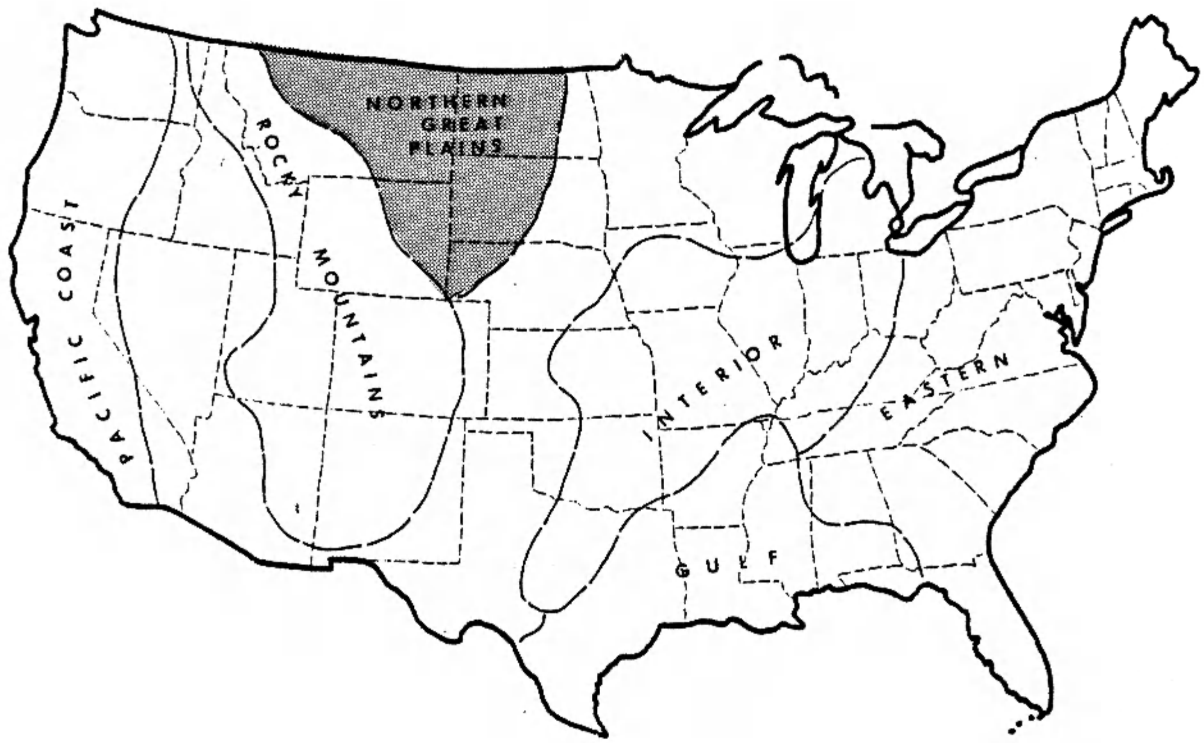


FIGURE 3.2 NORTHERN GREAT PLAINS MINING PROVINCE

(Source: Law, 1984)

Montana, Northeastern Wyoming, and the Northwest corner of Nebraska has large coal deposits which are being surface mined and large wetland acreages that are important to wildlife.

Coal Resources of the Northern Great Plains. The Northern Great Plains contain almost 50% of the coal reserves in the U. S. and about 20% of the world's known coal reserves (Power et al., 1978).

Most of the coal in the region is either lignite or subbituminous, which is softer than bituminous coal, but is low in sulfur. It usually occurs in thick seams relatively close to the soil surface. Coal seams 5 to 20 feet thick are common with seams up to 60 to 100 feet thick. The majority of the 2.5 trillion tons is strippable and the most easily accessible seams are often along wetland habitats where overburden is often eight feet or less (Gore and Johnson, 1981).

Almost all of this coal is currently extracted by strip mining making the potential for several million acres of land to be disturbed by mining in the Northern Great Plains.

Wetlands of the Northern Great Plains. The Northern Great Plains have some of the most important wetlands to wildlife in the country. Yet these wetlands are disappearing at faster rates than in almost any region in the U. S. (Figure 3.3, shows states and regions of the country with significant wetland losses).

Most of the wetland losses have occurred in the "prairie pothole" region of the Northern Great Plains. The "prairie pothole" region extends from south-central Canada to north-central U. S., covering about 300,000 square miles with roughly one-third in the United States. Due to glaciation thousands of years ago, the landscape is pock-marked with millions of pothole depressions, most less than two feet deep. Today these potholes have been disappearing at over 33,000 acres a year due mostly to agricultural drainage and irrigation and flood control projects (Rodiek, 1984). In North Dakota, pothole wetlands once covered over five million acres. Today, less than two million acres remain, a loss rate of over 60% (Tiner, 1984).

The prairie potholes are the most valuable inland wetland areas for waterfowl production in North America (Tiner, 1984). Although the region accounts for only 10% of the continent's waterfowl breeding area, it produces 50% of the yearly duck crop in an average year and even more than that in wet years (Smith et al., 1964). These pothole wetlands serve as primary breeding grounds for many kinds of ducks including mallard, pintail, wigeon, shoveler, gadwall, teal, canvasback, and redhead. These areas also

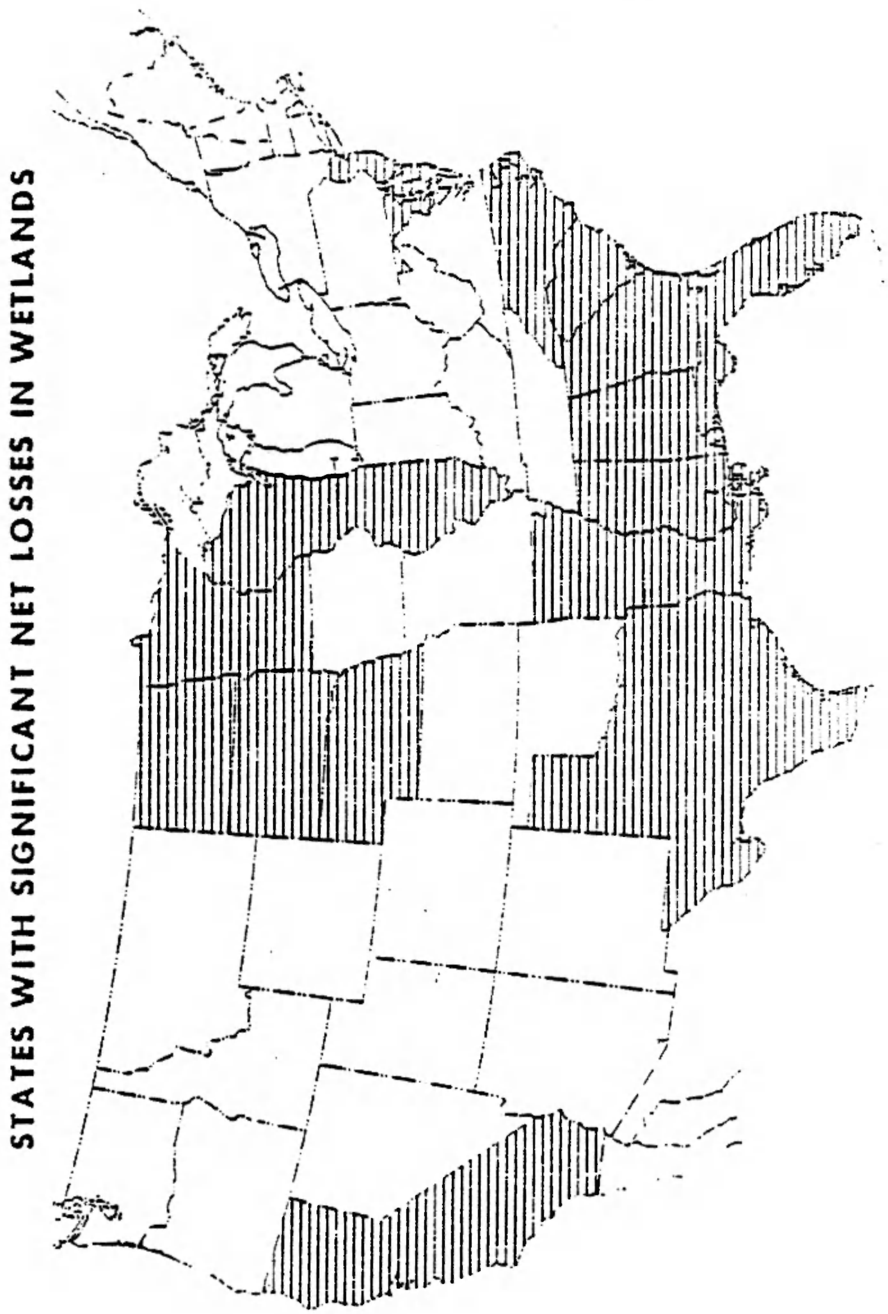


FIGURE 3.3 STATES WITH SIGNIFICANT WETLAND LOSSES
(Source: Tiner, 1984)

serve as important migratory resting habitats for a variety of birds and provide food, cover, and water for many other wildlife. (Figure 3.4, shows the highest priority waterfowl areas in the U. S.).

STUDY AREA CHOSEN FOR THE RESEARCH

The study area is located in McLean County, North Dakota, about 50 miles northwest of Bismarck, and about one mile southwest of the town of Underwood. Figure 3.5 shows the location of the study area. The study area was chosen for the following reasons:

1) The study area selected in McLean County, North Dakota, is located in the prairie pothole region of the Northern Great Plains Mining Province.

2) The Falkirk Mining Company, a wholly-owned subsidiary of the North American Coal Corporation, has developed detailed reclamation plans and methods to mine and replace prairie pothole wetlands at the Falkirk Mine. The Falkirk Mine, near Underwood, North Dakota, has two prairie pothole wetlands that have been rehabilitated after surface coal-mining. The wetlands are approximately 10 acres and 30 acres in size respectively, and have been revegetated since the spring of 1985.

The U. S. Fish and Wildlife Service has been involved in the rehabilitation process for the rehabilitated wetland complex since the plans were developed. They are following

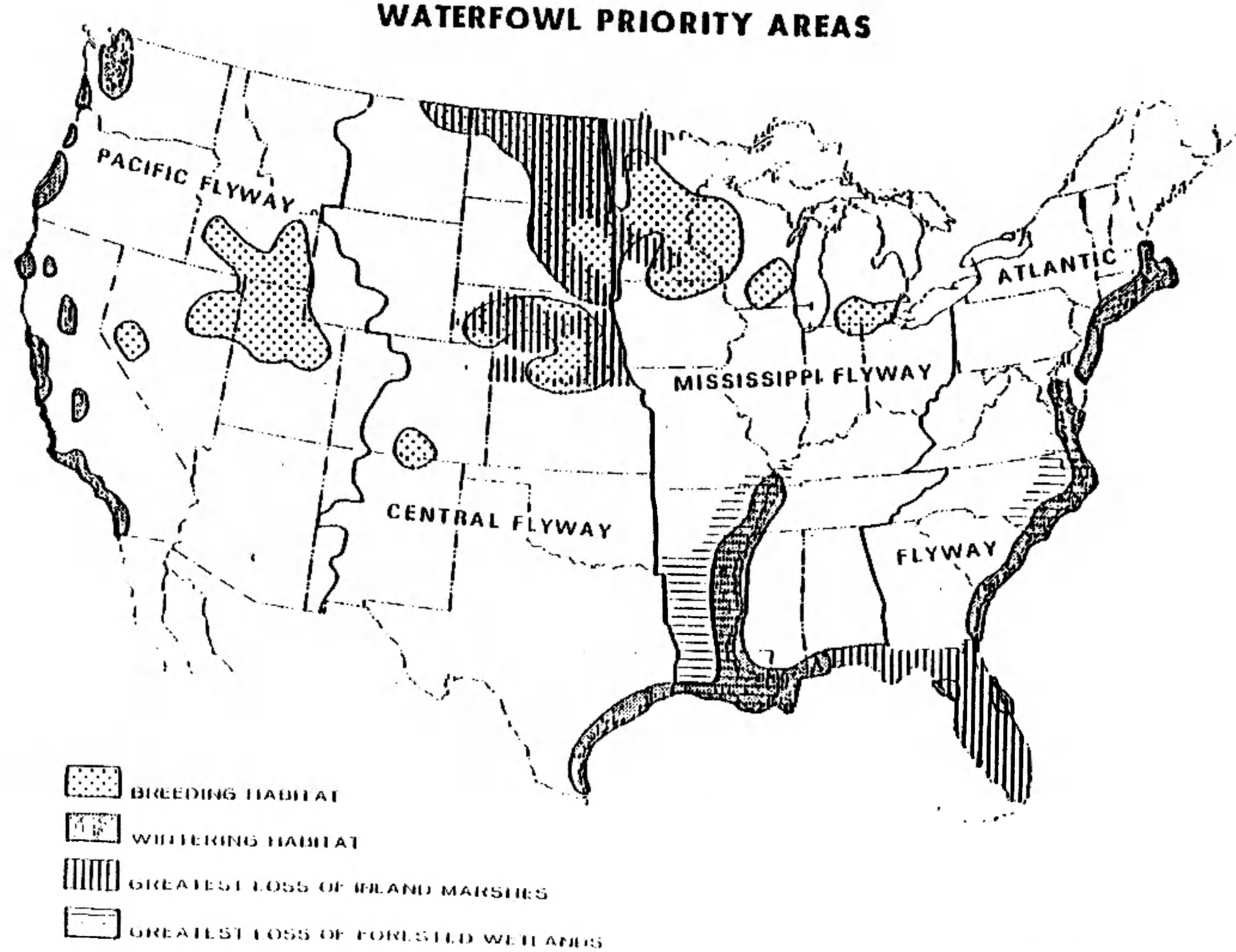


FIGURE 3.4 HIGHEST PRIORITY WATERFOWL AREAS IN THE U.S.
(Source: Tiner & Wilen, 1983)

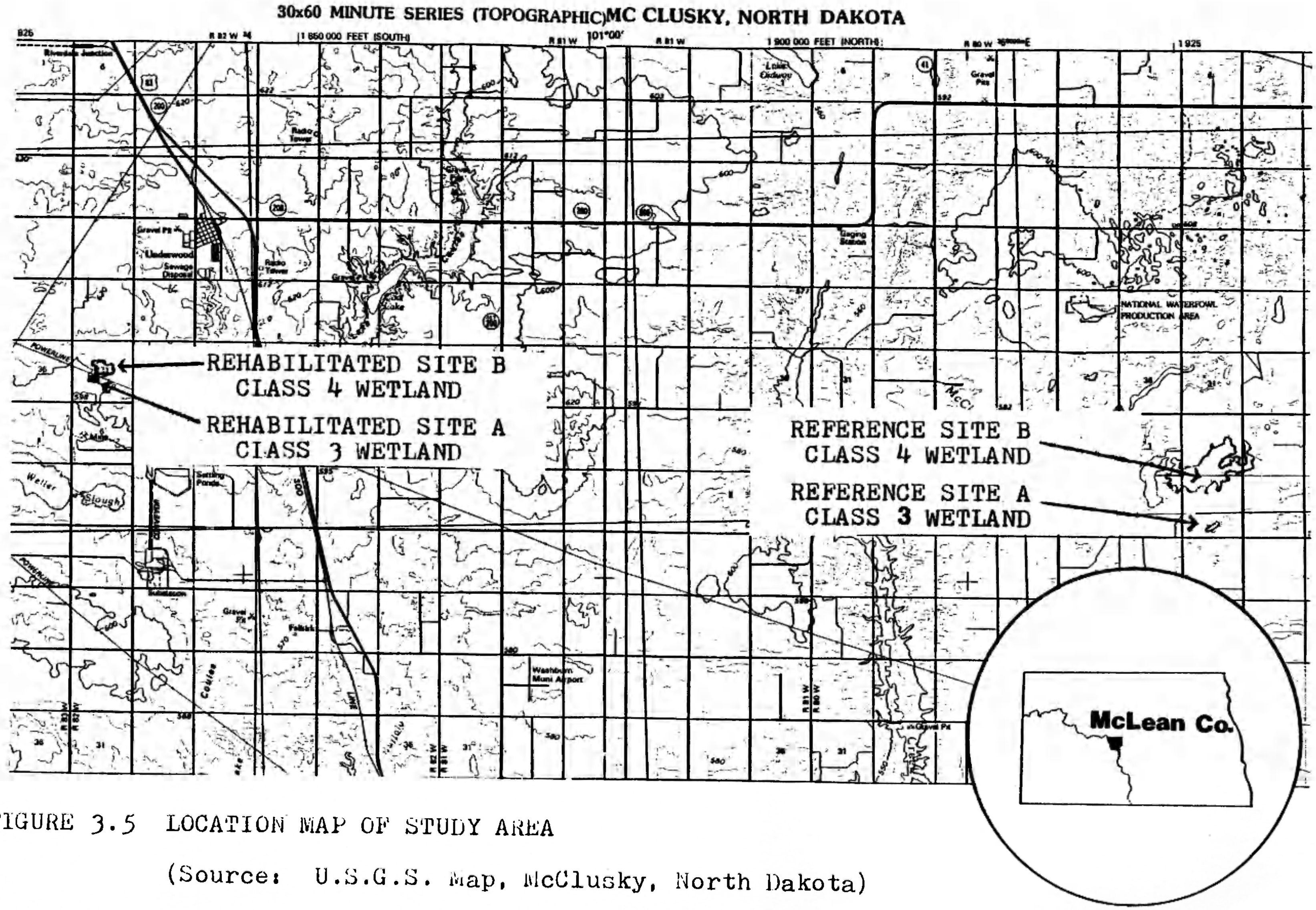


FIGURE 3.5 LOCATION MAP OF STUDY AREA

(Source: U.S.G.S. Map, McClusky, North Dakota) the progress of the wetland recovery as the basis in making a land trade with the Falkirk Mining Company. For a fee title exchange of the rehabilitated wetland complex (163 acres) to the U. S. Fish and Wildlife Service, the Falkirk Mining Company will receive a coal-mining permit on 560 acres of federal land at a future date near the present mine site.

Although the Falkirk Mining Company is monitoring a number of hydrologic, vegetative, and wildlife parameters, a procedure to assess the success of the rehabilitation comparing that to unmined, natural wetlands is needed.

3) Two unmined, natural wetlands areas within 12 miles of the mine site of the same wetland classes as the rehabilitated wetlands are available as reference areas to compare with the rehabilitated sites.

Using a classification system developed for natural ponds and lakes in the glaciated Prairie Pothole Region (Stewart and Kantrud, 1971) the rehabilitated and natural, unmined wetlands fall into Class 3 and Class 4 wetland types. (Table 3.2 illustrates the Stewart and Kantrud Wetland Classification System for the prairie pothole region of the Northern Great Plains).

These reference wetlands, like all prairie potholes are characterized by wetland vegetation that can be grouped into zones. The presence or abscence of these zones is critical in determining which class a wetland is classified as. Each zone has a different community structure and a distinct assemblage of plant species. The zones found in the prairie potholes are: Low prairie, Wet meadow, Shallow marsh, Deep marsh, Open water, Intermittent-alkali, and Fen. Only three of these zones are found in Class 3 and 4 wetlands, such as the study sites. These are: wet meadow zone, shallow marsh zone, and deep marsh zone. In each zone, characteristic plants may be found as a general mixture of species or may be represented by one or more distinct associations, each composed of one or more species. The zones are greatly influenced by differences in water permanence, permeability of bottom soil, and ground water conditions.

The natural occurence of unmined prairie pothole wetlands of the same wetland class as the rehabilitated wetlands in the same locality enables a more reliable and accurate comparison of the wetlands to be done in order to assess the rehabilitation success for wildlife.

TABLE 3.2 CLASSIFICATION OF PRAIRIE POTHOLE WETLANDS

CLASS	TYPE	DESCRIPTION
1	EMPHEMERAL POND	low prairie zone dominates the deepest part of the wetland.
2	TEMPORARY POND	wet meadow zone dominates the deepest part of the wetland. A low prairie zone is usually present.
3	SEASONAL POND/LAKE	shallow marsh zone dominates the deepest wetland area. Wet meadow zone & low prairie zone usually present. Deep marsh may occur.
4	SEMIPERMANENT POND/LAKE	deep marsh zone dominates deepest wetland area. Low prairie, wet meadow, & shallow marsh zones occur.
5	PERMANENT POND/LAKE	permanent open water zone dominates the deepest wetland area. Deep marsh, shallow marsh, wet meadow, & low prairie zones occur.
6	ALKALI PONDS/ LAKES	intermittent alkali zone is dominant in deepest wetland area. All zones but deep marsh are present.
7	FEN PONDS	fen dominates the deepest part of the wetland. Low prairie and wet meadow zones are present.

4) The Falkirk Mining Company has been very willing to cooperate with the researcher on the project. The company arranged for the researcher to visit the site and cooperated with the researcher during the on-site analysis in providing site data already collected, pre-mine

inventory information, base maps, aerial photographs, and color infra-red photographs of the unmined, natural reference and rehabilitated wetlands for 1985 and 1986. The Falkirk Mining Company also provided the expertise of the company's rehabilitation specialists to aid in conducting the on-site reconnaissance of the wetland biological and physical parameters. The company rehabilitation specialists have also been helpful in setting up interviews with the mining management, engineers, and rehabilitation equipment operators with by the researcher.

DATA REQUIRED AND DATA COLLECTION PROCEDURES

The second phase in the methodology was collecting data from the study site. The two major categories of data were, 1) physical and biological site factors and 2) wildlife parameters. The data was gathered from maps, aerial photographs and other remote-sensing techniques, Falkirk mining reports, U.S. Fish and Wildlife databases, State Fish and Wildlife reports, Soil Conservation Service soils reports, on-site reconnaissance, and personal telephone interviews with mining rehabilitation specialists, U.S. Fish and Wildlife biologists at the Praire Research Institute in Jamestown, N.D., and Bureau of Mines personnel in Bismarck, North Dakota.

PHYSICAL AND BIOLOGICAL FACTORS

The mining activities greatly disturb many of the physical and biological characteristics of the site. Therefore, it was necessary to inventory and analyze the physical and biological site characteristics of the rehabilitated mined land and compare them to the unmined natural reference wetlands to measure the success of the rehabilitation program. The data categories to be assessed are: 1) physiography, 2) hydrology, 3) soil, 4) vegetation, and 5) microclimate.

1) Physiography

The physiographic factors have a great affect on the plant and animal life by indirectly affecting the amount of solar radiation, temperature, moisture, and soils of the site. The following physiographic data variables were assessed:

A. Elevation--the elevation of the wetlands at their high and low water marks has important implications on the watershed patterns.

B. Slope--gradient of wetlands.

C. Aspect--direction that a slope faces in relationship to the sun.

D. Bedrock type and condition--bedrock underlying the wetlands as to type and condition.

E. Degree of dissection of landform--the types of landforms present surrounding the wetlands.

The physiographic data were collected by several methods. The data collected for the elevation, slope, aspect, and bedrock type and condition for the rehabilitated wetland by the Falkirk Mining Company were used to assess the differences between the pre-mine condition and the post-rehabilitation condition of the rehabilitated wetland. The U. S. Fish and Wildlife Service and the Falkirk Mining Company had some physiographic data of the same data variables for the wetland reference areas.

The use of U. S. Geological Survey maps of 1:250,000 and 1:24,000 scale were helpful in obtaining elevation, slope, and aspect data of the wetlands.

Aerial photographs were also used to obtain physiographic data. Low altitude color infrared photographs of medium scale (1:12,000) and natural color transparancies (1:12,000) were useful in determining the regional picture of the study area including the wetlands and the area surrounding them.

2) Hydrology

The amount and pattern of precipitation has a direct relationship on the hydrological pattern of the surface water of the wetlands. The hydrological data variables of the rehabilitated and reference wetlands were:

A. Water quality and quantity--the condition and amount of water in the wetlands as to average seasonal precipitation and inflow. Water quality was measured for pH, calcium, magnesium, sodium, sodium adsorption rate, hardness and nitrates.

B. **Watershed** stability--the area from which water drains to a single point and its effect on the wetland conditions.

The hydrological data were collected by on-site reconnaissance, the mining company, and remote sensing techniques. Some water quality and quantity data were collected by the researcher during the site reconnaissance stage. The researcher used data the Falkirk Mining Company had collected on the rehabilitated wetland water quality and quantity and watershed stability. The Fish and Wildlife Service had data on some of the hydrological parameters of the reference area that were used.

The use of remote sensing techniques was important in the collection of data on the hydrology of the wetlands. Color infrared and natural color transparencies were used to collect hydrological data concerning the watersheds of the wetlands in different seasons (May, July, and October) of different years (1985 and 1986). The use of a Landsat-5 Thematic Mapper digital floppy disk program and Thematic Mapper classified maps depicted the general hydrological classification of the wetlands researched. These materials, obtained from Ducks Unlimited, Inc., were very important to the study of the hydrological patterns of the study sites and are discussed in the Analysis section of this chapter.

3) Soil

Soils are among the most important factors in the successful rehabilitation of a wetland. Soils not only are critical for plant growth and survival but, their properties and chemistry will affect the erodibility and stability of the wetlands and eventual use by wildlife species. The most important soil variables identified for the study were:

A. Composition and structure--The chemical and physical make-up of the soil.

B. pH--soil acidity or alkalinity.

C. Texture--soil particle size distribution.

D. Topsoil thickness--actual depth of topsoil.

E. Organic matter content--source of nutrients for vegetative growth (especially nitrogen); necessary for good soil structure.

F. Water holding capacity--The ability of the soils to hold water (gravitational and hygroscopic water are the most important).

A major source for the soil data was the Soil Survey of McLean County, North Dakota (U. S. D. A. et al., 1979). The Soil Survey had data for all the data variables for both the rehabilitated and reference wetlands soils.

The Falkirk Mining Company had valuable soil data on the rehabilitated wetlands. The mining company records covered all the desired data variables. On-site samples also were tested by the researcher for pH, soil texture, and soil composition.

4) Vegetation

The vegetation has the most direct effect on the development of the wetland community. Hydric vegetation promotes zonation of the wetland plant community and has a direct effect on the wildlife of the habitat area. The data variables for the vegetation of the wetlands were:

A. Species composition--The actual floristic make-up of the rehabilitated and reference wetland communities.

B. Species diversity--The number of different flora species in the rehabilitated and reference wetland communities.

C. Spatial community variation--The spatial differences within the wetland plant community.

D. Successional pattern--The way the wetland plant community responds to succession during drawdowns (normal drought conditions) and floods (normal wet conditions).

E. Cover and Nutrition Values for Wildlife--The potential cover and food values of the wetland vegetation for wildlife.

The wetland vegetation data of the rehabilitated and reference areas was collected by a variety of methods. The most important was the field reconnaissance done by the researcher with the aid of the mining company rehabilitation specialists on the wetlands. The species lists resulting from this were compared to those done earlier in fall,1986, by the botanical consultant hired by the Falkirk Mining Company.

Data on the vegetation of the unmined, natural reference wetland areas was made available by the U. S. Fish and Wildlife Service which was used to compare with the vegetation seen on those reference sites by the researcher and mining rehabilitation specialists. The reference vegetation list was then used to compare with the vegetation list of rehabilitated wetland areas.

Low altitude color infrared aerial photographs of medium scale were very important in collecting visual data on the vegetation zones and condition of the vegetation of the wetlands. Although species composition and diversity could not be collected with these photographs, spatial vegetation community variations were easy to assess and from that the hypothesized successional pattern could be projected. Natural color transparencies and black and white (panchromatic) positive prints from the color infrared photographs were also used to visually assess the wetland vegetation patterns of the rehabilitated wetlands in comparison to the results to the unmined, natural reference wetlands using the same remote sensing techniques.

The use of Landsat 5-Thematic Mapper data analyzed and classified by Ducks Unlimited was of great value in assessing the vegetational zonation of the wetlands and the amount of acreage of each zone for all the wetlands studied. The use of these digital image processed products allowed for an accurate visual comparison of the wetland plant zones to the data obtained by "ground-truth" reconnaissane.

The vegetation cover and nutrition values for different wildlife groups are helpful data in forecasting the potential wildlife groups using the rehabilitated wetlands, but not observed by the field measures.

5) Microclimate.

The microclimate of the rehabilitated and reference wetlands was studied. The microclimatic conditions of the study area play an important role in the successful rehabilitation of the wetland communities. The microclimate has a direct effect on the vegetation growth, condition of vegetation, extent of the wetland areal size. The microclimatic data variables for 1985 and 1986 assessed were:

A. Site temperature--The average soil temperatures during the growing season and its effect on seed germination on the site.

B. Site moisture--The site soil moisture capacity and its effect on seed germination.

C. Solar radiation--The average amount of sunlight on the site and its affect on plant growth.

D. Wind--The effects of wind on plant growth, condition, soil temperatures, and soil moisture.

E. Surrounding landforms--The influence of the surrounding landforms on the site conditions.

The microclimatic data were collected from several sources. The Falkirk Mining Company had extensive site data on the microclimate of rehabilitated wetland. Soil Conservation Service and National Climatic Data Center had data of local site conditions near the rehabilitated and reference wetlands. The National Climatic Data Center has two climatic control stations, the Underwood and Washburn Stations, within 5 miles of the research and referance wetland sites which gave important data not unobtainable by on-site reconaissance. The climatic data of the wetlands were then assessed by comparing the results in 1985 and 1986 in an assessment matrix discussed in the analysis section of this chapter.

WILDLIFE PARAMETERS

The wildlife data variables were to relate the current wildlife of the rehabilitated wetland site to the pre-mine wildlife and project the potential wildlife composition and diversity after the rehabilitation by studying the wildlife of the unmined, natural reference wetland areas. Since wildife productivity is the most important land use goal of this research the physical and biological factors of the rehabilitation process were studied and compared to the unmined, natural wetland condition to assess their effect in increasing the wildlife potential of the site. The wildlife data variables studied to enable making this comparison were:

1) Wildlife species composition.

Premine Wildlife Inventory. A list of the wildlife species sited on the rehabilitated area prior to mining was compiled from field observations done in 1979 and 1980 as part of the mining permit to give an idea of the potential wildlife of the study area.

Waterfowl Species Composition. Since current accurate field data was not available for all the wildlife species listed in the premine inventory waterfowl were selected as a wildlife test group. Waterfowl species composition and diversity were chosen as indicators of the current wildlife productivity of the site for two reasons. One reason waterfowl were used as a test group was that the Falkirk Mine rehabilitation specialists had collected field data on the waterfowl composition for the rehabilitated and reference sites for both 1985 and 1986. The other reason waterfowl were selected as a test group was because waterfowl are probably the most important wildlife group to be served by the proper rehabilitation of the wetlands. As has already been discussed the prairie potholes are the most important waterfowl habitat areas in North America and waterfowl productivity is a prime concern of the rehabilitation efforts.

The waterfowl species on-site observations were done weekly by the Falkirk Mining Company in 1985 and 1986, during the waterfowl breeding season, from mid-June to mid-August, for both the rehabilitated and reference wetlands. These data were supplemented by site observations by the researcher during the migration season, in the fall of 1986.

2) Wildlife Diversity.

Waterfowl Species Diversity. Waterfowl diversity data was attained from field observations by Falkirk Mine rehabilitation specialists of broods (counts of hen ducks with their young) taken during the waterfowl breeding seasons of 1985 and 1986 for both the rehabilitated and the reference wetlands.

ANALYSIS OF DATA

The third process of the methodology was the analysis of data. The function of analyzing the data was to determine the success of the rehabilitated wetlands for wildlife use and be able to draw conclusions to recommend further their wildlife benefits. There were two variables involved in this analysis: 1) dependent and 2) independent. The physical and biological site characteristics were the independent variables which directly influenced the wildlife parameters or dependent variables. The rehabilitated wetland comparison to the reference wetlands was completed by the following steps: 1) an assessment matrix of the physical factors, 2) an analysis of the wetland vegetation , 3) an analysis waterfowl composition and diversity as a measure of wildlife productivity, and 4) an analysis using remote sensing and photogrammetric techniques for important wetland parameters.

1) ASSESSMENT MATRIX OF THE PHYSICAL FACTORS

The major function of the assessment matrix was to demonstrate the degree of suitability between the rehabilitated wetlands and the unmined, natural reference wetlands. Physiographic, hydrologic, soil, and microclimate data variables of the rehabilitated wetlands were assessed as to their comparison to the unmined, natural reference wetlands by ranking the comparison of each data variable as: low (little comparison), medium (some comparison), and high (high comparison). The assumption was that the unmined, natural reference wetlands have high wildlife values and the comparison of the data variables of the rehabilitated wetlands to those of the reference areas should indicate the present wildlife values of the rehabilitated wetlands.

2) VEGETATIONAL ANALYSIS

The vegetational analysis was based on data collected by the on-site reconnaissance and inventory of the wetland vegetation and the remote sensing and photogrammetric techniques of the rehabilitated and reference wetlands. From these analyses techniques the wetland vegetation species composition, species diversity, spatial variation, successional pattern, and cover and nutrition values for wildlife were determined.

The species composition and species diversity of the wetland vegetation was determined largely from the on-site inventory. The spatial community variation and pattern of the vegetation types was analyized by the use of various remote sensing techniques. The successional pattern was determined by the use of a wetland vegetation successional model which is described in detail below. The cover and nutrition values for wildlife were calculated using a vegetation database which will be described later in this section.

Wetland Vegetation Succession Model

Model Overiew. The wetland vegetation successional model was designed by Arnold G. Van Der Valk and follows H. A. Gleason's ideas on changes within plant communities (Van Der Valk, 1981). Gleason stated that any change in relative abundance of species in plant cover of an area or in its composition with time was a successional change. The rate of vegetation change is sometimes very rapid (ie., after surface coal-mining), but at other times can be very slow and almost imperceptible (Gleason, 1927).

The model is applicable to any type of freshwater wetland and enables the prediction of allogenic successions in the wetland due to either normal or unexpected environmental changes. The following model is presented as a qualitative model predicting only which species will be present, not their relative abundance.

In the Van Der Valk model, succession occurs whenever one or more new species become established, when one or more species already present are extirpated, or when both occur simultaneously in a wetland.

Changes in the plant composition of wetlands normally are the result of: 1) destruction of some or all of the existing vegetation by pathogens, herbivores, or humans (ie., surface coal-mining); 2) changes in the physical or chemical site conditions that favor the growth of some species over others (ie., nutrient or water levels); 3) interactions among plants (ie., competition or allelopathy); or 4) the invasion and establishment of new species (Van Der Valk, 1981). In all these instances realistic predictions about changes in the wetland vegetation composition can be made to develop a Gleasonian model of allogenic succession. To develop the model it is necessary to identify a limited number of key life history features sufficient to characterize the potential behavior of the wetland species of the site to predict the fate of the species when there are significant changes in the physical wetland environment.

Van Der Valk's model of freshwater wetland vegetation dynamics recognizes two basic types of wetland species based on their propagule longevity (seed life): 1) species with long-lived propagules present in the wetland's seed bank that can become established whenever suitable environmental conditions occur, and 2) species with short-lived propagules that can only become established in a wetland if the propagules reach the wetland during a period when the environmental conditions are suitable. In others words, wetland conditions allow only certain species to be established at a time and as wetland conditions change different types of species are then established. The extirpation of a species from a wetland in the model is due either to all the individuals of the species reaching the end of their normal life span before adding new individuals to the population, or a radical shift in the wetland environment that is unable to be tolerated by individuals of the species (ie., surface coal-mining).

Wetlands may be found in one of two different environmental states, with standing water (flooded) and without standing water (drawdown). The establishment, growth, and reproduction of all wetland species are influenced to some degree by the presence or absence of standing water and the impact of these two wetland environmental states on a species is an important feature of the model (Van Der Valk, 1981).

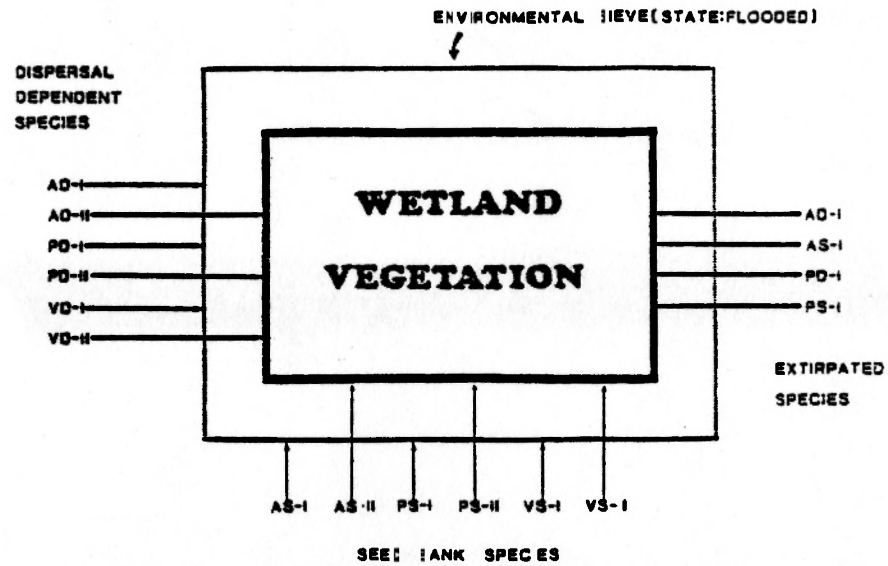
Model Description. Information on three key features of the life history of each species potentially present in a wetland is needed in this model: life span, propagule longevity, and establishment requirements.

Life span.- Wetland species can be placed in one of three groups on the basis of their potential life spans: 1) annuals (A-species), 2) perennials (P-species), and 3) vegetatively reproducing perennials (V-species). The annual group (A-species) includes mud-flat annual species (those present only during drawdowns when wetland is free of standing water), submersed and free-floating annual plants, and herbaceous species that are potentially perennials but behave as annuals in the temperate zone. The perennial plants (P-species) are classified as those species with or without vegetative reproduction and having a limited life span. Perennial plants with vegetative reproduction that do not have a definite life-span are classified as vegetatively reproducing perennials (V-species).

Propagule longevity.- The seeds and vegetative propagules of wetland species are placed in two ecological categories: 1) Dispersal dependent species (D-species), those with short-lived seeds and/or vegetative propagules and 2) Seed bank species (S-species), those species with long-lived seeds and/or vegetative propagules. Dispersal dependent species (D-species) with short-lived propagules are only able to become established on a site if there is a nearby source of viable propagules available and if those propagules reach the site when environmental conditions are suitable. Seed bank species (S-species) with long-lived propagules have seeds that are always present in the wetland soil (seed bank) where they have accumulated over many years. Thus, S-species can become established whenever suitable conditions for their establishement occur.

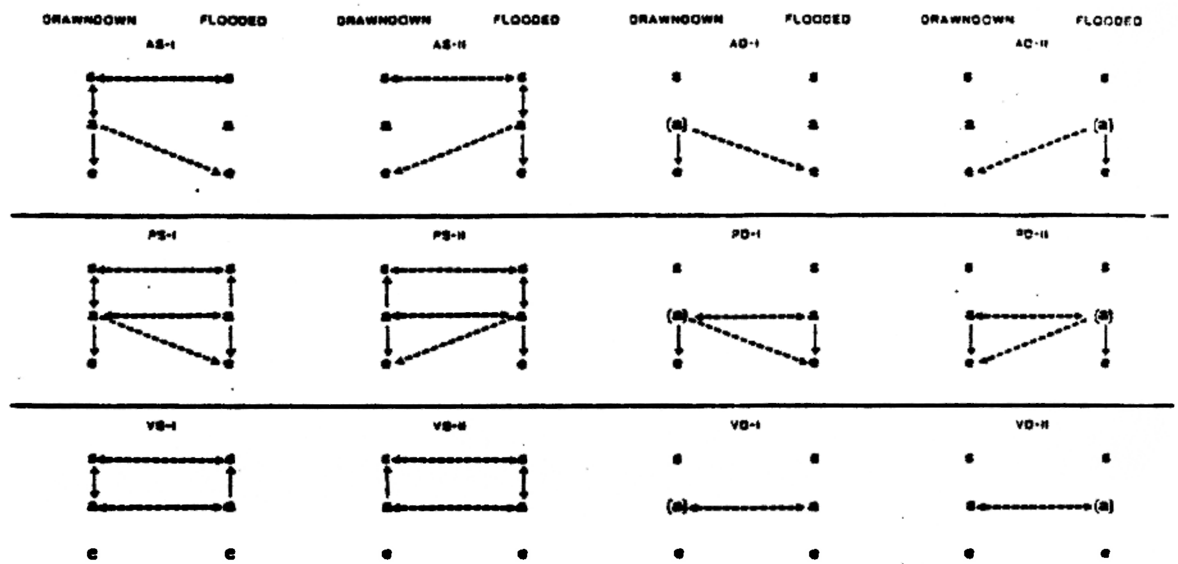
Propagule establishment requirements.- In wetlands new species can become established from seed or vegetative propagules depending on their seed germination or vegetative propagule establishment requirements. Wetland propagule establishment requirements can be broken down into two major types: 1) Drawdown species (Type-1), that can only become established when there is no standing water, and 2) Standing-water species (Type-2), that are able to be established when standing water is present. (Figure 3.6, shows the allogenic succession model in wetlands for flooded conditions).

By combining all three key life history features, 12 basic life history types are characterized. Figure 3.7, shows the potential species state transitions during drawdowns and flooded periods in wetlands for all 12 life history types. There are four annual species types: AS-1, propagules present in seed bank and established during a drawdown; AS-2, propagules present in seed bank, and established when the wetland is flooded; AD-1, propagules not found in the seed bank and established during a drawdown; and AD-2, propagules not present in the seed bank and established when the wetland is flooded. The perennial (P-species) and vegetative (V-species) life-span types each have four comparable life history types.



A model of allogenic succession in wetlands. The establishment and extirpation of species in this model are primarily a function of the physical environment. The environment behaves as a variable sieve that alternates between two states: drawndown (without standing water) and flooded (with standing water). As illustrated, the wetland is flooded. As a result only those species with the proper life history features can become established in the wetland, and other species, because of their life history characteristics, may be extirpated. When the wetland is drawndown, another set of species may become established and another set potentially will be extirpated.

FIGURE 3.6 A MODEL OF ALLOGENIC SUCCESSION IN WETLANDS
(Source: Van Der Valk, 1981)



Potential species state transitions during drawndown and flooded periods in a wet and for all 12 life history types. So id ines represent potentia transitions within an environmenta state, and dashed ines, transitions between environmental states. The three species states are: present as ong-ived propagu es in a persistent seed bank (s), mature adu ts (a), and ocally extinct (e). f estab ishment is dependent on the dispersa of propagu es from another site adu t popu ations are indicated in parentheses, (a).

FIGURE 3.7 POTENTIAL VEGETATION SPECIES TRANSITIONS DURING DRAWDOWNS AND FLOODED CONDITIONS IN WETLANDS

(Source: Van Der Valk, 1981)

Use of the Wetland Vegetation Succession Model. The model was used to predict the vegetation pattern of the rehabilitated wetland. To apply the model of succession to the Falkirk rehabilitated wetlands two crucial pieces of information were used: 1) the potential species of the wetland and 2) the life history type of each species.

It is the feeling of the researcher that the wetland vegetation succession model can be of great value in evaluating the rehabilitation success and the potential vegetation species of the rehabilitated wetland. If the potential vegetation of the rehabilitated wetland can be predicted according to changes within the wetland, this information can lead to better rehabilitation of the vegetative community and increased wildlife productivity.

The potential flora of the rehabilitated wetlands were obtained by the vegetation species lists compiled by mining company specialists and the botanical consultant, and on-site reconnaissance by the researcher of the species growing in the wetland at a given time. In addition the species found in the reference wetlands, but not in the rehabilitated wetlands, served as a comparison of the propagules of the rehabilitated wetland found only in the seed bank.

The life history type of each of the species in the potential flora was determined from the use of PIN (Plant

Information Network) Database developed by the U. S. Fish and Wildlife Service and the *Flora of the Great Plains* (McGregor et al., 1986).

Using the potential flora of the rehabilitated wetlands and the life history of the species, the researcher was able to predict the vegetation of the wetland area during a future drawdown and subsequent reflooding period. The predicted successional sequences in vegetation resulting from either flooding or drawdowns could be important in management of the wetlands for wildlife. If during the vegetative succession of the wetlands the occurrence or disappearance of important wildlife cover and nutrition floral species could be predicted, management techniques to best enhance or stimulate the growth of these species could be incorporated to increase the wildlife values of the sites. The successional model could also be used to look at the long-term effects of either flooding or drawdowns for proper wetland management of vegetation to further benefit wildlife.

Since a complete list of the potential flora of unmined, natural reference wetlands was not available to the researcher a list of the potential flora for a typical Class 3 and Class 4 prairie pothole wetland was used to compare the successional trends between natural and rehabilitated wetlands. The list of potential flora of the reference wetlands was compiled by combining the species inventory done by the researcher on the reference sites in Fall 1986 with the typical species of a Class 3 and Class 4 prairie pothole obtained from Stewart and Kantrud (1972).

Wetland Vegetation Cover and Nutrition Values for Wildlife

The vegetation potential for wildlife cover and nutrition was obtained by comparing the plant species lists of the rehabilitated and reference areas to the cover and nutritional values for those plants to different wildlife groups. The species lists were then compared to a list of wildlife cover and nutrition values compiled for over 5000 plant species in the Northern Great Plains contained in a database, Plant Information Network Database, developed by the U. S. Fish and Wildlife Service. The cover and nutrition values for each plant species were then calculated for seven different wildlife species/groups. The wildlife groups were: pronghorn antelope, mule deer, nongame birds (such as songbirds, shorebirds, and birds of prey), upland game birds (such as sharp-tailed grouse, ring-necked pheasant, mourning dove, wild turkey, and gray partridge), small mammals (rodents, rabbits, and carnivores), waterfowl (ducks and geese) and whitetail deer. Each plant species was rated using a scale of:

good=10, fair=5, and poor=1 for cover and nutrition value for wildlife. The cover value for each plant species were then totaled and averaged for an total and average cover value for each wildlife species/group. The nutrition value for each plant species was then totaled and averaged for each of the wildlife species/groups. The total cover and nutrition values were then totaled together and averaged for their habitat value.

3) <u>WILDLIFE ANALYSIS</u>

Wildlife Species Composition

The wildlife species composition was assessed by two methods. A pre-mine field inventory of the wildlife species sited on the rehabilitated area was used to give an idea of the potential wildlife in the wetland area. The field survey was taken in 1979 and 1980 as part of the mining permit process. Since no current data was available for all the wildlife species waterfowl were used as a test group to indicate the current wildlife conditions of the rehabilitated wetlands.

The waterfowl species composition of the research sites shows the duck and geese species currently using the sites. The waterfowl composition was calculated by duck and geese pairs, lone waterfowl males, and waterfowl males in groups of 5 individuals or less observed on the rehabilitated and reference wetlands by Falkirk rehabilitation specialists from mid-June to mid-August in 1985 and 1986.

It has been assumed that if the waterfowl composition has increased the habitat potential for other wildlife and therefore, the wildlife composition has been improved.

Wildlife Diversity

The waterfowl diversity of the wetlands also was important in assessing which duck and goose species were using the rehabilitated wetlands as potential nesting habitat as compared to the reference wetlands. It has been assumed that if the rehabilitated wetlands show improved diversity the wildlife productivity of all species has been improved.

4) REMOTE SENSING AND PHTOOGRAMMETRIC ANALYSIS

Wetland Classification using Landsat-5 Thematic Mapper Images.

The classified wetland maps of the research area were done by Ducks Unlimited to identify critical waterfowl production habitats, monitor habitat changes and losses, and improve waterfowl production estimates. The maps were made available to the researcher by Ducks Unlimited for use in the study and are depicted in Chapter 4-Results.

The Thematic Mapper capabilities on Landsat 5 were an improvement over previous Landsat methods for evaluating wetlands and vegetation. The increased resolution available with Landsat 5-TM meant reflectance variations within the wetland plant communities could be more closely defined on a quantative basis. Table 3.3 shows the bands available with Landsat 5 Thematic Mapper and their characteristics.

TABLE 3.3 LANDSAT 5 THEMATIC MAPPER CHARACTERISTICS

BAND	SPECTRAL WIDTH	PRIMARY USE
TM1	0.45-0.52 um	Increased water penetration; soil, land use, vegetation analyses.
TM2	0.52-0.60 um	Visible green reflectance peak of vegetation to analyze type & vigor.
TM3	0.63-0.69 um	Most important band for vegetation discrimination of plant types.
TM4	0.76-0.90 um	Vegetation density (biomass); water -land delineation.
TM5	1.55-1.75 um	Vegetation moisture measurement.
TM6	2.08-2.35 um	Water in plant leaves; hydrothermal mapping.
TM7	10.40-12.50 um	Plant heat stress; other thermal properties.

RESOLUTION: BAND 1-6 = 30 meters
BAND 7 = 120 meters

QUANTIZATION LEVELS: 256 bits

DATA RATE: 85 megabits/scene

The standard wetland inventory products produced from the Thematic Mapper data included reconnaissance maps, wetland classification maps, wetland basin identification maps, and wetland statistics summary reports. These data were able to be registered to any map or coordinate system and plotted as map overlays at any scale. The scale chosen and used by Ducks Unlimited was 1:24,000. All TM bands except band 7 (thermal) were used in the wetland analysis. The reconnaissance maps produced from Thematic Mapper Band 5 data aided in delineating wetlands, croplands, and various other land cover types. The wetland classification types were produced on translucent paper and depicted the various wetland types as different gray-tone patterns. The wetland types were open water, deep marsh, and shallow marsh. The deep marsh was defined as emergent wetland vegetation growing in a foot or more of water and shallow marsh as having vegetation growing in less than a foot of water. The wetland basin ID maps were also produced on translucent paper and designed to overlay the wetland classification maps so that each basin was identified by a number (Koeln et al., 1986).

Summary reports were also generated for each wetland classification map. For each wetland, the total acres, acres of each wetland type, the northwest UTM (Universal Transverse Mercator) or geographic coordinate, wetland perimeter, and a basin shape index were produced. A summary of the wetlands by wetland class was also provided for each map (Koeln et al., 1986).

The image processing software utilized in the study by Ducks Unlimited was ELAS (Earth Resources Laboratory Applications Software) and was developed by NASA at the National Space Technology Laboratories (Graham et al., 1985).

There were twelve major steps used by Ducks Unlimited in processing a Thematic Mapper scene to the required wetland informational products (Koeln et al., 1986). Detailed descriptions of ten of these steps are found in the ELAS manual (Graham et al., 1985). However, two steps (MUSCHMEAN and DUHT) were unique to the wetland process developed by Ducks Unlimited and require some further explanation.

The best Thematic Mapper bands for determining the wetland type were bands 3, 4, and 5. This was because these bands gave the most wetland vegetation community information, which was essential in classifying the wetlands as to type. Since with these bands the wetlands were distinctive, MUCSMEAN was used to group the spectral classes into informational types automatically. After color coding and displaying the wetland types in the classified data, the analyst modified the assignment of the spectral classes.

DUHT incorporated a connective component algorithm to process the wetland data. The following were calculated for each wetland: 1) the Universal Transverse Mercator or geographic coordinates of the northern and western extent of the basin, 2) total acreage, 3) acres of each wetland type, 4) wetland perimeter in miles, and 5) an index indicating the shape of the basin. The number of wetlands in the various size categories was also calculated.

DUHT first utilized a subfile (WETL) to designate which spectral classes of the classified image were used to form each wetland informational type.

The area covered on an existing published map was extracted from the full scene of classified data. A polygon describing Universal Transverse Mercator or geographic location of the map corners was used to extract the desired data. An intermediate file (INF1) containing the classified data for the map was created to identify the extent of each wetland. By following this process the INF1 file was converted into a binary file, in which a pixel had the value of 1 if it was a wetland pixel or Ø if it was not. Next, INF1 was read line by line, and each interval of wetland pixels on the current line was compared with those in the previous line to determine if they were part of the same wetland. Records that indicate which intervals were to be joined were written into a work file.

The work file was read in reverse, and each pixel of a contiguous wetland was assigned the same unique wetland basin number. This process produced a second intermediate file (INF2) that had consecutively numbered wetlands.

For each wetland in the INF2 file, the pixels of the various wetland types were totaled and converted into acres, and the wetland perimeter was simultaneously calculated. A basin shape index was also generated that represented the ratio of the perimeter to the circumference of a circle with the identical area as the basin. A circular wetland had an index value 1.0, while the more irregularly shaped a wetland became, the greater the index value. The greater the index value the greater the importance of the wetland for wildlife habitat, since more irregular wetland perimeters allow more diverse edges and vegetation patterns to be naturally developed. These statistics were tabulated in a wetland statistics file and also reformatted for incorporation into the wetland data base.

Histogram/Mean Brightness Response of Black and White Aerial Photographs.

Color infrared photography of the rehabilitated and reference sites taken on 7/2/85 and 6/25/86 at scales of 1:12,000, were photographed as black and white photographs to measure the brightness of the wetland areas. With the use of an Imageplus video image analysis system incorporated with the use of a microcomputer (640 K) the quantitative values of the brightness value for each sample area was calculated. The brightness was displayed as a histogram or representative frequency distribution of the relative light or dark areas of the wetlands. These light or dark areas represented the characteristic vegetation zones of the wetlands, wet meadow, shallow marsh, and deep marsh. The mean brightness was also calculated for these areas. By comparing the histograms/means of the rehabilitated wetlands from 1985 to 1986 the relative changes in the wetland vegetation zonation could be seen and measured. By comparing the histograms/means of the rehabilitated wetlands to the reference wetlands from 1985 to 1986 the comparison of the vegetation zonation of the rehabilitated wetlands to the reference wetlands, and changes in vegetation development could be measured.

The video image analysis system is based upon using a "floating spot" scanning a designated area recording a brighness value for a determined pixel size. The "floating spot" was first used on the 1985 rehabilitated wetland site A in a designated area which surrounded the wetland to determine the brightness response of the water and vegetation on 7/2/85. The process was then repeated for rehabilitated site B and the reference sites A and B for 7/2/85 to calculate the brightness responses. The "floating spot" was then repeated on the same approximate designated area for the rehabilitated and reference wetlands for the 6/24/86 imagery.

The values of brightness response for each of the wetland vegetation zones could not be calculated individually. However, the general changes in the wetland vegetation extent and condition and the water extent and condition could be determined fairly accurately with the system.

Color Infrared Imagery

The use of color infrared imagery enabled the rehabilitated wetlands to be compared to the reference wetlands with greater accuracy. The analysis of these photographs was important in giving hydrological information on the wetland size and quality, and the wetland vegetation patterns.

The color infrared aerial photographs were obtained from the Falkirk Mining Company for the rehabilitated wetlands in 1985 and 1986. These low altitude aerial photos were shot at a scale of 1:12,000 on 7/2/85 and 6/24/86.

The color infrared aerial photographs of the reference wetlands were obtained from the U. S. Dept. of Interior, Bureau of Reclamation in Bismarck, North Dakota. These low altitude photographs, also 1:12,000 scale, were taken on

7/5/85. No color infrared photos of the reference wetlands were available in 1986.

Natural Color Imagery

Natural color transparencies of the rehabilitated and reference wetlands were also used to assess the wetland sizes, condition, and wetland vegetation patterns.

The natural color transparencies were obtained from the McLean County Soil Conservation Service for both 1985 and 1986. The scale of the aerial photos was 1:12,000. The 1985 transparencies were taken 6/30/85 of the rehabilitated and reference wetlands, while the 1986 transparencies were taken for both wetlands on 7/3/86.

SITE SELECTION

A. Regional Selection Criteria
1. Coal resources present
2. Wetland acres present

B. Study Site Selection Criteria
1. Location within region selected
2. Presence of rehabilitated surface coal-mined wetlands
3. Presence of unmined wetlands of the same type as rehabilitated wetlands
4. Cooperation of a mining company

DATA COLLECTION

A. Physiography
1. Elevation
2. Slope
3. Aspect
4. Bedrock type & condition
5. Landform dissection

B. Hydrology
1. Water quality & quantity
2. Watershed stability

C. Soils
1. Composition
2. pH
3. Texture
4. Topsoil thickness
5. Organic matter content
6. Water holding capacity

D. Microclimate
1. Site temperatures
2. Site precipitation
3. Solar radiation
4. Wind speed
5. Surrounding landforms

[A–D: Physical Factors]

E. Vegetation
1. Species composition
2. Species diversity
3. Spatial community variation
4. Successional pattern
5. Cover & nutrition wildlife values

F. Wildlife
1. Species composition
2. Species diversity

[E–F: Biological Factors]

DATA ANALYSIS

A. Assessment Matrix
(physical factors)

B. Remote Sensing Techniques
1. Landsat-5 Thematic Mapper
2. Brightness Response of B&W
3. Color-Infrared Photos
4. Natural Color Photos

(physiography, hydrology, and vegetation)

C. Wetland Vegetation Succession Model
(vegetation)

D. Plant Information Network Database
(vegetation)

E. Waterfowl Pair Counts
(wildlife)

F. Waterfowl Brood Counts
(wildlife)

TABLE 3.1 PROCESSES AND METHODS USED IN STUDY

CHAPTER FOUR

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RESULTS

OVERVIEW

The results of the study have been organized into four sections. The first section contains an analysis of the physical factors of the rehabilitated and reference wetlands for 1985 and 1986. These physical factors include the physiographic, hydrologic, soils, and microclimatic indicators of the sites. The second section describes the results of the vegetational analysis of the rehabilited and reference wetland sites including the vegetation species composition, species diversity, spatial variation, successional patterns or trends, and the wildlife cover and nutrition values for seven important wildlife species or species groups. The third section contains the results of the migratory waterfowl species composition and diversity, using ducks and geese as a wildlife test group to measure the wildlife productivity of the rehabilitated sites in comparison to the reference sites. The fourth section has the results of the remote sensing and aerial photogrammetric visual analysis of the wetlands as used in the study to add vital wetland data and integrate with the ground truth information.

REVIEW OF LOCATION & CLASSIFICATION OF THE WETLANDS

Before discussing the results the locations, sizes, and wetland class of the rehabilitated and reference wetlands will be reviewed. The two rehabilitated wetlands , less than a quarter mile apart, are located in Township 146 North, Range 82 West, Section 31, just southwest of the town of Underwood, North Dakota. One rehabilitated wetland is approximately 10 acres in size (rehabilitated site A), while the other is approximately 30 acres in size (rehabilitated site B). The smaller rehabilitated wetland (site A) is classified as a Class 3 freshwater seasonal prairie pothole wetland based on criteria established by Stewart and Kantrud (1971). It is a common seasonal occurrence for Class 3 prairie pothole wetlands to be dry with only exposed mudflats by late summer-early fall in this region. The larger rehabilitated wetland (site B) is classified as a Class 4 freshwater semipermanent prairie pothole wetland using the same pothole wetland classification criteria as established by Stewart and Kantrud (1971). Most Class 4 prairie pothole wetlands are considered semipermanent and have standing water the entire year frequently, but may go dry every few years in late summer-early fall due to periodic drought conditions found in this region. Both wetland Classes 3 and 4 are characterized by having a wet meadow vegetation zone, shallow marsh vegetation zone, and some development of a deep marsh vegetation zone.

The two reference wetlands, about one half mile apart, are located in Township 145 North, Range 79 West, Section 7 are located about 17 miles from the rehabilitated wetlands. One of the reference wetlands (site A) is approximately 10 acres in size. The other reference wetland (site B) is approximately 57 acres in size, but the study only is concerned with the southwest half of the wetland which is about 25 acres in size (to match the size of the larger rehabilitated wetland). The smaller reference wetland (site A) is classified by Stewart and Kantrud (1971) as a Class 3, fresh to slightly brackish prairie pothole wetland. The larger reference wetland (site B) is classified as a Class 4, fresh to slightly brackish prairie pothole wetland. The site characteristics of the two reference wetlands match up with the rehabilitated wetlands well for the comparisons that were needed to do the study.

SECTION ONE

PHYSICAL FACTORS

The major results of the data collected on the physiography, hydrology, soils, and microclimate of the rehabilitated and reference wetlands are included in this section. Table 4.1 shows the assessment matrix of the general comparison of the physical conditions of the rehabilitated wetlands to the reference wetlands. The individual comparisons of the most important data variables of the physical conditions are outlined in each part of this section (Section One - Physical Factors).

TABLE 4.1 ASSESSMENT MATRIX COMPARISON OF PHYSICAL FACTORS (REHABILITATED WETLANDS TO REFERENCE WETLANDS)

COMPARISON OF 1985 & 1986:	HIGH	MEDIUM	LOW
PHYSIOGRAPHY:			
ELEVATION (HIGH TO LOW):		X	
SLOPE:	X		
ASPECT:	X		
BEDROCK TYPE/CONDITION:		X	
BEDROCK DEPTH:		X	
LANDFORM DISSECTION:		X	
HYDROLOGY:			
WATER QUALITY:			
pH:	X		
CALCIUM:		X	
MAGNESIUM:			X
SODIUM:			X
SODIUM ADSORPTION RATE:			X
HARDNESS:			X
NITRATES:		X	
WATER QUANTITY:	X (1985)	X (1986)	
WATERSHED STABILITY:	X		
SOIL:			
COMPOSITION:		X	
pH:	X		
TEXTURE:	X		
TOPSOIL THICKNESS:		X	
ORGANIC MATTER CONTENT:		X	
WATER HOLDING CAPACITY:		X	
MICROCLIMATE:			
SITE TEMPERATURES:	X		
SITE PRECIPITATION:	X (1985)	X (1986)	
SOLAR RADIATION:	X		
WIND SPEED:	X		
SURROUNDING LANDFORMS:	X		

Physiography. The physiographic factors measured were elevation, slope, aspect, bedrock type and depth, and landform dissection. Table 4.2 shows the physiographic features of the sites.

The water elevations of the wetlands at their low points varied from 1960 feet (above mean sea level) on rehabilitated wetland Site A and 1958 feet on rehabilitated wetland Site B to 1818 feet on reference wetlands Sites A & B. The high points in the water elevations for the wetlands were: 1963 (above mean sea level) for rehabilitated Site A, 1966 for rehabilitated Site B, 1820 for reference Site A, and 1822 for reference Site B.

The slopes of the wetlands ranged from 1% to 2.5% on the sites. An average slope of about 2% was found on both the rehabilitated and reference wetlands. The return of the slope to nearly premine grade was important in allowing the same approximate runoff rates into the rehabilitated wetlands as found in the average prairie potholes of the vicinity ie., as in the reference wetlands.

The aspect of the all the sites was primarily a north and south facing slopes. The aspect determines the angle and to some degree the amount of solar radiation on the rehabilitated potholes, influencing the vegetational pattern.

The bedrock type of all the sites consisted of glacial parent material, found throughout the glacial till. The bedrock occurred at depths greater than 60 inches deep in the unmined areas.

The landforms surrounding the wetlands varied from revegetated uplands and disturbed uplands in the mining production phase in the rehabilitated wetland area to uplands used primarily for rangeland and agriculture in the reference wetland area.

TABLE 4.2 PHYSIOGRAPHIC COMPARISONS OF THE WETLAND AREAS

	REHAB. A	REHAB. B	REF. A	REF. B
LOW ELEVATION:	1960	1958	1818	1818
HIGH ELEV. :	1963	1966	1820	1822
SLOPE:	1-2%	1-2.5%	1-2%	1-3%
ASPECT:	N-S	N-S	N-S	N-S
BEDROCK TYPE:	GL.TILL	GL.TILL	GL.TILL	GL.TILL
BEDROCK DEPTH:	>60"	>60"	>60"	>60"
LANDFORM DISSECTION:	UPLAND	UPLAND	UPLAND	UPLAND

Hydrology. The hydrological data variables assessed were water quality and watershed stability. The water quality of the wetland sites was measured for: pH, calcium, magnesium, sodium, sodium adsorption ratio, hardness, and nitrates. The water quality was measured on the rehabilitated and reference wetlands only for 1986 since no data was available for 1985. Table 4.3 shows the results of the water quality measures taken on the wetland sites in 1986.

The pH, calcium, and nitrate measurements were fairly comparable between the rehabilitated wetlands and the reference wetlands. The pH of the wetland sites ranged from 8.5 (Site A) and 8.8 (Site B) on the rehabilitated wetlands to 8.4 (Site A) and 8.3 (Site B) on the reference wetlands. The pH measurements of the wetlands were found to be in the average range for prairie pothole wetlands. Moyle (1945) found the average pH of the prairie potholes to be between 8.4 and 9.2. Since pH is a good indicator of the potential for vegetation growth leading to a stable ecosystem the pH ranges on the rehabilitated wetlands is very encouraging.

The calcium of the wetlands ranged from 27.7 mg/l (Site A) and 51.5 mg/l (Site B) on the rehabilitated sites to 52.2 mg/l (Site A) and 63.3 mg/l (Site B) on the reference sites. These calcium rates are close to the range found in a study of Wisconsin marshes (Klopatek, 1978) for marsh outflows (56-168 mg/l) indicating a more stable nutrient wetland base is becoming established.

Nitrates ranged from <1.4 mg/l (Site A) and .55 mg/l

(Site B) on the rehabilitated wetlands to 3.1 mg/l (Site A) and 2.3 mg/l (Site B) on the reference wetlands. Nitrates are among the most important elements found in marshes to vegetation development. Although the rehabilitated wetlands have lower totals than the reference wetland the fact that they compare at all at this point in the rehabilitation development is encouraging.

The results of the measures for magnesium, sodium, sodium adsorption ratio, and hardness varied greatly between the rehabilitated wetlands and the reference wetlands. The magnesium ranged from 30.4 mg/l (Site A) and 37.5 mg/l (Site B) on the rehabilitated wetlands and 75.8 mg/l (Site A) and 80.0 mg/l (Site B) on the reference wetlands. The magnesium rates are also important to plant growth and usually become established more slowly (Klopatek, 1978).

The sodium rate was 17.3 mg/l (Site A) and 24.2 mg/l (Site B) on the rehabilitated wetlands, but was 55.7 mg/l (Site A) and 106.8 mg/l (Site B) on the reference wetlands. The differences in the sodium rates could be due to the fact that the reference wetlands may be slightly more saline than the wetlands in the rehabilitated wetland area.

The rehabilitated wetlands had sodium adsorption rates of .54 (Site A) and .63 (Site B), while the reference wetlands had sodium adsorption rates of 3.3 (Site A) and

5.6 (Site B).

The hardness ranged from 194 mg/l (Site A) and 283 mg/l (Site B) on the rehabilitated wetlands to 505.0 mg/l (Site A) and 555.5 mg/l (Site B) on the reference areas. The differences in the hardness may reflect some of the differences in the species composition of the vegetation, since some flora are adapted to such hardness conditions as found in the reference wetlands.

The watershed stability calculated by the Falkirk Mining Company for the rehabilitated wetland Sites A & B appear in Figures 4.1 and 4.2.

TABLE 4.3 WATER QUALITY OF WETLAND SITES

	REHAB. A	REHAB. B	REF. A	REF. B
pH:	8.5	8.8	8.4	8.3
CALCIUM: (mg/l)	27.7	51.5	52.2	63.3
MAGNESIUM: (mg/l)	30.4	37.5	75.8	80.0
SODIUM: (mg/l)	17.3	24.2	55.7	106.8
SODIUM ADSORPTION RATE:	.54	.63	3.3	5.6
HARDNESS: (mg/l)	194.0	283.0	505.0	555.5
NITRATES: (mg/l)	<1.4	<.55	3.1	2.3

(mg/l=milligrams per liter)

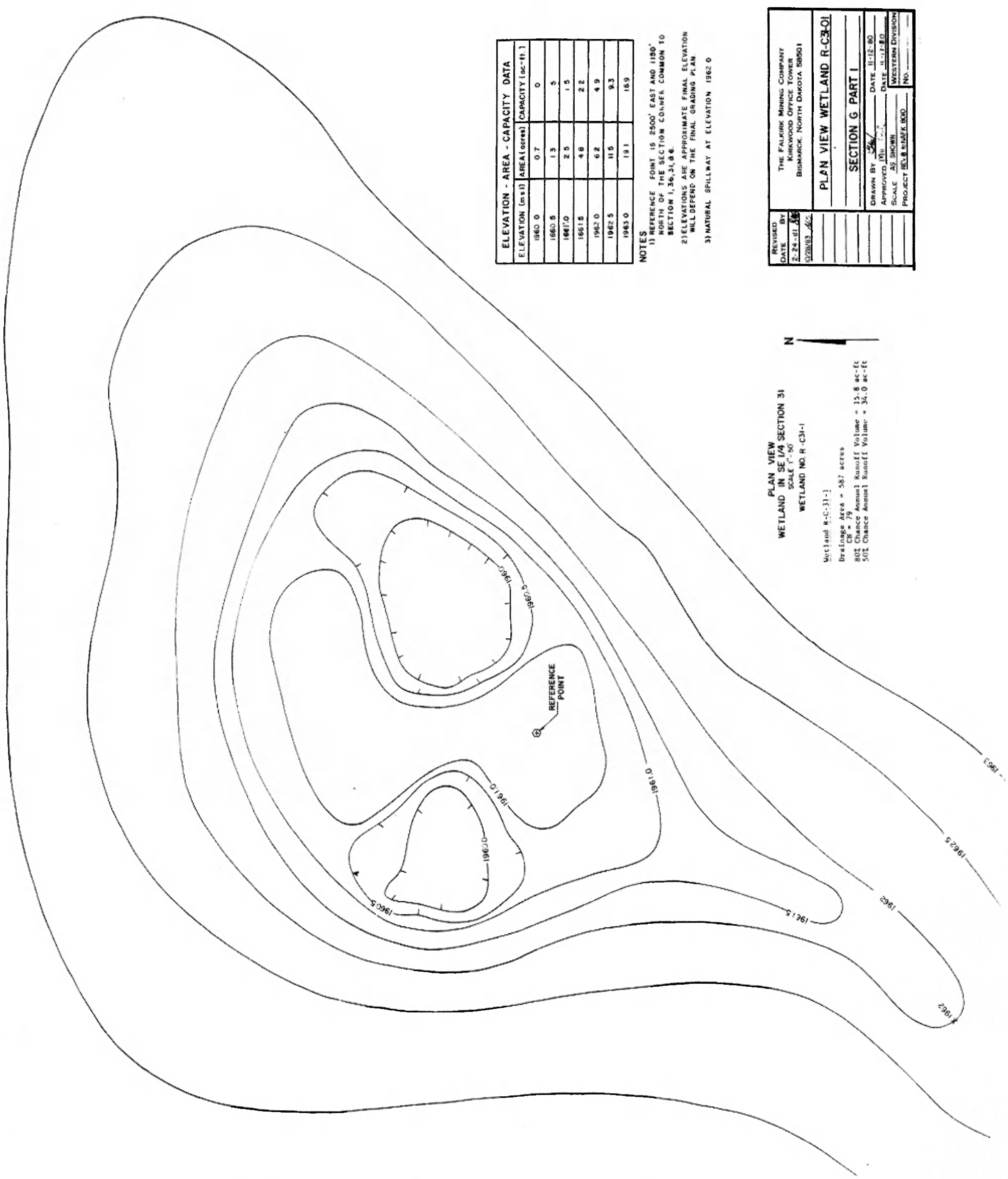

FIGURE 4.1 PLAN VIEW OF REHABILITATED WETLAND SITE A

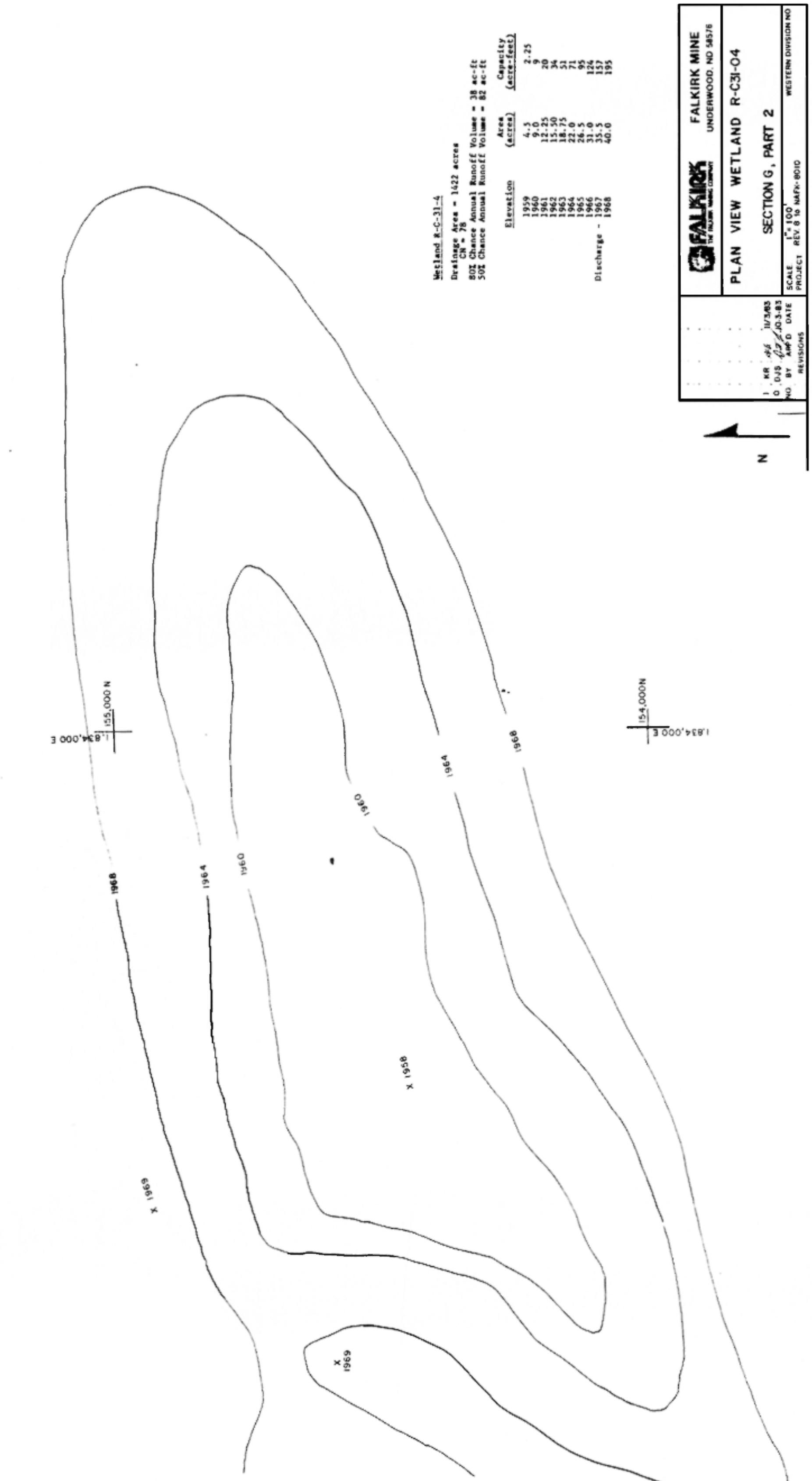

FIGURE 4.2 PLAN VIEW OF REHABILITATED WETLAND SITE B

The measures of the water quality of the rehabilitated and reference wetlands are relatively normal concentrations for the prairie pothole region. The pH, indicating more alkaline conditions, is fairly typical of the pothole wetlands. The rehabilitated wetlands are considered fresh water with low salinity and hardness rates. The salinity rates of the reference wetlands are higher indicating they are slightly saline. The difference in the salinity rates between the wetlands is not unusual for the prairie potholes. Fluctuations in sodium concentrations of dissolved solids in the prairie potholes can be found from 0-1000 mg/l in fresh water (rehabilitated wetlands), 1000-3000 mg/l in slightly saline water (reference wetlands), 3000-10000 mg/l in moderately saline water, 10000-35000 mg/l in very saline water (Sloan, 1972). The differences in the calcium, magnesium, hardness, and nitrates are all well within the normal ranges for the prairie potholes. These different rates may occur due to differences in the wetlands or from seasonal fluctuations of these minerals in the wetlands at the time of measurement.

Soil. The soil variables analyzed were composition, pH, texture, topsoil thickness, organic matter content, and water holding capacity. Table 4.4 shows the results of the soil variables on the rehabilitated and reference wetlands.

The soil composition of the rehabilitated wetlands differed somewhat from the reference wetlands. The rehabilitated sites had more diverse soil types than the soils of the reference sites with Parnell, Tonka, and Aquolls soils most common in the rehabilitated wetlands. The reference wetlands had fewer soil types and were composed mainly of Colvin, Parnell, and Williams soils.

The pH and texture of all the sites were fairly consistent. The pH ranged from 6.1 to 8.4 on the wetland sites. The texture was predominantly composed of loam, clay loams, and silty clays.

The topsoil thickness was <17" on the rehabilitated wetlands and between <9" (Site A) and <60" (Site B) on the reference wetlands.

The organic matter content was moderate on the rehabilitated wetlands and high on the reference wetlands.

The water holding capacity of the wetlands varied from .03-.24 in./in. on the rehabilitated wetlands to .11-.22 in./in. (Site A) and .14-.24 in./in. (Site B) on the reference areas.

TABLE 4.4 SOIL DATA OF THE WETLAND SITES

	REHAB. A	REHAB.B	REF.A	REF.B
COMPOSITION:				
AQUOLLS:	*	*	*	*
ARNEGARD LOAM:	*	*		
BOWDLE LOAM:	*	*		
COLVIN SILTY CLAY LOAM:				*
GRAIL SILTY CLAY LOAM:	*	*		
HAMERLY LOAM:	*	*		
MAX LOAM:	*	*		*
MAX ZAHL LOAM:	*	*	*	
PARNELL SILTY CLAY LOAM:	*	*	*	
TONKA SILT LOAM:	*	*		
WILLIAMS STONY LOAM:				*
WILLIAMS BOWBELL LOAM:	*	*	*	
pH:	6.1-8.4	6.1-8.4	6.1-8.4	6.1-8.4
TEXTURE:				
LOAM:	*	*	*	*
CLAY LOAM:	*	*	*	*
GRAVELLY CLAY LOAM:	*	*		*
SILTY CLAY LOAM:	*	*	*	*
SILTY CLAY:	*	*	*	
TOPSOIL THICKNESS:	<17"	<17"	<9"	<60"
ORGANIC MATTER CONTENT:	MODERATE	MODERATE	HIGH	HIGH
WATER HOLDING CAPACITY: IN./IN.:	.03-.24	.03-.24	.11-.22	.14-.24

<u>Microclimate.</u> The microclimate of the study areas was assessed for site temperatures, site precipitation, solar radiation, and wind speed for 1985 and 1986.

The average daily site temperatures of the rehabilitated and reference wetlands for the years 1985 and 1986 were quite similar. The average daily temperature for 1985 was 40.0°F on the rehabilitated wetlands and 41.1° F on the reference areas. The 1986 average temperature was 43.3 F on the rehabilitated sites and 43.8 °F on the reference sites. Table 4.5 shows the results of the site temperatures and site precipitation for 1985 & 1986.

The precipitation of the sites was fairly uniform in 1985, but differed in 1986 (Table 4.5). In 1985 the precipitation of the rehabilitated wetland area was 17.9 inches total and 18.8 inches total in the reference wetlands. The precipitation of the sites in 1986 was 23.4 inches total in the rehabilitated area and 19.2 inches total in the reference area, a difference of 4.2 inches more precipitation in the rehabilitated areas. The season with the biggest precipitation change in 1986 was during the optimal growing season for the wetland vegetation (Apr.-Oct.) when the precipitation of the rehabilitated area was 20.29 inches total as compared to 16.85 inches total for the reference area.

The solar radiation of the sites was calculated from an average number of clear days/month for the regional area of the wetlands. The monthly totals were: Jan. (6), Feb. (5), Mar. (6), Apr. (6), May (6), June (7), July (12), Aug. (13), Sept. (10), Oct. (10), Nov. (6), and Dec. (6). The average number of clear days/year for the regional area was 93 days.

TABLE 4.5 SITE TEMPERATURES & PRECIPITATION OF WETLANDS

	SITE TEMPERATURES (°F)				SITE PRECIPITATION (IN)			
	REHAB. A&B 1985	REHAB. A&B 1986	REF. A&B 1985	REF. A&B 1986	REHAB. A&B 1985	REHAB. A&B 1986	REF. A&B 1985	REF. A&B 1986
JAN.	7.6	21.5	8.4	23.4	.38	.38	.25	.32
FEB.	12.8	13.2	14.4	16.0	.11	.36	.12	.28
MAR.	32.1	38.8	33.9	40.6	1.72	.41	.60	.24
APR.	47.2	42.3	49.4	43.2	1.41	4.58	1.75	3.76
MAY	61.7	57.2	58.7	56.5	4.01	2.60	4.54	2.95
JNE.	60.4	67.8	60.9	66.9	2.17	2.78	2.60	2.38
JUL.	71.3	68.7	72.4	68.2	1.05	4.26	1.52	2.59
AUG.	64.4	67.3	65.5	65.3	3.00	2.29	4.09	1.85
SEP.	54.1	53.5	54.6	53.5	1.04	3.39	1.28	2.16
OCT.	44.1	45.2	46.9	46.1	1.72	0.39	1.53	1.16
NOV.	14.9	21.7	17.5	23.8	1.22	1.95	0.48	1.50
DEC.	9.2	22.6	10.9	22.6	.32	.00	.19	.00
AVG/ MON.	40.0	43.3	41.1	43.8				
YR/ TOT. INCHES					17.9	23.4	18.8	19.2

The wind speed measurements showed little variance between the rehabilitated sites and the reference sites for both 1985 and 1986. The wind speeds were taken at 6" above the ground during the optimal growth season for the vegetation (Apr.-Oct.). The average monthly wind speed in 1985 was 3.10 MPH for the rehabilitated wetland area and 3.20 MPH for the reference wetland area. The 1986 monthly wind speed was 3.10 MPH for both the rehabilitated and reference wetland areas. (Table 4.6 shows the results of the wind speed measurements taken monthly in 1985 & 1986.)

TABLE 4.6 WIND SPEED OF WETLAND SITES AT 6" ABOVE GROUND

	REHAB. A & B		REF. A & B	
	1985	1986	1985	1986
APR.	3.52	4.58	3.52	4.58
MAY	3.25	3.74	3.25	3.74
JUNE	2.95	3.39	2.95	3.11
JULY	2.87	2.23	2.85	2.41
AUG.	3.04	2.19	3.11	2.36
SEPT.	3.40	2.59	3.60	2.51
OCT.	3.15	3.15	3.15	3.15
AVG. MPH/ MONTH	3.10	3.10	3.20	3.10

*DATA AVAILABLE ONLY FOR VEGETATION GROWING SEASON

SECTION TWO

VEGETATIONAL ANALYSIS RESULTS

The vegetation was analyzed for species composition, species diversity, spatial variation, successional pattern, and wildlife cover and nutrition values. The results of each of these data variables are outlined in the headings below. The complete data of these variables, plus the potential biomass, short term revegetation value, and long term revegetation value, for each plant species in each vegetational zone of each of the wetland sites is included in Appendix A.

Species Composition. The species composition of the vegetation of the rehabilitated wetlands was compared with the vegetational species composition of the reference areas. The vegetation of the rehabilitated sites was inventoried separately in the field. The reference sites were also inventoried separately for vegetation, but appear in one table since the species composition of the two reference sites was identical. The results of the species composition of the sites appear in three tables. Table 4.7 has the results of the species composition of the vegetation on rehabilitated Site A. Table 4.8 contains the results of the species composition of the vegetation on rehabilitated Site B. Table 4.9 has the results of the vegetational species composition on the reference wetlands

TABLE 4.7 SPECIES COMPOSITION OF VEGETATION ON REHAB. SITE A

Genus	Species
Agropyron	elongatum
Agropyron	repens
Agropyron	smithii
Alisma	grameum
Alisma	plantago-aquatica
Alopecurus	aequalis
Amaranthus	albus
Amaranthus	graecizans
Amaranthus	retroflexus
Artemisia	biennis
Aster	ericoides
Aster	hesperius
Beckmannia	syzigachne
Bidens	comosa
Bidens	vulgata
Brassica	arvensis
Brassica	kaber
Carex	atheroides
Carex	lanuginosa
Chenopodium	berlandieri
Chenopodium	rubrum
Echinochloa	muricata
Eleocharis	acicularis
Eleocharis	engelmenia
Eleocharis	obtusa var. ovata
Eleocharis	palustris
Eleocharis	smallii
Gratiola	neglecta
Helianthus	annus
Hordeum	jubatum
Kochia	scoparia
Lactuca	serriola
Lycopus	americanus
Malva	rotundifolia
Mentha	arvensis
Myriophyllum	exalbescens
Panicum	capillare
Panicum	virgatum
Phalaris	arundinacea
Plagiobothrys	scouleri
Poa	palustris
Polygonum	coccineum
Polygonum	convolvulus
Polygonum	lapathifolium
Polygonum	ramosissimum
Populus	deltoides
Portulaca	oleracea
Potamogeton	gramineus
Potamogeton	pectinatus
Potamogeton	pusillus
Potamogeton	richardsonii
Potentilla	norvegica
Ranunculus	subrigidus
Rorippa	palustris
Rumex	maritimus
Rumex	mexicanus
Rumex	pseudonatronatus
Rumex	stenophyllus
Sagittaria	cuneata
Salix	amygdaloides
Salix	interior
Salix	lutea
Salsola	iberica
Scirpus	acutus
Scirpus	fluviatilis
Scirpus	heterochaetus
Scirpus	validus
Setaria	glauca
Setaria	viridis
Sparangium	chlorocarpum
Stachys	palustris
Typha	angustifolia
Typha	latifolia
Typha	x glauca
Zannichellia	palustris

TABLE 4.8 SPECIES COMPOSITION OF VEGETATION ON REHAB. SITE 3

Genus	Species
Agropyron	smithii
Alisma	gramineum
Alisma	planago-aquatica
Alopecurus	aequalis
Amaranthus	retroflexus
Artemisia	biennis
Beckmannia	syzigachne
Bidens	comosa
Bidens	vulgata
Brassica	kaber
Carex	atheroides
Chenopodium	berlandieri
Chenopodium	rubrum
Echinochloa	muricata
Eleocharis	acicularis
Eleocharis	obtusa var. obtusa
Eleocharis	palustris
Gratiola	neglecta
Hordeum	jubatum
Myriophyllum	exalbescens
Phalaris	arundinacea
Poa	compressa
Poa	palustris
Polygonum	coccineum
Polygonum	lapathifolium
Portulaca	oleracea
Potamogeton	foliosus
Potamogeton	friesii
Potamogeton	gramineus
Potamogeton	pectinatus
Potamogeton	richardsonii
Potamogeton	zosteriformis
Ranunculus	subrigidus
Rorippa	palustris
Rumex	maritimus
Rumex	mexicanus
Rumex	pseudonatronatus
Rumex	stenophyllus
Salix	amygdaloides
Salix	lutea
Scirpus	fluviatilis
Senecio	congestus
Setaria	viridus
Stachys	palustris
Typha	x glauca

TABLE 4.9 SPECIES COMPOSITION OF VEGETATION OF REF. SITES A & B

Genus	Species	Genus	Species
Alisma	gramireum	Lysimachia	hybrida
Alisma	plantago-aquatica	Marsilea	mucronata
Alopecurus	aequalis	Mentha	arvensis
Apocynum	sibiricum	Myriophyllum	exalbscens
Artemisia	biennis	Myriophyllum	heterophyllum
Asclepias	speciosa	Myriophyllum	verticillatum
Aster	hesperius	Phalaris	arundinacea
Aster	simplex	Phragmites	communis
Atriplex	patula	Plantago	eriopoda
Beckmannia	syzigachne	Poa	palustris
Boltonia	latisquama	Polygonum	amphibium
Calamagrostis	canadensis	Polygonum	coccineum
Calamagrostis	inexpansa	Potamogeton	diversifolius
Callitriche	hermaphroditica	Potamogeton	gramineus
Callitriche	heterophylla	Potamogeton	pectinatus
Carex	atheroides	Potamogeton	pusillus
Carex	laeviconica	Potamogeton	richardsonii
Carex	lanuginosa	Potamogeton	vaginatus
Carex	praegracilis	Potamogeton	zosteriformis
Carex	sartwellii	Potentilla	norvegica
Carex	vulpinoidea	Puccinellia	nuttalliana
Ceratophyllum	demersum	Ranunculus	cymbalaria
Chenopodium	rubrum	Ranunculus	flabellaris
Cicuta	maculata	Ranunculus	gmelini
Cirsium	arvense	Ranunculus	macounii
Distichlis	stricta	Ranunculus	sceleratus
Echinochloa	muricata	Ranunculus	trichophyllus
Eleocharis	acicularis	Rorippa	palustris
Eleocharis	palustris	Rumex	mexicanus
Eleocharis	smallii	Rumex	occidentalis
Elodea	canadensis	Rumex	pseudonatronatus
Epilobium	ciliatum	Rumex	stenophyllus
Glaux	maritima	Ruppia	maritima
Glyceria	borealis	Ruppia	occidentalis
Glyceria	grandis	Sagittaria	cuneata
Glycyrrhiza	lepidota	Salicornia	rubra
Helenium	aumtumnale	Salix	amygdaloides
Hierochloe	odorata	Scirpus	acutus
Hippuris	vulgaris	Scirpus	americanus
Hordeum	jubatum	Scirpus	fluviatilis
Juncus	balticus	Scirpus	heterochaetus
Juncus	dudleyi	Scirpus	maritimus
Juncus	interior	Scirpus	nevadensis
Juncus	torreyi	Scirpus	validus
Lactuca	olongifolia	Sclerochloa	festucacea
Lemna	minor	Sium	suave
Lemna	trisulca	Sonchus	arvensis
Lemna	turionifera	Sparganium	eurycarpum
Lycopus	americanus		

TABLE 4.9
CCNT'D.

Genus:	Species:
Spirodela	polyrhiza
Stachys	palustris
Suaeda	depressa
Teucrium	occidentale
Typha	angustifolia
Typha	domingensis
Typha	latifolia
Typha	x glauca
Utrica	dioica
Utricularia	vulgaris
Veronia	fasciculata
Zannichellia	palustris

Sites A & B.

<u>Species Diversity.</u> To determine the species diversity the number of different genus and species represented in each of the wetland sites species compositions was calculated. Table 4.10 has the results of the comparison of the species diversity of the rehabilitated and reference wetlands.

The species diversity of rehabilitated wetland Site A (Class #3 - semipermanent wetland) had 43 genera and 75 species represented. Rehabilitated Site B (Class #4 - permanent wetland) had 29 genera and 45 species represented. The reference wetlands, Site A (Class #3 - semipermanent wetland) and Site B (Class #4 - permanent wetland) both had 65 genera and 109 species represented.

TABLE 4.10 SPECIES DIVERSITY OF THE WETLANDS

	# GENERA REPRESENTED	# SPECIES REPRESENTED
REHAB. SITE A:	43	75
REHAB. SITE B:	29	45
REF. SITE A:	65	109
REF. SITE B:	65	109

<u>Spatial Variation.</u> There is spatial variation or pattern that exists consistently in most all prairie potholes. The prairie potholes are characterized by having

three distinct vegetation zones. These are: wet meadow zone, shallow marsh zone, and deep marsh zone. Although some species overlap into more than one zone, these zones each are usually distinct vegetation communities consisting of differing species. Zonation is an important form of horizontal segregation of the vegetation resulting in higher species diversity since no stratification pattern (vertical layering) of the vegetation occurs due to the absence of woody plants on the wetlands.

The rehabilitated and reference wetland sites all exhibited the typical zonation of the prairie pothole region. Each wetland studied had a distinct wet meadow zone, shallow marsh zone, and deep marsh zone. Appendix A shows the complete species composition breakdown of each of the sites by vegetational zone.

Wetland Vegetation Succession Pattern. The wetland vegetation succession was studied using the model described in Chapter 3. Three key features of the life history of a species were necessary to use the model: life-span, propagule longevity, and establishment requirements or methods. A wetland species has one of three potential life-spans: 1) annual (A-species), 2) perennials (P-species), and 3) vegetatively reproducing perennials (V-species). The propagule longevity depends on whether a species is: 1) a dispersal dependent species (D species, with short lived seeds) or, 2) a seed bank species (S species, with long viability in the topsoil). The establishment requirements of a species depend on whether germination occurs during: 1) drawdowns or dry conditions (Type 1) or, 2) standing water or flood conditions (Type 2).

By combining the key life features the possible combinations or life types are: 1) **AD1** - annual with no propagules in the seed bank, established during a drawdown; 2) **AD2** - annual with no propagules in the seed bank, established in standing water; 3) **AS1** - annual with viable seed in seed bank, established during a drawdown; 4) **AS2** - annual with viable seed in seed bank, established in standing water; 5) **PD1** - perennial with no propagules in seed bank, established during a drawdown; 6) **PD2** - perennial with no propagules in seed bank, established in standing water; 7) **PS1** - perennial with viable seed in seed bank, established during a drawdown; 8) **PS2** - perennial with viable seed in the seed bank, established in standing water; 9) **VD1** - vegetatively reproducing perennial with no propagules in the seed bank, established during a drawdown; 10) **VD2** - vegetatively reproducing perennial with no propagules in the seed bank, established in standing water; 11) **VS1** - vegetatively reproducing perennial with viable seed in the seed bank, established during a drawdown); 12) VS2 - vegetatively reproducing perennial with viable seed in the seed bank, established in standing water. Appendix A has the results of the species life types and the successional pattern in each zone of each of the wetlands.

Table 4.11 shows the different life types of the wetland vegetation and the zones they occur in for each of the sites. The wet meadow zone had the highest species diversity of the three zones in all the sites with 58 species found in rehabilitated site A, 35 species in rehabilitated site B, and 55 species in references sites A and B. Annuals made up a large percentage of the plant species in the rehabilitated sites with 51% in site A and 49% in site B, but only 13% in the reference sites A & B. This was to be expected since annuals are "pioneer species" and are generally found on more disturbed sites. The perennials accounted for 9 species (16%) on rehabilitated site A, 6 species (17%) on rehabilitated site B, and 11 species (22%) on the reference sites A & B. The long-lived perennials, V-species, were found to be most prevalent on the reference sites A & B with 36 species (65%) present. Rehabilitated site A had 19 species (33%) and site B 12 species (34%) V-species present.

The presence of nearly twice as many V-species (long-lived perennials) on the reference areas indicates a more

TABLE 4.11 WETLAND VEGETATION SUCCESSIONAL PATTERN

	WET MEADOW ZONE			SHALLOW MARSH ZONE			DEEP MARSH ZONE		
TY.	WMA%	WMB%	WMAB%	SMA%	SMB%	SMAB%	DMA%	DMB%	DMAB%
AD1	2=3%	0	0	0	0	0	0	0	0
AD2	0	0	0	0	0	0	0	0	0
AS1	28=48%	17=49%	7=13%	2=13%	0	5=19%	0	0	0
AS2	0	0	0	0	0	0	0	0	0
PD1	0	0	1=2%	0	0	0	0	0	0
PD2	0	0	0	0	0	0	0	0	0
PS1	9=16%	6=17%	11=20%	0	0	6=23%	0	0	0
PS2	0	0	0	0	0	1=4%	2=29%	1=13%	1=13%
VD1	0	0	0	0	0	0	0	0	1=3%
VD2	0	0	0	0	0	0	0	0	0
VS1	19=33%	11=31%	36=65%	13=87%	5=100%	13=50%	0	0	10=26%
TABLE 4.11 (CONT'D.)									
VS2	0	1=3%	0	0	0	1=4%	5=71%	7=87%	22=58%
TOT.	58	35	55	15	5	26	7	8	38

WMA=WET MEADOW ZONE REHABILITATED SITE A
WMB=WET MEADOW ZONE REHABILITATED SITE B
WMAB=WET MEADOW ZONE REFERENCE SITES A & B
SMA=SHALLOW MARSH ZONE REHABILITATED SITE A
SMB=SHALLOW MARSH ZONE REHABILITATED SITE B
SMAB=SHALLOW MARSH ZONE REFERENCE SITES A & B
DMA=DEEP MARSH ZONE REHABILITATED SITE A
DMB=DEEP MARSH ZONE REHABILITATED SITE B
DMAB=DEEP MARSH ZONE REFERENCE SITES A & B

stable vegetation community than on the rehabilitated sites, but the number of perennials present on the mined sites indicates that the succession is progressing towards a more stable development. Of all the wet meadow species only three were not species found present in the seed bank (S-type), and all but one were established during drawdown periods or Type 1 species.

The shallow marsh species diversity was lower than in the wet meadow zone with 15 species found on rehabilitated site A, 5 species on rehabilitated site B, and 26 species on reference sites A & B (Table 4.11).

Table 4.11 shows the percentages of the different life types occurring in the shallow marsh zones on the wetland sites. Annuals were present in small numbers with only 2 species (13%) on rehabilitated site A, and 5 species (19%) on the reference sites. Perennials (P-species) were found only on the reference sites with 7 species present (27%). Long-lived perennials (V-species) accounted for 13 species (87%) of the shallow marsh vegetation found on rehabilitated site A, 5 species (100%) of rehabilitated site B , and 14 species (54%) of the reference sites A & B. Many of the species found in the rehabilitated shallow marsh zones were more commonly found in the wet meadow zone of the reference areas, indicating that these species have not "succeeded" to their proper zone yet. The number of V-species in the rehabilitated shallow marsh zones is encouraging and points further to the wetland community development that is occurring on the rehabilitated areas. All the species present on the sites were seed bank (S) species with long-lived propagules in the topsoil and all but one were established during drawdown periods (Type 1).

The deep marsh zones had lowest species diversity on the rehabilitated sites, with 7 species on site A and 8 species on site B (Table 4.11). In contrast the reference sites A & B showed increased species diversity over the rehabilitated sites with 38 species present. No annuals were present in any of the deep marsh zones of any of the sites.

The percentages of life types occurring in the deep marsh zones of the wetland sites is found in Table 4.11. Perennials (P-species) were represented by 2 species (29%) on rehabilitated site A, 1 species (13%) on rehabilitated site B, and 5 species (13%) on the reference sites. Long-lived perennials (V-species) accounted for 5 species (71%) of rehabilitated site A, 7 species (87%) of rehabilitated site B, and 32 species (84%) of reference sites A & B. All of the species but one found in the deep marsh of the reference wetlands were long-lived or S-species. Type-2 or species established during flooding or in standing water accounted for all the deep marsh species in the rehabilitated sites and most of the reference sites. Ten species in the deep marsh reference sites were established during drawdowns. The lack of species diversity in the deep marsh zones of rehabilitated wetlands is to be expected presently since these wetlands are still developing the deep marsh patterns hydrologically. The vegetation establishment from the seed bank of the deep marsh species may also be slower considering the establishment must be from the shallow marsh out to the deep marsh.

Wetland Vegetation Nutrition and Cover Values for Wildlife. The Plant Information Network (PIN) Database developed for the vegetation of the Northern Great Plains and Rocky Mountains was used to calculate the nutrition and cover values for each plant species for seven major wildlife species or wildlife species groups of the rehabilitated and reference wetlands. These seven major wildlife species or groups were: pronghorn antelope, mule deer, nongame birds (songbirds, shorebirds, birds of prey, etc.), upland gamebirds (sharp-tailed grouse, ring-necked pheasant, mourning dove, wild turkey, gray partridge), small mammals (rodents, rabbits, and carnivores), waterfowl (ducks and geese), and whitetail deer.

Each plant species was given a rating of 1=poor, 5=fair, or 10=good for cover and nutrition for each of the seven wildlife species/groups. The ratings for the wildlife species/groups for cover were then totaled and averaged for a mean cover value for each plant species. The same was done for the nutrition values, to calculate an average nutrition value for each plant species found on the study sites. The average cover value and nutrition values for each plant species for each wildlife species/group were then totaled and averaged for a mean habitat value for each plant species. The total and average cover value, total and average nutrition value, and total and average habitat value for each species is listed in Appendix A.

The cover and nutrition value of each plant species each of the wetland vegetation zones for the rehabilitated wetlands was calculated and compared. Since the plant species of the reference wetlands (sites A & B) were nearly identical they were compiled into one group of reference wetland cover and nutrition values.

Figure 4.3 shows the results of the comparison of the average cover value to the average nutrition value in the wet meadow zone of rehabilitated wetland Site A. The majority of the species had both cover and nutrition values of less than 5 (36 of the 58 total zone species=62%), indicating medium to low cover and nutrition values for most of the wildlife in that zone. A total of 9 of the 58 species (16%) had cover values of greater than 5, but

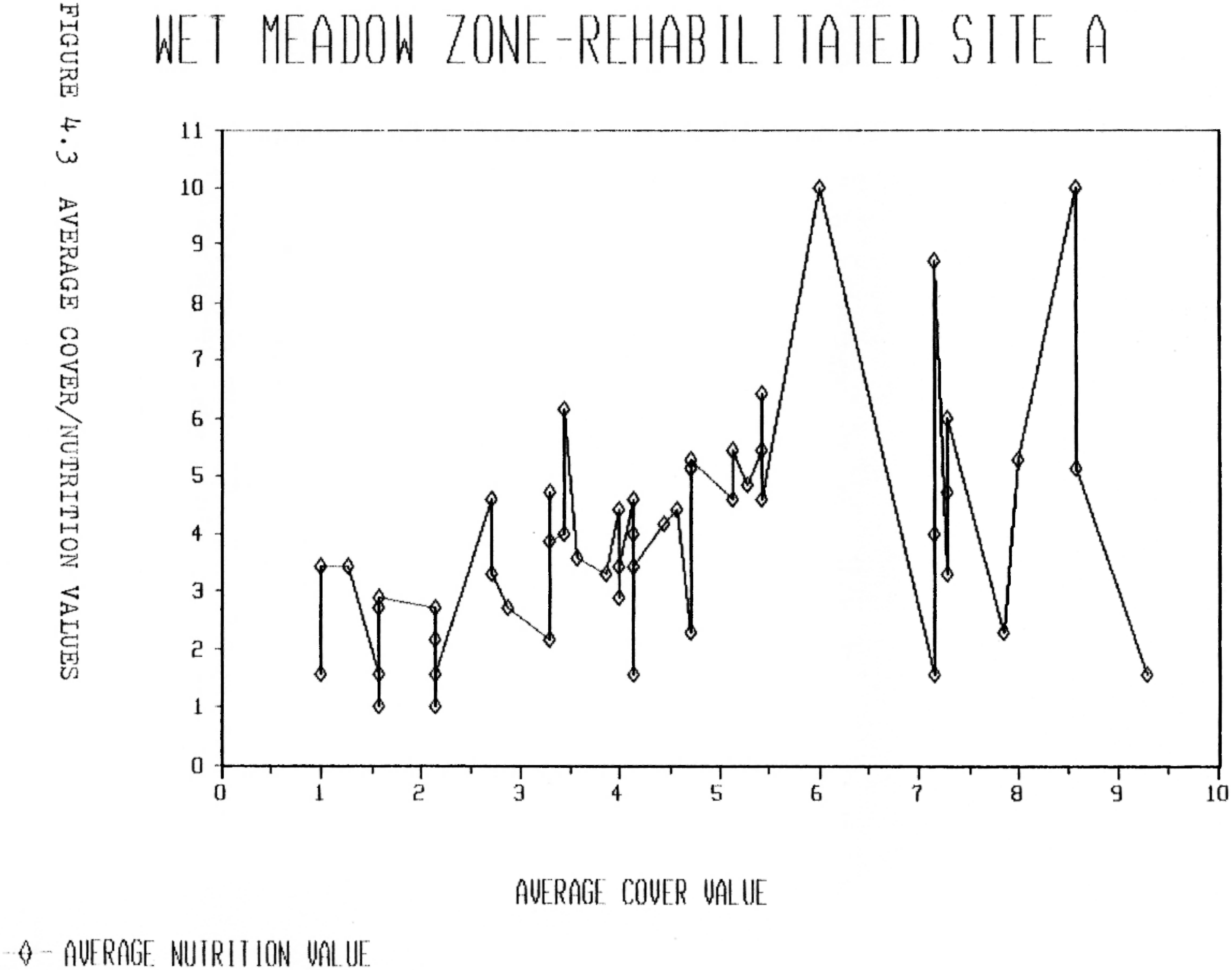

FIGURE 4.3 AVERAGE COVER/NUTRITION VALUES

nutrition values of less than 5 in wet meadow rehabilitation site A. Three species (5%) had high nutrition values (> than 5), but low cover values (< than 5). A total of 10 species (17%) had high cover and nutrition values, indicating these species were of high importance to wildlife in that zone.

The results of the wet meadow rehabilitated site B for cover and nutrition wildlife values are outlined in Figure 4.4. The wet meadow zone of rehabilitated site B had 23 of the 35 species found in that zone with cover and nutrition values of less than 5 (66%), or low cover and nutrition values for wildlife. Five species (14%) had high cover values and low nutrition values, while 3 species (9%) had high nutrition values and low cover for wildlife. Four species (11%) had both high wildlife cover and nutrition values.

Figure 4.5 shows the results of the cover and nutrition values for the wet meadow zone of the reference sites (Sites A & B). Of the 55 total species present in the zone 38 (69%) had low cover and nutrition values. Eleven species (20%) had high cover and low nutrition values, with 3 species (5%) having high nutrition and low cover wildlife values. Three species (5%) had high cover and nutrition values for wildlife.

The results of the cover and nutrition wildlife values

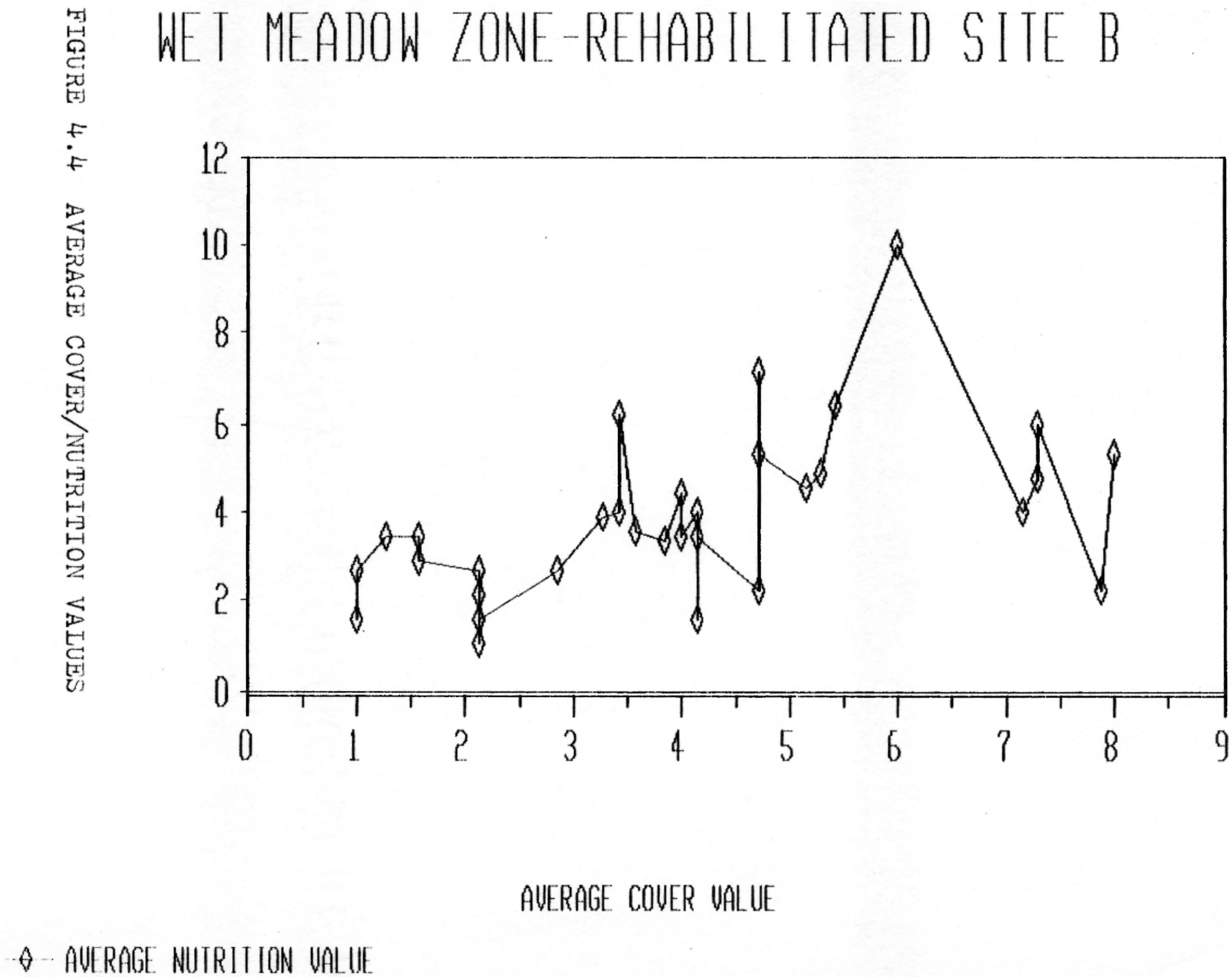

FIGURE 4.4 AVERAGE COVER/NUTRITION VALUES

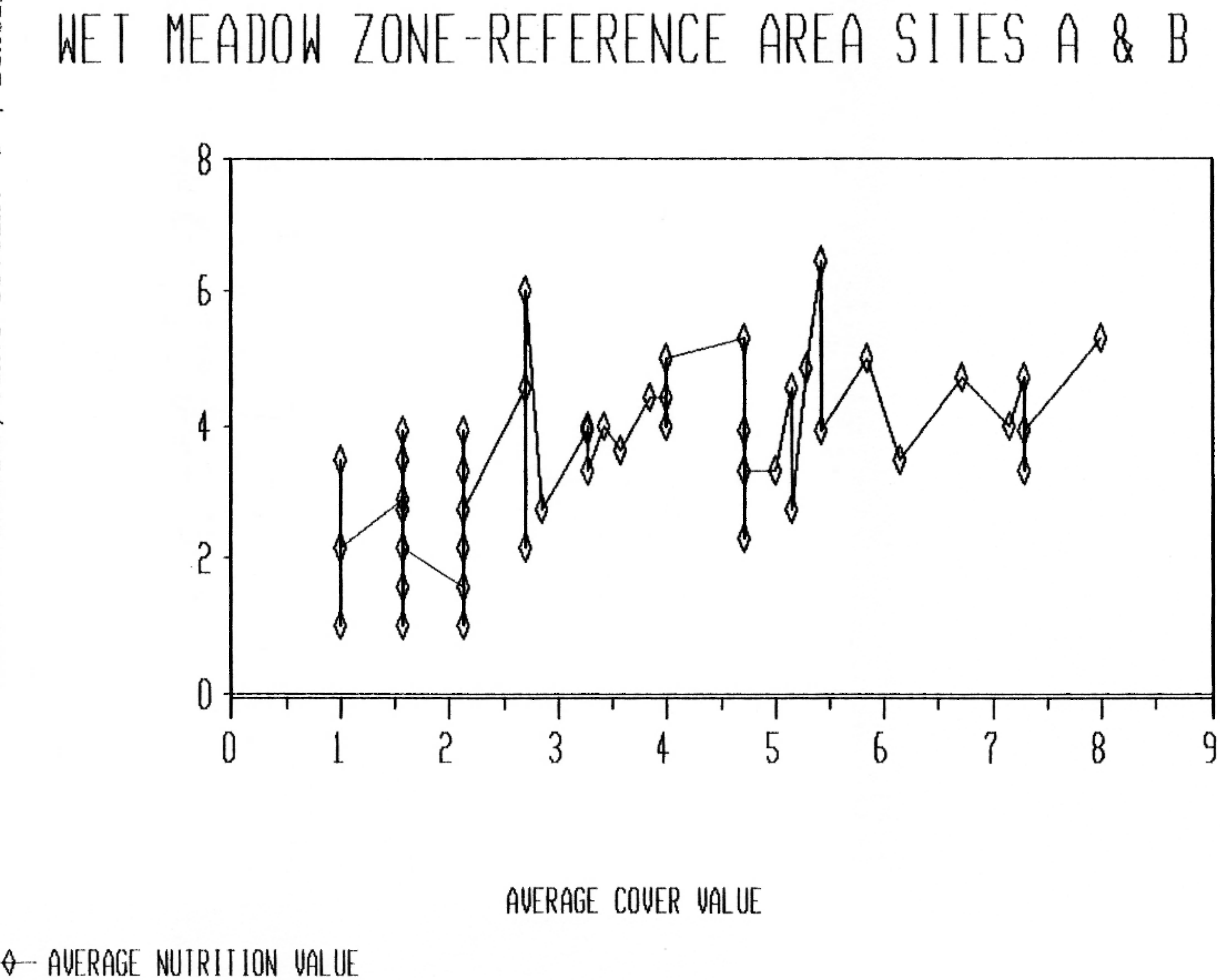

FIGURE 4.5 AVERAGE COVER/NUTRITION VALUES

for the shallow marsh zone of rehabilitated site A are found in Figure 4.6. Of the 15 total species present in this zone 7 (47%) had low cover and nutrition values, and 6 species (40%) had low nutrition and high cover values. Two species (13%) had high cover and nutrition wildlife values.

Figure 4.7 has the results of the cover and nutrition wildlife values for the shallow marsh zone rehabilitated site B. Two species (40%) of the 5 total species present in this zone had both low cover and nutrition values, while the remaining 3 species (60%) had high cover and low nutrition values. No species found had high nutrition wildlife values.

The wildlife cover and nutrition values of the shallow marsh zone in the reference areas (Site A & B) are found in Figure 4.8. Of the 26 total species found in this zone 17 species (65%) had low cover and nutrition wildlife values. Seven species (27%) had high cover and low nutrition values, with one species (4%) showing low cover and high nutrition values, and one species (4%) having both high cover and nutrition values.

Figure 4.9 shows the wildlife cover and nutrition values for the deep marsh zone rehabilitated site A. All of the total species (7) found in that zone had low cover and nutrition values (<5) for wildlife.

Figure 4.10 has the results of the wildlife cover and

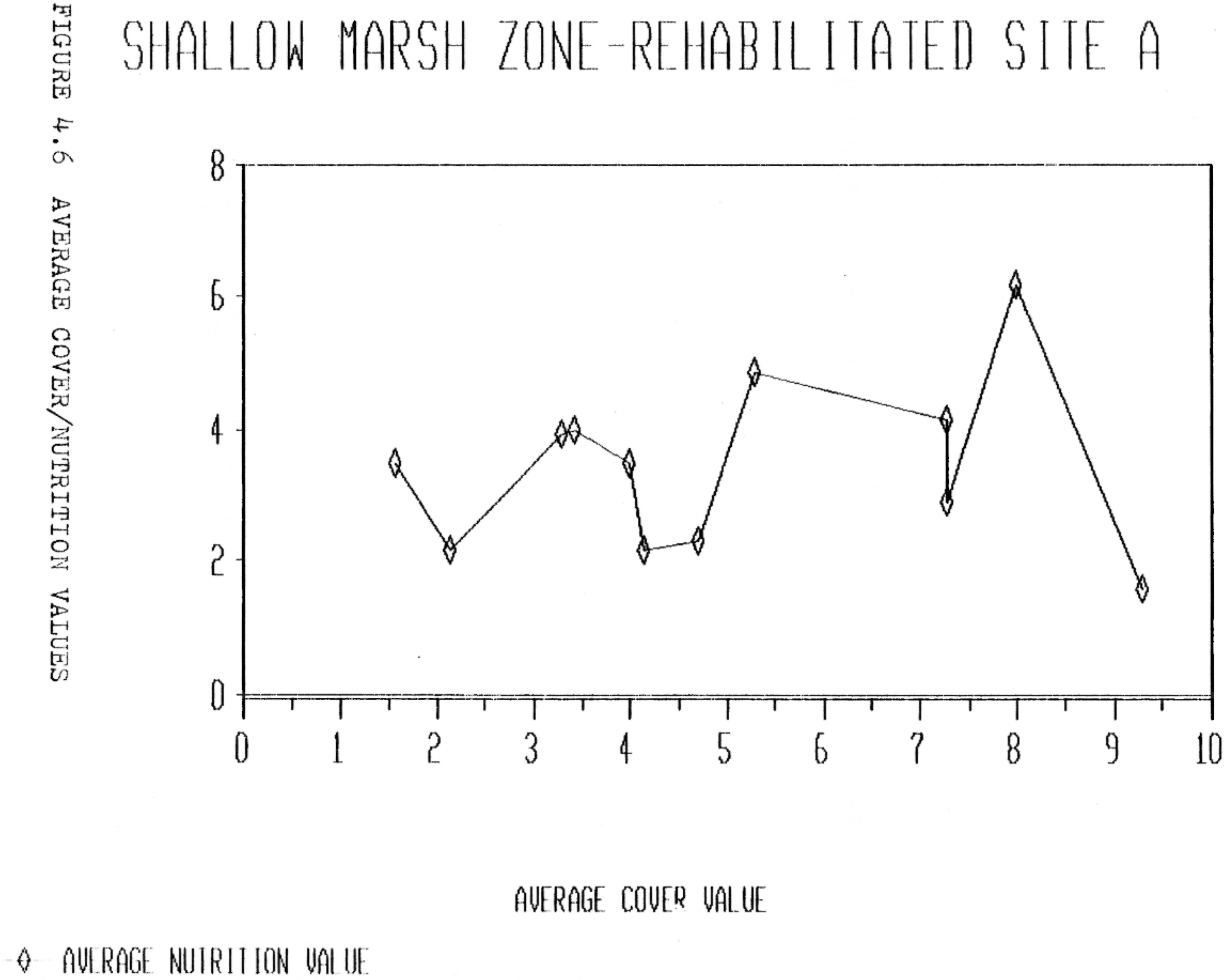

FIGURE 4.6 AVERAGE COVER/NUTRITION VALUES

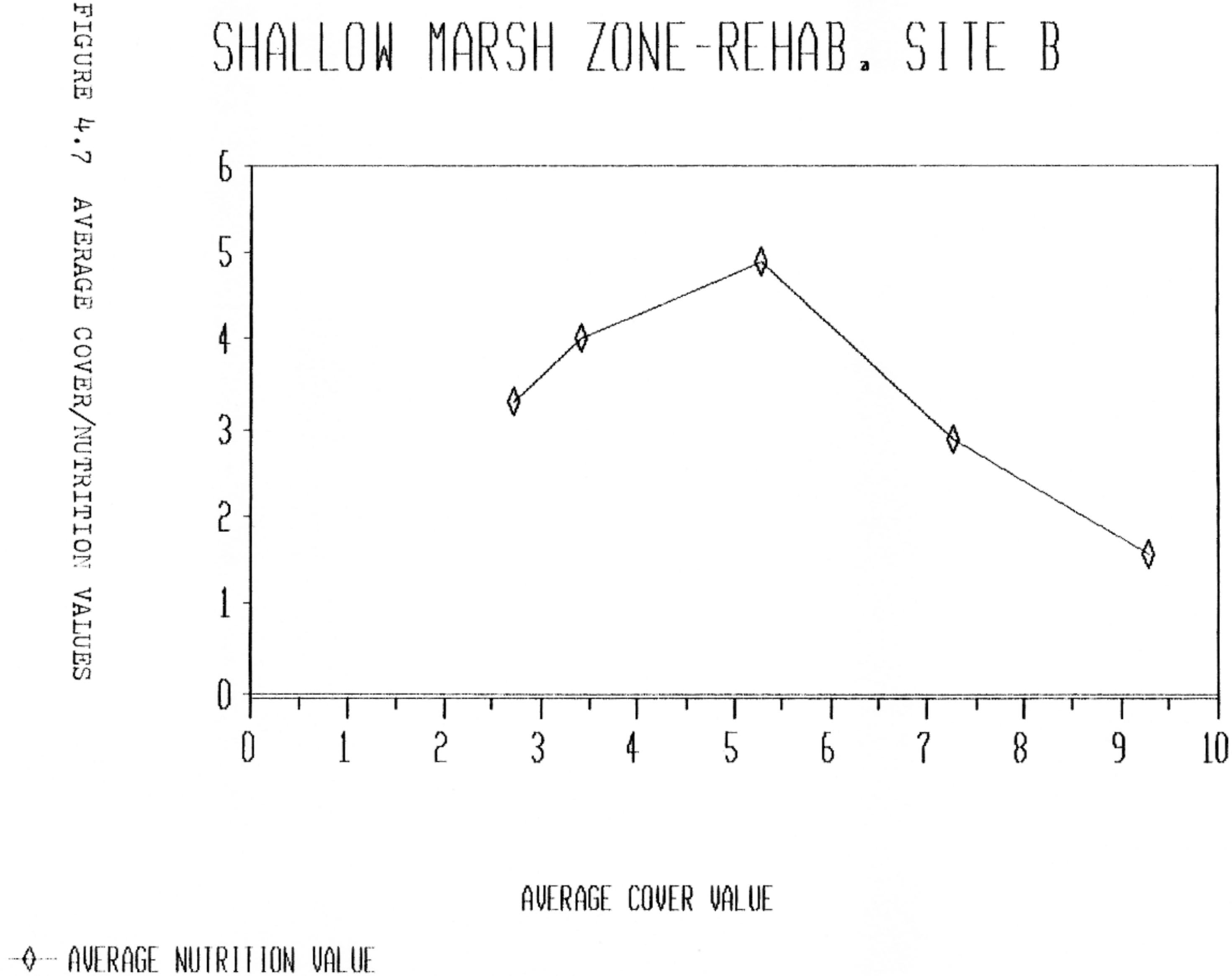

FIGURE 4.7 AVERAGE COVER/NUTRITION VALUES

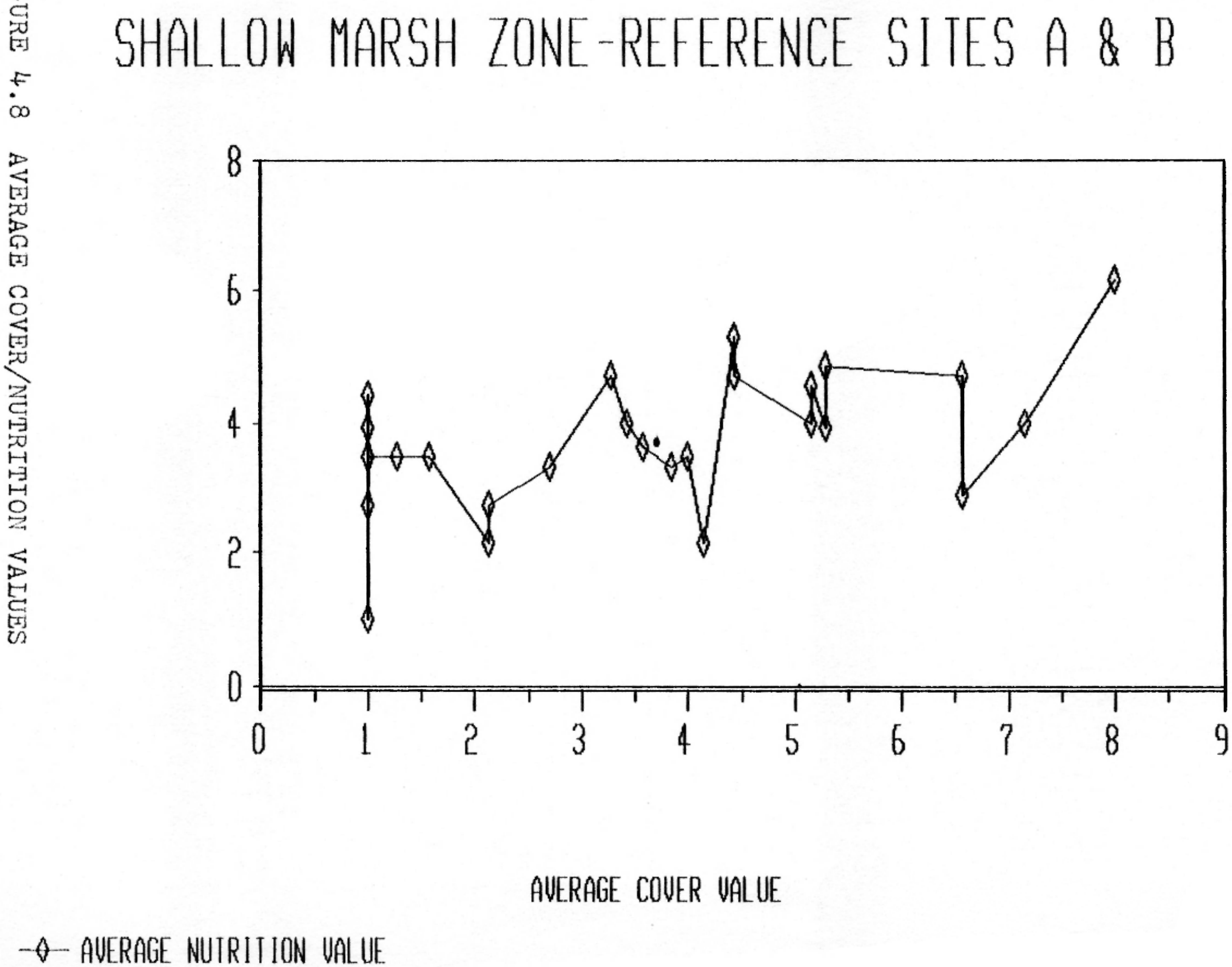

FIGURE 4.8 AVERAGE COVER/NUTRITION VALUES

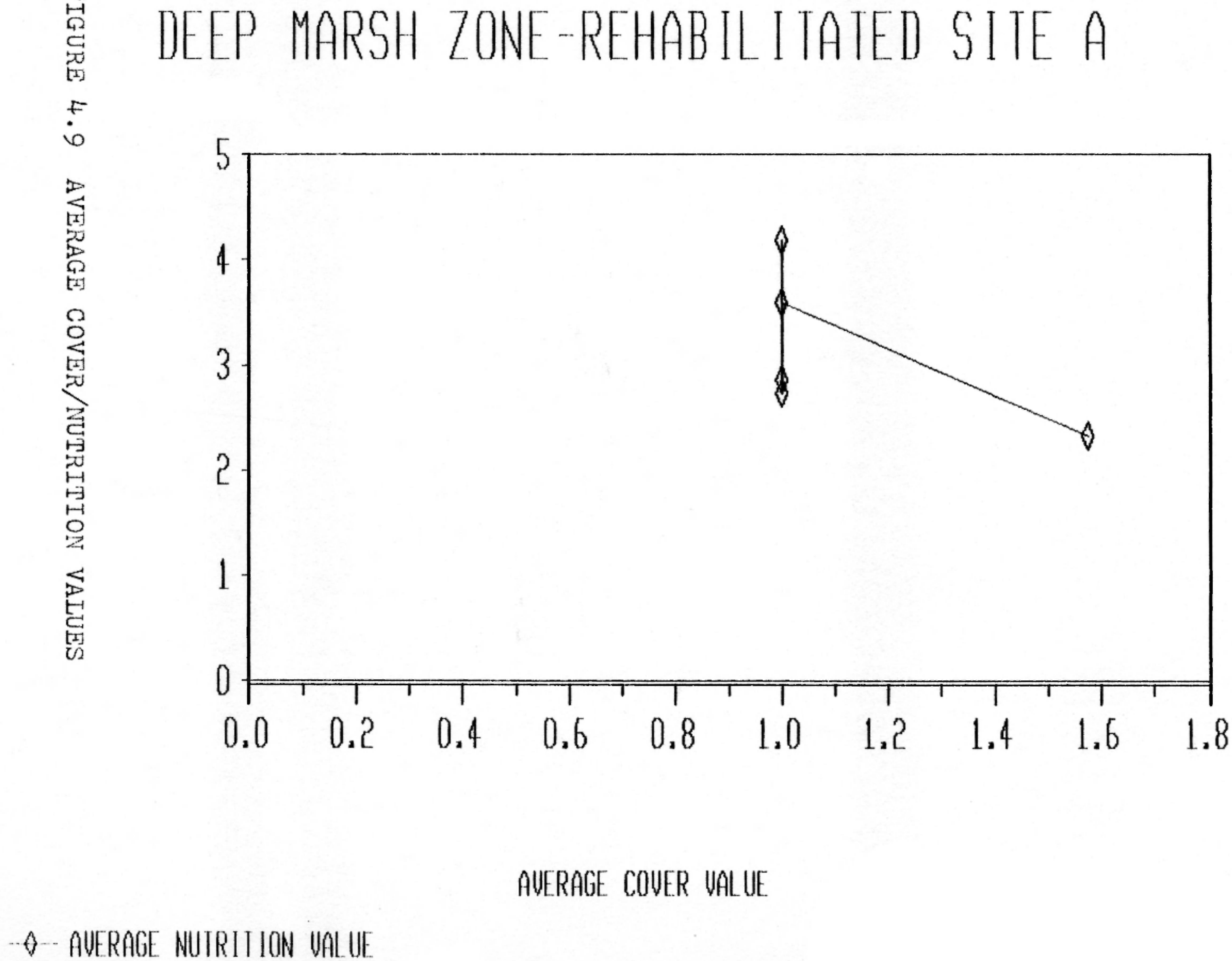

FIGURE 4.9 AVERAGE COVER/NUTRITION VALUES

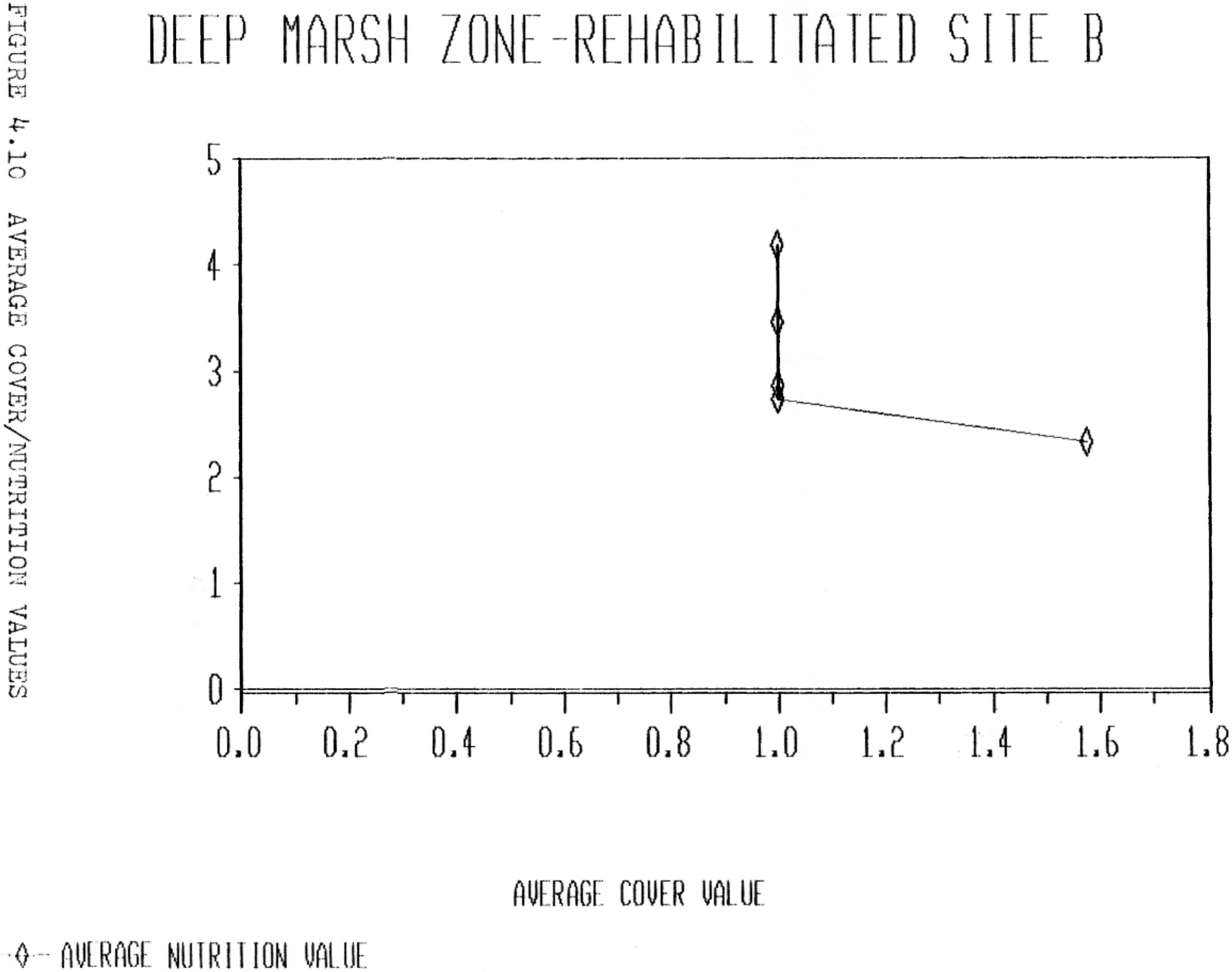

FIGURE 4.10 AVERAGE COVER/NUTRITION VALUES

nutrition values for the deep marsh zone rehabilitated site B. All of the species (8) found in this zone had both low cover and nutrition values (<5) for wildlife.

The results of the deep marsh wildlife cover and nutrition values for the reference site areas (Site A & B) are found in Figure 4.11. Seventy-six percent (29) of the total species present in this zone (38) had low cover and nutrition values for wildlife. Seven species (18%) had high cover and low nutrition values and 2 species (6%) had both high cover and nutrition wildlife values.

SECTION THREE

SPECIES COMPOSITION

Premine Inventory. The site of the rehabilitated wetlands and the surrounding mined area was inventoried prior to mining by consultants hired by the Falkirk Mining Company as part of the permit requirement process. The relationship of the premine inventory to the post-mined rehabilitated area is not to indicate the current presence of all the species listed, but rather to give a list of the potential species of the site. Table 4.12 indicates the number of species of various wildlife groups found on the premine inventory of the site in 1979 and 1980. The species included were only those species that were actually sited. Probable species inhabiting the wetland areas, and either sited or not sited are listed along with those sited

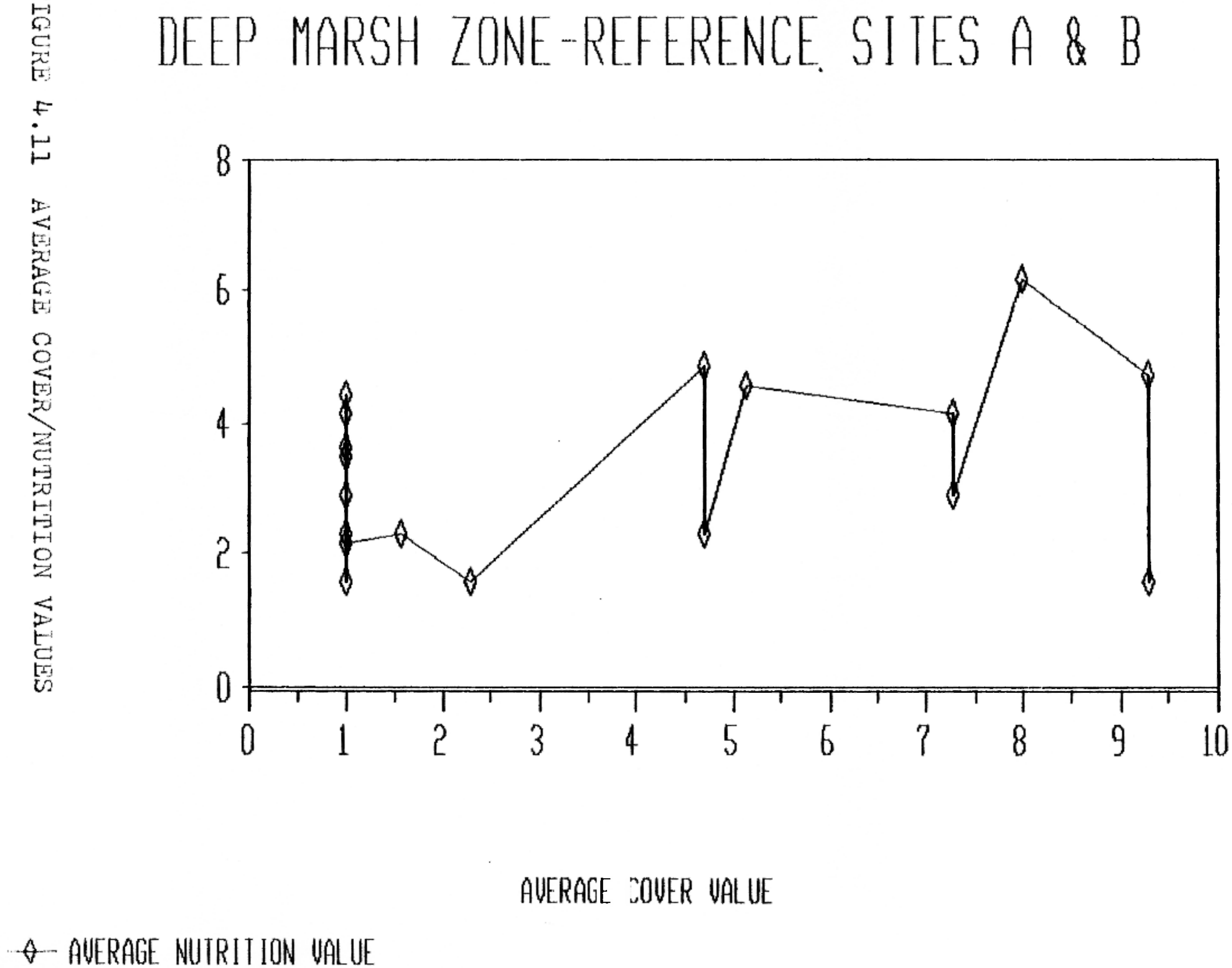

FIGURE 4.11 AVERAGE COVER/NUTRITION VALUES

in Appendix B.

TABLE 4.12 PREMINE SPECIES COMPOSITION OF REHAB. AREA

	MAMMALS	BIRDS	AMPHIBIANS	REPTILES	MACRO INVERTEBRATES
NO. OF SPECIES	27	140	3	2	93

<u>Waterfowl Pair Observations.</u> The waterfowl male and female pairs observed on the rehabilitated and reference wetlands during the breeding season were recorded by the Falkirk rehabilitation specialists at weekly intervals for both 1985 and 1986. These weekly site observations started in mid-June and continued until mid-August. Waterfowl pairs counts observed were recorded since they represent probable nesters (by pairs observed) on the wetland sites. Lone male waterfowl and male waterfowl in groups of 5 individuals or less were also counted in the pair counts, since these birds were there the entire breeding season and probably mated.

Table 4.13 has the results of the comparison of the waterfowl pairs observed on the rehabilitated and reference sites for 1985. Seven species of waterfowl were observed in pairs on the rehabilitated sites A & B in 1985. Of these three species (mallard, blue-winged teal, and gadwalls accounted for 76.3% of the pairs observed on the rehabilitated wetlands. The reference sites A & B had

greater species diversity with ten species of waterfowl observed in pairs on those wetlands in 1985. Mallards, gadwall, blue-winged teal, and pintail ducks accounted for 81.6% of the species composition and pairs observed on the reference wetlands in 1985. The overall ratio of pairs observed on the rehabilitated wetlands as compared to the reference wetlands in 1985 was 0.63:1.

TABLE 4.13 WATERFOWL PAIR OBSERVATIONS-1985

	REHABILITATED WETLANDS				REFERENCE WETLANDS			
	#A	#B	TOT.	% SP. COMP.	#A	#B	TOT.	% SP. COMP.
MALLARD	1	28	29	38.0%	12	9	21	17.5%
GADWALL	2	9	11	14.6%	10	9	19	15.8%
BL.-WINGED TEAL	3	15	18	23.7%	34	9	43	35.8%
PINTAIL	1	4	5	6.6%	8	7	15	12.5%
LESSER SCAUP	0	0	0	0.0%	0	3	3	2.5%
NO. SHOVELER	0	3	3	3.9%	3	7	10	8.4%
RUDDY DUCK	0	0	0	0.0%	0	2	2	1.7%
REDHEAD	0	4	4	5.3%	0	1	1	.8%
GR'N.-WINGED TEAL	0	6	6	7.9%	4	1	5	4.2%
AMER. WIGEON	0	0	0	0.0%	1	0	1	.8%
CANADA GOOSE	0	0	0	0.0%	0	0	0	0.0%
TOTALS	7	69	76	100.0%	72	48	120	100.0%

TABLE 4.13 (CONT'D.)

PAIR OBSERVATION RATIO (REHABILITATED/REFERENCE)= 0.63:1

Table 4.14 has the results of the comparison of the waterfowl observations on rehabilitated and reference wetlands for 1986. In 1986 ten species of waterfowl were seen in pairs on the rehabilitated wetlands as compared to eight species pairs seen on the reference wetlands. Of the ten species observed on the rehabilitated wetlands in 1986, three species (blue-winged teal, lesser scaup, and mallards) made up 48.5 % of the species composition. Of the eight species seen on the reference wetlands, gadwalls, blue-winged teal, mallards, ruddy ducks, and northern shovelers accounted for 80 % of the species observed. The ratio of pairs observed on the rehabilitated wetlands as compared to the reference wetlands was 1.19:1 (101 rehabilitated pairs to 85 reference pairs).

In comparing 1985 and 1986 results of the rehabilitated and reference wetlands, the rehabilitated wetlands had increases in the number of waterfowl pairs observed from 1985 to 1986 as compared to the reference wetlands in 1985 to 1986. The number of species observed in pairs on the rehabilitated wetlands increase from 7 in 1985 to 10 species in 1986, while the species on the reference wetlands decreased from 10 species in 1985 to 8 species in 1986. The total number of pairs observed on the rehabilitated wetlands increased from 76 pairs in 1985 to 101 pairs in 1986, especially on site A (Class 3, smaller rehabilitated wetland) where 28 pairs were observed in 1986 as compared to 7 pairs in 1985. The pair totals on the reference wetland decreased from 120 to 85 from 1985 to 1986. The probable reason for the fewer pair counts on the reference area in 1986 was the decreased wetland habitat available and the condition of the available habitat due to decreased rainfall in the reference area than in the rehabilitated wetlands during the waterfowl breeding season.

TABLE 4.14 WATERFOWL PAIR OBSERVATIONS-1986

	REHABILITATED WETLANDS				REFERENCE WETLANDS			
	#A	#B	TOT.	% SP. COMP.	#A	#B	TOT.	% SP. COMP.
MALLARD	9	5	14	13.9%	11	0	11	12.9%
GADWALL	4	5	9	8.9%	18	4	22	26.0%
BL.-WINGED TEAL	2	17	19	18.8%	10	4	14	16.4%
PINTAIL	2	7	9	8.9%	0	0	0	0.0%
LESSER SCAUP	1	15	16	15.8%	0	5	5	5.9%
NO. SHOVELER	0	8	8	7.9%	6	4	10	11.8%
RUDDY DUCK	0	3	3	3.0%	1	10	11	12.9%
REDHEAD	0	9	9	8.9%	4	0	4	4.7%
GR'N.-WINGED TEAL	4	0	4	4.0%	0	0	0	0.0%
AMER. WIGEON	6	1	7	6.9%	8	0	8	9.4%
TABLE 4.14 (CONT'D.)								
CANADA GOOSE	0	3	3	3.0%	0	0	0	0.0%
TOTALS	28	73	101	100.0%	27	58	85	100.0%

PAIR OBSERVATION RATIO (REHABILITATED/REFERENCE)= 1.19:1

WATERFOWL SPECIES DIVERSITY

Waterfowl Brood Observations. The number of waterfowl broods (young) observed were recorded for 1985 and 1986 on the rehabilitated and reference wetlands by the Falkirk rehabilitation specialists. Observations were conducted simultaneously with the pair observation counts between mid-June and mid-August for both 1985 and 1986.

Table 4.15 has the results of the waterfowl brood observations for 1985. Only one brood, a blue-winged teal, was observed on the rehabilitated sites A & B. The reference sites had a total of 8 broods observed with 3 different broods of blue-winged teal and pintail ducks each sighted. One gadwall and one northern shoveler brood were also observed. The ratio of broods observed on the rehabilitated areas as compared to the reference wetlands was Ø.25:1.

TABLE 4.15 WATERFOWL BROOD OBSERVATIONS - 1985

	REHABILITATED WETLANDS				REFERENCE WETLANDS			
	#A	#B	TOT.	% SP. COMP.	#A	#B	TOT.	% SP. COMP.
GADWALL	Ø	Ø	Ø	Ø.ØØ%	Ø	1	1	12.5%
BLUE-WINGED TEAL	Ø	1	1	1ØØ.ØØ%	1	2	3	37.5%
PINTAIL	Ø	Ø	Ø	Ø.ØØ%	2	1	3	37.5%
NO. SHOVELER	Ø	Ø	Ø	Ø.ØØ%	Ø	1	1	12.5%
TOTALS	Ø	1	1	1ØØ.ØØ%	3	5	8	1ØØ.Ø%

BROOD OBSERVATION RATIO (REHABILITATED/REFERENCE)=Ø.25:1

Table 4.16 has the results of the brood observations in the rehabilitated and reference wetlands in 1986. In the rehabilitated sites A & B a total of 32 broods representing 10 species were observed. A total of 25 broods, 7 species, were observed in the reference wetland sites A & B.

Table 4.16 shows mallard and american wigeon broods were most often observed on the rehabilitated sites in 1986 with 6 broods each observed (18.8% of species composition). Gadwall, blue-winged teal, and lesser scaup broods were observed on the rehabilitated wetlands with 5 broods (15.6% of species composition), 4 broods (12.5% of species composition), and 4 broods (12.5% of species composition) respectively.

Table 4.16 also indicates blue-winged teal, gadwall, mallard, and lesser scaup were the species with broods most frequently observed on the reference wetlands in 1986. Blue-winged teal accounted for 10 broods (40% of species composition), gadwall for 6 broods (24% of species composition, mallard for 5 broods (20% of species composition) and lesser scaup for 3 broods (12% of species composition).

Between 1985 and 1986 the number of broods observed increased from only 1 brood (blue-winged teal) in 1985, to 32 broods in 1986. The broods observed on the reference wetlands increased from 8 broods in 1985 to 25 broods, but there were fewer brood counts than on the rehabilitated wetlands. This was most certainly due to the decreased precipitation in the reference wetlands in 1986 and decreased surface water and less desirable nesting habitat.

TABLE 4.16 WATERFOWL BROOD OBSERVATIONS - 1986

	REHABILITATED WETLAND				REFERENCE WETLANDS			
	#A	#B	TOT.	% SP.	#A	#B	TOT.	% SP.
MALLARD	1	5	6	18.8%	3	2	5	20.0%
GADWALL	2	3	5	15.6%	4	2	6	24.0%
BLUE-WINGED TEAL	0	4	4	12.5%	5	5	10	40.0%
PINTAIL	1	2	3	9.4%	0	0	0	0.0%
LESSER SCAUP	0	4	4	12.5%	0	3	3	12.0%
NO. SHOVELER	0	0	0	0.0%	0	1	1	4.0%
RUDDY DUCK	0	1	1	3.0%	0	0	0	0.0%
AMER. WIGEON	2	4	6	18.8%	0	0	0	0.0%
CANADA GOOSE	0	3	3	9.4%	0	0	0	0.0%
TOTALS	6	26	32	100.0%	12	13	25	100.0%

BROOD OBSERVATION RATIO
(REHABILITATED/REFERENCE)=1.28:1.00

SECTION FOUR

REMOTE SENTING & PHOTOGRAMMETRIC ANALYSIS

Landsat 5-Thematic Mapper Classification. Landsat 5-Thematic Mapper images were produced by the process described in Chapter 3, by Ducks Unlimited for the rehabilitated and reference wetlands in 1986. These images were used to compare and quantify the total wetland acres, areal sizes of the wet meadow, shallow marsh, and deep marsh zones, shoreline perimeter of the wetlands in miles, and shoreline index of the rehabilitated and reference wetlands. Figure 4.12 shows the classified Thematic Mapper image of the rehabilitated wetlands and the surrounding wetlands in 1986. The darkest areas shown are open water, the dark gray tones with the white centroid are deep marsh, and the light gray areas represent shallow marsh. The same type of Thematic Mapper image was produced for the 1986 reference wetlands and the surrounding wetlands as seen in Figure 4.13.

Table 4.17 shows the results of the wetland statistics produced by the Software Module DUHT as part of the thematic mapper image processing of the six TM bands used (all except thermal band 7) as developed by Ducks Unlimited for the rehabilitated and reference wetlands in May, 1986.

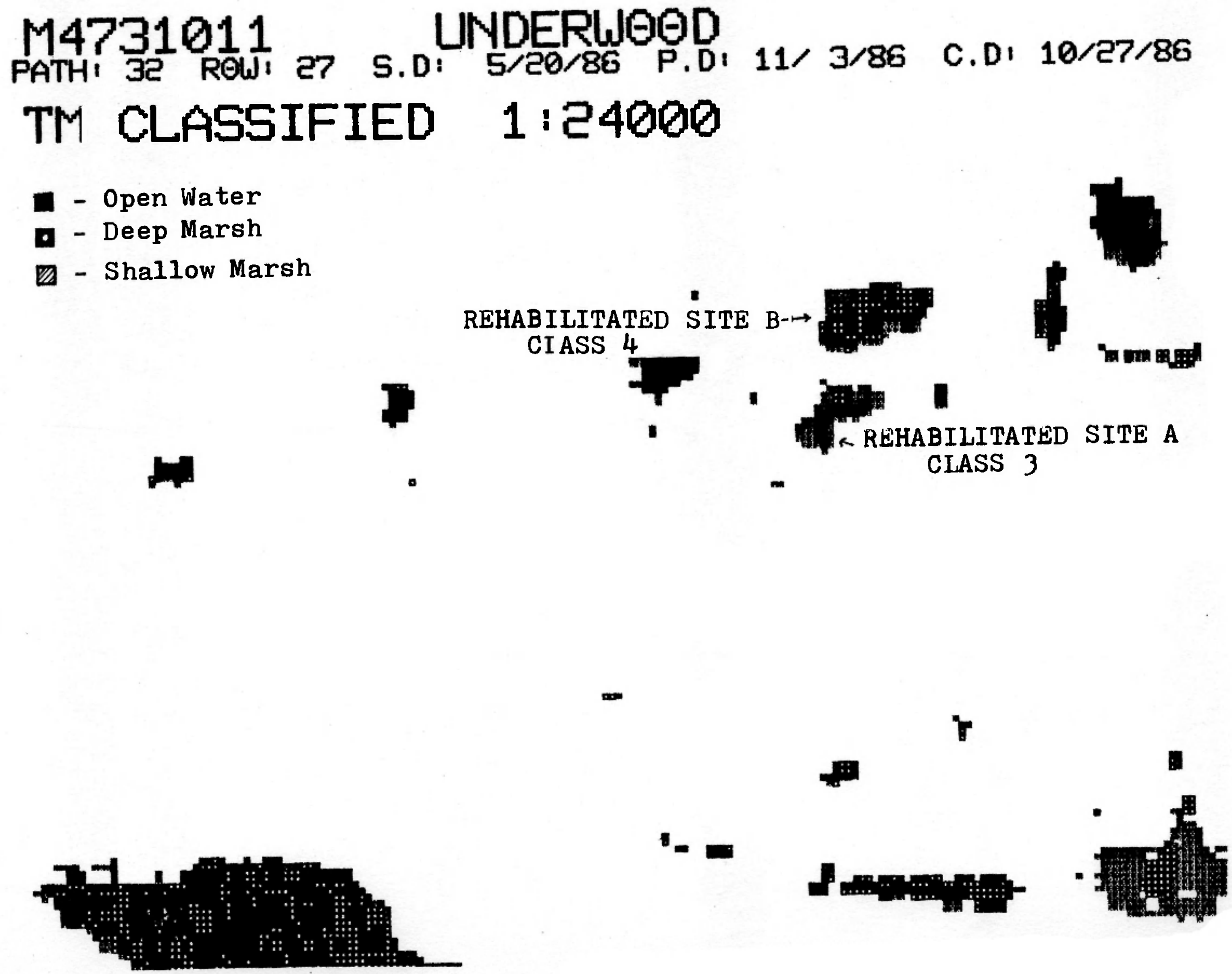

FIGURE 4.12 1986 CLASSIFIED THEMATIC MAPPER IMAGE OF REHABILITATED WETLANDS

(Source: Ducks Unlimited, 1986)

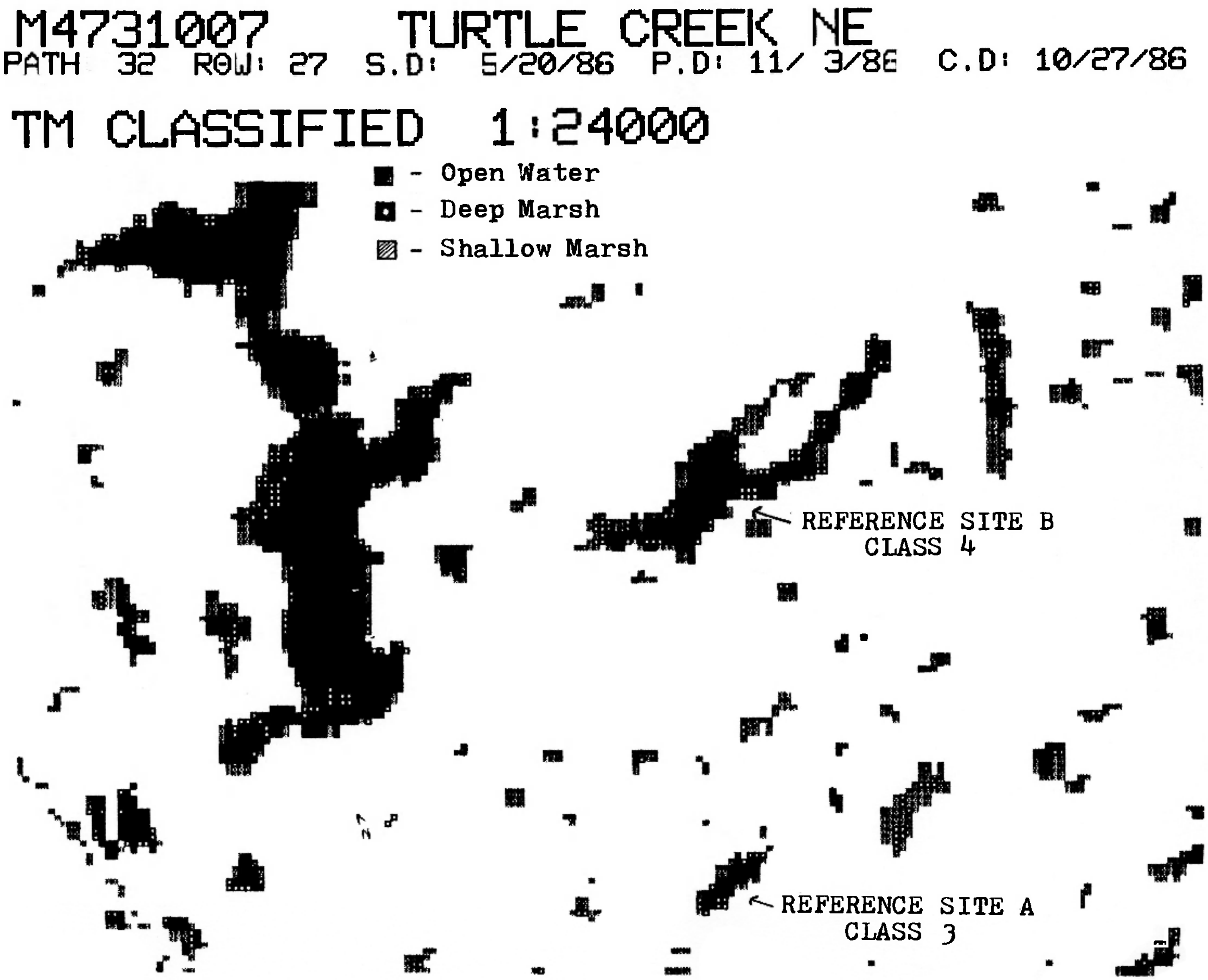

FIGURE 4.13 1986 CLASSIFIED THEMATIC MAPPER IMAGE OF REFERENCE WETLANDS

(Source: Ducks Unlimited, 1986)

TABLE 4.17 WETLAND STATISTICS PRODUCED BY SOFTWARE MODULE DUHT AS PART OF THEMATIC MAPPER PROCESSING

WETLAND NUMBER	TOTAL ACRES	ACRES OPENW	ACRES DEEPMAR	ACRES SHALLMAR	PERIMETER (MILES)	SHAPE INDEX
REHAB. A (CLASS 3)	11.6	4.9	0.2	6.4	0.67	1.401
REHAB. B (CLASS 4)	20.5	8.9	6.7	4.9	0.76	1.194
REF. A (CLASS 3)	7.8	4.0	1.6	2.2	0.57	1.447
REF. B (CLASS 4)	59.2	36.2	9.1	13.8	2.89	2.684

One of the most important wetland factors in Table 4.17 is the shoreline shape index. The shape index or basin shape index generated represents the ratio of the wetland perimeter to the circumference of a circle with the identical area as the wetland. A circular wetland an index value of 1.0, while the more irregularly shaped the wetland perimeter becomes, the greater the index value. The shape index of the Class 3 wetlands was slightly higher in the reference site A (1.447) as compared to the rehabilitaed site A (1.401) indicating the rehabilitated wetland has a fairly irregular shoreline and has good potential for wetland niche development for wildlife. The shape index of the Class 4 wetlands was much higher in the reference site B (2.684) than in the rehabilitated site B (1.194) indicating a much more convoluted shoreline in the reference wetland than in the rehabilitated wetland. The rehabilitated wetland site B shape index of 1.194 is very close to 1.0 indicating a nearly circular perimeter with lower wildlife niche development potential than in the reference wetland of a similar size.

The accuracy of the thematic mapper calculated total wetland acres for the reference wetlands was compared to the total wetland acres calculated for the same area from a study done in 1979 by the U. S. Fish and Wildlife Service (Koenig Study). The Koenig Study indicated the total wetland acres of the Class 3 reference site A as 8.298 acres compared to 7.8 acres for the same wetland in 1986, or an accuracy of 94%. The Class 4 reference site B was measured as 57.994 acres in 1979 as compared to 59.2 acres in 1986, or an accuracy of 98%.

<u>Histogram of Vegetation Brightness Response.</u> The brightness response of the wetlands was measured comparing the 1985 response to the 1986 response for the rehabilitated wetlands and comparing those to the reference wetlands. The brightness response refers to the relative differences in tonal qualities of light versus dark for a specified area. By using the methods described in the methodology quantitative values of brightness range for each wetland site for each year was calculated and displayed as a histogram. A histogram is a representative

frequency distribution of the differences in tonal qualities (dark and light) of the wetlands. By classifying the tonal areas to represent different vegetation zones within each wetland the differences in vegetation within each wetland can be revealed. The mean brightness of each wetland was also calculated and recorded above the histogram. The brightness was calculated using black and white photographs taken of the color infra-red negatives of the rehabilitated wetlands on 7/2/85 and 6/25/86.

Figure 4.14 has the results of the mean brightness and brightness range for the rehabilitated wetland Site A (Class 3) for 1985 and 1986. Histogram #1 shows the brightness sample taken in the marsh interior or open water area in 1985, showing little vegetation response in that zone. Histogram #2 shows the brightness sample taken of the wetland area including the wet meadow and shallow marsh zones in 1985. There is a higher brightness response than in Histogram #1 evident both from the histogram and the mean brightness (13.4 to 2.8). Histogram #3 has the brightness sample taken in the deep marsh zone and open water in 1986. In comparing the mean of the deep marsh/open water in 1986 to the deep marsh/open water of 1985 there is a definite increase in brightness response (8.2 to 2.8) resulting from the increase vegetation response found in the deep marsh zone. Histogram #4 has

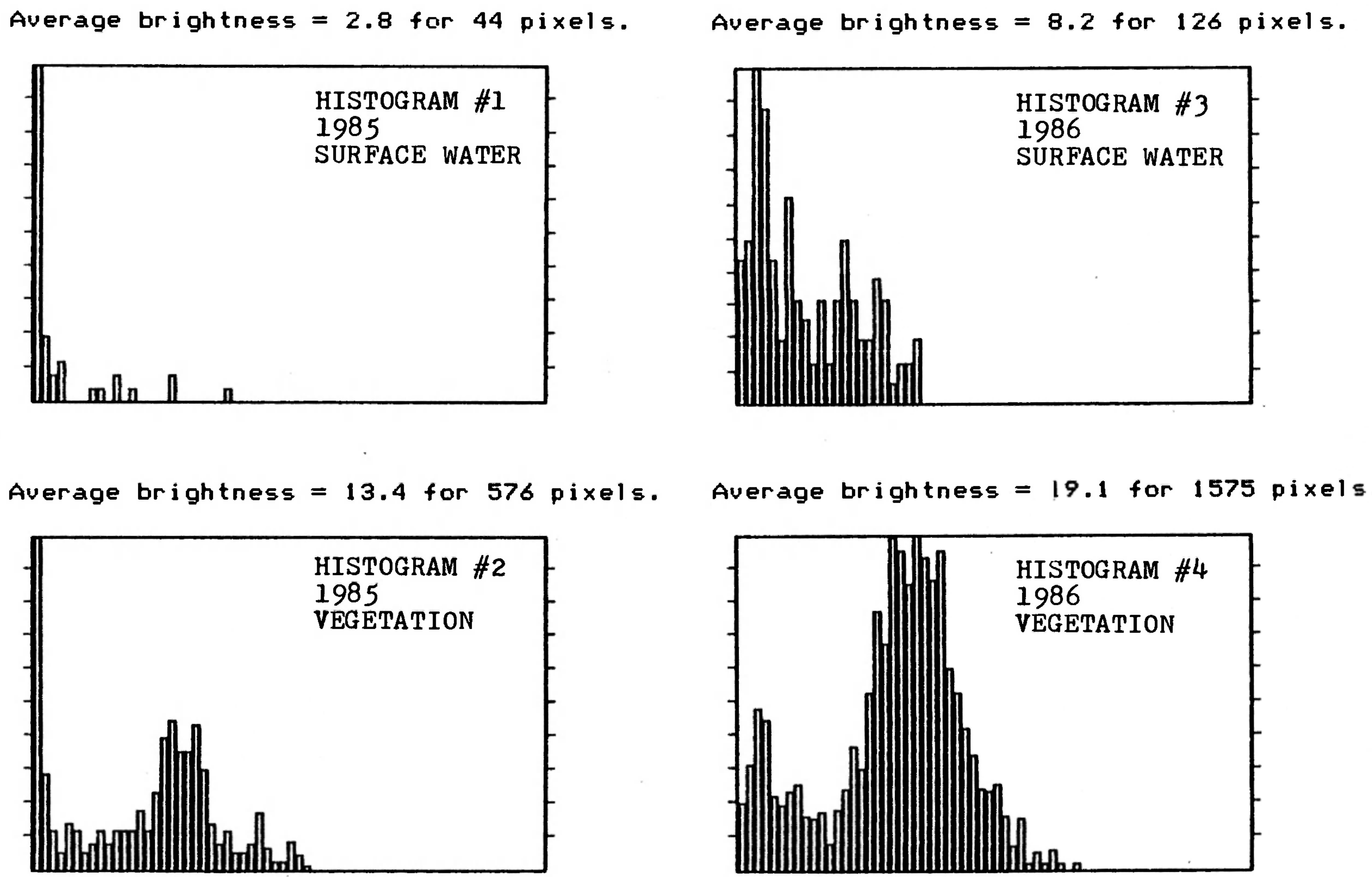

FIGURE 4.14 SURFACE WATER & VEGETATION BRIGHTNESS RESPONSE - REHAB. A 1985 & 1986

the results of the brightness sample taken of the wetland including the wet meadow and shallow marsh zones. The histogram and mean brightness both show a marked increase over the 1985 histogram and mean brightness for the wet meadow, shallow marsh, and deep marsh zones (19.1 to 13.4).

Figure 4.15 has the results of the histograms and mean brightness for rehabilitated wetland Site B (Class 4) for 1985 and 1986. There was no response recorded in the wetland deep marsh/open water zone in 1985 indicating no or very little vegetation response at that time in the zone (Histogram #1). Histogram #2 taken of the wetland area including the wet meadow zone and shallow marsh zone shows an increase in brightness response over Histogram #1 indicating the increased vegetation response of the wetland vegetation in those zones. Histogram #3 has the results of the deep marsh/open water zone taken in 1986 showing an increase in the mean brighness in that zone as compared to 1985 (1.3 to 0). Histogram #4 has the outcome of the sample taken of the wetland area including the wet meadow and shallow marsh zones. Although there is more brightness variation in the histogram from 1985 to 1986 the mean brightness actually decreased.

Figure 4.16 shows the histograms and mean brightness of the reference wetlands for 1985. No histogram or mean brightness was available for 1986, although the response

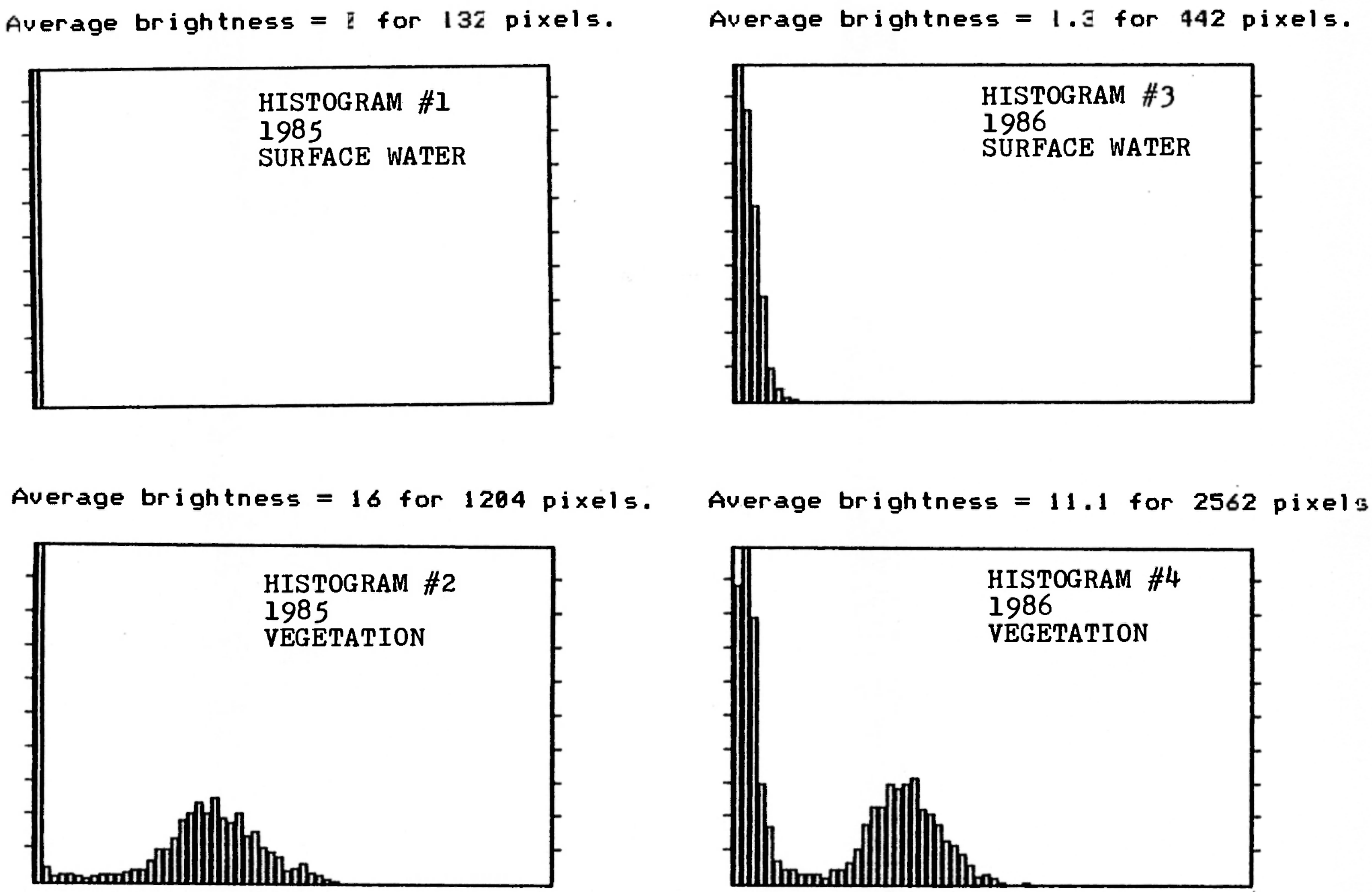

FIGURE 4.15 SURFACE WATER & VEGETATION BRIGHTNESS RESPONSE - REHAB. E 1985 & 1986

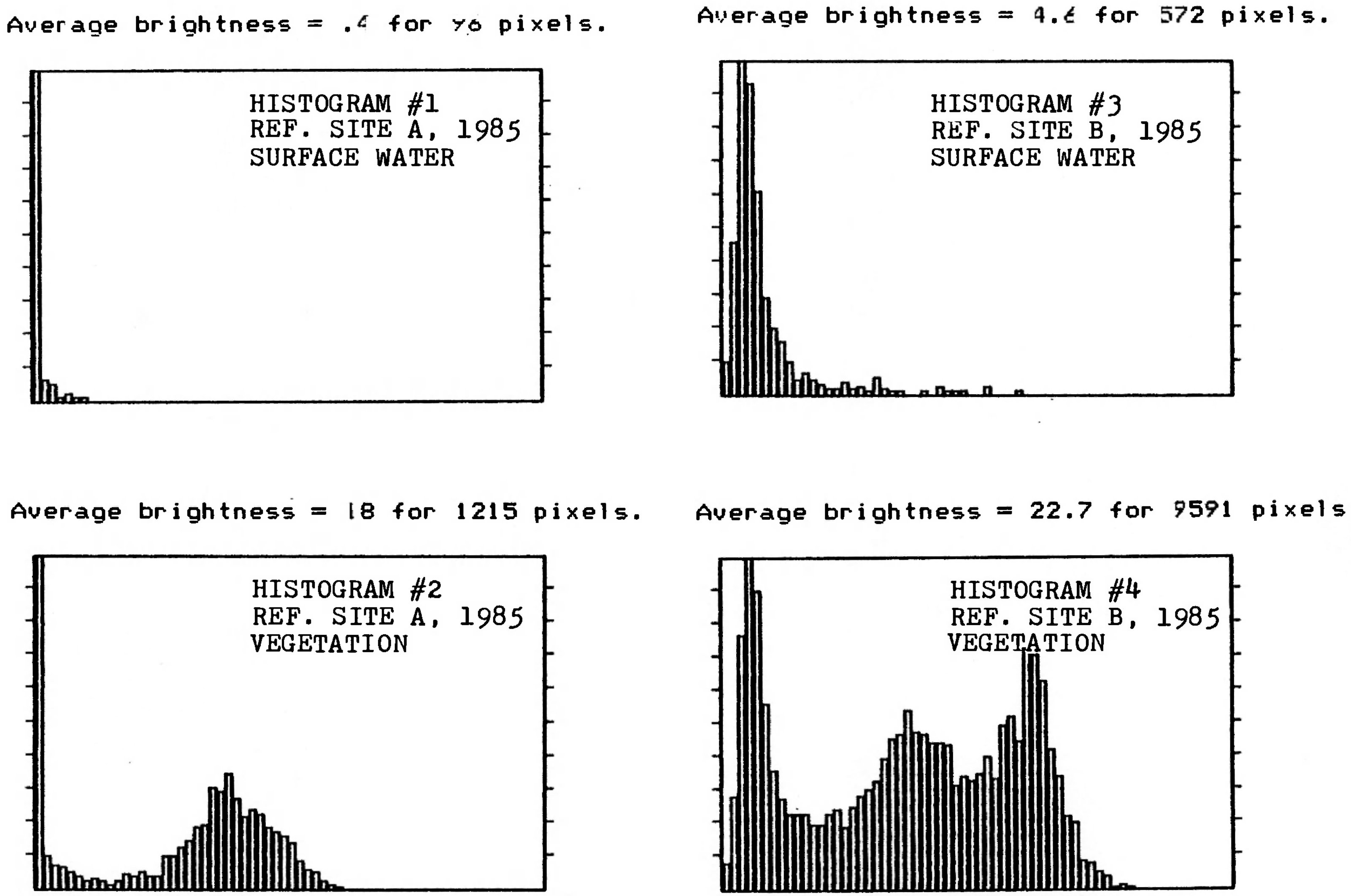

FIGURE 4.16 SURFACE WATER & VEGETATION BRIGHTNESS RESPONSE - REFERENCE AREAS 1985

should be somewhat similar. Histogram #1 shows the brightness response of the sample taken in the deep marsh/open water zone of reference Site A (Class 3). The low mean brightness (0.4) points to sparse vegetation response in the deep marsh zone. Histogram #2 has the brightness response of the reference Site A wetland including the wet meadow and shallow marsh zones. The higher mean brightness shows a fairly well developed wetland plant community surrounding the wetland. Histogram #3 has the brightness response of the reference Site B (Class 4) of the deep marsh/open water zone in 1985. The mean brightness indicates that a fairly well developed deep marsh plant community exists. Histogram #4 shows the brightness response of the reference Site B including the wet meadow and shallow marsh zones. The histogram and average brightness indicate a well developed wetland complex with good vegetation response in all the vegetation zones.

In comparing the brightness response between the rehabilitated and reference wetlands the histograms and mean brightness values indicate the rehabilitated sites are succeeding towards the reference values. Rehabilitated Site A already has reached a brightness response slightly greater than reference Site A (19.1 to 18) comparing the wetland value including the wet meadow and shallow marsh of

1986 to the same parameters of the reference for 1985. The brightness response results of the larger rehabilitated wetland, Site B, have been less dramatic when compared to the reference Site B. The rehabilitated Site B brightness response of the wetland including the wet meadow and shallow marsh zone in 1986 are still less than one-half that of the reference Site B for 1985 (11.1 to 22.7). This indicates that the larger rehabilitated wetland is undergoing much slower successional development than the smaller rehabilitated wetland (Site A).

The resolution of the brightness using black and white photographs taken of color infrared aerial photography indicated an increase in brightness pattern from 1985 to 1986 in the rehabilitated wetlands. The increase in brightness pattern can be attributed to the increased vegetation growth in the wet meadow, shallow marsh, and deep marsh zones pointing to the vegetation successional pattern and development of the rehabilitated wetland sites.

<u>Color Infrared and Natural Color Aerial Photography.</u> Color infrared and natural color aerial photographs were also used to compare the rehabilitated wetlands to the reference wetlands. The analysis of these aerial photographs gave results of the hydrological patterns from 1985 to 1986 on the study sites and gave results of the vegetation patterns of the wetland vegetation community.

The color infrared photos were taken on 7/2/85 and 6/24/86 on the rehabilitated sites and 7/5/85 on the reference sites. No color infrared photos were available for the reference sites in 1986. The natural color photos were taken on 6/30/85 and 7/3/86 for both the reference and rehabilitated sites.

The scales of all the color infrared and natural color low altitude aerial photographs taken in 1985 and 1986 was 1:12,000.

The hydrological analysis consisted of visually inspecting the study sites on the aerial photographs to see the hydrological patterns and conditions of the wetlands. The analysis was done by looking at the size, shape, pattern, and color of the wetlands.

The color infrared and natural color aerial photographs indicate more water was present in the rehabilitated wetlands in 1986 than in 1985 making the wetland sizes larger, especially the rehabilitated Site B (Class 4).

The shape of the shoreline of the rehabilitated wetland Site A was more convoluted (having a higher edge quality so important to wildlife) in 1986 than in 1985, while the rehabilitated Site B had a more linear shoreline in 1986 than 1985 due to the increased water volume in the wetland and the underdeveloped wetland vegetation communities.

The hydrological pattern of the wetlands indicates a stable watershed with only slight evidence of erosion occuring on the rehabilitated sites in either 1985 or 1986.

Infrared records a dark color in the wetlands indicating that only slight sediment run-off occured, lower than would be expected on a rehabilitated site. The amount of sediment run-off into the wetlands had decreased even further in 1986 as indicated by the darker water color than in 1985.

The reference wetlands were inspected through the color infrared and natural color aerial photographs for a comparison to the rehabilitated wetlands in 1985 and 1986.

The natural color aerial photos showed the reference wetlands in 1986 to be about two-thirds their size in 1985. This was obviously due to the fact that the precipitation in the reference area decreased dramatically in 1986 as compared to 1985 and was much less than in the rehabilitated wetlands at the time the photos were taken.

The shape of the shoreline of reference wetland Site A (Class 3) was not nearly as convoluted as reference Site B (Class 4). The reference Site B had a very irregular shoreline with high edge diversity.

The aerial photos indicate that the hydrological pattern was very stable with little erosion surrounding the wetlands.

The 1986 infrared and natural color photos show the surface water of the rehabilitated wetlands to have had a darker blue coloration than in 1985 indicating there was less sediment run-off. The dark blue almost black surface water color was consistent in the reference wetlands in both 1985 and 1986 even though there was less surface water on the reference sites in 1986, little sediment run-off.

The vegetation was analyzed with the color infrared and natural color photos using the same parameters as the hydrology, size, shape, pattern, and color to get an idea of the vegetation of the wetland community types or zones (wet meadow, shallow marsh, and deep marsh).

The color infrared photos show that the areal size of the vegetation communities in the rehabilitated wetlands increased greatly in the rehabilitated wetland Site A and some in rehabilitated wetland Site B from 1985 to 1986.

The shape and pattern of the vegetation in the rehabilitated site A was quite different in 1986 as compared to 1985. The successional development of the wet meadow, shallow marsh, and deep marsh zones was able to be seen in 1986. None of the zones were evident in 1985. In 1986 rehabilitated site B showed less zonation of the vegetation than rehabilitated site A, but had a wet meadow zone that was present that was not evident in 1985.

With the infrared the intensity of the color of the vegetation was bright red in 1986 as compared to lighter red tones in 1985 indicating healthier vegetation response in 1986.

The reference wetlands show fairly consistent size of the vegetation zones in both 1985 and 1986. The reference wetlands shape and pattern shows definite presence and zonation of all three zones (wet meadow, shallow marsh, and deep marsh) in 1985 and 1986. The intensity of the color of the vegetation was bright red indicating healthy vegetation is present on these wetlands.

CHAPTER FIVE

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CONCLUSIONS AND RECOMMENDATIONS

The major hypothesis of the research was: There are differences existing between current results of rehabilitation of wetland habitat on surface coal-mined lands and unmined and relatively undisturbed (natural) wetland as they affect wildlife.

The corollary hypothesis was: Surface coal-mined and rehabilitated wetlands will undergo a vegetational and associated habitat succession similar to the vegetational succession on relatively undisturbed natural wetlands, ultimately resulting in a wetland community closely resembling that of seasonal and semipermanent natural wetlands.

The purpose of the research was to address five major issues:

1) the evaluation of the practicality of rehabilitation of surface coal-mined lands for wildlife as a primary land use.

2) a comparison of the site conditions of rehabilitated surface coal-mined wetlands and unmined natural wetlands to measure the important wetland habitat characteristics for wildlife.

3) analyzing and comparing the vegetational succession on rehabilitated surface coal-mined wetlands to unmined natural wetlands using a Gleasonian model of wetland vegetation succession (Van der Valk, 1981) to determine the model's application on rehabilitated sites.

4) to evaluate the integration of various remote sensing techniques with on-site collected data to measure important wildlife parameters of wetland vegetation.

5) to develop a set of recommendations to improve wetland rehabilitation for wildlife.

The five major issues of the research will be used as a framework for analyzing the major and corollary hypotheses and discussing the research results.

EVALUATION OF REHABILITATED SURFACE COAL-MINED LANDS FOR WILDLIFE

The research found the rehabilitated wetland sites A & B to have good potential for wildlife, especially waterfowl. Waterfowl were used as wildlife test group to measure the success of the rehabilitation for wildlife. Since all wildlife must have quality habitat with food, cover, and water it can be assumed that if the waterfowl productivity is increasing, habitat improvement for other wildlife will follow.

The rehabilitated wetlands showed an increase in the number of waterfowl pairs observed in 1986 (101) as compared to the number observed in 1985 (76). The smaller rehabilitated wetland site A (Class 3) showed the greatest increase in waterfowl pairs with 7 pairs (1985) and 28 pairs (1986). Waterfowl broods were also observed in greater numbers on the rehabilitated wetlands in 1986 (32) as compared to 1985 (1).

The waterfowl pairs observed on the reference wetlands actually decreased from 120 pairs in 1985 to 85 pairs in 1986. The smaller reference wetland site A (Class 3) had the greatest decrease from 72 pairs in 1985 to 27 pairs in 1986. Although more broods were observed on the reference wetlands in 1986 (25) than in 1985 (8) the number was still less than was observed on the rehabilitated wetlands. These reductions can be partially attributed to less precipitation in the reference area during the nesting season resulting in a reduction in the reference size and conditions (especially in the reference site A).

These results indicate that the rehabilitated wetlands are improving as wildlife habitat rapidly and already rival the waterfowl numbers recorded in the reference area for 1986.

The observation of another significant nongame bird species, piping plover, on or near the rehabilitated wetlands in 1986 is also an encouraging sign of significant habitat quality and improvement. The piping plover, a small shorebird, is an endangered species that uses sandy or gravelly areas for nesting and requires wetland habitat nearby. The presence of this species on the rehabilitated wetland areas during the breeding season indicates possible nesting on the site.

COMPARISON OF REHABILITATED AND REFERENCE WETLAND SITE CONDITIONS

The comparison of the physical factors showed the physiography of the rehabilitated and reference wetlands to be quite similar. The elevation, slope, aspect, bedrock type and depth, and landform dissection of the rehabilitated and reference wetlands showed no significant differences.

The water quality measures for pH, calcium, and nitrates were quite similar in the rehabilitated and reference wetlands. The pH range indicates that the rehabilitated wetlands are not receiving any acidic runoff from the surrounding mine area and from the rehabilitated soils in place and are in a range adequate for good vegetation growth. The calcium rates indicate good nutrient potential for vegetation on the rehabilitated sites and are in the normal ranges for the prairie pothole region. The similarity between the rates of nitrates on both the rehabilitated and reference sites is surprising considering nitrogen is generally flushed out the pothole system rather easily. Nitrogen is perhaps the most complex element in the pothole system and is vital to ensure good vegetation cover and growth. To see the nitrogen at rates comparable to the reference wetlands points to a stable condition for this element.

The magnesium, sodium, sodium adsorption rates, and hardness varied more on the rehabilitated wetlands and the reference wetlands in 1986. The difference in the ranges for these elements probably represent seasonal fluctuations or individual differences in the wetlands due to the immaturity of the rehabilitated wetlands. The sodium rate of the reference site B is higher than the other reference site and the rehabilitated sites and may be classified as slightly saline fresh water while the other wetlands are considered fresh water.

The soils of the sites had fairly similar properties. The pH, texture, and water holding capacity were very similar on the rehabilitated and reference sites. The rehabilitated soils had a greater soil composition than the reference sites. The reference wetlands had greater topsoil thickness and organic matter content than the rehabilitated wetlands. The similarity in pH between the rehabilitated sites and the reference sites is an important indicator since pH has a direct influence on the developing plant communities. The texture and water holding capacity similarities indicate good potential for a characteristic prairie pothole to develop. The differences in topsoil thickness and organic matter content are good indicators as to the reasons the reference wetlands have higher plant species diversity. It can be assumed that over time the rehabilitated wetlands will show improved topsoil thickness and organic matter content as the wetland community continues to develop.

While the site temperatures, solar radiation, and wind speed displayed little variation in 1985 and 1986, the site precipitation varied. In 1985 the precipitation was 0.9" greater in the reference wetland area, but in 1986 the rehabilitated wetland area had 4.2" more precipitation than the reference wetland area. This would have a significant affect on the wetland conditions.

The factors covered in this section all help to determine the wetland conditions and have direct and indirect affects on the wildlife. The wildlife are directly affected by the microclimate (site temperatures, precipitation, wind, solar radiation, and surrounding landforms), and hydrology (water quality). The wildlife species composition is influenced indirectly by the physiographic conditions (elevation, slope, aspect, bedrock type and depth, and landform dissection) and soils (composition, pH, texture, topsoil thickness, organic matter content, and water holding capacity). These factors all have a direct influence on the wetland vegetation composition and diversity and directly affect the type and amount of cover and nutrition sources in the habitat available to wildlife.

COMPARISON OF THE VEGETATIONAL SUCCESSION ON THE REHABILITATED AND REFERENCE WETLANDS

The model for wetland vegetation succession analysis showed the vegetation of the wet meadow zones of the rehabilitated sites to be heavily composed of annual species (nearly 50%). In comparison the wet meadow zones of the reference wetlands were composed almost entirely of perennial species (87%). The high number of annual species in the rehabilitated sites follows the anticipated outcomes, since annuals are pioneer species easily able to be established in areas with sparse vegetation. As the mined wetlands have only been in place since 1985 the annuals represent the early stages of succession on the site and are already moving towards a more stable wetland vegetation community as evidenced by the number of perennials on the sites (nearly 50%). In comparison the reference wetlands show a more stable wetland vegetation community, as would be expected, with a high number of perennials present. The pattern of the rehabilitated wet meadow zones succeeding toward a stable vegetation community is important since this zone serves as a vital source of cover and food for wildlife, especially waterfowl.

The shallow marsh zones of the rehabilitated sites had a very high number of perennials present (over 87%), but much lower species diversity than the reference wetlands. The shallow marsh zones of the reference wetlands were composed of about 2.5 times as many species and different life types as the rehabilitated sites. There was evidence that some of the typical shallow marsh species are presently found in the wet meadow zones of the rehabilitated sites indicating that they have not yet succeeded to their natural zones. Proper shallow marsh zone development also plays an important role in wildlife productivity by providing vital food and cover.

A comparison of the deep marsh zone vegetation shows that the reference wetlands had a species diversity about 5 times as great as that of the rehabilitated wetlands. The species present on the rehabilitated sites were composed entirely of perennial species which indicates a move towards stability. It can be anticipated that species diversity of the rehabilitated deep marsh zones should increase in this zone over time. The deep marsh zone serves as important habitat for many non-game birds providing cover and food sources, and provides a great deal of food sources to waterfowl species.

The successional model of the vegetation indicated all but 2 species were established on the rehabilitated wetland sites by the seed bank naturally stored in the respread wetland topsoil. The fact that the seed bank was responsible for the establishment of most of the species present indicates that the natural characteristics of the wetland vegetation are in place and should continue to naturally succeed following the pattern of the reference wetlands.

All the species of the rehabilitated wetlands, except the deep marsh species, were established during drawdowns or periods when mudflats were prevalent on the sites. Most all of the deep marsh species have been established during flooded or standing water conditions. This type of establishment pattern indicates the importance of allowing the wetlands to follow the natural pattern of the prairie potholes to have fluctuating conditions, between drawdowns and flooding, in order to properly establish the wetland vegetation community.

EVALUATION OF REMOTE SENSING TECHNIQUES USED

The remote sensing techniques used to integrate with the ground-truth data or data collected on the sites were: Landsat 5-Thematic Mapper Classification, Histogram/Mean

Brightness Response using black and white imagery, Color Infrared aerial photos, and Natural Color aerial photos.

Landsat 5-Thematic Mapper Classification. The Landsat 5-Thematic Mapper Classification of the wetland sites for 1986 was made available by Ducks Unlimited Inc. for the research. The output made available consisted of an 18" x 24" Cibachrome print, an 18" x 24" classified print, and computer analyzed data of the wetland sites. The data and prints were important informational sources and were used to compare and quantify the total wetland acres; sizes of the wet meadow, shallow marsh, and deep marsh zones; shoreline perimeter in miles; and shoreline shape index of the wetland areas.

The shoreline shape index was an important factor in comparing the natural aspect of the wetland edge or perimeter of the wetlands. The smaller rehabilitated wetland site A (Class 3) had a comparable shoreline shape index to the smaller reference site A (Class 3) signifying good edge or perimeter is present. Such natural edge areas lead to the development of diverse niches which have a direct effect on the vegetation communities present and the wildlife productivity of the site. The larger rehabilitated site B (Class 4) had a much lower shoreline shape index than the reference site B (Class 4) indicating lower potential for edge and niche development.

When compared to data on the wetlands from a previous study, the reference wetland sizes calculated by the thematic mapper process were found to be 94% accurate on the reference site A and 98% accurate on the reference site B.

Histogram & Mean Brightness Response. The use of black and white photographs to calculate the histograms/mean brightness response of the wetlands was a good method for measuring change in the wetlands from one year to the next. The reflectance of the vegetation and water were measured using a grid method. The histogram/mean ratio showed the rehabilitated site A to have the most change from 1985 to 1986. This was due to the tremendous increase in the wetland vegetation development of the site in 1986. One drawback to this method was that it was difficult to accurately measure where the reflectance of the vegetation stopped and the water started in the shallow marsh and deep marsh zones on the histogram, making only a relative calculation possible.

Color Infrared Imagery. The color infrared low altitude aerial photographs were shot at a scale of 1:12,000 and were important in gaining visual data of the changes in the sites from 1985 to 1986. The CIR photos were used mainly to compare the hydrological patterns and the vegetation conditions and community pattern development in the rehabilitated wetlands as compared to the reference wetlands. The analysis was done by the use of a comparison based on size, shape, pattern, and color of the water and vegetation in the wetlands. The analysis showed the vegetation of the rehabilitated sites greatly improved from 1985 to 1986 and the quality of the vegetation was similar in the reference wetlands from 1985 to 1986. No pollution was indicated in the wetlands themselves, but the larger rehabilitated site A wetland indicated more sediment runoff by the lighter color present in 1985 and 1986. The watershed area of the rehabilitated wetlands showed little evidence of erosion occuring on the sites.

Natural Color Imagery. The natural color aerial photos were also shot at a scale of 1:12,ØØØ. They were used mainly to look at the difference in the wetland extent in 1985 as compared to 1986 on the rehabilitated and reference sites. The natural color photos showed the reference wetlands in 1986 to be about two-thirds their size in 1985. This was due to the decreased precipitation in the reference area in 1986. The rehabilitated sites showed about the same wetland perimeter in 1986 as in 1985.

RECOMMENDATIONS FOR REHABILITATING SURFACE COAL-MINED WETLANDS FOR WILDLIFE

The study of the rehabilitated wetlands at the Falkirk Mine has brought up many suggestions to improve the rehabilitation of surface coal-mined wetlands for wildlife over previously used methods. They are:

Physiography

1. The slope and aspect of the rehabilitated wetlands were very close to the premined conditions and allowed the wetlands to achieve a condition approaching natural stability exhibited by Class 3 and Class 4 prairie potholes.

2. The shoreline shape index indicated that the rehabilitated wetlands could have been improved for wildlife if they had been more convoluted or irregular. A more irregular shoreline perimeter allows more diverse plant community development and therefore, more diverse niches to be utilized by wildlife. This also allows the edge area to be increased allowing more diverse edges to be developed for wildlife.

3. The creation of islands out in the wetland has been shown to increase wildlife productivity (waterfowl) and increase nesting success by reducing losses due to predation. This could have been a way to increase the edge area, vegetative cover and nutrition value, and habitat quality of the larger rehabilitated site B (Class 4) wetland. Even though islands are not usually typical of the natural prairie potholes, on rehabilitated sites this strategy might be effective.

4. The size of the wetlands has proven to be an important aspect affecting wildlife productivity. In the rehabilitation process the size of the wetlands has more than doubled creating more wetland habitat for wildlife.

5. The rehabilitation of wetlands of different wetland classes is important to wildlife. By rehabilitating a Class 3 and Class 4 wetland the wildlife species diversity is increased. The development of heterogenous wetland types allows the wetlands to have different characteristics and to be managed differently, even in extreme climatic conditions, permitting local population shifts of wildlife to more optimal niches.

6. The juxtaposition or proximity of a single wetland to other wetlands is well exhibited by the rehabilitated wetlands. The close proximity of the wetlands to one another allows the wetlands to work as a wetland complex. Wetland complexes or clusters offer greater vegetative diversity and structure making them more attractive to wildlife.

Hydrology

7. The water quality was maintained by controlling runoff from the adjacent mine areas. Turbidity, chemical pollution, and sedimentation (although some was evident)

were well handled resulting in characteristic temperature patterns for the wetlands and allowing the wetland vegetation succession characteristics to be achieved.

8. By allowing the wetlands to undergo characteristic drawdowns and standing water phases the rehabilitated wetlands have undergone a successional development similar as that on unmined natural wetlands.

9. The ability to manipulate artificially the water-levels of the rehabilitated wetlands can enhance or regulate the growth or populations of major wetland wildlife. Drawdowns result in mudflat exposure encouraging the germination of the majority of the wetland plant species, which once established on mudflat continue to grow in flooded conditions. These mudflats also expose vital feeding areas for a number of waterfowl and shorebirds. According to Weller (1978) these drawdowns should occur in early spring prior to bird territory establishment or in fall prior to muskrats lodging for winter to enhance muskrat harvest and prevent wasteful mortality. Decompostion of plant materials is increased during drawdowns releasing essential growth nutrients for future plant community use and leads to a mosaic pattern of wetland plant distribution on the wetlands. Flooding or standing water provides the greatest quality habitat conditions of the wetlands for cover and feeding,

especially during the breeding season (for waterfowl), once the vegetation is established (during the drawdowns). The ability to fluctuate between the two conditions, drawdowns or flooding, allows the optimum number of wildlife to be produced on the wetlands.

Soils

10. The handling of the wetland topsoil prior to mining was vital to the development of the wetland vegetation. Prior to mining the wetland topsoil was stripped and stockpiled separately from the other topsoil of the mined area. The wetland topsoil was then carefully seeded with a cover crop of oats/rye immediately after stripping. During the rehabilitation phase the wetland topsoil was respread in the proposed wet meadow, shallow marsh, and deep marsh zones. Such careful handling of the wetland topsoil enabled the characteristic of high seed viability in the natural seed bank of wetland soils to produce the existing vegetation patterns under the proper conditions (drawdowns or standing water) depending on the species. The careful handling of the wetland topsoil also allowed the mycorrhizal relationships with certain plant species to be saved and may have also been important in the wetland plant community development.

Vegetation

11. The use of the native species available in the

soil bank allowed a more heterogenous plant community to develop with higher diversity and productivity. The native species not only promoted the natural succession pattern taking place on the rehabilitated wetlands, but established quickly and have greater food and cover value for wildlife than domesticated plant species.

12. Some sod plugs of native species were used in the rehabilitation process of the surface coal-mined wetlands (97 *Carex* spp., 11 *Sparganium* spp., 3 *Scirpus acutus* in Rehabilitated site A; 67 *Carex* spp., 179 *Polygonum coccineum*, 156 *Scirpus acutus*, & 14 *Scirpus validus* in Rehabilitated site B). Even though these had little bearing on the present vegetative community (due to the small number used) the cover and nutrition value of rehabilitated wetlands could be increased if plugs of species with the highest available cover and nutrition values were planted in the revegetation process to enhance the wildlife productivity quicker. However, the use of plugs is expensive and time consuming and may not be practical for larger wetland sites.

General

13. The management of rehabilitated wetlands as a wetland system (as was done on the rehabilitated wetlands), rather than for species management, results in benefits to all plants and wildlife, even though there is some evidence

of competition between species.

14. The water-cover ratio of the rehabilitated wetlands was about 25% vegetation cover to open water. Williams (1984) suggested the ratio of open water to vegetated area influences the wildlife productivity. Since those with 25-75% of the wetland occupied with cover plants were found to be utilized most by wildlife, the rehabilitated sites are in the desired range.

15. The use of new remote sensing tools such as the Landsat 5-Thematic Mapper imagery and use of digital information for the same imagery offer exciting new opportunites to document wetland conditions enabling management recommendations to be made more quickly and accurately. The use of such imagery will no doubt become even more improved and with the use of microcomputer capabilities changes in wetlands can be documented on a regular basis to aid in management of wetlands at a nominal cost to mining companies and rehabilitation specialists.

RECOMMENDATIONS FOR FURTHER RESEARCH

The study of wetland rehabilitation of surface coal-mined lands indicates there are many opportunities for further research. Some of the main areas noted worthy by the author for further research endeavors are:

1. A study identifying the role of landscape architects in the reclamation/rehabilitation process. The

development of strategies to further involve landscape architects in the planning and design of rehabilitation efforts as members of a multi-discplinary team of professionals such as biologists, hydrologists, geologists, engineers, and mining decision makers could be discussed.

2. There is a great need to take a comprehensive look at the national regulations for surface coal-mining, specifically the Surface Mining Control and Reclamation Act of 1977 and the National Environmental Policy Act of 1969, to see how wildlife parameters have been achieved or not achieved by the current guidelines set forth in the regulatory laws. A study of the wildlife parameters of several cases in different mining provinces in the U. S. as outlined by the regulatory laws would be appropriate.

3. A study of the impacts of other types of surface mining on wildlife. Mining of phosphates, gravel, uranium, copper, gold, peat, iron ore, etc. all have important consequences influencing the wildlife and general conditions of both terrestrial and aquatic habitats.

4. A study focusing on the role of the remote sensing techniques now available for land use planning decisions applied to rehabilitation of mined-lands. With the current capabilities of Landsat products, the new Spot satellite, and on-going developments, the remote sensing field allows a multitude of study opportunities for

landscape architects to do impact and assessment studies relating to land use.

5. The study of the importance of riparian habitats to wildlife and the rehabilitation of these areas along streams and rivers from a wide variety of impacts, including surface mining.

FINAL COMMENTS

The rehabilitation of the surface coal-mined wetlands in this study indicates a successful effort with high wildlife potential is being established. Although the rehabilitation effort here is to be applauded, it is the feeling of the author that wetland areas should be mitigated from such disturbance whenever possible and rehabilitation of wetland areas should be reviewed on a site to site and case to case basis for rehabilitation potential and feasibility. While the general characteristics of many wetlands are similar there are striking differences from wetland to wetland in some regions of the country, which in some cases would eliminate the possibility of rehabilitation of some important wetland attributes to wildlife.

The author also suggests that in the prairie pothole region only Class 1 and Class 2 pothole wetlands be considered for rehabilitation, as were done on the sites studied at the Falkirk Mine. These wetlands have characteristics that make them more easily rehabilitated with high natural qualities so important to wildlife. In some cases, such as the rehabilitated wetlands in this study, Class 1 and Class 2 wetlands can be improved to support higher wildlife productivity after the rehabilitation process than prior to mining. Given the current status of continued losses of Class 3 and Class 4 pothole wetlands yearly in the prairie pothole region mitigation of these wetlands should occur whenever possible.

The use of Class 1 and Class 2 wetlands to be rehabilitated as Class 3 and Class 4 wetlands, as was done on the Falkirk Mine, actually increased the wetland acreage prior to mining. This practice, whenever possible, should be encouraged since the Class 3 and Class 4 pothole wetlands have higher wildlife potential for more species of wildlife. These wetlands are more complex than Class 1 and Class 2 wetlands offering greater vegetation biomass and promoting the development of more diverse wildlife niches.

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APPENDIX A

VEGETATIVE DATA BY APPROPRIATE SITE & MARSH ZONE

WET MEADOW VEGETATION ZONE-REHABILITATED SITE A

GENUS	SPECIES	VEGETATION ZONE	LIFE TYPE	PROP. LONG.	ESTAB. METHOD	ANTELOPE C.V.	ANTELOPE N.V.	MULE DEER C.V.	MULE DEER N.V.	NONGAME BIRD C.V.	NONGAME BIRD N.V.	UPLAND GAMEBIRD C.V.	UPLAND GAMEBIRD N.V.	SMALL MAMMAL C.V.	SMALL MAMMAL N.V.	WATERFOWL C.V.	WATERFOWL N.V.	WHITETAIL DEER C.V.	WHITETAIL DEER N.V.	TOTAL COVER VALUE	TOTAL NUTR. VALUE	AVG. COV. VAL.	AVG. NUTR. VAL.	TOT. HAB. VAL.	AVG. HAB. VAL.	POT. BIO.	SHORT TERM REVEG.	LONG TERM REVEG.
Agropyron	elongatum	wmA	V	S	1	1	1	5	1	10	5	10	5	10	5	10	5	5	1	51	23	7.29	3.29	74	5.29	10	5	5
Agropyron	repens	wmA	V	S	1	5	1	5	1	10	1	5	1	10	1	10	5	5	1	50	11	7.14	1.57	61	4.36	10	5	10
Agropyron	smithii	wmA,wmB	V	S	1	5	1	5	1	10	1	10	1	10	1	10	10	5	1	55	16	7.86	2.29	71	5.07	5	5	10
Alisma	gramineum	wmA,wmB,smC	P	S	1	1	1	1	1	1	5	1	5	1	1	3	10	1	1	9	24	1.29	3.43	33	2.36	5	5	5
Alopecurus	aequalis	wmA,wmB,wmC,smC	V	S	1	1	1	1	5	1	1	5	1	1	5	5	5	1	1	15	19	2.14	2.71	34	2.43	5	5	10
Amaranthus	albus	wmA	A	D	1	1	1	1	5	1	5	5	1	1	1	5	1	1	1	15	15	2.14	2.14	30	2.14	5	5	1
Amaranthus	graecizans	wmA	A	D	1	5	1	1	5	5	5	5	1	1	1	5	1	1	1	23	15	3.29	2.14	38	2.71	5	5	1
Amaranthus	retroflexus	wmA,wmB	A	S	1	10	10	10	10	1	10	5	10	1	10	5	10	10	10	42	70	6.00	10.00	112	8.00	5	5	1
Artemisia	biennis	wmA,wmB,wmC	A	S	1	5	5	1	5	5	5	10	5	5	5	1	1	1	5	28	31	4.00	4.43	59	4.21	5	5	5
Aster	ericoides	wmA	V	S	1	1	5	1	10	10	5	10	5	5	5	1	1	1	1	29	32	4.14	4.57	61	4.36	1	5	5
Aster	hesperius	wmA,wmC	V	S	1	1	5	1	10	5	5	5	5	5	5	1	1	1	1	19	32	2.71	4.57	51	3.64	1	5	5
Beckmannia	syzigachne	wmA,wmB,wmC,smC	A	S	1	5	1	10	1	5	10	5	5	5	5	10	5	10	1	50	28	7.14	4.00	78	5.57	5	5	1
Bidens	comosa	wmA,wmB	A	S	1	1	1	1	1	1	5	1	1	1	1	1	1	1	1	7	11	1.00	1.57	18	1.29	1	5	5
Bidens	vulgata	wmA,wmB	A	S	1	1	1	1	1	1	5	1	1	1	1	1	1	1	1	7	11	1.00	1.57	18	1.29	1	5	1
Brassica	kaber	wmA,wmB	A	S	1	1	5	1	5	10	10	10	5	5	1	1	1	1	1	29	28	4.14	4.00	57	4.07	5	10	1
Brassica	arvensis	wmA	A	S	1	1	5	1	5	10	10	10	5	5	1	1	1	1	1	29	28	4.14	4.00	57	4.07	5	10	1
Carex	atheroides	wmA,smB,smC	V	S	1	1	1	1	5	5	5	5	5	5	1	1	5	1	1	19	23	2.71	3.29	42	3.00	10	1	5
Carex	lanuginosa	wmA,wmC	V	S	1	1	1	1	5	5	5	5	5	1	1	1	1	1	1	15	19	2.14	2.71	34	2.43	5	1	5
Chenopodium	berlandieri	wmA,wmB	A	S	1	1	1	1	1	10	1	10	5	5	1	1	1	1	1	29	11	4.14	1.57	40	2.86	5	5	1
Chenopodium	rubrum	wmA,wmB,wmC,smC	A	S	1	1	1	1	1	10	10	10	10	1	1	1	1	1	1	25	25	3.57	3.57	50	3.57	5	5	5
Echinochloa	muricata	wmA,wmB,wmC	A	S	1	1	1	5	1	10	5	5	5	10	10	10	10	10	1	51	33	7.29	4.71	84	6.00	5	10	1
Eleocharis	acicularis	wmA,wmB,wmC,smA,dmC	V	S	1	1	1	1	1	10	1	5	1	5	1	10	10	1	1	33	16	4.71	2.29	49	3.50	1	1	1
Eleocharis	engelmenia	wmA	A	S	1	1	1	1	1	5	5	5	1	5	1	10	10	1	1	28	20	4.00	2.86	48	3.43	1	1	1
Eleocharis	- obtusa var. ovata	wmA.wmB	A	S	1	1	1	1	1	10	5	5	5	1	1	10	10	1	1	29	24	4.14	3.43	53	3.79	1	1	1
Eleocharis	palustris	wmA,wmB,wmC,smA.smB	V	S	1	1	1	1	5	5	5	5	5	1	1	10	10	1	1	24	28	3.43	4.00	52	3.71	5	5	5

GENUS	SPECIES	VEGETATION ZONE	LIFE TYPE	PROP. LONG.	ESTAB. METHOD	ANTELOPE C.V.	ANTELOPE N.V.	MULE DEER C.V.	MULE DEER N.V.	NONGAME BIRD C.V.	NONGAME BIRD N.V.	UPLAND GAMEBIRD C.V.	UPLAND GAMEBIRD N.V.	SMALL MAMMAL C.V.	SMALL MAMMAL N.V.	WATERFOWL C.V.	WATERFOWL N.V.	WHITETAIL DEER C.V.	WHITETAIL DEER N.V.	TOTAL COVER VALUE	TOTAL NUTR. VALUE	AVG. COV. VAL.	AVG. NUTR. VAL.	TOT. HAB. VAL.	AVG. HAB. VAL.	POT. BIO.	SHORT TERM REVEG.	LONG TERM REVEG.
Helianthus	annus	wmA	A	S	1	5	10	10	10	5	10	10	10	5	10	5	1	10	10	50	61	7.14	8.71	111	7.93	5	5	1
Hordeum	jubatum	wmA,wmB,wmC	V	S	1	1	1	1	1	1	5	1	5	1	1	10	5	5	1	20	19	2.86	2.71	39	2.79	5	5	1
Kochia	scoparia	wmA	A	S	1	5	10	10	10	10	10	5	10	10	10	10	10	10	10	60	70	8.57	10.00	130	9.29	10	10	1
Lactuca	serriola	wmA	A	S	1	1	5	1	5	10	5	5	5	5	10	10	1	1	5	33	36	4.71	5.14	69	4.93	5	5	1
Lycopus	americanus	wmA,wmC	V	S	1	1	1	1	1	1	1	1	1	1	1	1	1	5	5	11	11	1.57	1.57	22	1.57	1	5	1
Malva	rotundifolia	wmA	A	S	1	1	1	1	1	5	5	5	5	1	5	1	1	1	1	15	19	2.14	2.71	34	2.43	5	5	1
Mentha	arvensis	wmA,wmC	V	S	1	1	1	1	1	1	1	5	1	1	1	1	1	1	1	11	7	1.57	1.00	18	1.29	5	1	5
Panicum	capillare	wmA	A	S	1	5	1	1	1	5	10	5	10	5	5	5	1	5	1	31	29	4.43	4.14	60	4.29	1	5	1
Panicum	virgatum	wmA	V	S	1	1	1	1	1	10	10	1	10	10	5	10	10	5	1	38	38	5.43	5.43	76	5.43	10	5	10
Phalaris	arundinacea	wmA,wmB,wmC,smC,dmC	V	S	1	1	1	5	5	5	10	5	5	5	5	5	5	10	1	36	32	5.14	4.57	68	4.86	10	5	10
Plagiobothrys	scouleri	wmA	A	S	1	1	1	1	1	5	1	5	1	1	1	1	1	1	1	15	7	2.14	1.00	22	1.57	1	5	1
Poa	palustris	wmA,wmB,wmC	V	S	1	1	5	1	10	10	5	10	5	5	5	10	5	1	10	38	45	5.43	6.43	83	5.93	5	5	5
Polgonum	coccineum	wmA,wmB,wmC,smA,smB,smC	V	S	1	5	1	1	1	5	10	5	1	1	10	10	10	10	1	37	34	5.29	4.86	71	5.07	5	5	5
Polygonum	convolvulus	wmA	A	S	1	1	10	1	5	5	1	1	1	5	10	5	1	5	5	23	33	3.29	4.71	56	4.00	1	5	1
Polygonum	lapathifolium	wmA,wmB	A	S	1	1	1	5	1	5	5	1	1	1	5	5	10	10	1	28	24	4.00	3.43	52	3.71	5	1	1
Polygonum	ramosissimum	wmA	A	S	1	5	5	5	5	5	5	5	5	1	5	1	1	10	5	32	31	4.57	4.43	63	4.50	5	1	1
Populus	deltoides	wmA	P	S	1	1	5	5	5	10	1	10	10	1	5	1	1	10	5	38	32	5.43	4.57	70	5.00	10	1	10
Portulaca	oleracea	wmA,wmB	A	S	1	1	1	1	1	5	5	5	5	1	1	1	1	1	1	15	15	2.14	2.14	30	2.14	1	5	1
Potentilla	norvegica	wmA,wmC	A	S	1	1	1	1	1	5	5	1	5	1	5	1	1	1	1	11	19	1.57	2.71	30	2.14	5	1	5
Rorippa	palustris	wmA,wmB,wmC	A	S	1	1	1	1	1	1	1	1	5	1	1	5	10	1	1	11	20	1.57	2.86	31	2.21	5	1	1
Rumex	maritimis	wmA,wmB,smA	A	S	1	1	1	1	5	5	5	5	5	5	5	5	5	1	1	23	27	3.29	3.86	50	3.57	5	5	5
Rumex	mexicanus	wmA,wmB,wmC	P	S	1	1	1	1	5	5	5	5	5	5	5	5	5	1	1	23	27	3.29	3.86	50	3.57	5	5	5
Rumex	pseudonatronatus	wmA,wmB,smC	P	S	1	1	1	1	1	5	5	5	5	5	5	5	5	5	1	27	23	3.86	3.29	50	3.57	5	5	5
Rumex	stenophyllus	wmA,wmB,wmC	P	S	1	1	1	1	5	10	10	10	10	5	5	5	5	1	1	33	37	4.71	5.29	70	5.00	5	5	5
Sagittaria	cuneata	wmA,wmC,smC	P	S	1	1	1	1	1	1	5	1	5	1	1	1	10	1	1	7	24	1.00	3.43	31	2.21	5	1	1
Salix	amygdaloides	wmA,wmB,wmC	P	S	1	1	1	10	5	10	10	10	10	10	5	5	1	10	5	56	37	8.00	5.29	93	6.64	5	1	5
Salix	interior	wmA	P	S	1	1	5	10	10	10	5	10	10	5	1	5	1	10	10	51	42	7.29	6.00	93	6.64	5	5	10
Salix	lutea	wmA,wmB	P	S	1	1	5	10	10	10	5	10	10	5	1	5	1	10	10	51	42	7.29	6.00	93	6.64	5	5	10
Salsola	iberica	wmA	A	S	1	10	5	10	5	5	5	5	5	10	10	10	1	10	5	60	36	8.57	5.14	96	6.86	5	1	1
Scirpus	fluviatilis	wmA,smA,smB,dmC	V	S	1	10	1	5	1	10	1	10	1	10	1	10	5	10	1	65	11	9.29	1.57	76	5.43	5	5	5
Setaria	glauca	wmA	A	S	1	5	1	5	1	5	10	5	10	10	10	1	5	5	1	36	38	5.14	5.43	74	5.29	5	1	1
Setaria	viridis	wmA,wmB	A	S	1	1	1	1	1	5	10	5	10	10	10	1	10	1	1	24	43	3.43	6.14	67	4.79	1	5	1
Stachys	palustris	wmA,wmB,wmC	V	S	1	1	1	1	1	5	1	5	5	1	1	1	1	1	1	15	11	2.14	1.57	26	1.86	1	1	5

WET MEADOW VEGETATION ZONE-REHABILITATED SITE B

GENUS	SPECIES	VEGETATION ZONE	LIFE TYPE	PROP. LONG.	ESTAB. METHOD	ANTELOPE C.V.	ANTELOPE N.V.	MULE DEER C.V.	MULE DEER N.V.	NONGAME BIRD C.V.	NONGAME BIRD N.V.	UPLAND GAMEBIRD C.V.	UPLAND GAMEBIRD N.V.	SMALL MAMMAL C.V.	SMALL MAMMAL N.V.	WATERFOWL C.V.	WATERFOWL N.V.	WHITETAIL DEER C.V.	WHITETAIL DEER N.V.	TOTAL COVER VALUE	TOTAL NUTR. VALUE	AVG. COV. VAL.	AVG. NUTR. VAL.	TOT. HAB. VAL.	AVG. HAB. VAL.	POT. BIO.	SHORT TERM REVEG.	LONG TERM REVEG.
Agropyron	smithii	wmA,wmB	V	S	1	5	1	5	1	10	1	10	1	10	1	10	10	5	1	55	16	7.86	2.29	71	5.07	5	5	10
Alisma	gramineum	wmA,wmB,smC	P	S	1	1	1	1	1	1	5	1	5	1	1	3	10	1	1	9	24	1.29	3.43	33	2.36	5	5	5
Alisma	plantago-aquatica	wmB,wmC,smA,smC	V	S	1	1	1	1	1	1	5	1	5	1	1	5	10	1	1	11	24	1.57	3.43	35	2.50	5	5	5
Alopecurus	aequalis	wmA,wmB,wmC,smC	V	S	1	1	1	1	5	1	1	5	1	1	5	5	5	1	1	15	19	2.14	2.71	34	2.43	5	5	10
Amaranthus	retroflexus	wmA,wmB	A	S	1	10	10	10	10	1	10	5	10	1	10	5	10	10	10	42	70	6.00	10.00	112	8.00	5	5	1
Artemisia	biennis	wmA,wmB,wmC	A	S	1	5	5	1	5	5	5	10	5	5	5	1	1	1	5	28	31	4.00	4.43	59	4.21	5	5	5
Beckmannia	syzigachne	wmA,wmB,wmC,smC	A	S	1	5	1	10	1	5	10	5	5	5	5	10	5	10	1	50	28	7.14	4.00	78	5.57	5	5	1
Bidens	comosa	wmA,wmB	A	S	1	1	1	1	1	1	5	1	1	1	1	1	1	1	1	7	11	1.00	1.57	18	1.29	1	5	5
Bidens	vulgata	wmA,wmB	A	S	1	1	1	1	1	1	5	1	1	1	1	1	1	1	1	7	11	1.00	1.57	18	1.29	1	5	1
Brassica	kaber	wmA,wmB	A	S	1	1	5	1	5	10	10	10	5	5	1	1	1	1	1	29	28	4.14	4.00	57	4.07	5	10	1
Chenopodium	berlandieri	wmA,wmB	A	S	1	1	1	1	1	10	1	10	5	5	1	1	1	1	1	29	11	4.14	1.57	40	2.86	5	5	1
Chenopodium	rubrum	wmA,wmB,wmC,smC	A	S	1	1	1	1	1	10	10	10	10	1	1	1	1	1	1	25	25	3.57	3.57	50	3.57	5	5	5
Echinochloa	muricata	wmA,wmB,wmC	A	S	1	1	1	5	1	10	5	5	5	10	10	10	10	10	1	51	33	7.29	4.71	84	6.00	5	10	1
Eleocharis	acicularis	wmA,wmB,wmC,smA,dmC	V	S	1	1	1	1	1	10	1	5	1	5	1	10	10	1	1	33	16	4.71	2.29	49	3.50	1	1	1
Eleocharis	obtusa var. ovata	wmA,wmB	A	S	1	1	1	1	1	10	5	5	5	1	1	10	10	1	1	29	24	4.14	3.43	53	3.79	1	1	1
Eleocharis	palustris	wmA,wmB,wmC,smA,smB	V	S	1	1	1	1	5	5	5	5	5	1	1	10	10	1	1	24	28	3.43	4.00	52	3.71	5	5	5
Gratiola	neglecta	wmB,smA	A	S	1	1	1	1	1	5	5	5	5	1	1	1	1	1	1	15	15	2.14	2.14	30	2.14	1	5	1
Hordeum	jubatum	wmA,wmB,wmC	V	S	1	1	1	1	1	1	5	1	5	1	1	10	5	5	1	20	19	2.86	2.71	39	2.79	5	5	1
Phalaris	arundinacea	wmA,wmB,wmC,smC,dmC	V	S	1	1	1	5	5	5	10	5	5	5	5	5	5	10	1	36	32	5.14	4.57	68	4.86	10	5	10
Poa	compressa	wmB	V	S	1	1	10	1	5	10	10	10	10	5	5	5	5	1	5	33	50	4.71	7.14	83	5.93	5	5	10
Poa	palustris	wmA,wmB,wmC	V	S	1	1	5	1	10	10	5	10	5	5	5	10	5	1	10	38	45	5.43	6.43	83	5.93	5	5	5
Polygonum	coccineum	wmA,wmB,wmC,smA,smB,smC	V	S	1	5	1	1	1	5	10	5	1	1	10	10	10	10	1	37	34	5.29	4.86	71	5.07	5	5	5
Polygonum	lapathifolium	wmA,wmB	A	S	1	1	1	5	1	5	5	1	1	1	5	5	10	10	1	28	24	4.00	3.43	52	3.71	5	1	1
Portulaca	oleracea	wmA,wmB	A	S	1	1	1	1	1	5	5	5	5	1	1	1	1	1	1	15	15	2.14	2.14	30	2.14	1	5	1
Ranunculus *	subrigidus	wmB,dmA,dmB	V	S	2	1	1	1	1	1	5	1	5	1	1	1	5	1	1	7	19	1.00	2.71	26	1.86	1	1	1
Rorippa	palustris	wmA,wmB,wmC	A	S	1	1	1	1	1	1	1	1	5	1	1	5	10	1	1	11	20	1.57	2.86	31	2.21	5	1	1
Rumex	maritimis	wmA,wmB,smA	A	S	1	1	1	1	5	5	5	5	5	5	5	5	5	1	1	23	27	3.29	3.86	50	3.57	5	5	5
Rumex	mexicanus	wmA,wmB,wmC	P	S	1	1	1	1	5	5	5	5	5	5	5	5	5	1	1	23	27	3.29	3.86	50	3.57	5	5	5
Rumex	pseudonatronatus	wmA,wmB,smC	P	S	1	1	1	1	1	5	5	5	5	5	5	5	5	5	1	27	23	3.86	3.29	50	3.57	5	5	5
Rumex	stenophyllus	wmA,wmB,wmC	P	S	1	1	1	1	5	10	10	10	10	5	5	5	5	1	1	33	37	4.71	5.29	70	5.00	5	5	5
Salix	amygdaloides	wmA,wmB,wmC	P	S	1	1	1	10	5	10	10	10	10	10	5	5	1	10	5	56	37	8.00	5.29	93	6.64	5	1	5
Salix	lutea	wmA,wmB	P	S	1	1	5	10	10	10	5	10	10	5	1	5	1	10	10	51	42	7.29	6.00	93	6.64	5	5	10
Senecio	congestus	wmB	A	S	1	1	1	1	1	5	1	5	1	1	1	1	1	1	1	15	7	2.14	1.00	22	1.57	1	1	1
Setaria	viridis	wmA,wmB	A	S	1	1	1	1	1	5	10	5	10	10	10	1	10	1	1	24	43	3.43	6.14	67	4.79	1	5	1
Stachys	palustris	wmA,wmB,wmC	V	S	1	1	1	1	1	5	1	5	5	1	1	1	1	1	1	15	11	2.14	1.57	26	1.86	1	1	5

WET MEADOW VEGETATION ZONE-REFERENCE SITE C

GENUS	SPECIES	VEGETATION ZONE	LIFE TYPE	PROP. LONG.	ESTAB. METHOD	ANTELOPE C.V.	ANTELOPE N.V.	MULE DEER C.V.	MULE DEER N.V.	NONGAME BIRD C.V.	NONGAME BIRD N.V.	UPLAND GAMEBIRD C.V.	UPLAND GAMEBIRD N.V.	SMALL MAMMAL C.V.	SMALL MAMMAL N.V.	WATERFOWL C.V.	WATERFOWL N.V.	WHITETAIL DEER C.V.	WHITETAIL DEER N.V.	TOTAL COVER VALUE	TOTAL NUTR. VALUE	AVG. COV. VAL.	AVG. NUTR. VAL.	TOT. HAB. VAL.	AVG. HAB. VAL.	POT. BIO.	SHORT TERM REVEG.	LONG TERM REVEG.
Alisma	plantago-aquatica	wmB,wmC,smA,smC	V	S	1	1	1	1	1	1	5	1	5	1	1	5	10	1	1	11	24	1.57	3.43	35	2.50	5	5	5
Alopecurus	aequalis	wmA,wmB,wmC,smC	V	S	1	1	1	1	5	1	1	5	1	1	5	5	5	1	1	15	19	2.14	2.71	34	2.43	5	5	10
Apocynum	sibiricum	wmC	V	S	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	7	7	1.00	1.00	14	1.00	5	1	5
Artemisia	biennis	wmA,wmB,wmC	A	S	1	5	5	1	5	5	5	10	5	5	5	1	1	1	5	28	31	4.00	4.43	59	4.21	5	5	5
Asclepias	speciosa	wmC	V	S	1	1	1	1	1	5	1	5	1	1	1	1	1	1	1	15	7	2.14	1.00	22	1.57	5	1	5
Aster	hesperius	wmA,wmC	V	S	1	1	5	1	10	5	5	5	5	5	5	1	1	1	1	19	32	2.71	4.57	51	3.64	1	5	5
Aster	simplex	wmC	V	S	1	1	1	1	5	5	5	5	5	1	5	1	1	1	5	15	27	2.14	3.86	42	3.00	5	5	5
Atriplex	patula	wmC	A	S	1	1	1	1	1	5	5	5	5	1	1	1	1	1	1	15	15	2.14	2.14	30	2.14	5	5	1
Beckmannia	syzigachne	wmA,wmB,wmC,smC	A	S	1	5	1	10	1	5	10	5	5	5	5	10	5	10	1	50	28	7.14	4.00	78	5.57	5	5	1
Boltonia	latisquama	wmC	V	S	1	1	1	1	1	5	5	5	5	5	1	1	1	1	1	19	15	2.71	2.14	34	2.43	1	5	1
Calamagrostis	canadensis	wmC	V	S	1	1	1	5	1	5	5	5	5	5	1	5	5	10	1	36	19	5.14	2.71	55	3.93	5	1	5
Calamagrostis	inexpansa	wmC	V	S	1	1	1	1	5	5	5	5	5	5	1	5	5	1	1	23	23	3.29	3.29	46	3.29	5	1	5
Carex	laeviconica	wmC	V	S	1	1	1	1	1	5	5	5	10	5	5	5	5	1	1	23	28	3.29	4.00	51	3.64	1	1	5
Carex	lanuginosa	wmA,wmC	V	S	1	1	1	1	5	5	5	5	5	1	1	1	1	1	1	15	19	2.14	2.71	34	2.43	5	1	5
Carex	praegracilis	wmC	V	S	1	1	1	1	1	10	5	10	10	10	1	10	10	5	5	47	33	6.71	4.71	80	5.71	5	1	5
Carex	sartwellii	wmC	V	S	1	1	1	5	1	10	5	10	5	10	5	10	5	5	1	51	23	7.29	3.29	74	5.29	5	1	5
Carex	vulpinoidea	wmC	P	S	1	1	1	1	5	5	5	10	5	5	1	5	10	1	1	28	28	4.00	4.00	56	4.00	10	1	5
Chenopodium	rubrum	wmA,wmB,wmC,smC	A	S	1	1	1	1	1	10	10	10	10	1	1	1	1	1	1	25	25	3.57	3.57	50	3.57	5	5	5
Cicuta	maculata	wmC	P	S	1	5	1	5	5	10	5	10	5	10	5	10	1	1	5	51	27	7.29	3.86	78	5.57	5	1	1
Cirsium	arvense	wmC	V	S	1	1	1	1	5	5	5	10	5	5	5	10	1	1	5	33	27	4.71	3.86	60	4.29	5	5	5
Distichlis	stricta	wmC	V	S	1	1	1	1	1	1	5	1	5	5	5	1	5	5	1	15	23	2.14	3.29	38	2.71	1	5	5
Echinochloa	muricata	wmA,wmB,wmC	A	S	1	1	1	5	1	10	5	5	5	10	10	10	10	10	1	51	33	7.29	4.71	84	6.00	5	10	1
Eleocharis	acicularis	wmA,wmB,wmC,smA,dmC	V	S	1	1	1	1	1	10	1	5	1	5	1	10	10	1	1	33	16	4.71	2.29	49	3.50	1	1	1
Eleocharis	palustris	wmA,wmB,wmC,smA,smB	V	S	1	1	1	1	5	5	5	5	5	1	1	10	10	1	1	24	28	3.43	4.00	52	3.71	5	5	5
Epilobium	ciliatum	wmC	V	S	1	1	5	1	5	1	5	1	5	5	1	1	1	1	5	11	27	1.57	3.86	38	2.71	5	10	1
Glaux	maritima	wmC	V	S	1	1	1	1	1	1	5	1	5	1	1	1	1	1	1	7	15	1.00	2.14	22	1.57	1	5	5

GENUS	SPECIES	VEGETATION ZONE	LIFE TYPE	PROP. LONG.	ESTAB. METHOD	ANTELOPE C.V.	ANTELOPE N.V.	MULE DEER C.V.	MULE DEER N.V.	NONGAME BIRD C.V.	NONGAME BIRD N.V.	UPLAND GAMEBIRD C.V.	UPLAND GAMEBIRD N.V.	SMALL MAMMAL C.V.	SMALL MAMMAL N.V.	WATERFOWL C.V.	WATERFOWL N.V.	WHITETAIL DEER C.V.	WHITETAIL DEER N.V.	TOTAL COVER VALUE	TOTAL NUTR. VALUE	AVG. COV. VAL.	AVG. NUTR. VAL.	TOT. HAB. VAL.	AVG. HAB. VAL.	POT. BIO.	SHORT TERM REVEG.	LONG TERM REVEG.
Glycyrrhiza	lepidota	waC	V	S	1	1	1	1	5	10	5	10	5	5	5	10	1	1	5	38	27	5.43	3.86	65	4.64	5	1	5
Helenium	autumnale	waC	P	S	1	1	5	1	1	5	5	5	10	5	10	1	1	1	10	19	42	2.71	6.00	61	4.36	5	5	5
Hierochloe	odorata	waC	V	S	1	5	1	5	1	5	5	5	5	5	5	5	5	5	1	35	23	5.00	3.29	58	4.14	5	5	5
Hordeum	jubatum	waA,waB,waC	V	S	1	1	1	1	1	1	5	1	5	1	1	10	5	5	1	20	19	2.86	2.71	39	2.79	5	5	1
Juncus	balticus	waC	V	S	1	1	1	1	1	10	5	10	5	10	1	10	10	1	1	43	24	6.14	3.43	67	4.79	5	1	5
Juncus	dudleyi	waC	V	S	1	1	1	1	1	5	5	5	5	5	5	5	5	1	1	23	23	3.29	3.29	46	3.29	5	1	5
Juncus	interior	waC	V	S	1	1	1	1	1	5	5	5	5	5	5	5	5	1	1	23	23	3.29	3.29	46	3.29	5	1	5
Juncus	torreyi	waC	V	S	1	1	1	1	1	5	5	5	5	5	5	10	10	1	1	28	28	4.00	4.00	56	4.00	5	1	5
Lactuca	olongifolia	waC	V	S	1	1	5	1	5	5	5	5	5	5	5	10	5	1	5	28	35	4.00	5.00	63	4.50	5	1	1
Lycopus	americanus	waA,waC	V	S	1	1	1	1	1	1	1	1	1	1	1	1	1	5	5	11	11	1.57	1.57	22	1.57	1	5	1
Lysimachia	hybrida	waC	V	S	1	1	1	1	1	5	5	5	5	1	1	1	1	1	1	15	15	2.14	2.14	30	2.14	5	1	1
Mentha	arvensis	waA,waC	V	S	1	1	1	1	1	1	1	5	1	1	1	1	1	1	1	11	7	1.57	1.00	18	1.29	5	1	5
Phalaris	arundinacea	waA,waB,waC,saC,oaC	V	S	1	1	1	5	5	5	10	5	5	5	5	5	5	10	1	36	32	5.14	4.57	68	4.86	10	5	10
Plantago	eriopoda	waC	P	S	1	5	5	5	5	5	5	5	5	1	5	1	5	5	1	27	31	3.86	4.43	58	4.14	5	1	5
Poa	palustris	waA,waB,waC	V	S	1	1	5	1	10	10	5	10	5	5	5	10	5	1	10	38	45	5.43	6.43	83	5.93	5	5	5
Polgonum	coccineum	waA,waB,waC,saA,saB,saC	V	S	1	5	1	1	1	5	10	5	1	1	10	10	10	10	1	37	34	5.29	4.86	71	5.07	5	5	5
Potentilla	norvegica	waA,waC	A	S	1	1	1	1	1	5	5	1	5	1	5	1	1	1	1	11	19	1.57	2.71	30	2.14	5	1	5
Ranunculus	macounii	waC	P	S	1	1	1	1	1	1	1	1	5	1	1	5	5	1	1	11	15	1.57	2.14	26	1.86	1	1	1
Rorippa	palustris	waA,waB,waC	A	S	1	1	1	1	1	1	1	1	5	1	1	5	10	1	1	11	20	1.57	2.86	31	2.21	5	1	1
Rumex	mexicanus	waA,waB,waC	P	S	1	1	1	1	5	5	5	5	5	5	5	5	5	1	1	23	27	3.29	3.86	50	3.57	5	5	5
Rumex	occidentalis	waC	P	S	1	1	1	1	1	5	5	5	5	10	5	10	5	1	1	33	23	4.71	3.29	56	4.00	5	5	5
Rumex	stenophyllus	waA,waB,waC	P	S	1	1	1	1	5	10	10	10	10	5	5	5	5	1	1	33	37	4.71	5.29	70	5.00	5	5	5
Sagittaria	cuneata	waA,waC,saC	P	S	1	1	1	1	1	1	5	1	5	1	1	1	10	1	1	7	24	1.00	3.43	31	2.21	5	1	1
Salix	amygdaloides	waA,waB,waC	P	S	1	1	1	10	5	10	10	10	10	10	5	5	1	10	5	56	37	8.00	5.29	93	6.64	5	1	5
Sonchus	arvensis	waC	V	S	1	5	5	10	5	1	5	5	5	5	5	5	5	10	5	41	35	5.86	5.00	76	5.43	5	1	1
Stachys	palustris	waA,waB,waC	V	S	1	1	1	1	1	5	1	5	5	1	1	1	1	1	1	15	11	2.14	1.57	26	1.86	1	1	5
Teucrium	occidentale	waC	V	S	1	1	1	1	1	1	5	1	5	1	1	1	1	1	1	7	15	1.00	2.14	22	1.57	5	1	1
Urtica	dioica	waC	P	D	1	1	1	1	1	5	1	5	1	1	1	1	1	1	1	15	7	2.14	1.00	22	1.57	10	1	5
Veronia	fasciculata	waC	P	S	1	1	1	1	1	5	5	5	5	1	5	1	1	1	1	15	19	2.14	2.71	34	2.43	1	1	5

SHALLOW MARSH VEGETATION ZONE-REHABILITATED SITE A

GENUS	SPECIES	VEGETATION ZONE	LIFE TYPE	PROP. LONG.	ESTAB. METHOD	ANTELOPE C.V.	ANTELOPE N.V.	MULE DEER C.V.	MULE DEER N.V.	NONGAME BIRD C.V.	NONGAME BIRD N.V.	UPLAND GAMEBIRD C.V.	UPLAND GAMEBIRD N.V.	SMALL MAMMAL C.V.	SMALL MAMMAL N.V.	WATERFOWL C.V.	WATERFOWL N.V.	WHITETAIL DEER C.V.	WHITETAIL DEER N.V.	TOTAL COVER VALUE	TOTAL NUTR. VALUE	AVG. COV. VAL.	AVG. NUTR. VAL.	TOT. HAB. VAL.	AVG. HAB. VAL.	POT. BIO.	SHORT TERM REVEG.	LONG TERM REVEG.
Alisma	plantago-aquatica	wmB,wmC,smA,smC	V	S	1	1	1	1	1	1	5	1	5	1	1	5	10	1	1	11	24	1.57	3.43	35	2.50	5	5	5
Eleocharis	acicularis	wmA,wmB,wmC,smA,dmC	V	S	!	1	1	1	1	10	1	5	1	5	1	10	10	1	1	33	16	4.71	2.29	49	3.50	1	1	1
Eleocharis	palustris	wmA,wmB,wmC,smA,smB	V	S	1	1	1	1	5	5	5	5	5	1	1	10	10	1	1	24	28	3.43	4.00	52	3.71	5	5	5
Eleocharis	smallii	smA,smC	V	S	1	1	1	1	1	5	5	5	5	5	1	10	10	1	1	28	24	4.00	3.43	52	3.71	5	5	5
Gratiola	neglecta	wmB,smA	A	S	1	1	1	1	1	5	5	5	5	1	1	1	1	1	1	15	15	2.14	2.14	30	2.14	1	5	1
Polgonum	coccineum	wmA,wmB,wmC.smA,smB,smC	V	S	1	5	1	1	1	5	10	5	1	1	10	10	10	10	1	37	34	5.29	4.86	71	5.07	5	5	5
Rumex	maritimis	wmA.wmB,smA	A	S	1	1	1	1	5	5	5	5	5	5	5	5	5	1	1	23	27	3.29	3.86	50	3.57	5	5	5
Scirpus	acutus	smA,dmC	V	S	1	1	1	5	1	10	5	5	10	10	1	10	10	10	1	51	29	7.29	4.14	80	5.71	10	5	5
Scirpus	fluviatilis	wmA,smA,smB,dmC	V	S	1	10	1	5	1	10	1	10	1	10	1	10	5	10	1	65	11	9.29	1.57	76	5.43	5	5	5
Scirpus	heterochaetus	smA,smC,dmC	V	S	1	1	1	5	1	10	10	10	10	10	10	10	10	10	1	56	43	8.00	6.14	99	7.07	10	5	5
Scirpus	validus	smA,dmC	V	S	1	1	1	5	1	10	10	10	10	10	10	10	10	10	1	56	43	8.00	6.14	99	7.07	10	5	5
Sparganium	chlorocarpum	smA	V	S	!	1	1	1	1	5	1	10	5	1	1	10	5	1	1	29	15	4.14	2.14	44	3.14	5	1	1
Typha	angustifolia	smA,dmC	V	S	1	1	1	5	1	10	5	5	10	10	1	10	1	10	1	51	20	7.29	2.86	71	5.07	5	1	5
Typha	latifolia	smA.dmC	V	S	1	1	1	5	1	10	5	5	10	10	1	10	1	10	1	51	20	7.29	2.86	71	5.07	10	1	5
Typha	x glauca	smA,smB,dmC	V	S	1	1	1	5	1	10	5	5	10	10	1	10	1	10	1	51	20	7.29	2.86	71	5.07	5	1	5

SHALLOW MARSH VEGETATION ZONE-REHABILITATED SITE B

GENUS	SPECIES	VEGETATION ZONE	LIFE TYPE	PROP. LONG.	ESTAB. METHOD	ANTELOPE C.V.	ANTELOPE N.V.	MULE DEER C.V.	MULE DEER N.V.	NONGAME BIRD C.V.	NONGAME BIRD N.V.	UPLAND GAMEBIRD C.V.	UPLAND GAMEBIRD N.V.	SMALL MAMMAL C.V.	SMALL MAMMAL N.V.	WATERFOWL C.V.	WATERFOWL N.V.	WHITETAIL DEER C.V.	WHITETAIL DEER N.V.	TOTAL COVER VALUE	TOTAL NUTR. VALUE	AVG. COV. VAL.	AVG. NUTR. VAL.	TOT. HAB. VAL.	AVG. HAB. VAL.	POT. BIO.	SHORT TERM REVEG.	LONG TERM REVEG.
Carex	atheroides	wmA,smB,smC	V	S	1	1	1	1	5	5	5	5	5	5	1	1	5	1	1	19	23	2.71	3.29	42	3.00	10	1	5
Eleocharis	palustris	wmA,wmB,wmC,smA,smB	V	S	1	1	1	1	5	5	5	5	5	1	1	10	10	1	1	24	28	3.43	4.00	52	3.71	5	5	5
Polgonum	coccineum	wmA,wmB,wmC,smA,smB,smC	V	S	1	5	1	1	1	5	10	5	1	1	10	10	10	10	1	37	34	5.29	4.86	71	5.07	5	5	5
Scirpus	fluviatilis	wmA,smA,smB,dmC	V	S	1	10	1	5	1	10	1	10	1	10	1	10	5	10	1	65	11	9.29	1.57	76	5.43	5	5	5
Typha	x glauca	smA,smB,dmC	V	S	1	1	1	5	1	10	5	5	10	10	1	10	1	10	1	51	20	7.29	2.86	71	5.07	5	1	5

SHALLOW MARSH VEGETATION-REFERENCE SITE C

GENUS	SPECIES	VEGETATION ZONE	LIFE TYPE	PROP. LONG.	ESTAB. METHOD	ANTELOPE C.V.	ANTELOPE N.V.	MULE DEER C.V.	MULE DEER N.V.	NONGAME BIRD C.V.	NONGAME BIRD N.V.	UPLAND GAMEBIRD C.V.	UPLAND GAMEBIRD N.V.	SMALL MAMMAL C.V.	SMALL MAMMAL N.V.	WATERFOWL C.V.	WATERFOWL N.V.	WHITETAIL DEER C.V.	WHITETAIL DEER N.V.	TOTAL COVER VALUE	TOTAL NUTR. VALUE	AVG. COV. VAL.	AVG. NUTR. VAL.	TOT. HAB. VAL.	AVG. HAB. VAL.	POT. BIO.	SHORT TERM REVEG.	LONG TERM REVEG.
Alisma	gramineum	wmA,wmB,smC	P	S	1	1	1	1	1	1	5	1	5	1	1	3	10	1	1	9	24	1.29	3.43	33	2.36	5	5	5
Alisma	plantago-aquatica	wmB,wmC,smA,smC	V	S	1	1	1	1	1	1	5	1	5	1	1	5	10	1	1	11	24	1.57	3.43	35	2.50	5	5	5
Alopecurus	aequalis	wmA,wmB,wmC.smC	V	S	1	1	1	1	5	1	1	5	1	1	5	5	5	1	1	15	19	2.14	2.71	34	2.43	5	5	10
Beckmannia	syzigachne	wmA,wmB,wmC,smC	A	S	1	5	1	10	1	5	10	5	5	5	5	10	5	10	1	50	28	7.14	4.00	78	5.57	5	5	1
Carex	atheroides	wmA,smB,smC	V	S	1	1	1	1	5	5	5	5	5	5	1	1	5	1	1	19	23	2.71	3.29	42	3.00	10	1	5
Chenopodium	rubrum	wmA,wmB,wmC,smC	A	S	1	1	1	1	1	10	10	10	10	1	1	1	1	1	1	25	25	3.57	3.57	50	3.57	5	5	5
Eleocharis	smallii	smA,smC	V	S	1	1	1	1	1	5	5	5	5	5	1	10	10	1	1	28	24	4.00	3.43	52	3.71	5	5	5
Glyceria	borealis	smC	V	S	2	1	1	5	5	5	10	5	5	5	5	5	10	5	1	31	37	4.43	5.29	68	4.86	5	5	5
Glyceria	grandis	smC	V	S	1	1	1	5	5	5	10	5	5	5	1	5	10	5	1	31	33	4.43	4.71	64	4.57	10	5	5
Phalaris	arundinacea	wmA,wmB,wmC,smC,dmC	V	S	1	1	1	5	5	5	10	5	5	5	5	5	5	10	1	36	32	5.14	4.57	68	4.86	10	5	10
Polgonum	coccineum	wmA,wmB,wmC,smA,smB,smC	V	S	1	5	1	1	1	5	10	5	1	1	10	10	10	10	1	37	34	5.29	4.86	71	5.07	5	5	5
Polygonum	amphibium	smC	V	S	1	5	1	1	1	5	5	5	5	5	5	10	10	5	1	36	28	5.14	4.00	64	4.57	5	5	5
Puccinellia	nuttalliana	smC	P	S	1	1	5	1	5	5	5	10	5	5	1	10	5	5	1	37	27	5.29	3.86	64	4.57	5	5	5
Ranunculus	cymbalaria	smC	V	S	1	1	1	1	5	1	5	1	5	1	5	1	5	1	1	7	27	1.00	3.86	34	2.43	1	1	1
Ranunculus	sceleratus	smC	A	S	1	1	5	1	5	1	5	1	5	1	5	1	5	1	1	7	31	1.00	4.43	38	2.71	1	1	1
Rumex	pseudonatronatus	wmA,wmB,smC	P	S	1	1	1	1	1	5	5	5	5	5	5	5	5	5	1	27	23	3.86	3.29	50	3.57	5	5	5
Sagittaria	cuneata	wmA,wmC,smC	P	S	1	1	1	1	1	1	5	1	5	1	1	1	10	1	1	7	24	1.00	3.43	31	2.21	5	1	1
Salicornia	rubra	smC	A	S	1	1	1	1	1	1	5	1	5	1	1	1	5	1	1	7	19	1.00	2.71	26	1.86	1	1	1
Scirpus	americanus	smC	V	S	1	1	1	5	1	10	5	10	10	5	5	10	10	5	1	46	33	6.57	4.71	79	5.64	10	5	5
Scirpus	heterochaetus	smA,smC,dmC	V	S	1	1	1	5	1	10	10	10	10	10	10	10	10	10	1	56	43	8.00	6.14	99	7.07	10	5	5
Scirpus	nevadensis	smC	P	S	1	1	1	1	1	5	5	5	10	5	5	5	10	1	1	23	33	3.29	4.71	56	4.00	5	1	1
Sclerochloa	festucacea	smC	V	S	1	1	1	1	1	5	5	5	5	1	5	10	10	1	1	24	28	3.43	4.00	52	3.71	10	5	5
Sium	suave	smC	P	S	1	1	1	1	1	5	5	5	5	1	1	1	1	1	1	15	15	2.14	2.14	30	2.14	1	5	1
Sparganium	eurycarpum	smC	P	S	2	1	1	1	1	5	1	10	5	1	1	10	5	1	1	29	15	4.14	2.14	44	3.14	5	1	1
Suaeda	depressa	smC	A	S	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	7	7	1.00	1.00	14	1.00		5	10
Typha	domingensis	smC	V	S	1	1	1	5	1	10	5	5	10	10	1	10	1	5	1	46	20	6.57	2.86	66	4.71	5	1	5

DEEP MARSH VEGETATION ZONE-REHABILITATED SITE A

GENUS	SPECIES	VEGETATION ZONE	LIFE TYPE	PROP. LONG.	ESTAB. METHOD	ANTELOPE		MULE DEER		NONGAME BIRD		UPLAND GAMEBIRD		SMALL MAMMAL		WATERFOWL		WHITETAIL DEER		TOTAL COVER VALUE	TOTAL NUTR. VALUE	AVG. COV. VAL.	AVG. NUTR. VAL.	TOT. HAB. VAL.	AVG. HAB. VAL.	POT. BIO.	SHORT TERM REVEG.	LONG TERM REVEG.
						C.V.	N.V.	C.V.	N.V.	C.V.	N.V.	C.V.	N.V.	C.V.	N.V.	C.V.	N.V.	C.V.	N.V.									
Myriophyllum	exalbescens	dmA,dmB,dmC	P	S	2	1	1	1	1	1	1	1	1	1	1	5	10	1	1	11	16	1.57	2.29	27	1.93	1	1	1
Potamogeton	gramineus	dmA,dmB,dmC	V	S	2	1	1	1	1	1	1	1	5	1	1	1	10	1	1	7	20	1.00	2.86	27	1.93	5	1	1
Potamogeton	pectinatus	dmA,dmB,dmC	V	S	2	1	1	1	1	1	10	1	5	1	1	1	10	1	1	7	29	1.00	4.14	36	2.57	5	5	5
Potamogeton	pusillus	dmA,dmC	V	S	2	1	1	1	1	1	10	1	5	1	1	1	10	1	1	7	29	1.00	4.14	36	2.57	5	5	5
Potamogeton	richardsonii	dmA,dmB,dmC	V	S	2	1	1	1	1	1	10	1	5	1	1	1	10	1	1	7	29	1.00	4.14	36	2.57	5	1	5
Ranunculus	subrigidus	wmB,dmA,dmB	V	S	2	1	1	1	1	1	5	1	5	1	1	1	5	1	1	7	19	1.00	2.71	26	1.86	1	1	1
Zannichellia	palustris	dmA,dmC	P	S	2	1	1	1	1	1	1	1	10	1	1	1	10	1	1	7	25	1.00	3.57	32	2.29	10	1	1

DEEP MARSH VEGETATION ZONE-REHABILITATED SITE B

GENUS	SPECIES	VEGETATION ZONE	LIFE TYPE	PROP. LONG.	ESTAB. METHOD	ANTELOPE C.V.	ANTELOPE N.V.	MULE DEER C.V.	MULE DEER N.V.	NONGAME BIRD C.V.	NONGAME BIRD N.V.	UPLAND GAMEBIRD C.V.	UPLAND GAMEBIRD N.V.	SMALL MAMMAL C.V.	SMALL MAMMAL N.V.	WATERFOWL C.V.	WATERFOWL N.V.	WHITETAIL DEER C.V.	WHITETAIL DEER N.V.	TOTAL COVER VALUE	TOTAL NUTR. VALUE	AVG. COV. VAL.	AVG. NUTR. VAL.	TOT. HAB. VAL.	AVG. HAB. VAL.	POT. BIO.	SHORT TERM REVEG.	LONG TERM REVEG.
Myriophyllum	exalbescens	dmA,dmB,dmC	P	S	2	1	1	1	1	1	1	1	1	1	1	5	10	1	1	11	16	1.57	2.29	27	1.93	1	1	1
Potamogeton	foliosus	dmB	V	S	2	1	1	1	1	1	5	1	5	1	1	1	10	1	1	7	24	1.00	3.43	31	2.21	5	1	1
Potamogeton	friesii	dmB	V	S	2	1	1	1	1	1	5	1	5	1	1	1	10	1	1	7	24	1.00	3.43	31	2.21	1	1	1
Potamogeton	gramineus	dmA,dmB,dmC	V	S	2	1	1	1	1	1	1	1	5	1	1	1	10	1	1	7	20	1.00	2.86	27	1.93	5	1	1
Potamogeton	pectinatus	dmA,dmB,dmC	V	S	2	1	1	1	1	1	10	1	5	1	1	1	10	1	1	7	29	1.00	4.14	36	2.57	5	5	5
Potamogeton	richardsonii	dmA,dmB,dmC	V	S	2	1	1	1	1	1	10	1	5	1	1	1	10	1	1	7	29	1.00	4.14	36	2.57	5	1	5
Potamogeton	zosteriformis	dmB,dmC	V	S	2	1	1	1	1	1	5	1	5	1	1	1	10	1	1	7	24	1.00	3.43	31	2.21	5	1	1
Ranunculus	subrigidus	wmB,dmA,dmB	V	S	2	1	1	1	1	1	5	1	5	1	1	1	5	1	1	7	19	1.00	2.71	26	1.86	1	1	1

DEEP MARSH VEGETATION ZONE-REFERENCE SITE C

GENUS	SPECIES	VEGETATION ZONE	LIFE TYPE	PROP. LONG.	ESTAB. METHOD	ANTELOPE C.V.	ANTELOPE N.V.	MULE DEER C.V.	MULE DEER N.V.	NONGAME BIRD C.V.	NONGAME BIRD N.V.	UPLAND GAMEBIRD C.V.	UPLAND GAMEBIRD N.V.	SMALL MAMMAL C.V.	SMALL MAMMAL N.V.	WATERFOWL C.V.	WATERFOWL N.V.	WHITETAIL DEER C.V.	WHITETAIL DEER N.V.	TOTAL COVER VALUE	TOTAL NUTR. VALUE	AVG. COV. VAL.	AVG. NUTR. VAL.	TOT. HAB. VAL.	AVG. HAB. VAL.	POT. BIO.	SHORT TERM REVEG.	LONG TERM REVEG
Callitriche	hermaphroditica	dmC	V	S	2	1	1	1	1	1	1	1	1	1	1	1	5	1	1	7	11	1.00	1.57	18	1.29	1	1	1
Callitriche	heterophylla	dmC	V	S	2	1	1	1	1	1	1	1	1	1	1	1	5	1	1	7	11	1.00	1.57	18	1.29	1	1	1
Ceratophyllum	demersum	dmC	V	S	2	1	1	1	1	1	1	1	5	1	1	1	5	1	1	7	15	1.00	2.14	22	1.57	1	1	1
Eleocharis	acicularis	wmA,wmB,wmC.smA,dmC	V	S	1	1	1	1	1	10	1	5	1	5	1	10	10	1	1	33	16	4.71	2.29	49	3.50	1	1	1
Elodea	canadensis	dmC	P	S	2	1	1	1	1	1	1	1	5	1	1	1	10	1	1	7	20	1.00	2.86	27	1.93	5	1	1
Hippuris	vulgaris	dmC	V	S	2	1	1	1	1	1	1	1	1	1	1	10	5	1	1	16	11	2.29	1.57	27	1.93	1	1	1
Lemna	minor	dmC	V	S	2	1	1	1	1	1	1	1	1	1	1	1	10	1	1	7	16	1.00	2.29	23	1.64	1	1	1
Lemna	trisulca	dmC	V	S	2	1	1	1	1	1	1	1	1	1	1	1	10	1	1	7	16	1.00	2.29	23	1.64	1	1	1
Lemna	turionifera	dmC	V	S	2	1	1	1	1	1	1	1	1	1	1	1	10	1	1	7	16	1.00	2.29	23	1.64	1	1	1
Marsilea	mucronata	dmC	V	S	2	1	1	1	1	1	1	1	1	1	1	1	10	1	1	7	16	1.00	2.29	23	1.64	1	1	1
Myriophyllum	exalbescens	dmA,dmB,dmC	P	S	2	1	1	1	1	1	1	1	1	1	1	5	10	1	1	11	16	1.57	2.29	27	1.93	1	1	1
Myriophyllum	heterophyllum	dmC	V	S	2	1	1	1	1	1	1	1	1	1	1	1	5	1	1	7	11	1.00	1.57	18	1.29	1	1	1
Myriophyllum	verticillatum	dmC	V	S	2	1	1	1	1	1	1	1	1	1	1	1	5	1	1	7	11	1.00	1.57	18	1.29	1	1	1
Phalaris	arundinacea	wmA,wmB,wmC,smC,dmC	V	S	1	1	1	5	5	5	10	5	5	5	5	5	5	10	1	36	32	5.14	4.57	68	4.86	10	5	10
Phragmites	communis	dmC	V	D	1	5	1	10	1	10	10	10	10	10	5	10	5	10	1	65	33	9.29	4.71	98	7.00	10	5	10
Potamogeton	diversifolius	dmC	V	S	2	1	1	1	1	1	5	1	5	1	1	1	10	1	1	7	24	1.00	3.43	31	2.21	5	1	1
Potamogeton	gramineus	dmA,dmB,dmC	V	S	2	1	1	1	1	1	1	1	5	1	1	1	10	1	1	7	20	1.00	2.86	27	1.93	5	1	1
Potamogeton	pectinatus	dmA,dmB,dmC	V	S	2	1	1	1	1	1	10	1	5	1	1	1	10	1	1	7	29	1.00	4.14	36	2.57	5	5	5
Potamogeton	pusillus	dmA,dmC	V	S	2	1	1	1	1	1	10	1	5	1	1	1	10	1	1	7	29	1.00	4.14	36	2.57	5	5	5
Potamogeton	richardsonii	dmA,dmB,dmC	V	S	2	1	1	1	1	1	10	1	5	1	1	1	10	1	1	7	29	1.00	4.14	36	2.57	5	1	5
Potamogeton	vaginatus	dmC	V	S	2	1	1	1	1	1	5	1	5	1	1	1	10	1	1	7	24	1.00	3.43	31	2.21	5	1	1
Potamogeton	zosteriformis	dmB,dmC	V	S	2	1	1	1	1	1	5	1	5	1	1	1	10	1	1	7	24	1.00	3.43	31	2.21	5	1	1
Ranunculus	flabellaris	dmC	V	S	2	1	5	1	5	1	5	1	5	1	5	1	5	1	1	7	31	1.00	4.43	38	2.71	1	1	1
Ranunculus	gmelinii	dmC	V	S	2	1	5	1	5	1	5	1	5	1	5	1	5	1	1	7	31	1.00	4.43	38	2.71	1	1	1
Ranunculus	trichophyllus	dmC	V	S	2	1	5	1	5	1	5	1	5	1	5	1	5	1	1	7	31	1.00	4.43	38	2.71	1	1	1
Ruppia	maritima	dmC	P	S	2	1	1	1	1	1	5	1	10	1	1	1	10	1	1	7	29	1.00	4.14	36	2.57	5	1	1
Ruppia	occidentalis	dmC	P	S	2	1	1	1	1	1	5	1	10	1	1	1	10	1	1	7	29	1.00	4.14	36	2.57	5	1	1
Scirpus	acutus	smA,dmC	V	S	1	1	1	5	1	10	5	5	10	10	1	10	10	10	1	51	29	7.29	4.14	80	5.71	10	5	5
Scirpus	fluviatilis	wmA,smA,smB,dmC	V	S	1	10	1	5	1	10	1	10	1	10	1	10	5	10	1	65	11	9.29	1.57	76	5.43	5	5	5
Scirpus	heterochaetus	smA,smC,dmC	V	S	1	1	1	5	1	10	10	10	10	10	10	10	10	10	1	56	43	8.00	6.14	99	7.07	10	5	5
Scirpus	maritimus	dmC	V	S	1	1	1	1	1	5	10	5	10	10	1	10	10	1	1	33	34	4.71	4.86	67	4.79	5	1	5
Scirpus	validus	smA,dmC	V	S	1	1	1	5	1	10	10	10	10	10	10	10	10	10	1	56	43	8.00	6.14	99	7.07	10	5	5
Spirodela	polyrhiza	dmC	V	S	2	1	1	1	1	1	1	1	5	1	1	1	10	1	1	7	20	1.00	2.86	27	1.93	1	1	1
Typha	angustifolia	smA,dmC	V	S	1	1	1	5	1	10	5	5	10	10	1	10	1	10	1	51	20	7.29	2.86	71	5.07	5	1	5
Typha	latifolia	smA,dmC	V	S	1	1	1	5	1	10	5	5	10	10	1	10	1	10	1	51	20	7.29	2.86	71	5.07	10	1	5
Typha	x glauca	smA,smB,dmC	V	S	1	1	1	5	1	10	5	5	10	10	1	10	1	10	1	51	20	7.29	2.86	71	5.07	5	1	5
Utricularia	vulgaris	dmC	V	S	2	1	1	1	1	1	1	1	5	1	1	1	5	1	1	7	15	1.00	2.14	22	1.57	5	1	1
Zannichellia	palustris	dmA,dmC	P	S	2	1	1	1	1	1	1	1	10	1	1	1	10	1	1	7	25	1.00	3.57	32	2.29	10	1	1

APPENDIX B

PRE-MINE WILDLIFE INVENTORY

OF REHABILITATED AREA

MAMMALS OBSERVED OR LIKELY TO OCCUR ON OR NEAR THE FALKIRK STUDY AREA

Common Name[1]	Presence[2]	Occurrence by Habitat[3]	Comments
Shrews			
Masked shrew	RES	Wo, We, O	
Short-tailed shrew	P	Wo, We, O, S	
Hats			
Little brown myotis	E	Wo, F, We	Roosts in hollow trees, old buildings
Keen's myotis	P	Wo, We	Hollow trees
Long-eared myotis	P	Wo, We, F	Uses old buildings
Silver-haired bat	P	Wo, F, We	Uses old buildings
Big brown bat	P	Wo, We	Uses hollow trees
Red bat	P	Wo	
Hoary bat	P	Wo	
Rabbits and Hares			
Eastern cottontail	C	Wo, S, We	
White-tailed jackrabbit	O	C, O	
Rodents			
Least chipmunk	P	Wo	
Thirteen-lined ground squirrel	C	O, C	
Franklin's ground squirrel	P	O, Wo, We	Edge of woods; unlikely to occur
Richardson's ground squirrel	C	O	
Gray squirrel	O	Wo	Wooded margins of Coal lake
Fox squirrel	O	Wo, O	Wooded margins of Coal Lake
Northern pocket gopher	S, RES	C, Wo	
Olive-backed pocket mouse	P	O	
Hispid pocket mouse	P	O, F	

Common Name[1]	Presence[2]	Occurrence by Habitat[3]	Comments
Beaver	O	We	Coal Lake
Western harvest mouse	P	O	
Deer mouse	C	We, Wo, O, C, S, F	
White-footed mouse	P	Wo	
Northern grasshopper mouse	P	O, C	
Bushy-tailed woodrat	S	Wo	
Southern red-backed vole	C	Wo, We, S	
Meadow vole	C	We, Wo, O, C	
Prairie vole	IES	O, S	
Muskrat	O	We	
Norway rat	P	F, T	
House mouse	P	Cr, F, T	
Meadow jumping mouse	IES	We, O, Wo	Moist areas
Porcupine	S	Wo	
Carnivores			
Coyote	O	Wo, We, Cr, O, S	
Red fox	C	Wo, We, Cr, O, S	
Raccoon	O	All	
Least weasel	C	Wo, We, O	
Long-tailed weasel	C	Wo, We, Cr, O, S	Near water
Mink	C	We, Wo	
Badger	S	O	
Striped skunk	C	All	
Western spotted skunk	P	Wo, We, O	Very unlikely
Bobcat	P	Wo, We	
Hoofed Mammals			
White-tailed deer	O	Wo, We, O, C, S	Primarily around Coal Lake
Pronghorn	IES	O, Cr	

1/ All common names are those used by Jones, et al. (1975).

2/ Presence: P = presence possible due to species distribution and preferred habitat (Genoways and Jones 1972, Burt and Grossenheider 1964, and Hall and Kelson 1959); O = animal observed during field studies on or near the study area by ERT personnel; C = animal captured or found dead by ERT personnel; S = definitive sign observed by ERT personnel; IES = animal confirmed by Institute of Ecology Study (Sambor and Seabloom 1975).

3/ Habitat of study area where species was observed or is likely to occur:
C = Cropland; We = Wetland and associated aquatic habitat; O = Oldfield/grassland communities; S = Shelterbelts and Fencerows; Wo = Wooded; F = Farmsteads, active and inactive, including buildings and associated plantings; T = Towns.

BIRDS OBSERVED OR LIKELY TO OCCUR ON
THE FALKIRK STUDY AREA

Common Name[1/]	Presence[2/] and Field Period Observed	Expected Residence Status[3/]	Occurrence by Habitat[4/]	Comments
Western grebe	M	M, S	Aq	Seen at Coal Lake only.
Red-necked grebe	Lit.	M	Aq	
Horned grebe	M	M, S	Aq, We	
Eared grebe	M, J	M, S*	Aq, We	Breeding pairs on Weller Slough.
Pied-billed grebe	O, A, M, J	M, S*	Aq, We	Common on most semipermanent wetlands with dense vegetation.
White pelican	J	M, S	Aq	Probable visitor from Lake Sakakawea area; Coal Lake only.
Double-crested comorant	A, M, J	M, S*	Aq	Probably visitors from Lake Sakakawea area; possible breeder on Coal Lake.
Great blue heron	O, A, M, J	S	Aq, We	No nesting observed on-site. Probable visitors from nearby nesting areas; Coal Lake only and permanent wetlands.
Black-crowned night heron	M, J	S	Aq, We	Coal Lake only.
American bittern	M, J	M, S*	Aq, We	Coal Lake only.
Whistling swan	Lit.	M	Aq	
Canada goose	O, A, M, J	M, S*	Aq, C, We	
White-fronted goose	A	M	Aq, C	Seen as flyovers only.
Snow goose	O	M	Aq, C	
Mallard	O, A, M, J	S*, M	Aq, C, We, O	
Pintail	O, A, M, J	M, S*	Aq, We, C, O	
Gadwall	A, M, J	S*, M	Aq, C, We, O	
Blue-winged teal	O, A, M, J	M, S*	Aq, We, C, O	
Green-winged teal	O, A, M	M, S*	Aq, We, C, O	
American wigeon	O, A, M	M, S*	Aq, We, C	

Common Name[1]	Presence[2] and Field Period Observed	Expected Residence Status[3]	Occurrence by Habitat[4]	Comments
Northern shoveler	O, A, M, J	M, S*	Aq, We, C, O	
Wood duck	A, M, J	S*	Aq, We, Wo	Vicinity of Coal Lake only.
Redhead	A, M, J	S*	Aq, We	
Canvasback	O, A, M	M, S*	Aq, We	
Ring-necked duck	O, A	M	Aq	
Greater scaup	A	M	Aq	
Lesser scaup	O, A, M	M, S*	Aq, We, O	
Common goldeneye	Lit.	M	Aq	
Bufflehead	O, A	M	Aq	
Ruddy duck	M	M, S*	Aq	
Common merganser	A	M	Aq	
Red-breasted merganser	Lit.	M	Aq	
Hooded merganser	Lit.	M	Aq	
Turkey vulture	IES	S	C, O	
Goshawk	Lit.	M	Wo	
Cooper's hawk	Lit.	M, S	Wo	
Sharp-shinned hawk	Lit.	S, M	Wo	
Marsh hawk	A, M, J	M, S*	We, Wo, C, O	Abundant throughout study area.
Rough-legged hawk	Lit.	M, W	C, O, We	
Ferruginous hawk	J	M, S	C, O	
Red-tailed hawk	O, M	M, S	C, O, Wo, We	
Swainson's hawk	A, J	M, S	C, O, Wo, We	
Broad-winged hawk	Lit.	M	Wo	
Golden eagle	Lit.	M	C, O	
Bald eagle	Lit.	M	Aq, C, Wo	

Common Name[1]	Presence[2] and Field Period Observed	Expected Residence Status[3]	Occurrence by Habitat[4]	Comments
Osprey	P	M	Aq, Wo	
Prairie falcon	Lit.	M	C, O	
Peregrine falcon	Lit.	M	Aq, Wo, O	
Merlin	Lit.	M	Wo, C	
American kestrel	A	M, S*	C, O	
Turkey	M	R	Wo	Lone female observed at Coal Lake.
Ring-necked pheasant	All	R*	C, Wo, We, S	Common only around shrubby draws near Coal Lake.
Gray partridge	All	R*	Wo, C, We	Common in waste areas, roadsides, ditches throughout.
Sharp-tailed grouse	All	R*	O, Wo, C	Coal Lake appeared to have important wintering concentration.
Whooping crane	Lit.	M	Aq, We, C	
Sandhill crane	IES	M	Aq, We, C	
Virginia rail	J	M, S*	We	
Sora	M, J	M, S*	We	
Yellow rail	Lit.	M	We	
American coot	O, A, M, J	S*	Aq, We	
American avocet	O, M, J	M, S*	Aq, We	Coal Lake edges only
American golden plover	Lit.	M	O	
Black-bellied plover	Lit.	M	O	
Piping plover	Lit.	M, S	O	
Semipalmated plover	M	M	We, O	
Killdeer	A, M, J	S*, M	We, O, C	Abundant throughout.
Mountain plover	Lit.	M	O	
Long-billed curlew	Lit.	M	Aq, We, O	
Marbled godwit	M	M, S*	Aq, We, O	
Hudsonian godwit	Lit.	M	We, O	

Common Name[1]	Presence[2] and Field Period Observed	Expected Residence Status[3]	Occurrence by Habitat[4]	Comments
Upland sandpiper	M, J	M, S*	Ag, O	
Buff-breasted sandpiper	Lit.	M	O	
Solitary sandpiper	M	M	Aq, We	
Spotted sandpiper	IES	M, S	Aq, We	
Willet	M, J	M, S*	Aq, We, O	
Greater yellowlegs	O, A, J	M	Aq, C, We	
Lesser yellowlegs	A, M	M	Aq, We	
Stilt sandpiper	M, J	M	Aq, We	
Short-billed dowitcher	M	M	Aq, We	Coal Lake only.
Long-billed dowitcher	M, J	M	Aq, We	Coal Lake only.
Sanderling	Lit.	M	Aq, We	
Pectoral sandpiper	Lit.	M	Aq, We	
Dunlin	M	M	Aq, We	Coal Lake only.
White-rumped sandpiper	M	M	Aq, We	
Baird's sandpiper	M	M	Aq, We	
Least sandpiper	M	M	Aq, We	
Semipalmated sandpiper	M	M	Aq, We	
Western sandpiper	M	M	Aq, We	
Common snipe	O, A	M, S	Aq, We	
Wilson's phalarope	M	M, S*	Aq	
Northern phalarope	Lit.	M	Aq	
Herring gull	Lit.	M	Aq	
California gull	Lit.	M, S	Aq	
Ring-billed gull	A, M	M, S	C, Aq	Observed primarily at Coal Lake.
Franklin's gull	A, M	M	Aq, O, We	

Common Name[1]	Presence[2] and Field Period Observed	Expected Residence Status[3]	Occurrence by Habitat[4]	Comments
Bonaparte's gull	Lit.	M	Aq	
Common tern	M, J	M, S	Aq	Observed only at Coal Lake.
Forster's tern	Lit.	M, S	Aq	
Caspian tern	Lit.	M	Aq	
Black tern	M, J	M, S*	Aq, We	
Rock dove	M	R*	Ag, F, T	
Mourning dove	A, M, J	S*, M	O, S, F, We C	
Black-billed cuckoo	IES	S*, M	Wo, S	
Great horned owl	O, A, M, J	R*	Wo, O, C, S	
Long-eared owl	Lit.	M, S*	Wo	
Short-eared owl	Lit.	M, S*, W	O, We	
Snowy owl	Lit.	M, W	O	
Burrowing owl	M, J	M, S*	O, C	
Common nighthawk	IES	M, S*	C, O	
Chimney swift	Lit.	S, M	T	
Ruby-throated hummingbird	Lit.	M	Wo	
Belted kingfisher	M, J	M, S*	We	Coal Lake area only.
Common flicker	All	R*	Wo, C, We, O, S, F, T	
Red-headed woodpecker	M	M, S*	Wo, We	
Yellow-bellied sapsucker	Lit.	M	Wo, S	
Hairy woodpecker	A, J	R*	Wo, S	
Downy woodpecker	F	R*	Wo, S	
Eastern kingbird	M, J	M, S*	We, Wo, C, O, S	
Western kingbird	M, J	M, S*	C, O, S	

Common Name[1]	Presence[2] and Field Period Observed	Expected Residence Status[3]	Occurrence by Habitat[4]	Comments
Great crested flycatcher	Lit.	M	Wo, We	
Eastern phoebe	M	M	Wo, We C	
Willow flycatcher	M	S, M	Wo	
Least clycatcher	M, J	M, S*	Wo, S	
Eastern wood pewee	Lit.	M, S	Wo	
Horned lark	All	R*	C, O	
Barn swallow	M, J	M, S*	All	
Cliff swallow	P	M, S*	Wo	
Tree swallow	IES	M	Wo	
Bank swallow	M, J	M, S*	Aq, We, O, Ag	Abandoned gravel pit near Coal Lake.
Rough-winged swallow	Lit.	M, S*	Aq, We, Wo	
Purple martin	Lit.	M, S	T, F	
Blue jay	M, J	M, S*, W	Wo, T, S, F	
Black-billed magpie	O, F, A, M	R*	Wo, S, O	
Common crow	O, A, M, J	M, S*, W	Wo, C, O, S, T, F	
Black-capped chicadee	All	S, R*	Wo	
White-breasted nuthatch	Lit.	R*	Wo	
Brown creeper	Lit.	M	Wo	
House wren	M, J	M, S*	Wo, S, We, F	
Long-billed marsh wren	J	M, S*	We	
Short-billed marsh wren	J	M	We	
Gray catbird	J	S*, M	Wo, S	
Brown thrasher	M, J	S*, M	So, S, F	Common in shelterbelts, farmyards.
American robin	O, A, M, J	M, S*, W	Wo, C, O, T, F, S	
Hermit	Lit.	M	Wo	

Common Name[1]	Presence[2] and Field Period Observed	Expected Residence Status[3]	Occurrence by Habitat[4]	Comments
Veery	M	M, S*	Wo, We	
Eastern bluebird	Lit.	M, S*	Wo, C, F, S	
Ruby-crowned kinglet	M	M	Wo, S	
Water pipit	Lit.	M	O, C	
Sprague's pipit	J	M, S*	O	
Bohemian waxwing	Lit.	W	Wo, S, F, T	
Cedar waxwing	O, M	M, W	Wo, S, F, T	
Northern shrike	O	M, W	C, O	
Loggerhead shrike	Lit.	S*	Wo, C, O	
Starling	O, M, J	R*	C, O, F, T Wo, S	
Red-eyed vireo	IES	M, S	Wo	
Philadelphia vireo	P	M	Wo	
Warbling vireo	J	M, S*	Wo	
Black-and-white warbler	Lit.	M, S*	Wo	
Orange-crowned warbler	Lit.	M	Wo	
Yellow warbler	M, J	M, S*	Wo, We	
Palm warbler	Lit.	M	Wo	
Chestnut-sided warbler	Lit	M	Wo	
Ovenbird	Lit.	M, S	Wo	
Common yellowthroat	M, J	M, S*	Wo, We	
Yellow-breasted chat	Lit.	M, S*	Wo, We	
Mourning warbler	Lit.	M	Wo	
Wilson's warbler	Lit.	M	Wo	
Canada warbler	Lit.	M	Wo	
American redstart	Lit.	M, S*	Wo	

Common Name[1]	Presence[2] and Field Period Observed	Expected Residence Status[3]	Occurrence by Habitat[4]	Comments
House sparrow	A, M	R*	S, C, O, T, F	
Bobolink	M, J	M, S*	C, O, We	
Western meadowlark	O, A, M, J	S*	C, O	
Yellow-headed blackbird	A, M, J	S*, M	We, C	
Red-winged blackbird	A, M, J	S*, M	We, C, F, S	
Rusty blackbird	O	M, W	We, Wo	
Brewer's blackbird	J	M, S*	O, S, F	
Common grackle	M, J	M, S*	We, Wo, C, O, S, F	
Brown-headed cowbird	O, M, J	M, S*	We, Wo, O, S, F	
Orchard Oriole	J	M, S*	S, F	
Northern oriole	M, J	M, S*	Wo	
Scarlet tanager	P	M		
Cardinal	Lit.	M	Wo, C	
Rose-breasted grosbeak	Lit.	M	Wo	
Black-headed grosbeak	J	M, S	Wo	
Indigo bunting	Lit.	M, S*	Wo	
Lazuli bunting	Lit.	M, S*	Wo	
Purple finch	Lit.	M	Wo, C, S, F	
Common redpoll	Lit.	W	O, C	
American goldfinch	O, A, M, J	M, S*	Wo, C, O, S	
Red crossbill	O	M, W	Wo	
Dickcissel	IES	M, S*	We, Wo, C, O	
Rufous-sided towhee	IES	M, S*	Wo, S	
Savannah sparrow	M	S*, M	We, Wo, C, O	
Grasshopper sparrow	M, J	S*, M	O	

Common Name[1]	Presence[2] and Field Period Observed	Expected Residence Status[3]	Occurrence by Habitat[4]	Comments
Baird's sparrow	M, J	S*, M	O, C	
LeConte's sparrow	Lit.	M	We	
Sharp-tailed sparrow	Lit.	M	O, We	
Lark bunting	M, J	S*	C, O	
Vesper sparrow	M	S*	C, O	
Lark sparrow	Lit.	M, S*	C, Wo, O	
Dark-eyed junco	O, F, A	M, W	Wo, C, S	
Tree sparrow	O, A, M	M, W	W, S, C	
Chipping sparrow	M, J	M, S*	Wo, C, S	
Clay-colored sparrow	M, J	M, S*	We, Wo, O, C	
Field sparrow	Lit.	S*	C, S	
Harris' sparrow	Lit.	M	S, C	
White-crowned sparrow	Lit.	M	S, Wo	
White-throated sparrow	Lit.	M, W	Wo, S	
Fox sparrow	Lit.	M	Wo, S	
Lincoln's sparrow	Lit.	M	We	
Swamp sparrow	Lit.	M	We	
Song sparrow	O, A, M, J	M, S*, W	We, Wo, S	
McCown's longspur	Lit.	M, S	O, C	
Chestnut-collard longspur	A, M, J	M, S*	O	
Lapland longspur	O, F	M, W	O, C	
Smith's longspur	Lit.	M	O, C	
Snow bunting	F	W	O, C	

SUMMARY OF RAPTOR OBSERVATIONS, FALKIRK STUDY AREA 1979-1980

Species	Season	Habitat	Comments
Marsh hawk	A, M, J	Ubiquitous	Hunting, probably nesting in grasslands
Redtail hawk	O	Grassland	Hunting over Oldfield 1 transect
Redtail hawk	M	Grassland & Cropland near wetland	NE¼ S15 T146N R82W; Hunting
Redtail hawk	M	Grassland/cropland	Hunting, North of Oldfield 1
Swainson's hawk	A	Grassland/cropland	Hunting, Oldfield 1
Swainson's hawk	A	Cropland/grassland	S25 T145N R82W
Ferruginous	J	Cropland	Fence post, S13 & T145N R82W
Great horned owl	O	Wetland	East end of Coal Lake
Great horned owl	J	Cropland	¼ mile north Wetland 6
Great horned owl	M	Wetland	S14 T145N R82W
Great horned owl	M	Shelterbelt near Wetland	Perched in tree
Great horned owl	M	Shelterbelt	Perching-Supplemental Songbird Area #3
Great horned owl	M	Woody draw	Perching in tree near end of road survey route
Burrowing Owl	J	Cropland	Perched near burrow

1/ Common names are those defined by the American Ornithologist's Union (AOU) Checklist of North American Birds (AOU 1957) and subsequent revisions (AOU 1973, 1976).

2/ Lit. = presence considered likely due to species distribution, and presence of preferred habitat in study area.

O = Observed by ERT personnel in October 1979
F = Observed by ERT personnel in February 1980
A = Observed by ERT personnel in April 1980
M = Observed by ERT personnel in May 1980
J = Observed by ERT personnel in July 1980

IES = Confirmed by Institute for Ecological Studies in 1975 (Sambarn and Seabloom 1975).

3/ Expected residence status: R = Year round resident; M = Visitor only during migration periods; W = winter resident; S = Summer resident of study area or nearby but not expected to breed on study area due to lack of habitat; S* = Summer resident and expected breeder, as determined by observations by ERT personnel or presence of suitable habitat in study area.

4/ Habitats in which observed or expected to occur:

We - Wetlands, including temporary, semi-permanent, and permanent wetlands.
Aq - Aquatic habitats, deeper, permanent areas such as Coal Lake, Weller Slough.
O - Oldfield/Native Prairie grassland communities.
Wo - Wooded areas including those with shrub stratum only and those with tree and shrub strata.
C - Cropland, including seeded, fallow and stubble fields.
F - Farmsteads, including associated buildings.
S - Shelterbelts and fencerows
T - The town of Underwood; Falkirk mine.

REPTILES AND AMPHIBIANS OBSERVED OR LIKELY TO OCCUR ON THE FALKIRK STUDY AREA

Common Name[1]	Presence[2]	Habitat[3]
Amphibians		
Blotched tiger salamander	O	We
Plains spadefoot	P	O
Great Plains toad	P	O
Woodhouse's toad	P	O
Canadian toad	P	We
Boreal chorus frog	O	We
Northern leopard frog	O	We
Reptiles		
Common snapping turtle	P	We
Western painted turtle	P	We
Western plains garter snake	O	O, We
Red-sided garter snake	O	O, We
Plains western hognose snake	P	O
Eastern yellow-bellied racer	P	Cr, O, Wo
Western smooth green snake	P	O, We
Bullsnake	P	O
Prairie rattlesnake	P	O

1/ Nomenclature follows Conant (1975).

2/ Presence: P = presence possible due to species distribution and preferred habitat (Conant 1975 and Wheeler 1966); O = observed by ERT personnel during field studies on or near the study area.

3/ Habitat of study area where species was observed or is likely to occur: Cr = Cropland; S = Shelterbelts and Fencerows; O = Oldfield/grassland communities; We = Wetland and associated aquatic habitat; Wo = Woody communities.

SPECIES LIST BY COLLECTION DATE OF BENTHIC MACROINVERTEBRATES
COLLECTED FROM AQUATIC ENVIRONMENTS,
FALKIRK STUDY AREA, 1979 - 1980

TAXA	October, 1979		May, 1980		July, 1980	
	Ekman	Dipnet	Ekman	Dipnet	Ekman	Dipnet
Oligochaeta (worms)						
Lumbriculidae			X		X	X
Naididae			X			
Tubificidae	X	X	X		X	X
Hirudinea (leeches)						
Erpobdellidae						
unknown species A	X		X		X	
unknown species B	X	X	X		X	
unknown species C			X		X	X
unknown species D					X	X
unknown species E					X	
Glossiphoniidae						
Glossiphonia sp.				X	X	
Helobdella sp.			X	X	X	
Nematoda (round worms)			X		X	
Gastropoda (snails)						
Lymnaeidae						
Lymnaea sp.	X		X	X	X	X
Physidae						
Physa sp.	X	X	X	X	X	X
Planorbidae						
Gyraulus sp.	X	X	X	X	X	X
Helisoma sp.			X		X	
Pelecypoda (clams)						
Sphaeriidae						
Pisidium sp.	X		X		X	X
Unionidae						
unknown genus	X					
Amphipoda (scuds)						
Talitridae						
Hyalella azteca	X	X	X	X	X	X
Hydracarina (mites)	X		X	X	X	X

TAXA	October, 1979		May, 1980		July, 1980	
	Ekman	Dipnet	Ekman	Dipnet	Ekman	Dipnet
Ephemeroptera (mayflies)						
Baetidae						
Callibaetis sp.	X	X		X	X	X
Caenidae						
Caenis sp.	X		X	X	X	X
Odonata (dragonflies, damselflies)						
Aeshnidae						
Anax sp.					X	
Coenagrionidae						
Enallagma sp.			X	X	X	X
Lestidae						
Lestes sp.	X	X	X	X		X
Libelluidae						
Sympetrum sp.					X	X
Unknown genus	X					
Hemiptera (true bugs)						
Corixidae						
Hesperocorixa vulgaris	X	X	X	X	X	X
Sigara sp.		X		X		X
Immature Corixidae			X	X	X	X
Gerridae						
Gerris sp.				X		X
Notonectidae						
Notonecta sp.			X	X	X	X
Veliidae						
Microvelia sp.				X		
Trichoptera (caddisflies)						
Hydroptilidae						
unknown genus						X
Leptoceridae						
Mystacides sp.		X	X	X	X	X
Oecetis sp.				X	X	
Triaenodes sp.					X	X
Limnephilidae						
Limnephilus sp.			X	X	X	
Philarctus sp.					X	
Molannidae						
Molanna sp.	X	X	X	X	X	
Phryganeidae						
Agrypnia					X	
Phryganea sp.					X	

TAXA	October, 1979 Ekman	October, 1979 Dipnet	May, 1980 Ekman	May, 1980 Dipnet	July, 1980 Ekman	July, 1980 Dipnet
Polycentropodidae						
Polycentropus sp.	X				X	
Unknown Pupae			X			
Unknown Trichoptera	X					
Coleoptera (beetles)						
Chrysomelidae						
unknown genus			X	X		
Curculionidae						
unknown genus						X
Dytiscidae						
Agabus sp.	X	X	X			
Coptotemus sp.				X	X	
Dytiscus sp.				X	X	
Graphoderus sp.				X		
Hygrotus sp.		X			X	
Laccodytes sp.				X	X	X
Matus sp.				X		
Rhantus sp.			X	X	X	
unknown larvae				X		
Haliplidae						
Haliplus sp.	X	X		X	X	X
Hydrophilidae						
Berosus sp.	X			X	X	
Helochares sp.				X		X
Helophorus sp.					X	X
Hydrochus sp.				X		
unknown genus						X
Diptera (true flies)						
Ceratopogonidae						
Palpomyia group sp.	X		X	X		X
Chironomidae						
Ablabesmyia sp.	X	X	X	X	X	X
Chironomus sp.	X		X		X	X
Cricotopus sp.	X		X	X	X	X
Cryptochironomus sp.	X		X		X	
Cryptotendipes sp.			X		X	
Dicrotendipes sp.			X	X	X	
Endochironomus sp.	X	X	X	X	X	X
Glyptotendipes sp.	X	X	X		X	X
Heterotrissocladius sp.			X	X	X	
Microosectra sp.	X	X	X	X	X	X
Parachironomus sp.			X		X	X

TAXA	October, 1979 Ekman	October, 1979 Dipnet	May, 1980 Ekman	May, 1980 Dipnet	July, 1980 Ekman	July, 1980 Dipnet
Phaenopsectra sp.			X			
Polypedilum sp.			X		X	
Procladius sp.	X	X	X		X	X
Rheotanytarsus sp.					X	X
Tanypus sp.			X	X	X	X
unknown Chironomini	X		X	X	X	X
unknown Orthocladiinae			X	X	X	X
unknown Tanypodinae					X	
Pupae			X	X	X	X
Culicidae						
Chaoborus sp.	X	X	X		X	X
Pupae					X	
unknown Culicinae						X
Empididae						
unknown genus			X			
Ephydridae						
unknown genus				X		X
Muscidae						
unknown genus	X					
Psychodidae						
Pericoma sp.			X			
Stratiomyidae						
Eulalia sp.				X		
Tabanidae						
Chrysops sp.			X		X	
Tipulidae						
Holorusia sp.				X		X
Tipula sp.				X	X	X
unknown genus				X		
unknown Diptera pupae	X		X	X		
TOTAL - 95	34	20	52	50	65	48

WETLAND REHABILITATION OF SURFACE COAL-MINED LANDS
FOR WILDLIFE

by

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ABSTRACT

A great potential exists for rehabilitating wetland habitats or creating new wetland habitats to benefit wildlife. Surface coal-mined lands can serve as tremendous laboratories for such studies.

While rehabilitation of surface coal-mined lands has come a long way since the enactment of federal legislation regulating the reclamation and mining standards in the United States, very little has been addressed involving the rehabilitation of wetland ecosystems.

The study of wetland rehabilitation of surface coal-mined lands for wildlife focuses on a comparison of rehabilitated surface coal-mined wetland habitat with an unmined natural wetland area in the same region in the United States. The study site chosen was the Falkirk Mine with two rehabilitated surface coal-mined wetlands located near Underwood, North Dakota. Two similar unmined, natural wetlands were used as reference areas to compare to the rehabilitated sites. The important physiographic, hydrologic, soil, vegetative, and microclimatic parameters of these prairie pothole wetlands affecting wildlife were measured and compared for 1985 and 1986 between the rehabilitated and unmined wetland conditions.

The results showed the anticipated wetland vegetative succession of the rehabilitated wetlands to be following a similar pattern as on the unmined reference wetlands. The rehabilitated areas showed marked improvement in vegetation cover and nutrition value for wildlife, and a noted increase in wildlife productivity and diversity from 1985 to 1986.

The results of the study led to a set of recommendations to further increase the wildlife benefits on surface coal-mined wetlands.

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