

Water for Agriculture and Wildlife and the Environment Win-Win Opportunities

**Proceedings from the
USCID Wetlands Seminar**

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Preface

The papers included in these Proceedings were prepared for the 1996 **Wetlands Seminar** *Water for Agriculture and Wildlife and the Environment — Win-Win Opportunities*. The seminar, sponsored by the U.S. Committee on Irrigation and Drainage and the Bureau of Reclamation, was held in Bismarck, North Dakota, June 27-29, 1996.

The purpose of the Wetlands Seminar was to bring together professionals of disciplines involved with agriculture and wetlands, to exchange information and seek solutions to competing issues that might satisfy the needs of all interests.

The Seminar included Technical Sessions and a Poster Session on four topics:

- Agriculture and Wetlands Compatibility
- Wetlands and Water Quality
- Water for Wetlands: Appropriation/Allocation
- Fish and Wildlife Diversity and Productivity

This Proceedings includes 32 papers presented during the Seminar and a dinner address by featured speaker Lloyd A. Jones, Vice President of Field Operations, Delta Waterfowl.

The U.S. Committee on Irrigation and Drainage and the 1996 Wetlands Seminar General Chairman extend their appreciation to the speakers, authors, participants and session moderators.

Jerry Schaack
Seminar General Chairman
Carrington, North Dakota

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SESSION I KEYNOTE:
AGRICULTURE AND WETLANDS COMPATIBILITY

Jay A. Leitch¹

ABSTRACT

The U.S. Swamp Lands Acts of the mid-nineteenth century set the stage for a negative mind set regarding wetlands that would persist to the present. No where has that mind set been as persistent as in agriculture. Issues surrounding the definition of wetland, property rights, and the role of science go largely unresolved. While wetlands and agriculture were incompatible a century ago, their differences have been ameliorated through technology, education, and cultural shifts. Today, there are many good examples of cooperation and compatibility between agriculture and wetlands.

INTRODUCTION

I am going to set the stage for the six papers that follow by providing a bit of history and a sense of where we are today and where we might be going with respect to agriculture and wetlands.

Until recently wetlands were seen as obstacles to agricultural development in the United States. Agriculture was responsible for conversion of more wetlands to other uses than perhaps any other human activity up to this point.

Wetland chronology in the Upper Great Plains

10,000 BC: glaciers retreated leaving millions of PRAIRIE POTHoles that were from only a fraction of an acre to over a hundred acres in size

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1849, '50, '60: SWAMP Lands Acts, 65 million acres of swamp land given to 15 states if they would develop it and put it to productive uses. This began the negative mind set about wetlands.

1862: Homestead Act, settlers tamed the landscape. However, the technology to directly impact wetlands was not yet available so they had to farm around these obstacles.

1889: North Dakota became a state -- about 5 million acres of wetlands existed.

1934: Migratory Bird Hunting Stamp (Duck Stamp) allowed the federal government to use easements and fee title purchases to protect wetlands valuable for waterfowl production.

1943: USDA program to cost-share drainage is implemented. This added to the mind set that wetlands and agriculture were not compatible. Farmers are still using 12-foot grain drills and 40 horsepower tractors, so farming around wetlands is still mostly a nuisance.

1944: PL 566, federal government encourages drainage through coordination and mainstem ditches.

1954: Circular 39 describes wetland types (e.g., types I, II, III, IV and V) and identifies some of their values. The seed is planted that wetlands may have social values beyond waterfowl production.

1962: Reuss Amendment prohibits drainage subsidies for types III, IV, and V wetlands, advancing further the notion of public values.

1960: Environmental movement gives big boost to wetland protection. Federal government's aggressive wetland easement purchases began a controversy that is alive today. Large 4-wheel drive tractors and wider farm implements began to show up, causing wetlands to be more than just a nuisance to farming. Farmers have the horsepower to improve drainage on their cropland.

1972: Section 404 of the Clean Water Act is enacted. Although not intended to be a wetland protection law, it was later interpreted to include wetlands as "waters of the United States" and capable of supporting interstate commerce.

science of natural resources use and management is broadened to include other landscape features and the full range of human values, it is likely only to add to controversy rather than lessen it.

These three issues are part of understanding the compatibility of wetlands and agriculture.

COMPATIBILITY

The compatibility of agriculture and wetlands spans a continuum from mutually exclusive to complementary. In the past, most agricultural activities were incompatible with wetlands (mutually exclusive); some were compatible; and few, if any, were complementary. However, as society, science, and agriculture have matured, fewer and fewer agricultural activities are totally incompatible with the maintenance of wetlands in agricultural land or in the rural landscape.

Compatibility can be viewed as physical, cultural, economic, or institutional/legal. The latter three can be overcome with "non-structural" fixes, but can be the most troublesome. For example, cultural compatibility involves the pioneering mind set of second and third generation farmers and the attitudes of neighbors and bankers that "clean fields" are better. Economic compatibility involves the incentives or penalties for wetland use and their effect on the bottom line. Finally, institutional/legal compatibility includes property rights issues and the role of the various levels of government.

Mutually Exclusive

Activities are mutually exclusive when they can not both be done at the same time in the same place. Exclusiveness is a function of space, competition, and philosophy. For example, you can not both go fishing Saturday morning and fly to Tokyo; nor can you build a shopping mall and an airport in the same location. But you can go fishing and read a book, and you can design a shopping concourse within an airport terminal or beneath the runway.

Cultivated crops are spatially incompatible with wetlands in fields (Fig. 1). Wetlands must be adequately drained to provide the optimal soil-water conditions. Spring farming and nesting ducks are also mutually exclusive.

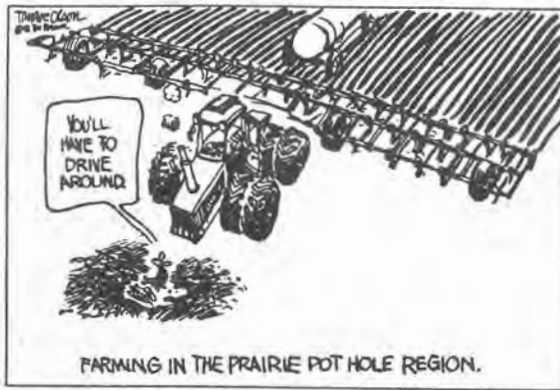


Fig. 1. Cartoon by Trygve Olson (*The Fargo Forum*, 1991).

Space: Certainly farmers cannot grow row crops and preserve cattails in the same space. Nor can they operate center pivots through wetlands (although pivot wheel tracks have been built across wetlands). Technology has helped to overcome some of the space compatibility issues, but some will always remain.

Competition: There is also competition among users of wetlands, such as between consumptive users (hunters) and nonconsumptive users (birders).

Philosophy: Philosophy relates back to the culture issue. Farmers were encouraged for a century or longer that wetlands were unproductive and should be drained. This mind set is still strong. Also, the idea that square fields and straight rows are "good farming" prevents some wetland protection.

Compatible

Some wetland and agriculture activities that are spatially exclusive are compatible temporally. In other words, while two activities cannot be carried out simultaneously, they may be feasible sequentially. Others may be compatible in space and time, such as grazing, haying, and sediment control.

Irrigation and other forms of intensive farming might, at first, be thought of as exclusive; but accommodations can be made for "odd areas". In this instance, wetlands can be part of the agricultural landscape, while not actually in the field.

Government rules and regulations have forced farming to be more compatible with wetlands. They also raise the cost of production and may shift environmental problems elsewhere in the landscape or to another country. In other words, forced compatibility comes at a cost.

As demands for agricultural production increase so does production technology. In moving from past to present, technology has both contributed to the conflict and helped to resolve it. It has contributed through introduction of bigger equipment that makes it difficult to farm around obstacles in fields. Technology has helped lesson the conflict through precision or site-specific farming and reduced tillage management.

Complementary

Man-made wetlands, such as sewage lagoons for feedlot runoff, provide both agricultural and natural functions. Wetlands maintained for water supply can provide flood control and wildlife habitat. The sustainable agriculture movement, especially its emphasis on biodiversity, will lead to more complementarity between agriculture and wetlands. Fee hunting, popular in South Dakota, Texas, and some other states, can help wetlands become an economic complement to a farm enterprise.

Each of the constraints to complementarity--physical, cultural, economic, and institutional--can be eased with research, development, and changes in attitudes and institutional structures. However, there may not be a much room substantial improvements in complementarity, unless uses for indigenous wetland plants, such as cattails, are developed.

CONCLUSIONS

The chasm that once was deep and wide between agricultural and wetland interests has narrowed and become less deep due to changes in technology and culture. Some of the change was forced by legislation, other by economics and culture. Farmers have adapted to these changes--they usually do. The following six papers are nice examples of some of the compatibility and cooperation that is occurring.

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BROOD HABITAT FOR DUCKS
AND AN IRRIGATION SYSTEM FOR FARMERS:
A CALIFORNIA CASE STUDY

Marilyn Cundiff-Gee¹

Dave Smith²

ABSTRACT

We developed a project to restore 104 acres of wetlands and increase the economic viability and commercial flexibility associated with a wheat farm in the Sacramento Valley, California. Prior to the project, only 270 acres of the 910-acre farm could be irrigated; the remainder of the property was undeveloped land suitable only for dryland wheat and safflower production. A conjunctive use project was developed to restore wetlands and improve irrigation and farming capability. Seven wetland units were constructed on areas of the farm that produced low crop yields and were costly to maintain. A comprehensive irrigation system was developed that included two pumps, two wells, and numerous water control structures. A tailwater recovery system was completed that maximized water supply and flexibility for both agricultural and wetland purposes. In return for the capital improvements, a 25-year management agreement was developed requiring the landowners to annually (1) flood the restored wetlands from February through July, (2) grow 350 acres of wheat, and (3) delay wheat harvest until after the nesting season. While creating spring and summer wetland habitat for duck broods and a multitude of other avian species, the project provided irrigation capability for an additional 505 acres, bringing the total irrigated lands to 775 acres. A critical component of the project was the unique partnership developed between state and federal agencies, a nonprofit organization and private landowners. By pooling fiscal and technical resources and providing the landowner with incentives, the following benefits were realized: increased commercial farming opportunities, wetland restoration and long-term management, and most importantly, the creation of an environment wherein development and management of wetlands has become an asset, rather than a liability to the landowner.

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INTRODUCTION

The Central Valley of California is one of the most important wintering areas for waterfowl in North America (Bellrose 1980, Heitmeyer 1989a), supporting approximately 60 percent of the ducks and geese wintering in the Pacific Flyway (U.S. Fish and Wildlife Service [USFWS] 1978). However, nearly 95 percent of the Central Valley's historic wetlands have been lost (Gilmer et al. 1982). Of the remaining 300,000 acres (121,599 ha) of wetlands, two-thirds are privately owned and managed for the purposes of providing wintering waterfowl habitat and duck hunting opportunities (Heitmeyer 1989a). The remaining one-third consists of State wildlife areas and National Wildlife Refuges (Central Valley Habitat Joint Venture [CVHJV] 1990).

Significant wetland restoration has been conducted on private land since the CVHJV developed a plan to restore waterfowl populations to levels that existed in the mid-70s. Most restoration has resulted in the conversion of large blocks of agricultural land into wetland complexes through traditional processes such as the acquisition of fee and perpetual conservation easements. Although they are often referred to as the "crown jewels" of the Central Valley, wetlands do not provide enough food and nesting cover to support populations of waterfowl as proposed in the CVHJV Implementation Plan (Heitmeyer 1989b). If the goals of the CVHJV are to be achieved, incentives to foster a wildlife friendly approach to farming must be encouraged. While the importance of grain fields and cereal crops is recognized in the CVHJV Plan, relatively few attempts have been made to integrate wetlands into farming operations; even fewer projects have been initiated by wildlife agencies to conjunctively improve agronomic potential and wetland resources on private lands.

In this paper we present the methodology and processes used to develop a wetland restoration and agricultural enhancement project on a wheat farm in Glenn County, California. By accomplishing both agricultural and wildlife objectives, the project has been widely supported by wildlife interests, farmers and the local community.

THE TOOL BOX FOR INNOVATION

The Inland Wetlands Conservation Program was established within the California Wildlife Conservation Board (WCB) which recognized the importance of public/private partnerships as a tool to achieve the resource goals called for in the CVHJV Plan. Whereas most of California's previous wetland initiatives were national in origin or narrowly focused, WCB's program was structured with sufficient authority and flexibility to implement innovative habitat protection efforts that are locally driven and are based on the unique needs and opportunities that exist in the Central Valley.

The purpose of this program is defined in statute, i.e., to carry out the objectives of the CVHJV. However, unlike many other habitat programs, the Inland Wetland Conservation Program was provided with the legislative authority to work with local stakeholders and issue grants and loans to nonprofit organizations, special districts, state and local entities and Resource Conservation Districts. This approach enables the WCB to utilize a variety of nontraditional methods of protecting valuable waterfowl habitat such as leasing property in need of restoration; purchasing restorable wetlands and then selling the wetlands back to the private sector; purchasing less than fee interests to protect, in perpetuity, critical agricultural lands, i.e., agricultural conservation easements; and purchasing water and water rights. Most importantly, the WCB is able to provide landowner incentives tailored to the specific landowner and conservation need.

INTEGRATING AGRICULTURE AND WETLAND OBJECTIVES

In California, wetland and agricultural interests have historically been polarized due to competing demands for water and other resources. Most of the State's historic wetlands were drained in the early 1900's for agricultural and reclamation projects (Frayer et al. 1989). Until recently, water supplies for the remaining wetlands were largely inadequate (U. S. Bureau of Reclamation [USBR] 1989). Lacking suitable fresh water supplies, wetland owners in the Grasslands area of the San Joaquin Valley used agricultural drainwater to flood their wetlands in the late 1970's and early 1980's. This alternative supply led to selenium contamination at the Kesterson National Wildlife Refuge, prompting ten years of costly cleanup and environmental mitigation. It was only with the passing of the Central Valley Project Improvement Act in 1992 that over 100,000 acres of Central Valley wetlands were finally guaranteed a firm supply of federal project water.

Recently, there has been a reversal in wetland trends in California. As a result of the efforts of progressive landowners and state and federal wildlife agencies, 42,508 acres (17,215 ha) have been converted from farmland back to wetlands since 1986 (CVHJV 1996). Most of the restored acreage was converted from farmland or pasture land to wetlands for the establishment of duck hunting clubs, wildlife areas and refuges. However, such restoration has not occurred without its critics.

California's Central Valley is the nation's most important agricultural area; eleven of its counties produce 250 different commodities with a market value of \$13.3 billion (American Farmland Trust 1995). Citing adverse impacts to rural economies, some local governments in the Sacramento Valley have vigorously opposed fee-title land acquisitions for wetland restoration purposes. While numerous organizations, coalitions and commodity groups representing California agriculture have expressed their concern over the loss of farmland to a number of non-agricultural uses, primarily urban expansion (American Farmland Trust 1995), some commodity organizations have been particularly sensitive to wetland

protection and restoration efforts that eliminate agricultural uses on productive farmland. In recognition of these often strained relationships and the value of working together to integrate agricultural and wetland objectives, a unique project was developed with the intent of improving the wetland resources and agricultural values of a Sacramento Valley wheat farm.

LOW PRE-PROJECT AGRICULTURAL AND RESOURCE VALUES

The vast majority of the Sacramento Valley can be irrigated, and rice is the predominant commodity crop. Nonetheless, tracts of undeveloped land remain in existence. The 910-acre (369 ha) Beck Ranch is located in a portion of Glenn County that is characterized by level ricefields. The ranch is unique in that it features topographic relief representative of the historic Sacramento Valley landscape. Nearly all of the property's wetlands were eliminated as reclamation projects along the Sacramento River and its tributaries altered the region's natural hydrologic cycles. The low-lying areas of the Beck Ranch were farmed to dryland crops because they lacked their historic wetland hydrology. Prior to the project, only 270 acres (109 ha) of the farm could be irrigated and safflower and wheat were grown on the non-irrigated acres.

The landowners initiated a tailwater return project in the late 1980's to improve irrigation efficiency, but did not have the economic resources to complete the return system or drill two wells that would allow optimum use of abundant groundwater supplies that were available to the property. By 1993, the Beck Ranch had limited economic opportunities. Eucalyptus firewood propagation and a licensed pheasant club were used to supplement farm income. Concurrently, wildlife populations were at moderately low levels due to the lack of water during the late spring and summer. Although the wheat fields provided habitat for ground-nesting birds, haying was often done in mid-spring because irrigation water was not available to ensure a good grain crop. Haying is known to cause nest destruction and hen mortality (see review in Sargeant and Raveling 1992), and likely resulted in the mortality of nesting ducks on the Beck Ranch prior to the project as it did on other nearby hayfields (Loughman et al. 1991).

BREEDING DUCKS AND WHEAT FIELDS

The Central Valley is widely recognized for its value to wintering waterfowl (see reviews in USFWS 1978, Gilmer et al 1982, Heitmeyer 1989a). Less well known is the fact that the Central Valley supports a substantial population of breeding ducks, primarily mallards (McLandress et al. 1996). Previous breeding estimates (119,000 mallards; Munro and Kimball 1982) were low due to survey methodology, but CDFG recently revised its waterfowl surveys to conform to standardized procedures used in the cooperative breeding ground survey (USFWS and Canadian

Wildlife Service [CWS] 1987). The revised surveys now indicate a breeding population of at least 350,000 mallards in California (Zezulak et al. 1991, CWS and USFWS 1996).

Investigations of mallard nesting biology throughout the Central Valley indicate that, at least in surveyed areas, nest densities and success are extremely high (McLandress et al. 1996). During three years of nest searching on state and federal wildlife refuges in the Sacramento Valley, (McLandress et al. 1996) found an average of over 0.4 mallard nests/acre. Overall mallard nest success (Mayfield method) was 32.3% for the five-year statewide study (McLandress et al. 1996).

Duck nesting is also prevalent in agricultural areas of the Sacramento Valley, especially wheat fields and fallow "set-aside" ricefields. Yarris and Loughman (1990) and Loughman et al. (1991) found approximately 0.75 nests/acre in set-aside fields and over 2.0 nests/acre in Sacramento Valley wheatfields, respectively. Central Valley wheat fields differ markedly from those in northern regions of North America in that plant growth coincides with duck nesting chronology. Due to the long growing season, the wheat is typically tall (> 16 inches [40cm]) and provides dense nesting cover by early April. Mallards nest earlier in California than in northern breeding grounds (cf. Hammond and Johnson 1984, Lokemoen et al. 1990, McLandress et al. 1996); the peak of nesting in the Sacramento Valley occurs in April and May.

BROOD HABITAT - THE LIMITING FACTOR

Although mallard nest densities and success are typically very high in the rice-growing region of the Sacramento Valley, brood survival appears to be limited by habitat availability during the spring (Yarris 1995). Rice culture involves ground preparation and planting from March through May. The fields are flooded in late April and May, but do not provide cover for the duck broods until about mid-June (Yarris 1995). With only ditches available as early season brood habitat during his study in 1993 and 1994, Yarris (1995) found duckling survival to be very poor. However, survival increased 4-fold in late season. This temporal increase in survival probability was attributed to the increased suitability of ricefields as brood habitat once the rice plants matured sufficiently to provide protection from predators (Yarris 1995). Based on these findings and several years of previous anecdotal evidence, it was determined that although duck nesting effort was relatively high on the Beck Ranch, additional spring-summer wetlands were needed to maximize duck production.

Palustrine emergent wetlands flooded continuously from early March until late July are rare in the Sacramento Valley. Most Central Valley seasonal wetlands are drained in March or April and are not re-flooded until September or October (Heitmeyer 1989a); however, as is the case in other key wintering areas, short

duration (1-2 week) summer irrigations are sometimes used to increase moist-soil seed production (Smith et al. 1994, Fredrickson and Taylor 1982). In addition to local ducks, spring-summer wetlands are extremely important to a host of wetland dependent wildlife including great egrets, (*Casmerodius albus*), snowy egrets (*Egretta thula*), black-crowned night herons (*Nycticorax nycticorax*), virginia rails (*Rallis limicola*), American avocets (*Recurvostra americana*), black-necked stilts (*Himantopus mexicanus*), white-faced ibis (*Plegadis chili*), ring-necked pheasants (*Phasianus colchicus*) and the state listed Giant garter snake (*Thamnophis couchii gigas*).

DEVELOPMENT OF AN AGRICULTURE/WETLAND SOLUTION

Many programs that provide assistance to private landowners are structured such that only certain activities and types of projects are eligible for cost-sharing assistance. In California, there are a multitude of federal, state and private programs available to assist landowners with habitat restoration projects. However, because of restrictive eligibility requirements and/or program criteria, many worthy projects do not qualify for cost-sharing assistance.

In the case of the Beck Ranch, the landowners did not have the resources to improve the farm by establishing additional irrigation capability. Moreover, a wetland conservation easement was not feasible because the property could not easily be converted into a high quality duck hunting club due to its rolling topography and lack of surface water rights. Economically speaking, most Sacramento Valley landowners can only convert farmland into wetlands by selling conservation easements and then establishing duck clubs. The Central Valley's natural hydrology has been altered so drastically that most wetlands must now be artificially flooded, often at a significant annual cost to the landowner, and duck club memberships are usually needed to generate such revenue. Small-scale habitat improvements were not an option for these landowners because they needed to increase the agronomic value of the farm that was on the brink of economic failure. Thus, traditional wetland programs were not applicable.

Capitalizing on WCB's programmatic flexibility, we tailored a project to fit the Beck Ranch by first recognizing the needs of the landowners. Once it was determined that an expanded irrigation system was their highest and most urgent priority, and essentially their only means of improving the agronomic value of the farm, a team of wildlife professionals developed a list of habitat restoration and management actions that would be needed to achieve desired wildlife objectives, commensurate with the funding provided for the capital improvement.

To protect the State's investment and assure the long-term viability of the project, WCB, the landowners, and the California Waterfowl Association (CWA) developed a binding three-way, 25-year agreement. As the grantee, CWA supervised the

development and construction of all capital improvements, and by working cooperatively with the landowner and all of the stakeholders associated with the project, developed a management plan for the property. The management plan required the landowners to (1) restore 104 acres (42 ha) of wetlands in low-lying, unproductive agricultural areas, (2) flood the restored wetlands from February through July each year, (3) annually grow 350 (142 ha) acres of wheat, and (4) delay wheat harvest until after the duck nesting season.

In return for this commitment by the landowners, WCB provided the \$200,000 necessary to restore the wetlands and install a comprehensive irrigation system including two wells, a network of ditches, two lift pumps, three inverted siphons, and numerous water control structures. An important feature of the project is a complex tailwater return system that allows maximum recirculation and water use efficiency. The wetlands are an integral part of the system because they will serve as shallow irrigation reservoirs at certain times of the year. Additional water necessary to meet the wetland flooding requirements must be pumped from the new wells at the landowner's expense.

In 1996 its first year of operation, the project has already provided significant agricultural and wetland benefits. Foremost, irrigated acreage has been increased by 505 acres (205 ha), with 775 acres (314 ha) of the farm now under irrigation. By irrigating the wheat, yields are certain to increase and mid-spring haying will no longer be necessary even after the 25-year agreement expires. Further, crop diversification is underway and irrigated crops such as sugar beets, squash, and cucumbers can now be grown on the property.

Wetland values have also increased dramatically. Over 5,000 waterfowl were recorded during March 1996, thus it appears that the ponds will be of significant value to spring staging waterfowl. Mallards and other duck species are utilizing the Beck Ranch for brood-rearing; early indications are that brood survival will be reasonably good in 1996. Resource values will increase in future years as wetland vegetation matures and additional cover is provided. Local biodiversity has been improved substantially due to the presence of highly productive spring-summer wetlands.

DEPOLARIZE AGRICULTURAL AND CONSERVATION INTERESTS

The trade-off between increased agricultural production and preserving a diversity of wildlife habitat on private lands oftentimes becomes a choice based upon economic factors. In many cases, as agricultural production increases, the diversity of wildlife habitat decreases. This happens because lands that are more fertile, in other words those that are best suited for agricultural production, are cultivated first and, as such, end up with a lower degree of natural biodiversity. However, as agricultural technologies increase and cultivation moves into less fertile areas of the

ecosystem, (which have a higher degree of biodiversity because they were not initially cultivated) the trade-off between increased agricultural production and preserving wildlife habitat becomes greater. In areas of marginal farmland, gains in agricultural acreage are often not justified by the resulting crop yields. Yet, such agricultural conversion results in large decreases in biodiversity (Howitt 1995, Huston 1993, Weitzman 1992).

Herein lies the conflict faced by many private landowners concerned with maintaining an abundance of diverse wildlife habitat yet dependent upon higher yields and greater crop diversity. For wildlife managers and organizations, the challenge becomes one of providing sufficient incentives to the private landowner to encourage the preservation of less fertile land for wildlife purposes and limiting agricultural production to quality farmland.

To preserve the agricultural integrity and productivity of the Beck Ranch, the brood ponds were restored on areas of the farm that were expensive to cultivate. These areas had poor soils and were difficult to farm. While the cost per acre to maintain the farming operation has been reduced, the value of the farm to nesting ducks and their broods has increased substantially. More importantly, crop diversity and crop yields were increased without sacrificing any critical wildlife habitat.

Another important aspect of the project is the relationship between the incentive provided to the landowner, i.e., the capability to irrigate 775 acres of farmland, and the diversity of wildlife benefits that will be obtained from the private landowner. In return for the \$200,000 incentive, important habitat will be maintained by the landowner for 25 years. Thus, managing the brood ponds has become an asset to the landowner and not a liability. Further, the property remains on the local property tax roles, the local community is benefitting financially by having a successful farm operation and nesting ducks are benefitting from the quality habitat.

From the perspective of a public agency, the cost/ benefits associated with this project further demonstrate the need for incentives designed to meet the needs of the landowner and the unique habitat located on the private land. For example, if traditional means of preserving the habitat were utilized and a wetland conservation easement was purchased by a public entity, this same project would have cost the taxpayers approximately \$675,000 (WCB 1996). Alternatively, if this property was owned-in-fee by a public entity, it is estimated that the same management effort would cost \$1.125 million over the 25-year life of the project. This price tag however, does not include the economic losses to the agricultural industry, nor does it include the economic loss to the local community with respect to reduced property taxes or the third party economic losses associated with the total conversion of agricultural land to wildlife habitat.

The monetary incentive to the landowner was not the only factor that contributed to the success of this project. This project reflects a unique partnership between the

agricultural industry and the conservation community. Early in the design of this project, we recognized that this particular piece of farmland provided a tremendous opportunity to increase the population of locally breeding ducks. However, inherent within this recognition was the understanding by the conservation community that maintaining a productive agricultural operation was equally important to the local and state economy. As such, efforts were made to understand the unique needs of the landowner and, by working together, we identified mutually beneficial ways by which the property could be developed to meet the financial and agricultural needs of the landowner and the needs of the waterfowl.

The two needs were not mutually exclusive. The successes of the wildlife aspects of the project were dependent upon the success of the agricultural operation. If the landowner incentive was not sufficient to provide the economic means by which the agricultural operations could become successful and profitable to the landowner, habitat for the breeding ducks would not have been created.

The incentives tailored to meet the needs of the Beck Ranch and those of the conservation community have resulted in habitat restoration and management by the landowner. This project promotes voluntary land stewardship rather than regulating land management practices for the exclusive benefit of wildlife. Current controversies over private property rights have shown that a non-regulatory approach to preserving wildlife habitat may be more successful than regulating and mandating specific land management practices. Understanding the importance of integrating wildlife habitat into commercial farming operations is sometimes a difficult transition for many within the conservation and agricultural communities. However, by identifying mutual areas of interest, coupled with the knowledge and expertise of stakeholders within the agricultural industry and conservation community, conjunctive use efforts, such as those demonstrated by this project are possible.

CONCLUSION

Although still in its infancy, the project has accomplished the two major objectives it was designed to achieve. It increased irrigation capability by 505 acres (205 ha) and restored 104 (42 ha) of spring-summer wetlands. The importance of this project however, goes beyond simply increasing the irrigation capability and providing habitat for ducks. The project exemplifies accomplishments that can be achieved when the agricultural industry and the conservation community in the Central Valley work together to mutually benefit agriculture and conservation interests. To the extent that incentives or cost-share assistance can be tailored to meet the unique needs of private landowners, the dichotomy between agricultural production and diversity of wildlife habitat should be reduced.

With increasing fiscal demands placed upon governmental entities, coupled with declining revenue sources, it is becoming more and more difficult for federal and state resource agencies to address critical issues facing our fish and wildlife resources. Developing projects designed to integrate the needs of agriculture and wildlife provides one avenue whereby a cost effective, win-win opportunity can be implemented, benefitting the private landowner and the wildlife species dependent upon the privately-owned land. While the techniques used to develop this project may not be the panacea to all of our resource problems, this approach could provide a cost-effective answer to increasing both biodiversity on farmland and cooperation between the agricultural industry and the conservation community. In the Central Valley of California, where 11 counties contribute \$13.3 billion in agricultural revenue to the State economy and where 60% of the Pacific Flyway waterfowl population winters, efforts designed to integrate agricultural production and the needs of wintering and breeding ducks is imperative.

Acknowledgments

The success of this project can be largely attributed to the individuals and organizations that believe resource management practices can result in quality land stewardship beneficial to the people of California. We kindly acknowledge the dedication, commitment, technical expertise, advice and encouragement provided by Dr. John Eadie, University of California at Davis, Wendell Gilgert, District Conservationist Natural Resources Conservation Service; the Glenn County Resources Conservation District; Paul Hofmann, California Department of Fish and Game; Richard Shinn, Craig Isola, Dr. Robert McLandress, and the staff of the California Waterfowl Association; and most importantly, the entire Beck family whose patience and dedication was an inspiration to us all.

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OPPORTUNITIES LOST THROUGH FAILURE TO DEVELOP IRRIGATION IN CENTRAL SOUTH DAKOTA

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ABSTRACT

In the mid-1980s, several irrigation projects were evaluated and proposed for development as part of the Pick-Sloan Missouri Basin Project. Included as part of the Central South Dakota project was the evaluation of waterfowl enhancement opportunities. During these studies, it was found that waterfowl production is generally limited, even though there may be wetlands available, by an inadequate number of wetlands that maintain water throughout the duck brood rearing season. With proper planning the development of these proposed irrigation projects would have provided the source of water for the increased production of waterfowl.

This paper discusses in some detail an evaluation made in association with the Bureau of Reclamation's proposed CENDAK Irrigation Project. Three of six Central South Dakota counties located in the CENDAK Project area were evaluated for the potential to increase wildlife productions. Forty thousand two hundred (40,200) acres of wetlands were identified in these counties as having enhancement potential on the basis of wetland permanency, size, and proximity to planned irrigation canals and the source of water that the project would provide.

In conjunction with the irrigation study, the U.S. Fish and Wildlife Service selected four wetland areas for further evaluations. Changes in duck population were evaluated by a mallard production simulation model. Three different types of management actions were evaluated. The first action, which just provided supplemental water from the irrigation system to existing wetlands, produced an increase in the recruitment rate at up to 660 percent greater than present conditions. Production of young increased up to 28 times over present conditions as

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a result of supplying supplemental water. The other two Management Action plans required more extensive development but had similar results.

Development costs for the three management actions varied depending upon the amount of land in private ownership. The development cost ranged from \$86 per wetland acre for supplemental water management to \$680 per wetland acre for a more extensive action plan at a wetland that was entirely in private ownership. Federal cost sharing could be available if enhancement was included as part of the Federal Water Project. Similar waterfowl enhancement opportunities are likely to exist in other parts of the Great Plains through better integration of irrigation projects and fish and wildlife enhancement.

INTRODUCTION

The history of large irrigation projects in the Dakotas goes back to as early as 1939 when Congress directed the Bureau of Reclamation to develop an irrigation plan to provide relief for the drought-stricken states of the Dust Bowl. This plan eventually was integrated with a plan developed by the Corps of Engineers to control flooding in the Missouri Basin. Combined, the plan became known as the Pick-Sloan Missouri Basin Program. In addition to benefits from irrigation and flood control the Pick-Sloan Plan provided benefit from hydro-electric power, navigation, recreation and fish and wildlife. Several projects materialized out of the Pick-Sloan Plan in both North and South Dakota. We are now near the center of one of these projects, the Garrison Diversion Unit. The paper will discuss a project that was a spin-off of another project authorized under Pick-Sloan Plan in South Dakota, the Oahe Unit.

Construction on the Oahe Unit was initiated in 1974 and it was terminated in September of 1987 because of the lack of local support stemming in part from environmental concerns with the project, and objections from those outside the project area to having some of their lands condemned for wildlife mitigation.

CENDAK IRRIGATION PROJECT

In the fall of 1980, when it became apparent that the Oahe Unit would not be constructed, leaders in six South Dakota counties lying between the Missouri and James Rivers in the Central South Dakota region began

to contact land owners to determine the interest in developing a multi-purpose project. The farmers in each of the six counties formed an organization to pursue that effort and CENDAK Water Supply System, Incorporated, was formed. Using local funds collected from the county organizations and from land assessments on nearly 400,000 acres of land of which land owners expressed an interest to irrigate, studies were conducted by consulting engineers working for CENDAK. These studies, reviewed by Reclamation, showed that feasibility studies were warranted. In 1982, Congress authorized studies to determine the feasibility of alternative uses of the uncompleted facilities of the Oahe Unit. The Bureau of Reclamation/State/ CENDAK studies of the economic, engineering, environmental aspects resulted in a planning report/draft environmental statement, which was released in 1986.

The CENDAK study was unique in several respects: It was the result of a grassroots effort to seek water development in Central South Dakota; funds were obtained from interested land owners to pursue initial studies; and it was studied cooperatively by the Bureau of Reclamation, U.S. Fish and Wildlife Service, South Dakota Department Game and Fish, South Dakota Department of Water and Natural Resources and CENDAK Water Supply System, Inc. which was represented by the consultants Bookman-Edmonston Engineering, Inc. It had been proposed from the start that CENDAK Project would be a replacement for the terminated Oahe Unit. The uncompleted features of the Oahe project would be utilized by the CENDAK Project. The main purpose of CENDAK Project would be to provide project water for sprinkler irrigation to those landowners with desires to develop irrigation to stabilize feed supplies for the livestock industry of the state. The source of the water for the project would be Lake Oahe, behind the Oahe Dam near Pierre, South Dakota. The irrigated area of 474,000 acres would be disbursed throughout a gross area of 2.5 million acres located in the six county area lying from Pierre and the Missouri River eastward to the James River near Heron, South Dakota, a distance in excess of 100 miles.

The primary benefit of the firm water supply was to supplement precipitation for 474,000 acres which would provide greater stability to the economic and social conditions in Central South Dakota. Wildlife would enjoy benefits from assured water supplies, food, and cover. The plan also proposed that a wetland trust would be established to fund Wildlife habitat enhancement.

Even though studies found the CENDAK Project to be economical and financially feasible, objections to the size of the project grew and opposition developed for reasons beyond the scope of this paper. In 1988, CENDAK Water Supply Systems Inc. requested a rescoping report be prepared on reducing the size of the project from 474,000 acres to 300,000 acres. At the same time, an alternative financing program was developed for a locally constructed project which provided a reduction in the total cost of 30 percent. Unfortunately even the rescoped project did not moved forward due to a building up of resistance in Congress and among the environmental community to large scale federal water projects.

WILDLIFE AND WATERFOWL ENHANCEMENT

With that as some background, let me discuss some of the opportunities that were lost to the wildlife and waterfowl enhancement potential. The local sponsors of the CENDAK Project recognize that the construction and operation would preserve and offer significant potential for the enhancement of wildlife habitat. As mentioned earlier the principal purpose of the project was to stabilize livestock operation. The current conditions were and still are resulting in the instability of livestock operations and was forcing land owners to convert to grain production and the consolidation of farming operations. This consolidation meant that existing wildlife habitat along fences and homesteads would disappear. The stability of the livestock operation would allow many of these fences and homesteads to remain. The benefit of bringing water into this area would provide major opportunities for wildlife and waterfowl enhancement in addition to the mitigation required to offset losses due to project construction. There would be numerous opportunities to enhance and create wetlands particularly in the drought years and even the unenhanced wetlands would benefit because land owners would not need to graze or cut them for the limited amount of cattlefeed in drought years.

ON-FARM MITIGATION

The local sponsors prepared a rather unique on-farm mitigation program for wildlife habitat. The sponsors believe that each water user should be responsible for mitigating his net wildlife habitat losses resulting from irrigation. The concept was that each water user would be responsible for providing mitigation measures on his farm or by participating in a

pool for wetland or woodland habitat losses on his irrigated land. Mitigation for predominately unavoidable habitat losses on cropped tame grass and native grass converted to other irrigated crops would be shared by all water users in relation to the amount of irrigated acreage. The local district would establish a pooling program for water users unable to provide on-farm mitigation sites through which payments would be made by such water users for wetlands and woodland mitigation obligations. Water users land devoted to mitigation measures would remain in private ownerships for the mitigation plans and conditions duly recorded with the county recorder as a continued obligations. Mitigation obligations of the water users would be incorporated in a water service contract between the water users and the local district. Non performance would be a basis for remedial measures including termination of water service. Finally, the local districts obligations to implement, maintain, monitor and enforce on-farm mitigation would be incorporated in the water service contract with Reclamation.

WETLAND OPPORTUNITIES

A study conducted by the U.S. Fish Wildlife Service in the CENDAK Project area identified in detail, some of the possible opportunities existing in South Dakota to help reverse the trend of declining populations of waterfowl. Critical population levels of many duck species were evident in 1985, when the U.S. Fish and Wildlife continental duck breeding survey recorded the lowest number of ducks in a 31 year survey history.

Many factors beyond the scope of this paper are responsible for the declining number of waterfowl at this point of history. The federal government has long recognized that waterfowl production is a very important wetland value and has developed policies to discourage wetland draining and filling, but the loss of wetlands continued. It was recognized that some federal irrigation projects would have the potential to provide a source of water that could be used to stabilize and increase the size of wetlands where waterfowl habitat is severely limited. Some irrigation projects might cause additional loss of acres of wetlands through the development but properly planned wetland enhancement opportunities from these projects would be possible once the unavoidable wildlife impacts of the projects have been totally compensated. It appears that in some areas, waterfowl production is limited by inadequate brood rearing habitat, even though there might be abundant breeding pairs

and nesting habitat present. The development of more permanent wetland for brood rearing in these areas through such practices as the construction of suitable ponds, development of island complexes, and provisions of supplemental water, can provide for dramatic increases in waterfowl production. Providing supplemental water supply can be particularly effective in areas in where brood rearing wetlands are in short supply and temporarily flooded wetlands with management potential are abundant. This obviously would be specially so during drought years when brood rearing habitat is critical. Generally, the additional sources of water are not readily available for such purposes.

DETAILED STUDIES

The U.S. Fish and Wildlife Service addressed the potential for bringing water through the CENDAK Project in order to develop brood rearing areas in the Project's central and western counties where wetlands are generally limited and where temporary wetlands suitable for water management are plentiful. The U.S. Fish and Wildlife Service identified in their 1986 study opportunities for wetland and wildlife enhancement in three central and western counties within the CENDAK Project area. The wetlands were screened and those that it appeared would benefit from supplemental water were identified and mapped. Criteria for selection included wetland size and wetland proximity to irrigation canals. Generally, larger wetlands were chosen because they would provide the best brood rearing habitat and a lower development cost than small wetlands. Through this three county area, approximately 40,200 acres of wetlands, were selected. It was recognized that this selection of potential wetlands should be just considered as a pool from which could be developed a waterfowl enhancement program, recognizing that considerable work could be required before individual wetlands could be actually selected for the plan.

As part of the overall wetland enhancement opportunity study, the U.S. Fish and Wildlife Service looked at four specific wetland areas, selecting from the potential pool of available wetlands. Potential costs associated with the selected wetland waterfowl management could be applied to other wetlands in the pool as well. The wetland areas were representative of the limitation of the waterfowl habitat in the three county Central South Dakota area. The U.S. Fish and Wildlife Service used a mallard production simulation model which was developed at the Northern Prairie Wildlife Center to evaluate the effects of the supplemental water

management, upland nesting cover management, and development of islands for nesting purposes on waterfowl production in the wetland areas.

The evaluations were based on three management actions building on each other, to increase the brood rearing habitat. The first management action was basically to provide additionally good quality water to the existing wetlands. Water permanence would be increased from the present wetlands classifications (temporary or seasonally flooded) to semi-permanently flooded areas. Wetland areas would remain the same size and all the other land use conditions would remain on the same base line. The second management action looked at the management of the upland areas to produce better nesting habitat. The third management action adds the development of nesting islands in the wetlands to the water and to the upland management actions.

The results of the model simulation predicted large increases in the mallard reproduction rates for all four areas under the management actions. The water management action alone, according to the U.S. Fish and Wildlife Studies, could be expected to produce an increase in recruitment rate for the four areas ranging from 530 to 660 percent greater than present recruitment. Equally outstanding and surprising increases in young produced over the present conditions were documented in the study. The water management action alone produced a 5 to 28 fold increase in young produced over present conditions. Although the other two management practices of upland nesting cover and island development also produces potential increases in production, those increases were not as great as provided by additional water.

BENEFITS AND COSTS

No water project would be complete without looking into some of the benefits and cost of the management actions. Obviously the on farm mitigation costs were to be achieved through the efforts of the farmers in order to receive the benefits of the additional water to the farms. This was not to be a project cost and the benefits from mitigation would offset any losses that would incur in project construction.

The estimated costs associated with implementing waterfowl management procedures evaluated by the mallard model at the four wetland areas provided an idea of what similar development at other wetland sites in

the three county area could be. Costs per wetland acre for Management Action I ranged from \$86 to \$108. For Management Action III the total costs ranged from \$155 per wetland acre to \$680 per wetland acre. Acquisition costs were the most expensive element of each development plan. Where a large proportion of the wetland is already in public ownership this item would be minimized. Alternatives to fee title would reduce the cost of developing enhancement areas. Federal cost sharing could be available if the enhancement was included as part of a Federal Water Project.

The enhancement benefits due to implementing wildlife management procedures, unfortunately, are not described in dollar and cents terms. The study concluded that wildlife recruitment rates from the water management action only would be increased as much as 660 percent compared to present conditions and production of young could be increased up to 28 times the present condition. The upland nesting cover and island development actions would also produce substantial increase in production.

As a indicator of outside interest for this type of enhancement from water projects, Ducks Unlimited stated in a letter to U.S. Fish & Wildlife Service, dated March 26, 1985, that it would be inconceivable that the CENDAK Project would not contain many waterfowl enhancement projects and that Duck Unlimited would be interested in participating in such a program when the CENDAK Project is in operation.

CONCLUSIONS

In concluding, while recognizing that some water projects may have contributed to the reduction of wildlife habitat. It can be shown that properly designed projects which take into account wildlife and waterfowl enhancement opportunities could go along ways towards reducing the decline in wildlife and waterfowl in the Northern Great Plain area. It is almost inconceivable to think that bringing water into an area for irrigation and agriculture use could not also be used to enhance wildlife and waterfowl habitats. There has been many opportunities lost through the failure to develop irrigation in Central South Dakota and these opportunities are not only related to the agriculture communities, the municipal and industrial users but also to environment enhancement.

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CONCEPTUAL PLAN FOR THE
TURTLE LAKE IRRIGATION AND WILDLIFE AREA

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ABSTRACT

The Turtle Lake Irrigation Area (TLIA) is located in near the town of Turtle Lake in central North Dakota. The TLIA is adjacent to the McClusky Canal, a project feature of the Garrison Diversion Unit (GDU), which transports Missouri River water into the area. The GDU Reformulation Act of 1986 authorized the development of 13,700 acres (5,500 hectares) of irrigation in the TLIA.

The conceptual plan presented in this paper is the first step in a process to develop a water delivery project, which places equal emphasis on wildlife, irrigation and economic development in the Turtle Lake area of North Dakota. The planning process and the conceptual plan emphasize sharing of wildlife and agricultural benefits on the same parcels of land, avoidance of environmental impacts, development of wildlife and agriculture enhancement features, and on-site mitigation. The process and concepts are unique relative to normal project-planning efforts and project features.

The plan is the result of a cooperative effort by local landowners, with assistance from an interagency planning team, comprised of federal, state and local agencies to envision a multipurpose water development project. The project has not been developed as of 1996; however, planning and implementation efforts are proceeding.

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INTRODUCTION

General

The Turtle Lake Irrigation Area (TLIA) is located in McLean County near the town of Turtle Lake in central North Dakota (Figure 1). The TLIA is adjacent to the McClusky Canal, a project feature of the Garrison Diversion Unit (GDU), which transports Missouri River water into the area.

This paper presents an innovative, conceptual, and integrated land-use development plan which enhances the Turtle Lake area for wildlife, irrigated agriculture, and economic development (Figure 2). The plan recommends development by a combination of groundwater management, use of Missouri River water from the already completed McClusky Canal, and land management practices. Please see Reference 1 for more details of the conceptual plan.

Agriculture and wildlife coexist at all levels in North Dakota. However, extensive agricultural development, while increasing the food base for some species of wildlife, is often at the expense of wildlife habitat. Conversely, increased wildlife production in an area can result in problems for landowners. For example, increased crop depredation, loss of production on lands dedicated to wildlife habitat, and potential trespass and property damage problems may occur as a result of increased wildlife populations.

Development of the TLIA allows a unique opportunity for utilizing land for its best suited and most easily developed purpose. Proper planning, design, and construction practices will permit development of a balanced project. Lands that lend themselves to irrigation development, with minimal effect on wetlands and other habitats, would be developed for that purpose. Lands requiring extensive modification to allow for successful irrigation would be used for other purposes such as wildlife habitat and/or dryland farming. This plan was prepared as a cooperative effort to determine the advantages which might be realized by including wildlife, recreation, and irrigation as **equal partners** in area development planning and thus enhancing irrigation development in North Dakota.

Factors Affecting Traditional Irrigation Development

It is felt that the location of the TLIA, combined with the implementation of the concepts included in this plan, will address and alleviate many of the following issues which affect traditional irrigation development on other portions of the GDU and North Dakota:

- The TLIA lies entirely within the Missouri River basin, therefore, development will not impact Canada.
- Two national wildlife refuges (NWRs) are associated with the TLIA. Audubon NWR is impacted by current GDU operations, and efforts are underway to mitigate those impacts. Development of the TLIA would not cause additional impacts to Audubon NWR or Lake Nettie NWR located within the boundaries of the TLIA. Some enhancement features are included for the Lake Nettie NWR.
- Off-site mitigation for wetland impacts requires purchase of four acres of land for each wetland acre lost. Experience, to date, indicates acquisition and development costs of approximately \$800 for each acre (\$324 per hectare) purchased in addition to a continuing O&M cost of \$13 per acre (\$5 per hectare).
- In October 1990, the cost for off-site mitigation for potential wetland impacts in the TLIA was estimated at \$7,656,000. Most of these costs would be eliminated if development would proceed as recommended in the Conceptual Plan.
- A goal of the Conceptual Plan is to eliminate the need for off-site mitigation and, therefore, land acquisition which removes land from county tax roles.

THE PROJECT AREA (EXISTING)

Existing project features are described below:

Water Quantity

The Turtle Creek basin encompasses about 310 square mile (80,000 hectares). Turtle Creek is an intermittent stream which was formed by glacial

meltwater erosion and redeposition and normally flows only in the spring from snowmelt and after spring rains. Most of the surface water infiltrates the sand and gravel deposits and is stored in the soil or becomes groundwater.

The quantity of usable groundwater in the Turtle Creek basin is variable. Most of the buried major aquifers are confined or partially confined and often are under artesian pressure. Unconfined water table aquifers near the ground surface are found in most of the glacial outwash deposits in the TLID. Large areas of wetlands are supported by this near surface water table.

Water Quality

The quality of the surface water varies and reflects the amount of seasonal inflow/outflow and the geologic landform. Fresh water is found in areas where there are greater amounts of inflow and outflow and less evapotranspiration. Saline and slightly saline water occurs in closed basins and areas with small amounts of outflow.

The first 21 miles (34 kilometers) of the McClusky Canal, a GDU project feature completed in 1975, are within the Turtle Creek basin. The canal is the major source of water for the uses described in this paper. The quality of the water in the McClusky Canal (600-650 ppm) is excellent for all proposed uses.

Farm Practices

Both livestock and cultivated crops are important to the agricultural economy of the Turtle Lake area. Dryland farming is dominant. About 50 percent of the total farm income in the TLIA is derived from livestock and livestock products, and about 6,000 head of livestock are produced annually. The main dryland crops being grown in the Turtle Lake area are wheat, barley, corn, and hay crops.

Approximately 1000 acres (400 hectares) are currently being irrigated in the Turtle Lake area. About 150 acres (60 hectares) are irrigated with water from the McClusky Canal under temporary water service contracts with the Bureau of Reclamation and the remainder is irrigated with groundwater. Irrigated yields are 2 to 3 times greater than dryland yields.

Wetlands and Wildlife

The TLIA is a glacial outwash area located within the Prairie Pothole Region (PPR) of North Dakota. The average density of wetlands to uplands within the boundary of the TLIA is approximately 14 percent wetlands. Wetlands and wetland complexes are a vital part of the environment and are a link in the continuous hydrologic cycle. Wetlands provide temporary storage of runoff and flood flows which are gradually released either into the atmosphere or groundwater. They are also beneficial to agriculture, especially for animal production and many wetland grasses and sedges annually yield high quality forage for grazing and haying.

Many recreational values are also associated with wetlands. Hunters, trappers, birdwatchers, artists, photographers, cross country skiers, canoeists, and many other people enjoy the benefits of wetland complexes, and their activities contribute to the North Dakota economy.

The prairie wetland complex is the most important wildlife habitat in the TLIA. Nearly all wildlife in the area benefit directly or indirectly from this type of habitat. Wetland habitat, with associated uplands, is essential to breeding, nesting, rearing, feeding, and protection of various species of waterfowl, shorebirds, fish, and furbearers (mink, muskrat, beaver). Other upland wildlife which utilize the wetland habitat for food and cover include the white-tailed deer, pheasant, sharp-tailed grouse, Hungarian partridge, raccoon, songbirds, raptors, and fox.

Lake Williams, a 1000 acre (400-hectare) saline wetland, located within a chain of wetlands near the TLIA is a very important wetland complex which has been listed as a natural fall staging area for the California gull, piping plover, Caspian tern, lesser sandhill crane, and whooping crane.

Land Use Summary

Land uses in the TLIA have been divided into two general categories - wetlands and uplands. Please refer to reference 1 for specific details and descriptions of these land uses.

Fisheries

The North Dakota Game and Fish Department (GFD) currently manages Crooked Lake and Brush Lake for sport fishery purposes. Crooked Lake is a 650 acre (260-hectare) lake located 10 miles (17 kilometers) north of the town of Turtle Lake. Fishery investigations in Crooked Lake date back to 1953. The primary species present at that time included northern pike, walleye, yellow perch, and black bullhead.

Brush Lake is a 200 acre (80-hectare) lake, which has a maximum depth of 19 feet (6 meters) and about 12 miles (19 kilometers) of shoreline. The GFD actively manages Brush Lake as a sport fishery for species such as northern pike, walleye, and bluegill. Management is, however, complicated by periodic low lake levels, nutrient loading, and the threat of winter-kill.

In periods of prolonged drought, Crooked and Brush Lakes usually experience drops of several feet in water elevations. This results in winter-kill and destruction of the fisheries. A supply of high quality water, which would be available under the project plan would greatly alleviate this problem.

THE CONCEPTUAL PLAN AND ITS COMPONENTS

The **planning process** itself is unique relative to traditional water project planning efforts in North Dakota and the United States. An interagency planning team was formed to aid in preparation of this document. Representatives of interested agencies and organizations held numerous planning meetings and were involved throughout the study process.

The following statement was agreed upon to describe the group's purpose:

"To formulate and present an innovation, conceptual, land-use development plan which enhances the Turtle Lake project area equally for wildlife, irrigated agriculture and economic development."

The Agricultural Component

The agricultural objectives of the plan are (1) the development of 13,700 acres (5500 hectares) of irrigation to provide opportunities for diversification of farm enterprises and stabilized

production of farm products (2) implementation of BMPs (best management practices) for irrigated agriculture (3) development of subirrigation on approximately 3200 acres (1300 hectares) of land for both agricultural and wildlife benefits, and (4) development of irrigable lands with minimal impacts to wetlands (Figure 3).

The various aspects which will be considered and implemented under the agricultural component include:

- Classification of lands to determine irrigability for various crops and conditions
- Types of irrigation systems (the center pivot is the most popular)
- Implementation of Best Management Practices
- Research related to ongoing practices
- Cultural practices
- Irrigation management
- Fertility management
- Pesticide management
- Extension programs

The Wildlife Component

The wildlife objective for the TLIA is a net increase of wildlife habitat and augmentation of food and water sources in such a manner as to substantially increase wildlife abundance and diversity. The particular objectives for wetlands are to prevent a net loss of wetlands, maintain wetland diversity, enhance existing wetlands, and create and/or restore additional wetlands.

The primary issues which will be considered relative to the wildlife component consist of:

- Identification of wetlands
- Dedication of wildlife lands
- Adoption of wildlife management practices
- Development and Maintenance of wildlife cover
- Identification of practices to provide food for wildlife
- Structural practices
- Agricultural practices which benefit wildlife
- Utilization of available programs to enhance wildlife

Class 4 Lands-The Combined Agricultural/Wildlife Component

Perhaps the most unique feature of this plan is the proposed management of approximately 3200 acres (1300 hectares) of Class 4 lands (see figure 2) for the benefit of both wildlife and agriculture. These class 4 lands are lands that normally have groundwater within 2 feet (0.6 meter) of the ground surface and often contain wetlands. They are designated Class 4, indicating limited irrigation capability, because crops would be limited to hay and pasture. These Class 4 lands are often too wet to provide usable hay or pasture, or too dry to provide high quality waterfowl habitat.

The groundwater management concept would provide water to the wetlands in the spring and early summer, for waterfowl habitat, and would control the water table for improved hay and pasture production in late summer and fall. Water for maintaining wetlands in the spring would be natural waters, plus project water added from the McClusky Canal or the groundwater control system if necessary. Water would be delivered to the wetlands from turnouts along the distribution system, and would flow overland to flood wetland areas to the desired level. The groundwater removed in July, August, and September to control the water table for hay and pasture will be discharged into the water supply system for delivery for irrigation or other uses.

The Fisheries Component

Fishery enhancement features of the project would be largely related to stabilization of water levels. Provision of in stream flows in Turtle Creek from near Crooked Lake to the Missouri River would provide fish habitat and improve fish spawning areas in the creek. The North Dakota Game and Fish Department and cabin owners support the delivery of water to Brush and Crooked Lakes to stabilize water levels and prevent winterkill.

The Recreation Component

The recreational opportunities of the TLIA attract visitors throughout the year for sightseeing, photography, hunting, fishing, and other activities. The Lakes Brekken-Holmes area currently provides many hours of fishing and other recreation. Reclamation and cooperating agencies would coordinate with the

Turtle Lake Park Board to identify additional development opportunities in the Brekken-Holmes area.

Improvements such as improving access, parking areas, boats ramps, rest rooms, picnic, fishing piers, and boats ramps would be developed and installed.

The Project Features

The conceptual plan of development includes the delivery of water to irrigate 13,700 acres (5,500 hectares) of land, wildlife and fisheries enhancement, and stabilization of certain lakes and streams for recreational purposes. The objectives can be accomplished by the construction of a series of pumping plants, open channels, pipeline distribution systems, horizontal well/pipe drain systems, low-head dikes, and screening facilities. The source of water for the project will be Audubon Lake (Missouri River).

Economic Analyses

No economic or financial analyses have been completed at this time; however, it is anticipated that the preliminary economic feasibility study, comprehensive economic feasibility study and financial analysis will be completed during the next phase of this study.

The Development Sequence

Most of the project area can be divided into three blocks, each served by an individual distribution system and intake from the McClusky. Each block includes both irrigation and wildlife features. It is recommended that development take place by blocks and by farm units within the blocks. This would provide an opportunity to demonstrate and evaluate the effectiveness and benefits of irrigation and wildlife enhancement features. It would also allow adjustments to be made to project features as development proceeds, and would allow time for landowner to become familiar with benefits of various project features.

FINDINGS AND RECOMMENDATIONS

Findings and Recommendations

The interagency planning team agreed upon the following findings and recommendations:

- A project can be formulated which would develop irrigated agriculture in the TLIA and, at the same time, enhance wildlife, fish, recreation, and regional economic growth. Additional cost estimates, cost allocations, economic analyses, and financial analyses need to be completed.
- Development within each of three blocks should proceed by farm unit based on landowner interest. Development by blocks, and by farm units within individual blocks, would provide an opportunity to demonstrate and evaluate the effectiveness and benefits of irrigation and wildlife enhancement features. It would also allow adjustments to be made to project features as development proceeds, and would allow time for landowners to become familiar with benefits of various project features.
- Formation of an interagency planning team allowed an earlier and greater public involvement in the planning process and proactive rather than the traditional reactive agency participation.
- Project development would result in greater use of existing GDU features. Additionally, development of the wildlife enhancement features would complement existing public wildlife areas in the vicinity.
- Implementation of the TLIA Conceptual Plan would result in an increase in wildlife habitat and habitat management capabilities, and an increase in agricultural productivity and diversity.
- The plan recommends formation of an Irrigation and Wildlife Advisory Team (Advisory Team), with federal, state, and local representation. This Team, in consultation with the Soil Conservation Service, would work with landowners who have direct significant input to develop wildlife and irrigation plans for individual farm units.
- Mitigation is proposed to be accomplished by avoidance and by on-site mitigation features within the TLIA. This eliminates the need for acquisition and development of lands in other areas of North Dakota for mitigation.
- Avoidance of impacts would be accomplished, in part, by managing the groundwater table on

approximately 1300 hectares of Class 4 lands for the benefit of both agriculture and wildlife.

- Horizontal well and drain systems would be used to manage the groundwater in conjunction with surface water from the project supply system to maximize water use for the benefits of both wildlife and agriculture. The open canals provide a means to deliver water to the project areas, deliver and store water for wetland habitat, control the water table, and remove excess water during wet periods.
- Best Management Practices for irrigated agriculture would be developed for the TLIA and implemented through a cooperative Advisory Team.
- Recreation and fisheries benefits would be derived from stabilization of Brush and Crooked Lakes. Joint use of supply systems will increase efficiency by utilizing the system during off-peak periods to provide water to Crooked Lake. The pipeline constructed to supply water to Brush Lake could potentially deliver water to hundreds of acres of wetlands along the pipeline route in dry years.
- Water would be delivered to the Lake Nettie NWR and plans are to develop a long-term water management plan for Lake Williams, which is part of a large saline wetland complex that supports the United States largest concentration of piping plovers, a threatened species.

CONCLUSION

The TLIA Conceptual Plan discusses multi-use water resource development and utilizes concepts which have been implemented on a somewhat fragmented basis under traditional development. This comprehensive approach envisions optimum benefits for irrigated agriculture, wildlife and economic development within the project, including mitigation. The economic analysis procedures for this project will be similar to those normally used by Reclamation and other federal agencies in the United States. It is expected that a favorable benefit cost ratio will result from such a study since mitigation, recreation development and drainage costs will be lower than in traditional irrigation projects.

Although this concept has not been implemented in the United States as a whole, it is believed that optimum benefits can be achieved and perhaps, more importantly, it appears to be a more acceptable approach to future water resource development.

REFERENCES

Bureau of Reclamation et al, September 1993, "Turtle Lake Irrigation and Wildlife Area" U.S. Department of the Interior, Bureau of Reclamation.

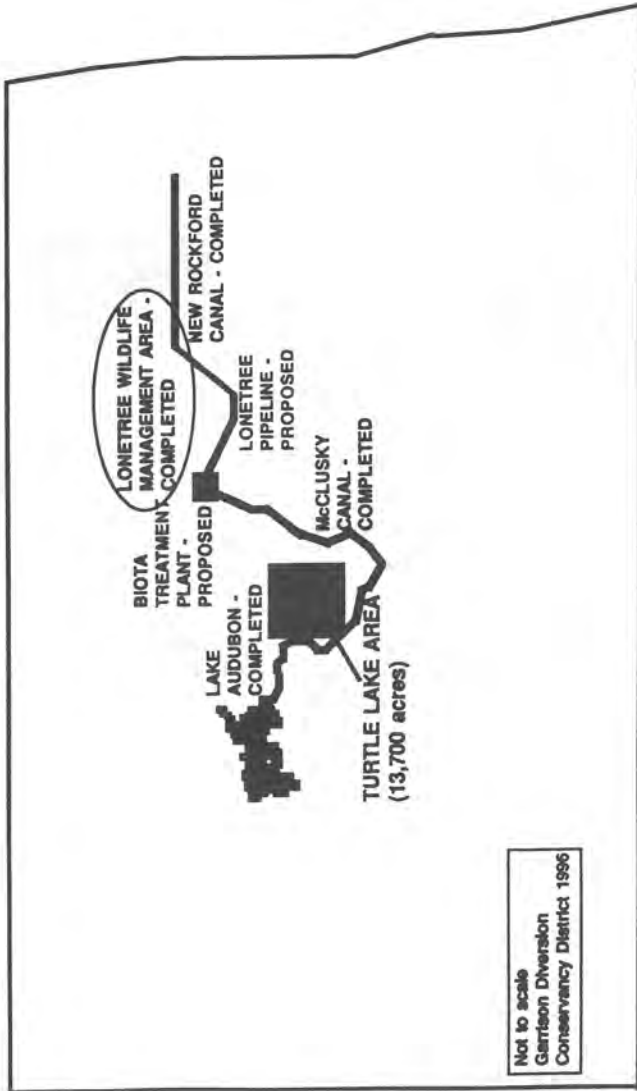


Figure 1. Map of North Dakota showing the Garrison Diversion Unit and the Turtle Lake Irrigation Area

Turtle Lake Irrigation Project Area

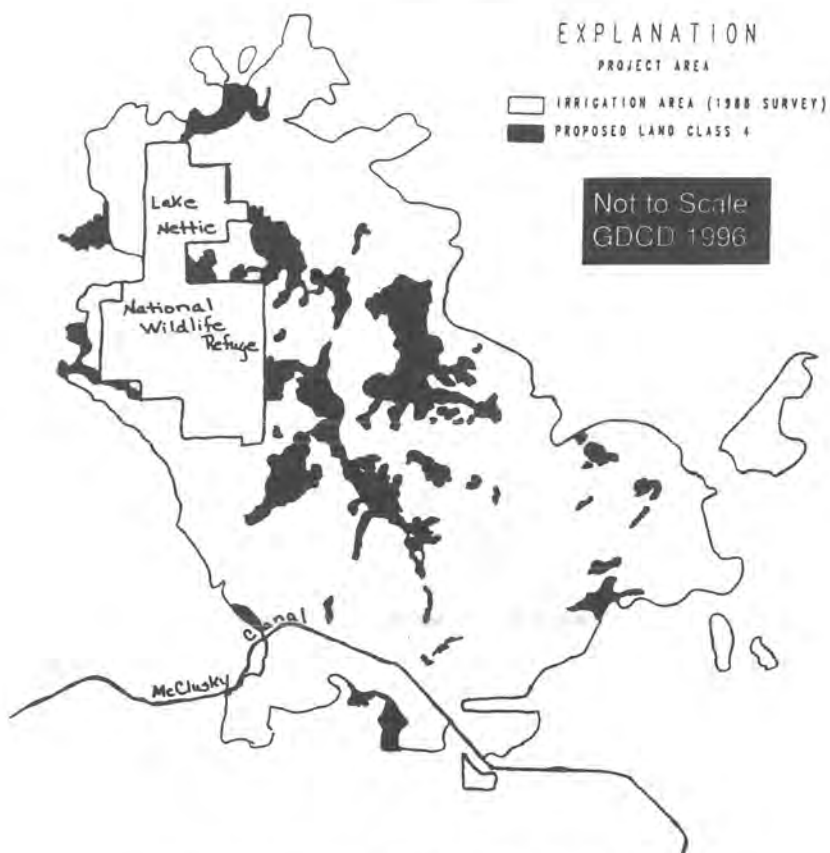


Figure 2. Project area of the Turtle Lake Irrigation Area showing proposed irrigation and Class 4 areas



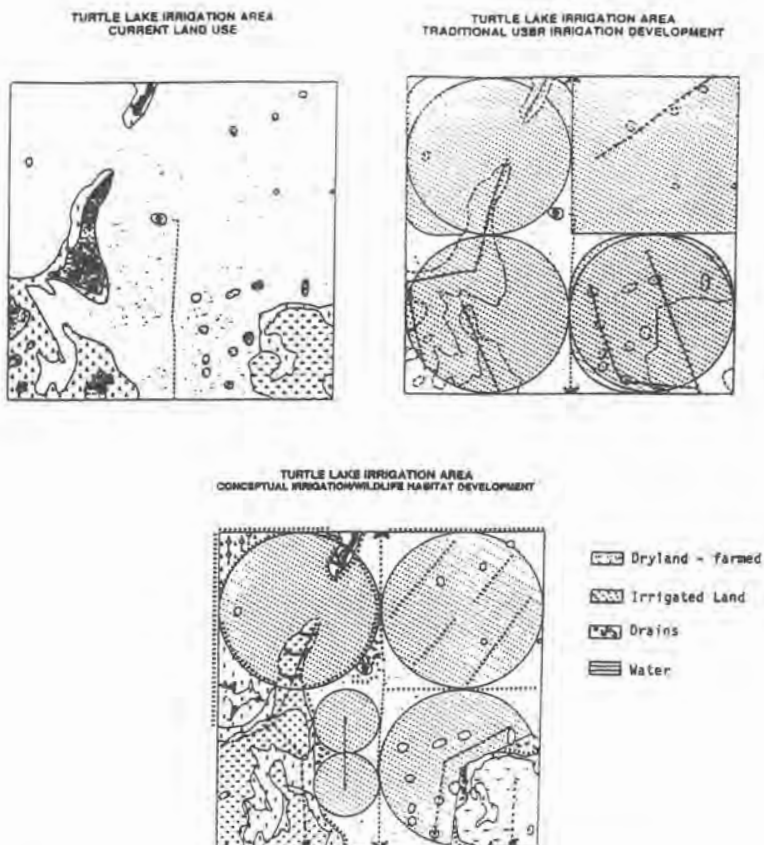


Figure 3. Comparison of impacts to wetlands from development of irrigable lands

AGRICULTURE AND WILDLIFE IN CALIFORNIA'S CENTRAL VALLEY: MUTUALLY EXCLUSIVE OR WIN-WIN?

Michael A. Bias¹ and Jack M. Payne²

ABSTRACT

Because of the importance of California's Central Valley and private lands to waterfowl, Ducks Unlimited (DU) increased its conservation effort on private lands in 1990. This private land effort, delivered from DU's Western Regional Office in Sacramento, is known as Valley CARE (Conservation of Agriculture, Resources, and the Environment). Valley CARE emphasizes agricultural enhancement and wetland restoration and enhancement conservation efforts among the three geographically distinct areas of the Central Valley: the Sacramento Valley, the Sacramento-San Joaquin Delta (Delta), and the San Joaquin Valley. From surveys conducted by DU of water districts in the Sacramento Valley, during 1993-94, rice growers winter-flooded at least 90,000 acres (36,423 ha) of harvested rice fields; during 1994-95, winter-flooded rice acreages increased to over 140,000 (56,658 ha); and during 1995-96, at least 100,000 acres (40,470 ha) of harvested rice fields were winter-flooded. DU also works with farmers in the Delta to winter-flood harvested corn and wheat for shorebirds, swans, geese, ducks, and other waterbirds. Cooperating landowners contributed nearly 17,000 flooded acres (6,880 ha) during 1994-95 and about 16,000 acres (6,475 ha) during 1995-96 to over 30,000 acres (12,141 ha) that were flooded in the Delta during those years. The expected agronomic values and economic benefits of agricultural enhancement appear to be as high as expected and the biological values are substantial. Close to 30% of all waterbirds using rice fields are non-waterfowl species and half of these are shorebirds. DU also has expanded the Valley CARE effort in the Central Valley to establish a series of permanent wetland restorations and enhancements along with the agricultural systems. This mosaic landscape approach is fundamental to the ongoing management efforts for migratory waterbirds in California's Central Valley. This program's results demonstrate what can be accomplished when private conservation groups and agricultural organizations work together and with traditional government wildlife agencies for the mutual benefit of agriculture and conservation.

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INTRODUCTION

For the past 50 years the primary strategy for dealing with wetland losses and declining waterfowl populations has been to protect wetlands through land acquisition by state or federal agencies. In recent years it has become increasingly obvious that the acquisition strategy can be effective only if it is complimented by strong efforts to maintain wetlands and other waterfowl habitats on private lands (Payne and Wentz 1992). This is especially true in California's Central Valley, where >95% of the historic wetlands base has been lost or modified. Of the 285,000 acres (115,340 ha) of wetlands left in the Central Valley, two-thirds are privately owned and managed for duck hunting (Heitmeyer et al. 1989).

The Central Valley of California is 400 miles (644 km) long, lying between the Coast Range and the Sierra Nevada, and includes the Sacramento Valley, the San Joaquin Valley, and the Delta-Suisun Marsh complex. Historically, the Central Valley contained four million or more acres of natural wetlands and 6,000 miles (9,656 km) of stream, river, and associated riparian habitats. Today, fewer than 300,000 acres (121,410 ha) of wetlands and 950 miles (1,529 km) of riparian woodlands remain (Gilmer et al. 1982). The original wetlands, riparian areas, and associated habitats are known to have provided some of the continent's most important living space for neotropical migrant birds (especially shorebirds and wading birds), unique plants and insects, and a diversity of other wildlife. Today, the remaining wetlands and associated habitats host a number of federal and state listed threatened and endangered species. These wetlands also support large numbers of more common species, but in high densities. If more common species are to avoid declining numbers and endangered species are to maintain viable populations, we must reverse the decline of natural wetland and riparian habitats on which these species depend.

The remaining wetlands in the Central Valley, along with seasonally-flooded and non-flooded agricultural land, support up to 60% of all waterfowl wintering in the Pacific Flyway and 20% of those wintering in the entire U.S. (U.S. Fish and Wildlife Service 1978). Of particular importance, California winters >20% of all mallards, wigeon, green-winged teal, shovelers, canvasbacks, and ruddy ducks; >30% of all lesser snow geese and tundra swans; >50% of all pintails, white-fronted geese, and Ross' geese; >80% of all cackling and Great Basin Canada geese; and 100% of the Aleutian Canada and tule geese in the U.S. No other area in North America is as important for wintering waterfowl; ironically however, no other wintering area has undergone as great a wetland loss. It is apparent that because of limited wetland resources, waterfowl populations have supplemented foods obtained in wetlands with residual agricultural grains. The large waterfowl populations in California from the 1940s through the 1970s could not have been maintained without large areas of small grain crops (Heitmeyer et al. 1989). With only a fraction of the original wetland and

riparian habitat base of the Central Valley remaining, the diversity of migratory birds and other wildlife are dependent on certain types of agriculture, primarily small grains. Improved management of these lands to mimic wetlands could accommodate increased populations of threatened and endangered species, neotropical migrants, and migratory waterfowl.

Today even the farmlands of the Central Valley are under severe threat, exacerbating the problem of loss of natural habitat. The American Farmland Trust has identified the farmlands of California's Central Valley as the most threatened agricultural region in the United States (American Farmland Trust 1995). However, agricultural lands represent an excellent opportunity to initiate habitat restoration and enhancement efforts and a conservation ethic outside of government preserves (Ratti and Scott 1991).

In recognition of the importance of private lands to waterfowl in California's Central Valley, DU increased its efforts with farmers, ranchers, and private duck clubs in 1990. These efforts are designed to assist the private landowner's objectives, be they agricultural or wildlife, in addition to enhancing and restoring waterfowl habitat. This program, delivered from DU's Western Regional Office in Sacramento, is known as Valley CARE (Conservation of Agriculture, Resources, and the Environment).

VALLEY CARE - SPECIFIC OBJECTIVES AND PURPOSES

With support from the National Fish and Wildlife Foundation, The Hofmann Foundation, the California Wildlife Conservation Board, and others, DU's Valley CARE Program helped to provide solutions to many of the wetland conflicts that exist in California's Central Valley. Valley CARE enhances, protects, and restores wetlands on private land; adds to the public wetland base; enhances agricultural lands for a diversity of wildlife; provides education for a broad range of the public; and establishes new partnerships among the agricultural community, businesses, public agencies, and other conservation organizations.

Valley CARE focuses its conservation efforts on the three geographically distinct areas of the Central Valley: the Sacramento Valley, the Delta, and the San Joaquin Valley. Within each of these areas our primary efforts towards the private landowners are 1) agricultural enhancement, 2) wetland restoration and enhancement, and 3) communication and education. Valley CARE's goals for agricultural enhancement and wetland restoration and enhancement are based upon the goals of the Central Valley Habitat Joint Venture (CVHJV) Implementation Plan (CVHJV 1990). Throughout the nine basins of the Central Valley, CVHJV goals for agricultural enhancement through winter flooding of harvested agricultural fields is 249,215 acres (100,857 ha).

Wetland enhancement and restoration goals for the Central Valley total 411,555 acres (166,556 ha) (CVHJV 1990).

AGRICULTURAL ENHANCEMENT

Sacramento Valley

The Sacramento Valley of California is the major rice-producing area of the State. Rice has been an important crop in California since 1912 (Gilmer et al. 1982). Total rice base in the Sacramento Valley is about 600,000 acres (242,820 ha). Rice planted in the Sacramento Valley averaged 403,900 acres (163,458 ha) from 1981 to 1994 (California Department of Food and Agriculture, unpubl. rpts.).

After rice growers harvest the grain in the fall, they are faced with managing rice straw residue (up to 4 tons/acre [16,368 kg/ha]) in preparation for the following year's crop. The straw must be disposed of prior to planting to avoid a variety of seedling establishment and other agronomic problems. Rice straw is high in silica and other components that make it difficult to decompose, unlike the straw of wheat or other small grains. Burning historically has been the principal method of rice straw disposal; it is efficient, effective, and inexpensive. However, rice straw burning is being phased out in the Sacramento Valley under the Rice Straw Burning Reduction Act of 1991. Began with a 10% reduction of burning in 1992, burning will be banned or greatly reduced by 2000. As burning is being phased out, alternative methods of disposal must be found (Wrynski et al. 1995).

Because an average 346 lbs/ac (388 kg/ha) of rice seed remains in unburned fields after harvest (Miller et al. 1989), rice lands offer a unique opportunity to provide supplemental wintering habitat for many species of waterbirds. Research efforts to date have shown that there are substantial benefits to a broad variety of wildlife from the winter-flooding of rice lands. DU is involved in a wide-scale effort with rice growers, resource agencies, agricultural commodity groups, and other conservation groups to develop methods to winter-flood, in a proper manner, harvested rice fields (Payne et al. 1995).

Working with rice farmers, DU recently pioneered the use of rolling, crushing, and flooding rice stubble and straw as an alternative to burning the straw. Initial tests and operational practices demonstrate that the new practice is accomplishing the objectives of the rice grower to decompose waste straw, control weeds and disease, and provides winter habitat and food sources for waterbirds. The practice of rice straw rolling is proving cost effective in comparison to alternative agronomic methods, which do not have the same

wildlife benefits. The practice also eliminates air pollution created by the practice of burning, which is now tightly regulated (Wrynski et al. 1995).

In response to the Rice Straw Burning Reduction Act, some evidence exists that acreage estimates of winter-flooded rice fields have been increasing. Harvested rice fields in private duck club ownership are usually reflooded in the fall for waterfowl hunting. Some landowners lease their fields for hunting (Gilmer et al. 1982). During the late 1970s about 79,000 acres (31,971 ha) of harvest rice fields were flooded for waterfowl hunting (California Department of Fish and Game 1979). Winter-flooded rice acreages estimated from surveys conducted by DU of water districts in the Sacramento Valley have shown that during 1993-94, and the first year of the Valley CARE Program, rice growers in the Sacramento Valley winter-flooded about 90,000 acres (36,423 ha). During 1994-95, winter flooding of rice increased to over 140,000 acres (56,658 ha), with Valley CARE staff providing direct technical assistance to growers on 76,876 acres (31,112 ha) of rice ground (Ducks Unlimited 1995, Payne et al. 1995). During 1995-96, at least 100,000 acres (40,470 ha) of harvested rice fields were winter-flooded.

However, these survey estimates showing continued increases since the burning ban went into effect may be imprecise. Spell et al. (1995) used recent Landsat Thematic Mapper (TM) scenes of the Sacramento Valley to determine the change in winter-flooded rice fields between 1988 and 1993. Their results indicated that 133,000 acres (53,825 ha) of rice fields were flooded during the winter of 1988/89 and 142,000 acres (57,467 ha) were flooded in 1993/94. Currently, work is being conducted to use TM scenes from other years and months to determine if winter-flooding of rice fields has increased or the results of Spell et al. (1995) were an artifact of rainfall events prior to the acquisition of the TM scenes used in their study.

Many of the rolled, winter-flooded fields were developed as Valley CARE demonstration sites. Staff from DU and cooperating agencies and agricultural commodity organizations conducted field days and ranch tours for rice farmers, environmentalists, and others, who have interests in this approach. Cooperating groups included several Resource Conservation Districts, County Farm Bureaus, the Natural Resources Conservation Service, the California Rice Industry Association, as well as other organizations. DU provided funds, technical assistance, advice, and equipment to help create this landscape-scale change.

Using other funds (primarily from the U.S. Bureau of Reclamation), the University of California at Davis, National Biological Service, California Waterfowl Association, and the Point Reyes Bird Observatory (all under contract to DU) are conducting basic research into the biological and agronomic values and problems associated with the practice of winter flooding. Approximately \$2 million will be invested in this research effort by the

conclusion of the studies (Payne et al. 1995).

Delta

The Delta encompasses the mid-portion of the Central Valley from Sacramento south to the Stanislaus River. The Delta was historically one of California's most significant waterfowl areas. Reclamation and development (i.e., agricultural, residential, and industrial) have eliminated wetlands from most of the region. Private duck hunting clubs consist primarily of post-harvest flooded corn fields. The major agricultural crops grown in the Delta are corn, winter wheat, tomatoes, sorghum, alfalfa, pasture, orchard fruits, and grapes (CVHJV 1990).

The Delta and adjacent Suisun Marsh are also focal areas for the Valley CARE Program. DU has worked with farmers in the Delta to winter-flood harvested corn and wheat fields for neotropical birds (especially shorebirds), swans, geese, ducks, and other waterbirds. Cooperating landowners contributed nearly 17,000 flooded acres (6,880 ha) during 1994-95 (Payne et al. 1995) and about 16,000 acres (6,475 ha) during 1995-96 to over 30,000 acres (12,141 ha) that were flooded in the Delta during those years. Our long term goal in the Delta is to establish a growers' management group that will continue this practice over the long-term with limited outside involvement.

Winter-flooding of Delta lands provides benefits to substantial numbers of migratory birds as well as private landowners. The practice provides winter water and food for waterbirds and it assists the farmer by slowing or preventing erosion and land subsidence, preventing weed growth, and reducing soil salinity. Valley CARE biologists provide guidance on timing, depth, and duration of flooding and other management techniques through formal planning with the landowner. Direct assistance also is provided through redesign of water delivery structures and other engineering services provided by DU engineers.

San Joaquin Valley

The San Joaquin Valley is another of the three focal areas for the Valley CARE Program. The San Joaquin Valley includes the Grasslands Area and the Tulare Basin. Historically, more than one million acres (404,700 ha) of seasonal and permanent wetlands were located in the San Joaquin Valley. Today <5% of the original wetland base remains with private ownership representing >70% of the remaining wetlands. Resident and migrant waterbirds depend on these wetlands for survival and declining populations can be attributed to the lack of available wetland habitat (U.S. Fish and Wildlife Service 1978).

Agriculturally-based enhancement projects are at a premium in the San Joaquin Valley. Valley CARE's initial effort in the San Joaquin Valley has focused on livestock grazing within the existing wetland ecosystems, but future emphasis on the surrounding agricultural community should provide additional opportunities for agricultural enhancement. Increased presence in the region will help gain better understanding of the difficulties this region faces. Lack of water and "wildlife unfriendly" farming are the two most critical factors affecting enhancement or restoration activities. Future work will include working on proper water utilization and developing a working relationship with local farmers. Currently, we are working with rice farmers in the Grasslands Area to provide winter-flooded rice fields and cotton farmers in the Tulare Lake area of the Tulare Basin to develop winter-flooded wheat and safflower fields within their cotton farming rotations.

"More Than Ducks"

The expected agronomic values and economic benefits of winter-flooding harvested small grain fields appear to be as high as expected and the biological values are substantial (Ducks Unlimited 1995). The results for migratory bird use of rice fields are very revealing. Winter-flooded rice fields are not only valuable for waterfowl but also neotropical migrants, wading birds, and shorebirds are just a few of the non-waterfowl species that benefit from the supplemental habitat promoted on agricultural areas (Payne et al. 1995).

In bird-use surveys conducted by Point Reyes Bird Observatory of wetlands in the Central Valley, rice fields held a substantial portion of all shorebirds surveyed at all times of the year. During the winter period, when cooperators were actively flooding rice lands, rice fields in the Sacramento Valley held 68% of all shorebirds surveyed. Of the total shorebirds, 85% of the dunlins, 70% of the dowitchers, 70% of the killdeers, 67% of unidentified small sandpipers, 53% of the yellowlegs, and 31% of the least sandpipers were found on flooded rice fields (Page et al. 1994).

In bird-use surveys conducted by the National Biological Service of both dry and flooded rice fields, 30% of birds using rice fields were non-waterfowl species. Of these, half were shorebirds. Of shorebirds, 75% were composed of dunlins and long-billed dowitchers. Sandhill cranes, white-faced ibis, and egrets predominated 70% of the wading birds using rice fields. For ducks, northern pintail, American wigeon, and to a lesser extent, mallards and northern shovelers accounted for 98% of the duck species using rice fields. White geese, snow and Ross', comprised over 70% of the geese surveyed with greater white-fronted geese accounting for >23%. Canada geese, mostly cackling Canada geese, which are in need of protection, accounted for about 3%, with tundra swans accounting for <3% of the total geese and swans surveyed (Bias

and Day 1995).

We conducted bird-use surveys of enhanced agricultural fields during 1994/95 in the Delta. Of the total birds counted during 1994/95, ducks comprised 87%, swans comprised 4%, cranes comprised 4%, shorebirds comprised 2%, and coots comprised 2% of the birds using enhanced agricultural fields. Of the ducks counted during 1994/95; 58% were pintails; 27% were mallards; 12% were shovelers; and the remaining 3% was comprised of gadwall, green-winged teal, cinnamon teal, American wigeon, ruddy duck, canvasback, and bufflehead. Of the shorebirds counted during 1994/95; 51% were dunlins; 27% were long-billed dowitchers; 9% were black-necked stilts; 7% were common snipe; and the remaining 6% was comprised of killdeer, long-billed curlew, willets, and greater yellowlegs (Bias et al. 1995).

We changed our survey protocol to include also bird-use of non-flooded agricultural fields during 1995/96 in the Delta. Of the total birds counted during 1995/96, ducks comprised 51%, swans comprised 18%, geese comprised 14%, coots comprised 10%, cranes and shorebirds each comprised 3%, and gulls comprised 1%. Pintails (60%) and mallards (29%) composed the majority of the ducks counted during 1995/96. Dunlins (56%), common snipe (36%), and long-billed dowitchers (6%) composed the majority of the shorebirds counted during 1995/96.

These results reflect the substantial value of enhanced agricultural fields for a broad diversity of wildlife. As the winter flooding practice increases and as we learn more about how to benefit wildlife from this effort, we anticipate the value of the practice will increase; thus, benefitting the continent's wildlife, especially migrant shorebirds and waterfowl.

WETLAND ENHANCEMENT AND RESTORATION

While conservation of waterfowl can be partly accomplished by manipulating factors that affect survival and recruitment (e.g., sport harvest, predator control, nest structures) or working within specific landscape types (e.g., agriculture), long-term solutions that will sustain desirable population levels of waterfowl must focus on protecting and restoring ecologically functional habitat complexes (Ducks Unlimited 1994). Therefore, Valley CARE focuses also its conservation efforts on enhancing and restoring natural wetland ecosystems. This mosaic landscape approach is fundamental to ongoing management efforts for migratory waterbirds in the Central Valley.

During 1994, DU's Valley CARE Program enhanced and restored 3,596 acres (1,455 ha) of wetlands among four private properties. Total cost of these projects was \$80,500 with Valley CARE contributing \$40,250. Other

cooperators on these projects were the landowners and the U.S. Fish and Wildlife Service's Partners for Wildlife Program.

Our private wetland enhancement and restoration program increased substantially during 1995. We completed 24 individual projects that affected 8,195 acres (3,317 ha) for a total cost of \$616,900, of which Valley CARE contributed \$116,000. Other cooperators on these projects were the landowners, the U.S. Fish and Wildlife Service's Partners for Wildlife Program, the California Wildlife Conservation Board.

To qualify for restoration assistance through the Valley CARE Program, private land must be enrolled in an easement program and the landowner must sign a long term site-specific agreement with DU in which the Valley CARE investment is protected. The landowner also must agree to follow a management plan, written by Valley CARE staff, which remains in effect for the length of the site specific agreement. Promoting these activities has helped DU biologists develop a positive rapport with the private lands community.

These private restored or enhanced wetlands, restoration and enhancements on federal refuges and state wildlife areas, and remaining agricultural lands are managed to provide year-round habitat for wildlife. Water management on these enhancements and restoration projects attempts to mimic the original, natural wetlands in the Central Valley. The resulting mosaic of habitat types support a greater diversity of species than a strict farming operation that floods seasonally for farming or hunting purposes.

CONCLUSION

The success to date of the Valley CARE Program is substantial. Valley CARE is helping to change the landscape of California's Central Valley and leave a legacy of improved agricultural practices; provide increases of wetland and riparian habitat types; and benefit the continent's neotropical bird, waterbird, threatened and endangered species, and other wildlife populations (Payne et al. 1995). The Program's results demonstrate what can be accomplished when private conservation groups and agricultural organizations work together and with traditional state and federal wildlife agencies for the mutual benefit of agriculture and conservation. Further, the results of this paper show that agriculture and wildlife in the Central Valley of California can be a "win-win" situation.

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WATER FOR AGRICULTURE AND WATERFOWL

Paul M. Bultsma¹

ABSTRACT

Waterfowl need a variety of wetland types along with secure uplands to successfully complete their annual life cycle. This production habitat is used on the Northern Great Plains primarily during the spring and summer seasons. Ducks Unlimited, Inc. (DU) creates and restores various types of wetland habitat for waterfowl depending on the unique characteristics and opportunities provided by the landscape. Diversions from irrigation channels and return flows from irrigated fields are used by DU whenever possible to provide water for developed or created wetland habitat.

DU has completed over 600 projects out of its Great Plains Regional Office since it opened in 1984. In total over 82,000 surface acres of wetland habitat have been restored, created, or enhanced. All of those projects have benefited waterfowl and many other wildlife species, and most of those projects have also provided benefits to other special interest groups. Hay production, livestock grazing, sediment control, domestic water, irrigation, ground-water recharge, and flood control are some of the other benefactors of DU projects.

DU seeks to provide for the habitat needs of waterfowl and at the same time provide benefits to both public and private landowners. It is important to have wildlife habitat developments that are compatible with profitable and sustainable agriculture.

INTRODUCTION

DU is a private, not-for-profit conservation organization whose mission is to help fulfill the annual life cycle needs of North American waterfowl. DU believes that waterfowl conservation must focus on the protection and restoration of ecologically functional habitat complexes or systems, and has designed its programs accordingly. The function of DU's Great Plains Regional Office (GPRO) is to protect, enhance, and restore waterfowl habitat in the Northern Great Plains where a significant number of waterfowl nest during the spring and summer months. The GPRO staff develops habitat in 9 states. Since 1984, over 600 projects have been completed involving over 82,000 acres. The types of

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habitat projects developed vary significantly from state to state as well as within portions of states. The goal is to address the factors limiting waterfowl in any particular habitat complex.

DUCK BIOLOGY

After spending the winter months on wetlands and in flooded grain stubble fields in the southern part of the United States, ducks begin their spring migration back to the breeding grounds on the Northern Great Plains. The birds generally begin to arrive in late March as breeding pairs, and almost immediately commence breeding activity. They quickly search out shallow wetlands that provide ducks the critical territorial space and food resources they need to sustain them through the nesting season. These small wetlands, called breeding pair ponds, warm quickly providing a nutritious bloom of invertebrates required for the special rigors of egg production and incubation. Although many of these wetlands may be considered a nuisance to farming operations, they are vital to fulfilling the life cycle needs of ducks and other migratory birds. A breeding pair pond can be as small as a fraction of an acre in size, and have only a few inches of water in it. Some disappear several days or a few weeks after the soil is frost-free and are called temporary ponds. Other breeding pair ponds may contain water until early to mid-June, and are called seasonal wetlands. In all cases these wetlands fulfill a critical function in the life cycle of waterfowl and other water birds.

The second phase of duck production on the prairies begins with the initiation of active nest building. This may start for some species as early as mid-April. Nesting activity continues throughout the spring with hatching occurring through late July. Although some ducks may continue to use wetlands during the nesting period, the actual nesting sites for most species of waterfowl are located on the uplands. It is during this period of time that female ducks, in addition to their eggs and young, are extremely vulnerable to destruction from a variety of predators that destroy nests and sometimes kill the hen. Red fox are especially noted for killing nesting ducks. The hen and her nest are also vulnerable to the many agricultural activities and other uses that may be occurring on the landscape during this time period.

The third phase of duck production is brood rearing. This generally occurs on large, semi-permanent wetlands that have a mixture of emergent and submergent vegetation, along with open water areas. These tend to be larger and deeper wetlands, being up to several hundred surface acres in size. The water depth may exceed 6 feet or more, and will usually last through the summer months until after the young waterfowl are fully fledged. These hemi-marsh wetlands provide the security and food resources necessary for broods to grow and gain flight for the

fall migration. These wetlands usually have other societal values in addition to the habitat provided for waterfowl.

Knowledge of these three phases of basic duck biology, and how this process fits with agricultural practices and other uses on the Northern Great Plains landscape, is important. Understanding both the waterfowl and agriculture cycle enables DU and similar conservation interests to encourage and participate in win-win practices for both agriculture and waterfowl.

BREEDING PAIR PONDS

Pair ponds are developed to attract breeding waterfowl to a landscape that already has good brood-rearing habitat and upland nesting cover. Breeding pairs are often quite territorial during the breeding season. Increasing the number of individual wetlands and surface acres of water, increases the number of breeding pair territories a particular landscape can support. Adding ponds to large grass covered landscapes can significantly increase the number of breeding pairs using that habitat for production. Breeding pairs attracted to a particular landscape by these small ponds subsequently nest in the surrounding upland habitat and when their eggs hatch, hens seek out the available brood habitat in that area.

Pit retention dams and spreader dike systems are often appropriate for breeding pair habitat in areas west of the Missouri River in the Great Plains States. They are generally only constructed where there is readily available brood habitat, and most are on privately owned land.

Pit retention dams with several surface acres can be built with earthen embankments that extend across natural water ways. These created wetlands are limited to watersheds of only a few hundred acres. Natural spillways must exist to accommodate larger precipitation events. These ponds are usually quite shallow, at least at the upper end. In addition to duck use, these small ponds may be designed to benefit the livestock interests also using the same landscape. Ponds can be built with a pit that will store livestock water through summer months most years. This water is available to grazing livestock as they rotate through the pastures, generally having little impact on the waterfowl in the area.

Other types of breeding pair habitat include spreader dike systems. This type of wetland usually has a larger surface area than the pit retention dams. The water depth is shallow and is highly attractive to breeding waterfowl. The spreader dikes are generally located below reservoirs which can often provide the needed brood-rearing habitat late in the summer. The spreader dike systems should be flooded early in the spring to attain the maximum surface acreage and attract the

greatest number of breeding waterfowl pairs. These systems are often designed with water control structures so the cells of water can be drawn down in June to stimulate forage production which can be hayed or grazed by livestock. The spring flooding or irrigation enhances forage production.

Another method for development of breeding pair habitat is to restore small wetlands that have been drained in the prairie pothole region east of the Missouri River. The Conservation Reserve Program (CRP) provided a number of opportunities for restoration of natural basins on previously farmed land. These restorations have been quite simple to construct with only a small amount of soil needed to plug the channels and complete the projects. Landowners with CRP contracts have already agreed to a 10-year period of non-agricultural use of the land, therefore restoring the wetlands has not been in conflict with any agricultural practice.

Similar opportunities exist for landowners entering or returning to livestock production, or those in need of more forage production for their existing livestock enterprises. DU has assisted some landowners who had drained wetlands by plugging the drains and installing water control structures at the same time. The water control structures are closed during the early spring period to create shallow water which functions as territorial space for breeding pairs. After most of the breeding pair activity is completed in June, the water control structures can be opened and the water drained from the wetland. This often amounts to irrigated forage production for the landowner which can be grazed or used for hay production. This type of project is generally only developed where there is adequate secure upland cover for successful nesting and semi-permanent water for brood rearing habitat in the immediate vicinity.

In all of these examples private landowners experience some type of direct benefit from the presence of the wetland. Those values include:

- (1) Water for livestock
- (2) Forage for livestock
- (3) Drought insurance for livestock operations
- (4) Groundwater recharge
- (5) Floodwater retention

DU has participated in other types of wetland development for breeding pairs on public land. These developments involve the creation of wetlands with shallow water habitat in the tributaries above large reservoirs. In these cases the wetlands have been useful to waterfowl and also have reduced the sediment reaching the downstream reservoir. As the water passes through the wetland the water velocity slows and the sediment drops out of the water. Clean water then proceeds downstream to the reservoir, extending its life.

UPLAND NESTING HABITAT

Tall, dense vegetative cover on the uplands up to a mile away from water can serve as nesting habitat for waterfowl. The CRP acres have been particularly beneficial to nesting waterfowl and other ground nesting birds. The use of rotation grazing systems, grass plantings, conservation tillage, winter cereal crops, and other activities that increase the height and density of vegetative cover on the land will generally benefit nesting waterfowl. The critical time for having this cover on the land is generally from the middle of April through the middle of July. DU is actively working with private landowners to help establish these practices that benefit not only waterfowl but also provide some value to the landowner.

BROOD REARING PONDS

Waterfowl brood rearing wetlands are normally deeper in water depth and often larger in size than are breeding pair ponds. DU has developed several hundred of these on both public and private land. They are generally developed in areas with expansive grassland habitat but often relatively vacant of breeding waterfowl due to lack of ponded water. Brood ponds should provide a reliable source of water until after the brood rearing season. The typical brood wetland has a natural watershed of several thousand acres, or an irrigation water source to insure an adequate water supply for the waterfowl breeding season. Many wetlands of this type are developed in Montana, Wyoming, and the western Dakotas.

The typical site is relatively flat which optimizes the number of water surface acres for the costs involved. An earthen embankment is constructed across a natural constriction in the drainage system to impound the runoff. A primary water control structure is often placed in the embankment to handle frequent, small precipitation events and excavated emergency spillways are generally designed to handle the larger, less frequent events in combination with the primary spillways.

The shallow, upstream portions of these ponds provide the mixture of aquatic vegetation and invertebrates needed by rapidly growing waterfowl broods. The objective is to have 50% of the pond surface covered with emergent vegetation interspersed throughout the wetland. That interspersed vegetation is generally not present until after the created wetland has been in existence for several years.

The agricultural value of these wetlands is generally related to the livestock water they provide. The climate on the Northern Great Plains is semi-arid, so water sources for livestock are a welcome addition to the landscape.

Some brood wetlands are built in areas where irrigation return flow water is available from agricultural fields above the wetland. These sites are particularly attractive in the dryer climates of Montana and Wyoming. The irrigation return flows can be a more reliable source of water than is often available from natural runoff. Irrigation water can also be regulated or controlled better than natural runoff. The control can be a benefit in managing the vegetation in the wetland basin.

SUMMARY

DU has been successful in identifying numerous ways to develop habitat that benefits waterfowl and at the same time help the landowner and general public. DU will continue to seek partners and find ways that provide habitat for wildlife, and benefit the environment and agriculture.

**WETLANDS AND BACKWATERS BELOW DAMS
RESTORING AND REJUVENATING IMPORTANT HABITATS:
CASE STUDY: GLEN CANYON DAM**

David L. Wegner

ABSTRACT

Wetland habitats are critical to many threatened and endangered species throughout the world. Development of lands for municipal, industrial and urban uses has resulted in these critical habitats being lost. Protection and maintenance of the remaining wetlands is critical as development continues and effective ecosystem size declines.

Wetlands below dams are defined by the hydrology and geomorphology of the river system downstream. Water releases are characterized by their stochastic variability and sediment load. Wetlands in Southwestern United States rivers often begin their lives as backwaters and evolve into marsh habitats as they become more stable and vegetation emerges within the shallow water habitats. Dams can be used to develop, maintain and rejuvenate wetland resources if properly managed.

The gates of Glen Canyon Dam were closed in 1963 and with it the waters of Lake Powell began backing up. Prior to the dam controlling the flows, limited backwaters and marshes existed in the Grand Canyon due to the large annual flow variability of the Colorado River. With the dam controlling the annual and daily releases of water, backwaters and the wetland habitats were allowed to develop and evolve. The backwaters and marshes that became the most stable were the return current channels associated with reattachment bars. Marsh and wetlands evolved from the backwater habitats as sediment was captured and emergent aquatic vegetation and riparian plants stabilized the waters edge.

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Since 1985 the wetland and backwater habitats have been filling in with riparian vegetation and sediment. In the spring of 1996 an experimental ecologically designed controlled flood was released from Glen Canyon Dam through the Grand Canyon to rejuvenate and restore critical backwater habitats. It is anticipated that as the backwaters stabilize, the wetland and marsh habitats will be restored.

INTRODUCTION

Dams have traditionally not been thought of as providing important habitats for native and endangered species. In fact one of the primary impacts of dams has been the loss of endangered species habitats necessary for completion of critical life stages. In the Southwestern United States wetlands, marshes and backwaters are unique and important habitats for many endangered and native species. These habitats are critical to the long term maintenance of species and to providing the opportunity for increased biodiversity and improvement of the ecological health of the unique water resources.

The issue of compatibility and balance between social and natural resource concerns is at the crux of many of today's environmental problems. The Endangered Species Act of 1973 (16 U.S.C. 1532 et seq.), the National Environmental Policy Act of 1969 (42 U.S.C. 4321 et seq.) and the Clean Water Act (33 U.S.C. 1251 et seq.) are three of the most important laws which require a more in-depth evaluation of environmental impacts associated with the management of water. Marshes and wetlands have been tilled, drained and "developed" in hopes of increasing aquatic productivity and reducing "wasted" land. That philosophy has been changing over the last 15 years as the social perspective have changed and people are realizing the value of wetlands and natural riverine processes.

Wetlands and backwaters today provide an important factor in the equation for maintaining viable populations of waterfowl and avifauna, native fish species, resultant biodiversity of ecosystems, and sustainable habitats and species for the future.

Protection, development, restoration and rejuvenation of these areas are essential if we are to maintain the ecological health and consequently the terrestrial and aquatic populations of the United States.

In order to develop and/or restore these critical wetlands and backwater habitats we need to understand the dynamic variability and geomorphic processes that form and shape these environments and the biological activities that define the level of productivity. Understanding the stochastic nature of hydrology, water quality, plant evolution, and species interactions are essential if we are to successfully manage wetlands and backwaters and provide the habitats necessary for survival. Misreading or not understanding basic ecological relationships and processes will dictate that we waste valuable time, money and most importantly natural and ecological resources.

In order to accomplish the wetland tasks at hand an improved effort of linking science with developing partnerships, cooperative approaches and compatible processes is necessary. Clearly the historic development of large water projects and legislative approaches are not going to remedy the loss of these resources. Today we need to work more effectively at utilizing the combined talents of the agencies, understanding the ecological thresholds and integrating local people and groups into the solution.

Success in terms of increased wetlands, backwaters and consequently healthy ecosystems can only be accomplished on the long term if an innovative and flexible approach is realized. The approach must include an Adaptive Management perspective that will allow for identifying and using scientific information to make better management decisions and to utilize an active approach to solving our basic ecosystem problems.

The intent of this paper is to use, as a case study, the role and relationship of the wetlands and backwaters along the Colorado River through the Grand Canyon. From this example a case will be made for the protection and rejuvenation of these unique habitats through innovative dam operation and water management means. Finally the concept of Adaptive Management will be outlined as a necessary approach for the future management at Glen Canyon Dam.

BACKGROUND

The Colorado River has been actively developed and controlled by man for the past 80 years. This has been accomplished through the combined efforts of Federal, State and private entities. The majority of the development occurred prior to the advent of the National Environmental Policy Act (NEPA), the Endangered Species Act (ESA) and the Clean Water Act. As a consequence water and hydropower development took precedent over concern for the environmental or cultural resources downstream. Today, over 14 major Federal dams and an additional 30 State, private and tribal dams and diversion structures control the waters of the Colorado River basin.

The Colorado River system evolved over the last 500 million years as a closed basin. This has resulted in a unique environment and assemblage of species, especially the native fish and amphibian resources. As the dams were being built and the water controlled, the seasonal and permanent habitats that previously supported the unique assemblage of species and ecosystem processes were lost. Fragmented wetland and marsh habitats cannot support the same level of species numbers or biodiversity when they are physically cut off from their genetic source areas upstream and normal geomorphic processes are not functioning.

Glen Canyon Dam was authorized by the United States Congress in 1956 as part of a comprehensive river basin development program called the Colorado River Storage Project (43 U.S.C. 617). This project provided for Congressional authorization for Glen Canyon Dam, eleven participating irrigation projects and several other Federal dams in the Upper Colorado River system. Construction of Glen Canyon Dam was completed in 1963, well before the advent of NEPA and the ESA. Consequently no environmental considerations were given to the management and operation of the dam and downstream releases.

Pre-Glen Canyon Dam wetlands and backwaters were not permanent fixtures on the Colorado River landscape. They were ephemeral, intermittent habitat features that formed along the rivers edge in direct response to that years runoff water, sediment and climate. The mainstream river was the primary habitat area and wetlands and backwaters were used periodically and often in a transitory sense. Other habitats were

available. Post-Glen Canyon Dam though has been a different story.

Since the gates of Glen Canyon Dam were closed, the river flow has changed from one dominated by seasonal and annual variability to one defined by daily fluctuating flows dictated by power demands and constrained annual volumes. The water released from Glen Canyon Dam is pulled from the hypolimnion of Lake Powell and is characterized by cold, nutrient poor, clear water. Not representative of the river system that the native fish, macroinvertebrate, amphibian and avifauna species evolved under. Wetland and backwater habitats do exist in selected areas of the Grand Canyon and are today, due to their uniqueness, characterized as the biological hotspots for the environmental resources in the Grand Canyon.

Wetlands in the Grand Canyon have some very specific characteristics which make them unique habitats. They evolve as part of a backwater complex through time. The backwaters are initially formed in response to fluvial geomorphic processes. As the slower water environment is created, emergent aquatic plants and processes are initiated and evolution to a small wetland is begun. Characteristics of these habitats is a slower water environment that allows for diurnal warming of the water mass. Often the slowed waters in the wetlands will allow for the a 2 to 5 degree Centigrade increase in the water temperature. Enough to support the native larval fish and a more diversified aquatic food base. The slowed water also allows for the accumulation of organic matter which when decomposing provides a source of nutrients, especially carbon, nitrogen and phosphate that will enhance the insect and plant diversity.

Backwaters and wetlands in the Grand Canyon are formed in association with debris flows, channel constrictions and/or unique geomorphic environments. These habitats are deposited in eddies defined by channel constrictions. The largest backwaters typically occur as return current channels on reattachment bars. These reattachment bars are dynamic and their stability varies over relatively short time scales of days to years. The backwaters and wetland development exhibit considerable temporal variation. Biogeochemical and hydrologic processes affect the backwaters and subsequent wetland development by controlling nutrient and sediment delivery and defining flowpaths of the nutrient flux. Substrate, available water and unique

plant life demarcate these habitats from other riparian habitats. The wetlands though are not stable. Annually and seasonally changing hydrology, climate and the encroachment of riparian plants limit the lifespan of these unique habitats. As the backwaters become more stable, they begin the evolution to wetland and marsh habitats.

BACKWATER AND WETLAND REJUVENATION AND RESTORATION

The Glen Canyon Environmental Studies (GCES) Phase I results (Bureau of Reclamation, 1989), concluded that uncontrolled floods from Glen Canyon Dam were ecologically damaging. The uncontrolled nature of the 1983, 1984, and 1985 high flow releases from Glen Canyon Dam served up a disastrous scenario in regards to sustaining and maintaining the wetland habitats. The key aspect was "uncontrolled flood" in relation to the threshold levels of what the ecosystem could handle.

From 1989 through 1995, the GCES Phase II program refocused the scientific effort to include an ecosystem perspective, focusing on ecological processes and species responses. From these studies (Wegner, et. al. 1995) a refinement of the 1989 conclusion evolved. A primary conclusion was that "controlled floods" were a necessary factor in the ecosystem health equation and that sustaining the viable populations of native and endangered species required a dynamic flow element in the releases from Glen Canyon Dam. Backwater and wetland areas had been filling in with riparian vegetation and sediment. Critical habitats for native fish and birds was being lost at an alarming rate.

In the fall of 1995 the GCES study group along with partners from the environmental, tribal, water and power perspective began to work on the design of an experimental **Beach and Habitat Building Flow** from Glen Canyon Dam. The primary objectives of the flow would be to:

- * Restore and rejuvenate critical ecosystem processes
- * Redistribute sediments
- * Provide additional habitats for native and endangered fish and avifauna species
- * Protection of important cultural concerns

Over the course of a six month planning period, backed up by extensive scientific information, a controlled beach and habitat building release from Glen Canyon Dam was designed. Concurrent with the technical study design was the negotiation of critical administrative and approval documents, including an Environmental Assessment on the impacts of such a release, a Biological Opinion on the impact to endangered species, a special flow deviation approval from the seven Colorado River Basin states and the Secretary of the Interior, approval from the eight Native American tribes and finally research permit approval from the National Park Service.

With the administrative approval in hand the final shape of the experimental beach and habitat building flow was defined (Wegner, et.al. 1996).

Timing:	March 26-April 2, 1996
Duration:	Seven (7) days
Magnitude:	45,000 cfs (compared to maximum of 20,000 cfs under interim flow schedule)
Upramp/Downramp:	4,000 cfs/hr and 1,500 to 500 cfs/hr respectively
Minimum flow:	8,000 cfs on either end of the high flow

The primary objective of the program was to mobilize sediments from the bottom of the Colorado River channel and redeposit it along the near shore edges. Through this process wetland and backwater habitats would be scoured clean, sediments mixed up and organic matter incorporated into the soil mixtures (Figure 1). Habitat development and rejuvenation was an objective of the program.

A specific marsh area, Kwagunt Marsh located at River Mile 55.5 (Figure 2) was chosen for specific study on backwater rejuvenation and wetland evolution (Stevens, et.al, 1996). This wetland has historically been an area of use by native larval fish and avifauna species.

Five different experiments were conducted at Kwagunt Backwater and Marsh and are defined in Table 1:

Table 1. Specific Studies at Kwagunt Marsh

Microclimate	Thermal, flow and climate stability studies
Geochemistry	Nutrients and water chemistry changes and mobiliation
Hydrology and sediment	Geomorphological changes, scour and aggradation
Native fish and food base	Fish distribution, plankton distritution, benthic mass, and fish diet studies
Riparian vegetation	Changing vegetation types

The data collected from these studies is to be integrated into a site specific ecosystem model that can be utilized to predict responses to other backwaters and marshes throughout the Grand Canyon. This will allow for a scientific evaluation of the interrelationships between physical backwater development and biological responses and evolution of marshes.

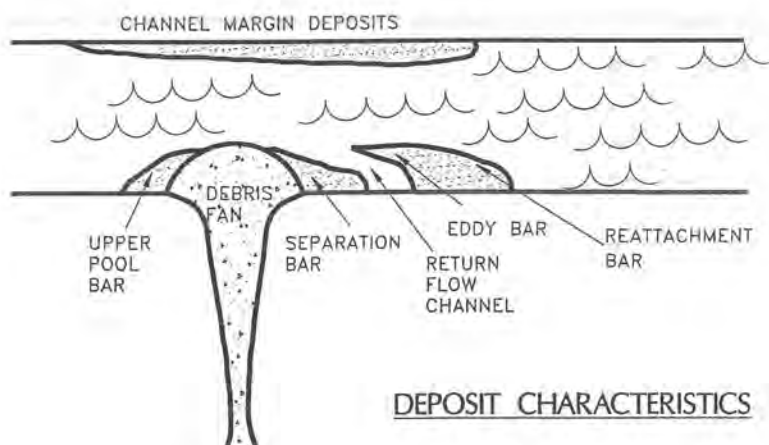


Fig. 1. Mobilization and deposition of sediments

Additional studies were conducted at Vasey's Paradise (River Mile 32) on the relationship of river flow on endangered Kanab Ambersnail (*Oxyloma haydeni kanabensis* Pilsbry) which lives in a very unique habitat defined by the river level and natural spring levels out and on the emergent and riparian vegetation habitats.

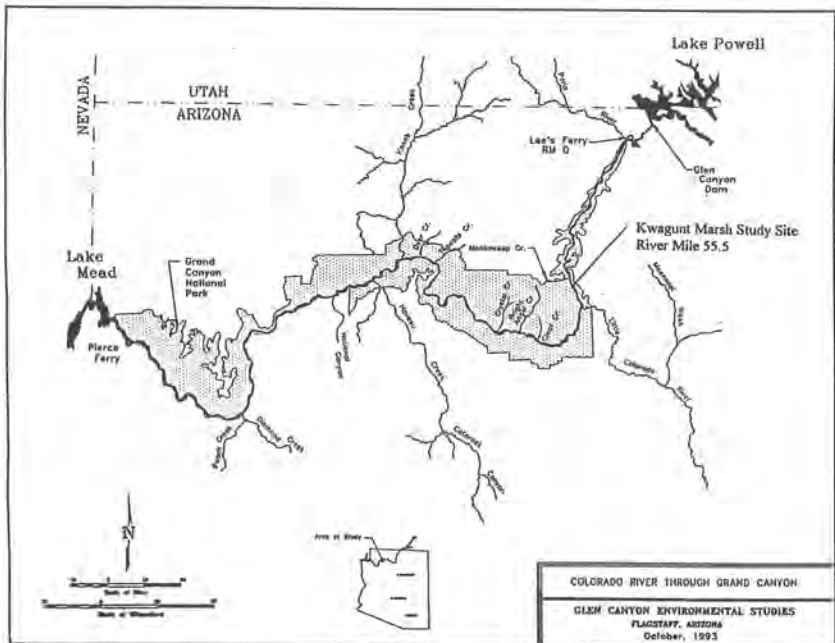


Fig. 2. Location of backwater and marsh studies

The initial results indicate that the **physical** aspects of the mobilization and rejuvenation of the sediments and organic matter was predicted correctly. Reshaping of the backwaters did occur and substrates for wetland plants were deposited. Now the study of the evolution of the backwaters to wetlands can be initiated. Over the next several months the reemergence of aquatic vegetation and use by both avifauna and aquatic species will be monitored.

SUMMARY

Backwaters, wetlands and marsh habitats are very important ecosystem features in the landscape ecology of the United States. Whether those habitats exist below Glen Canyon Dam or in the prairie lands of North Dakota they all provide unique and vital elements to the sustainability of species and ecological processes.

Over the course of the last 80 years we have made a concerted effort to drain, develop and in other ways negatively impact these wetland habitats. Now we have learned, the hard way, that these ecosystem habitats provide important elements in maintaining the biodiversity and sustainability of the ecosystem. The challenge before us now is to determine what is left, develop partnerships for their rejuvenation, restoration of wetlands and to find new and innovative management techniques. Based on the basic scientific results, a logical process can be developed that will allow the agencies and public to develop partnerships in the balancing act of social obligations and environmental considerations.

The development of an Adaptive Management program for the operation of Glen Canyon Dam and the interaction with the other management priorities is dependent upon a continual updating of the technical information data base. The NEPA evaluation process is predicated upon the ability to determine cause and effect and predict the impacts of actions.

Information gained through the Glen Canyon Environmental Studies program and prior Grand Canyon and Colorado River research will form the basis of the Adaptive Management program with continued information flow provided through long-term monitoring and additional research. A critical linkage must be developed among the basic research elements, dam operations, adaptive management and education. The National Research Council in 1991 reiterated the need for an innovative approach to the future management of Glen Canyon Dam.

The concept of Adaptive Management has taken a big conceptual and application step forward at Glen Canyon Dam. Through the course of the Glen Canyon Environmental Studies, the Bureau of Reclamation has developed a new approach to finding that balance

between our historic mandates and the environmental and cultural considerations. The new paradigm of Adaptive Management requires active participation between stakeholders, environmentalists and the public and holds great potential for finding innovative ways to restore and rejuvenate wetland habitats.

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**MULTIPURPOSE CONSTRUCTED WETLANDS
FOR WATER QUALITY IMPROVEMENT,
ENVIRONMENTAL ENHANCEMENT AND OTHER PUBLIC BENEFITS**

Christie Moon Crother¹

ABSTRACT

The Eastern Municipal Water District (EMWD), in cooperation with the Bureau of Reclamation and National Biological Service, is investigating the use of multipurpose constructed wetlands for wastewater treatment, reclaimed water reuse, environmental enhancement, wildlife habitat creation, and public education and recreation opportunities. The incorporation of multipurpose constructed wetlands in EMWD's water resources management program provides a cost-effective, innovative resource management option that complements existing water and wastewater systems in an environmentally attractive manner. Located at the Hemet/San Jacinto Regional Water Reclamation Facility (H/SJ RWRP), the Wetlands Research Facility and the Hemet/San Jacinto Multipurpose Constructed Wetlands were constructed between 1991 and 1994.

The research facility consists of two half-acre wetlands plant propagation cells; eight 50 by 230-foot research cells; and a reverse osmosis/saline vegetated marsh pilot study. The large wetlands occupies an adjacent 50 acre site. Both facilities, supplied with secondary treated wastewater from the H/SJ RWRP, are used for on-going wetlands research in addition to providing wastewater treatment, habitat for wildlife diversity, and educational and recreational public benefits. Following its transit through the wetlands, the reclaimed water enters EMWD's reclaimed water distribution system for use by agriculture, landscape irrigators, and others.

The design of the large wetlands includes specific design considerations to improve water quality performance. Opportunities for wildlife enhancement were also considered in the arrangement of wetlands

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components and in the incorporation of special wildlife features while also providing for educational and passive recreation opportunities. This project introduces a new application - it is truly multipurpose - incorporating water treatment, recovery, and reuse with wildlife values, public education and recreation, and enhancement of environmental resources. This award-winning project is just one element in EMWD's effort to meet the needs of the future while enhancing the natural environment and providing other public benefits in a unique and exciting manner.

INTRODUCTION

Drought is a recurring fact of life in Southern California. The limited water supply could potentially stall economic growth, both in terms of development and the continued viability of agriculture, and may be available only in restricted amounts for environmental uses. In the years ahead, the situation will require creative solutions, new technologies, and imaginative approaches to water resources management. One concept generating interest is water reclamation through the reuse of municipal wastewater.

Approximately 20% of the water sold by the Eastern Municipal Water District (EMWD) for municipal use is groundwater; the remainder is "imported water" purchased from the Metropolitan Water District of Southern California and delivered through the Colorado River Aqueduct and the California Aqueduct. Located in western Riverside County, California, EMWD encompasses over 550 square miles, provides water and wastewater service to a population of approximately 400,000, and owns and operates five Regional Water Reclamation Facilities which generate over 33,000 acre feet of reclaimed water per year. With the increasing uncertainty about imported water, both in terms of cost and availability, EMWD has identified reclamation and reuse of treated wastewater, groundwater resources management, and water conservation as priorities.

As part of this strategy, EMWD, along with the U.S. Bureau of Reclamation (USBR) and the National Biological Service (NBS), is investigating the use of multipurpose constructed wetlands for wastewater treatment, reclaimed water reuse, environmental enhancement, wildlife habitat creation, and public education and recreation opportunities. EMWD is evaluating the use of wetlands to treat nitrate-contaminated groundwater, recharge groundwater basins,

concentrate desalter brine, and treat storm water runoff.

It makes sense to turn what was once termed "wastewater" into a resource that generates revenue, extends the potable water supply, and provides agricultural and other irrigation water for arid and semi-arid areas. Reclaimed water is in great demand by several types of customers including 60 agricultural users, 53 landscape irrigators, four golf courses, four private duck clubs, and one state wildlife area. When planned pipelines are completed, eight schools, eight parks, a cemetery, more than a dozen golf courses, and additional streetscapes, open space and agricultural customers will be added to the list of reclaimed water users. Unsold reclaimed water is transferred to storage ponds and used to meet peak demands or is used for groundwater recharge. It is the policy of EMWD to promote the use of reclaimed water, to provide for the conservation and reuse of all water resources, and to utilize reclaimed or other non-potable water for any approved purpose to the maximum extent possible under the laws of the State of California. At its Hemet/San Jacinto Regional Water Reclamation Facility (H/SJ RWRP), EMWD, in cooperation with the USBR and NBS, has built a Wetlands Research Facility and a large Multipurpose Constructed Wetlands. Water for both is secondary treated reclaimed water supplied by the H/SJ RWRP which, after treatment in the wetlands, then enters the reclaimed water distribution system to be sold to agricultural and other reclaimed water users.

WETLANDS RESEARCH FACILITY

This 7.8 acre (3.16 hectare) site (Fig. 1) consists of nursery or plant propagation cells, research cells, and a reverse osmosis/saline vegetated marsh pilot study. Built sequentially and constructed over a three year period, the Wetlands Research Facility was originally conceived to serve as a center to examine fundamental wetlands processes such as wastewater treatment and salt accumulation, as well as design, operation and maintenance aspects of constructed wetlands.

Nursery Cells

Two 0.5 acre (0.2 hectare) nursery or plant propagation cells were constructed and planted in 1991 with California and hardstem bulrush (*Scirpus californicus* and *Scirpus acutus*). The bulrush species were selected because they are native to the area and provide

excellent wastewater treatment opportunities and habitat resources for wildlife. Initial vegetation studies provided critical information regarding optimum plant propagation and transplanting procedures for installing larger wetlands systems. The nursery cells provided plant material for the research cells and for the Multipurpose Constructed Wetlands and will provide material for future projects.

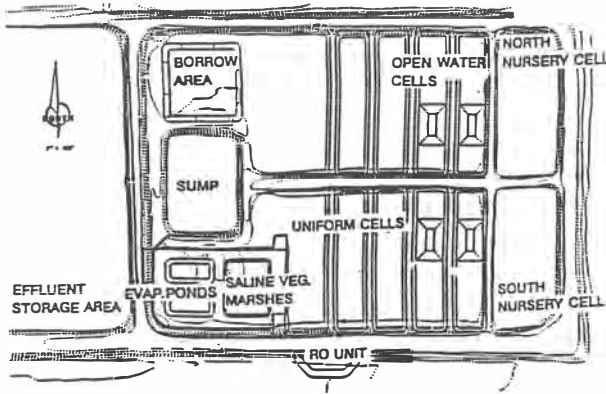


Fig. 1 - USBR/NBS/EMWD Wetlands Research Facility

Research Cells

Eight 50- by 230-foot (approximately 15- by 70-meter) research cells were constructed and planted with California bulrush from the nursery cells in 1992. A transplant success rate of over 99% was achieved. Four of the cells are single-phase or fully vegetated and four are three-phase or have a marsh-pond-marsh configuration. The cells are used to test and evaluate a variety of wetlands processes and system operations issues and are available to qualified researchers for various types of on-going wetlands research. An initial monitoring program was conducted by EMWD to provide baseline data. The research units have been monitored to observe plant growth, study water quality dynamics, and evaluate effectiveness in addressing wildlife habitat needs.

RO/Saline Marsh Pilot Study

Constructed in 1993, this component consists of a six

gallons per minute (22.7 liters/minute) reverse osmosis (RO) desalination unit designed and constructed at the USBR's Denver office; two 20- by 80- by 2-foot deep (6.1- by 24.4- by 0.6-meter) lined, saline vegetated marsh ponds; and two similarly sized, lined evaporation ponds. Feed water to the RO system is trucked to the site from a brackish groundwater well. Since a number of the groundwater basins within EMWD's service area are brackish or of marginal quality, the District is interested in using desalting units for reclaiming such groundwater for municipal and industrial use while remediating the poor quality groundwater basins. In inland areas, brine disposal is a major cost element in the use of desalters. This pilot study focuses on the feasibility of using the reject or brine stream from the desalter in saline vegetated marshes to reduce brine volume through evaporation, thereby decreasing brine disposal costs. This may also provide an additional use of brackish water in arid areas to sustain much-needed habitat and green belts. Research focuses on the ability of the reject stream to sustain the saline marshes, the potential accumulation or concentration of toxic materials, and the bioproductivity of the marshes.

A Research Coordination Committee, consisting of representatives from EMWD, USBR, NBS, the U.S. Geological Survey (USGS), and the University of California at Riverside (UCR), evaluates and approves research proposals and oversees the research efforts. On-site coordination and facilitation of research projects is handled by EMWD staff. Research studies currently being conducted at the site include:

- ▶ Survivability of Pathogenic Microorganisms in Wetlands Systems (UCR)
- ▶ Biological Control and Ecology of Mosquitoes Inhabiting a Constructed Wetlands (UCR)
- ▶ Mathematical Model for Design and Management of Constructed Wetlands (UCR)
- ▶ Nitrogen Dynamics Study (NBS/UCR)
- ▶ On-going monitoring (NBS/EMWD)
- ▶ Saline Marsh Program (NBS/EMWD)
- ▶ Organic Carbon Transformation Study (USGS)
- ▶ Bird Census, Species Count, & Avian Usage Study (Calif. State Polytechnic Univ., Pomona)

HEMET/SAN JACINTO MULTIPURPOSE CONSTRUCTED WETLANDS

This 50 acre (20.2 hectares) site (Fig. 2) consists of approximately 26 acres (10.5 hectares) of wetlands with

the remainder in upland habitat. Built and planted in 1994, this large demonstration wetlands is a three-phase (marsh-pond-marsh) system consisting of (1) five separate treatment arms, (2) a combined open water and marsh habitat area, and (3) a final polishing wetlands. One million gallons per day (mgd) (378.8 kiloliters per day) of secondary treated wastewater from the H/SJ RWRP flow into the five arms, then combine in the open water area, and then flow through the final wetland to enter the reclaimed water distribution system for use by agriculture and other users. Retention times in the wetlands range from 10 to 18 days. From the air, the system is amoeba-shaped; on the ground, the curved lines give the appearance of a natural system. The conceptual design was developed by the USBR Denver office, and the final design drawings and specifications were completed by CH2M Hill, Santa Ana, California.

The design of the large wetlands was predicated on two beneficial use objectives: (1) water quality improvement and (2) the creation of wildlife habitat. Emergent marsh wetlands exhibit water quality improvement especially suited to the organic loading common in treated municipal wastewater discharges. Water resources design considerations to improve water quality performance of the system include:

- a) a three-phase, marsh-pond-marsh, system with directly connected components;
- b) inlet marshes sized for process functions, while the elongated shape promotes even flow and localizes intensive treatment near the inlets;
- c) slower flow rates through the inlet marsh areas and faster flow rates in the open pond and outlet marsh to reduce internal production and evaporation effects;
- d) the arrangement of islands and a planting scheme intended to induce even flow distribution and mixing zones traversing flow through the marsh; and
- e) the subdivision of inlet and outlet marshes to allow periodic maintenance without requiring shutdown of the entire wetlands system.

The water-supply system was computer modeled to ensure uniform flow to all five inlet marshes. The wetlands have been sized for an ultimate treatment capacity of five mgd. Retention times in the marshes are based on an 18-inch water depth. The inlet marshes are each sized to provide retention times of five to ten days,

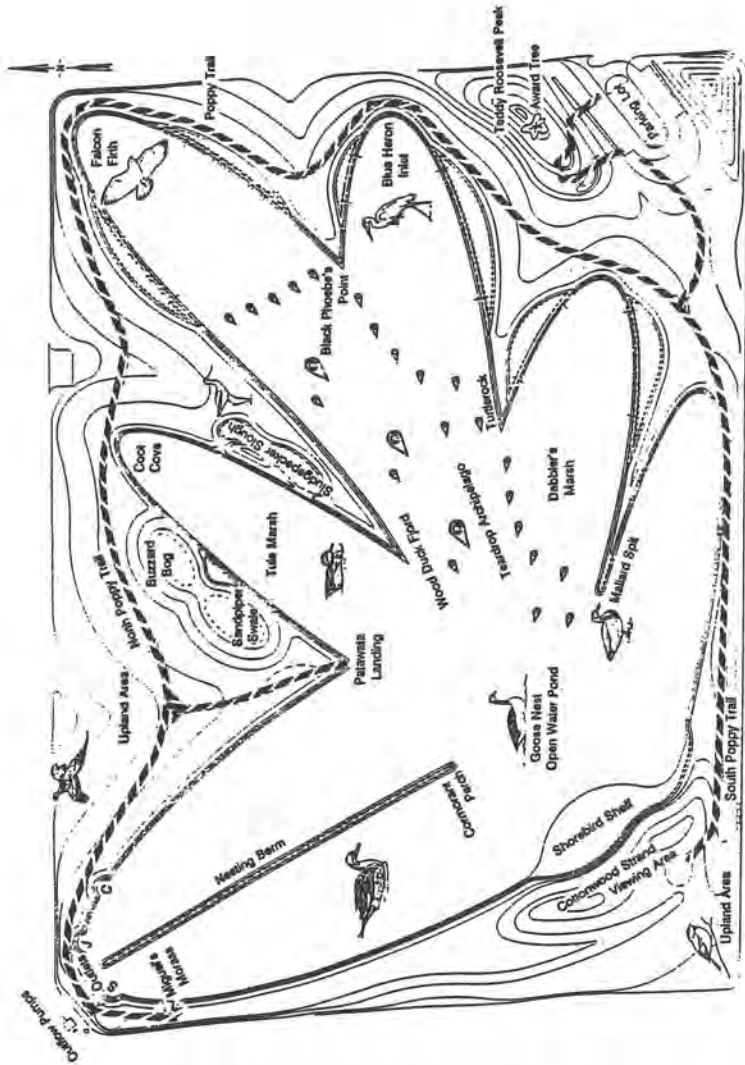


Fig. 2 Multipurpose Constructed Wetlands
Hemet/San Jacinto Regional Water Reclamation Facility

based on nitrogen removal processes starting with reclaimed water containing moderate levels of ammonia. The open pond area, with a depth of six feet, is primarily sized for a short retention time of two to three days. The outlet marsh is sized for a retention time of four to five days, with the intent of providing final filtration of internally produced inputs and reduction of dissolved-carbon produced from decay of vegetation.

In the arrangement of wetlands components and in the incorporation of specialized wildlife features into the overall design, opportunities for wildlife enhancement were also considered including:

- a) a habitat-intensive central pond area isolated from operational activities at the inlets;
- b) two types of moist soil areas;
- c) islands to provide isolated nesting habitat;
- d) pond bench and riparian areas to diversify and increase shoreline habitat;
- e) public amenities and access features designed to minimize interference with wildlife while allowing public viewing, education and recreation opportunities; and,
- f) a landscaping plan including seeding with native grasses and a selective planting of trees and shrubs.

Wetlands for wastewater treatment have received widespread interest as communities nationwide attempt to solve water and wastewater management problems. In previously constructed treatment wetlands, the final step in the treatment process is disposal, and the wetland is designed with the single purpose of treatment in mind. This project introduced a new application, incorporating water treatment, recovery, and reuse with wildlife values, public education and recreation, and enhancement of environmental resources -- it is truly multipurpose.

BENEFITS

Be they natural or man-made, wetlands provide a wide range of benefits. Constructed wetlands can be designed to meet specific needs and provide specific benefits. They also can accommodate multiple purposes which provide multiple benefits -- the best option for public agencies responsible for stewardship of natural resources and prudent expenditure of public funds.

Water Supply/Water Quality Benefits

Multipurpose constructed wetlands can protect and extend the existing water supply. If designed to treat secondary wastewater, they can directly affect the reclaimed water supply. If water produced from the wetlands is of suitable quality to be recharged into groundwater basins, diminishing groundwater resources can be supplemented; or, in some areas, reclaimed water can be recharged as part of a groundwater remediation program. Foremost is the maximum utilization of local resources to reduce dependence on costly and potentially unreliable imported sources.

Water quality benefits are also evident. For example, the research cells demonstrated the ability of the wetlands to remove fairly high levels of BOD₅ (biological oxygen demand) and TSS (total suspended solids) during an unusual treatment plant upset. With secondary effluent into the cells with BOD₅ levels as high as 42 mg/L (milligrams per Liter) and TSS levels as high as 68 mg/L, the effluent from the research cells averaged 7 mg/L BOD₅ and 3 mg/L TSS.

The research cells have also demonstrated that the three-phase, marsh-pond-marsh system is superior to the single-phase, fully vegetated cells in the removal of total inorganic nitrogen by a ratio of 51% to 7% respectively.

The Multipurpose Constructed Wetlands, which has been on-line continuously since February 1996, has already shown that secondary reclaimed water quality can be improved by wetlands treatment. The initial sampling results show a 93 percent removal of nitrite nitrogen, 65% removal of TKN (total Kjeldahl nitrogen), 71% ammonia removal, and a 73 percent removal of BOD₅. In the summer of 1995, the wetlands had no flow due to excessive demands for reclaimed water and regulatory concerns. At that time, the total coliform bacteria level was at 8,000 MPN/100ml (most probable number per 100 milliliters), while the non-chlorinated effluent that had supplied the wetlands was in the range of 170,000 MPN/100ml. Weekly sampling since February of this year has shown the same trend. Total coliform levels in the wetlands effluent have been averaging approximately 8,000 mg/L.

One focus of the wetlands component of the reclaimed water program is the development of design, construction, and operational criteria that will provide a cost-effective and environmentally sensitive

alternative for advanced wastewater treatment in semi-arid areas of the West.

Environmental Benefits

Millions of migratory birds funnel through the Pacific Flyway each winter on a transcontinental flight from Alaska and Canada to Latin America. Rivers, marshes and ponds serve as refueling stops, offering birds rest and food along the way. California, a critical 700 mile (434 kilometer) link in this migratory corridor, has lost 91% of its wetlands in the past century. EMWD is located on the Pacific Flyway and has the opportunity to provide vital habitat for migratory and resident waterfowl and shorebirds. Opportunities for wildlife enhancement were considered in the arrangement of the wetlands components and environmental features have been specifically designed to increase habitat diversity and wildlife propagation. At the Hemet/San Jacinto site, more than one hundred species of birds have been observed using the site, many for breeding and the rearing of young. Visitors include a variety of ducks; Canada geese; raptors such as golden eagles, hawks and owls; numerous shorebirds; songbirds; and herons and egrets. Threatened and Endangered Species and Species of Special Concern which have visited the site include snow geese, bald eagles, white-faced ibis, double-crested cormorants, northern harriers, tri-colored blackbirds, burrowing owls, bank swallows, and peregrine and prairie falcons. White-faced ibis nested in multiple locations in the wetlands for the first time in the spring of 1996.

Although the Multipurpose Constructed Wetlands and the Wetlands Research Facility are surrounded by farmland and some encroaching development, a surprising number of terrestrial mammals have discovered and frequent the secluded marshes. They are occasionally spotted and their tracks are evident, providing additional opportunities for nature study for school children. Visitors and residents include opossum, foxes, coyotes, bobcats, skunks, weasels, cottontails and jackrabbits, ground squirrels and mice.

This project complements the nearby San Jacinto Wildlife Area (SJWA), a State of California, Department of Fish & Game refuge. EMWD has provided over 5,300 acre feet of reclaimed water to the SJWA since 1989, making it the first and only state wildlife refuge to take advantage of reclaimed water for wildlife habitat development. There, reclaimed water has proved to be

very successful for the growth of waterfowl food plants and for attracting waterfowl. It is the only water source that is both available and affordable.

Public Involvement Opportunities and Public Benefits

Opportunities for public use and benefit abound at the wetlands and new uses continue to become evident as time passes. Local elementary school children, as well as high school and college students, use the site as an environmental science lab; ecological field trips are popular with the students. EMWD staff has developed educational tours and programs as well as educational resource materials for teachers to use before, during, and after visiting the wetlands. Colleges and universities utilize the site for research, class tours, and as an outdoor classroom and laboratory. Bird Check Lists and a Visitor's Guide have been developed by EMWD staff for use with tours, school groups and individual visitors. The California Department of Fish and Game has also provided some educational materials and display posters.

The wetlands create an excellent opportunity to educate and inform the public about the value of reclaimed water and water conservation. Such education is of vital importance in water-scarce, expanding areas and is necessary to further EMWD's water resources management programs.

Public interest in the site is high and is increasing. It is well known among bird watchers and is one location used by the Audubon Society for its Annual Christmas Bird Count. The California Waterfowl Association and Southern California Ducks sponsored a Wetlands Habitat Improvement Day during which volunteers built and installed nest boxes for Wood Ducks, Mallard hen houses, and floating nest platforms for Canada Geese. The nests are routinely monitored and local citizens are learning how to periodically check and maintain these nest sites.

Friends of the Wetlands -- a community fundraising effort -- is underway to provide public amenities such as signs, trail improvements, benches and tables for an outdoor classroom, and, possibly, a used mobile home for a Nature/Education Center and mini-museum. Silhouette-style signs of ducks, a goose, and a falcon have been created, donated and installed as trail markers and direction indicators.

A sixteen-year-old high school sophomore from Riverside, California conducted a successful environmental science project at the Wetlands Research Facility which resulted in a second place medal at the 1996 California State Science Fair. The title of her project is "Are Wetlands an Effective Means of Reducing Total Coliform, Enterococci, and Fecal Coliform Concentrations in Sewage? Are Continuous Vegetated One-Phase Wetlands More Effective than Open-Water Area Three-Phase Wetlands?"

The West Valley High School, Hemet, California, Chapter of the Future Farmers of America (FFA) applied for and received one of only eighteen 1996 National FFA Environmental Stewardship Grants for a project at the Hemet/San Jacinto Multi-purpose Constructed Wetlands and Wetlands Research Facility. Elements of the student project include:

- a) constructing mallard hen houses;
- b) developing land adjacent to the wetlands to provide upland shelter, forage, nest sites and feed;
- c) improving the existing viewing blind to harmonize with the environment and increase usability;
- d) creating identification charts, photos, and posters to be used in the viewing area as educational resource materials;
- e) draining, tilling, and planting a one acre lowland area with native forage grasses for wildlife and maintaining the site as a grass feeding station; and,
- f) developing a cooperative 5-year plan for continued wetlands improvements.

Under its "Rotatree Program," in conjunction with the National Tree Trust, the Rotary Club of Moreno Valley, California is growing ten dozen saplings of cottonwood, sycamore, alder, and maple trees which will be planted around the wetlands by the FFA students in the fall of 1997.

In addition to the locals who have toured, visited, and studied at the site, many national and international visitors have come to tour the project including two groups from Australia, several from Taiwan and the Republic of China, and a delegation from fourteen Middle East countries sponsored by the U.S. State Department as part of the Middle East Peace Process. Articles and papers on the project have appeared in numerous publications including one in the People's

Republic of China.

The success of the Multipurpose Constructed Wetlands is evidenced by the regional, state, and national awards garnered by the project. They include:

- ▶ California Local Government Commission
1992 Award for Innovation in Water Conservation.
- ▶ Inland Empire West Resource Conservation
District 1993 Conservation Partnership Award
for Water Quality.
- ▶ Association of Metropolitan Sewerage Agencies
1994 Research and Technology Award.
- ▶ Association of California Water Agencies
1994 Theodore Roosevelt Environmental Award
for Excellence in Natural
Resources Management.

CONCLUSION

This cooperative research project provides specific information on the use of multipurpose constructed wetlands in a comprehensive water reclamation and reuse program that will result in design, construction, and operational criteria for different applications throughout the West. The project is already serving as a model for efforts in other areas. Southern California, as an expanding, yet semi-arid area, requires creative and cooperative solutions to provide water services to its ever-increasing population while continuing to enhance the environment and improve the quality of life. Wastewater was once a liability, something to be disposed of or thrown away. Today, it is an asset. For every gallon of water that can be reused at least once means that one more gallon can remain underground; or one more gallon need not be imported from Northern California or the Colorado River. Multiple reuse is even more prudent and effective.

The incorporation of multipurpose constructed wetlands into EMWD's water resources management program provides a cost-effective, innovative resource management option that complements existing water and wastewater systems in an environmentally attractive manner. The wetlands improve water quality while providing for habitat creation, environmental enhancement, and public

education and recreation. The reclaimed water is then used once again for agriculture and other irrigation and special uses. EMWD, in this cooperative effort with USBR and NBS, is meeting the needs of the future while enhancing the natural environment and providing other public benefits in a unique and exciting manner.

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WATER QUALITY BENEFITS OF CONSTRUCTED WETLANDS:

SPRING CREEK WETLAND, BOWMAN, NORTH DAKOTA

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Tommy E. Myers²

ABSTRACT

Bowman Haley Reservoir is a US Army Corps of Engineers flood control and water supply reservoir located along the North Dakota, South Dakota state line. Although the lake initially had good water quality, the lake is suffering from eutrophication and experiences excess algae growth and low winter dissolved oxygen levels. As part of an overall watershed management plan initiated by the Soil Conservation Service (SCS), a 24 acre wetland was constructed off the main channel of Spring Creek, a major tributary into Bowman Haley Reservoir. The wetland was constructed as a cooperative effort between the USACE, the Bowman Slope Soil Conservation District, and Ducks Unlimited. The project had the dual objectives of providing improved water quality in Spring Creek below the wetland and the production of waterfowl. This wetland was monitored for two growing seasons to measure its' ability to remove nutrients and suspended sediments from diverted creek flows. Monitoring indicated the wetland had the potential to provide water quality improvement at the site. However, the immaturity of the wetland, and the operation of the wetland to maximize waterfowl usage are thought to have limited the actual pollution abatement benefits. Analysis of this project provides engineering guidance on achieving water quality improvements at constructed wetland sites.

INTRODUCTION

In this paper the basic concepts of non-point source pollution (NPSP) and the application of wetlands, as part of an overall watershed management plan, will be presented. The basis for constructed wetland design as well as maintenance and operation of constructed wetlands for the control of NPSP will also be discussed. The Spring Creek Wetlands, a constructed wetland of regional significance, will be used to illustrate some of the points discussed in the preceding discussion of constructed wetlands for the control of NPSP.

Water Quality Impairment

Non-point source pollution is the conveyance of substances or materials from area sources in the form of polluted surface runoff that diminishes the designated uses of receiving waters. Suspended solids, as well as dissolved chemicals, are non-point source pollutants that impair water quality. Non-point sources of pollution include contaminated runoff from urban areas, agricultural fields, animal feedlots, and roadways. Silviculture, construction, and other land

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disturbing activities also contribute to NPSP.

Since the introduction of the Clean Water Act, PL 92-500 (Federal Water Pollution Control Act Amendments of 1972), substantial progress has been made in reducing point pollutant loads to streams, rivers, lakes, and estuaries. Still, about 30 percent of U.S. surface waters do not fully support their designated uses; and recent evaluations point to NPSP as a major cause of current water quality impairment (Baker 1992). Approximately three-fourths of lake water quality impairment is due to NPSP (Fig. 1). Point sources, natural causes, combined sewer overflows (CSOs) and a variety of other and unknown sources make up the remaining causes of impairment.

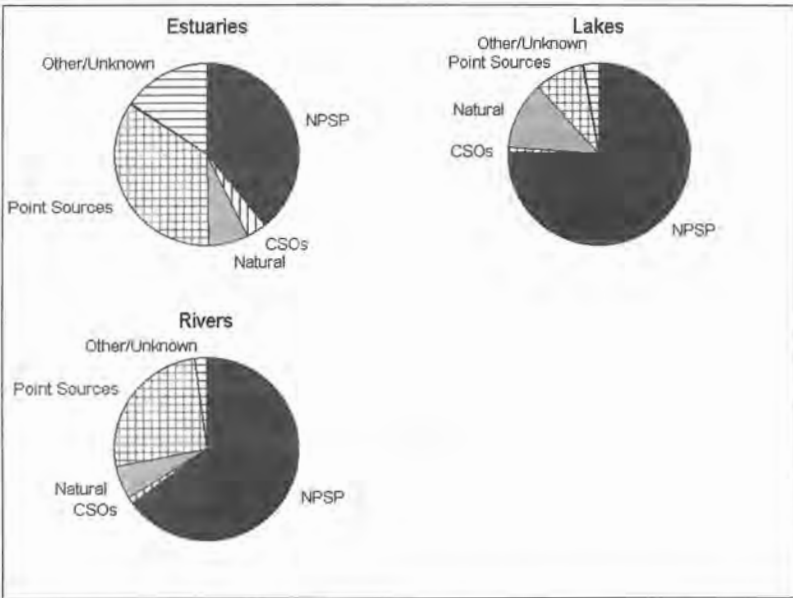


Fig. 1 Sources of Water Quality Impairment in the United States (Baker 1992).

NPSP is a threat to water supply and recreational uses of US Army Corps of Engineers (USACE) lakes and reservoirs. Agriculture, the single largest contributor of NPSP in rivers and lakes (Fig. 2), is the predominant land use around many lakes and reservoirs. USACE lakes and reservoirs in urbanized areas also receive runoff containing a variety of inorganic and organic chemicals. There are numerous instances in which water quality at USACE lakes and reservoirs was pristine for several years after construction of the lake or reservoir. In time, however, water quality slowly deteriorated to the point of raising serious concerns about impairment of uses. Example USACE projects include, but are not limited to, Bowman-Haley Reservoir, Bowman, ND, Cherry Creek Reservoir, Denver, CO, Perry Lake, Perry, KS, Pawnee Lake, Lincoln, KS, and Rathbun Lake, Rathbun, IA.

Constructed Wetlands as a NPSP Management Tool

Realizing that NPSP is the major source of water quality impairment in the United States, steps are then needed to eliminate and control NPSP. Unlike

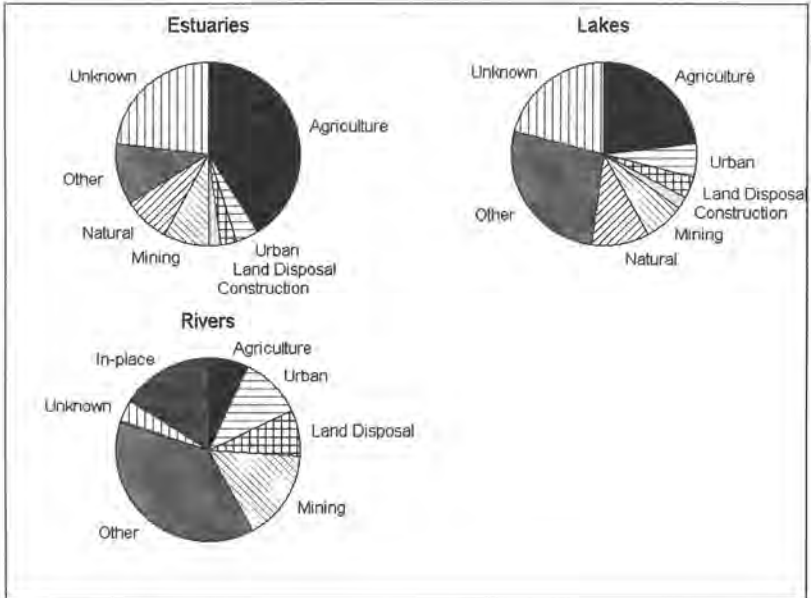


Fig. 2 Sources of Non-point Source Pollution in the United States (Baker 1992).

point source pollution control, NPSP control mandates total watershed management. Management practices that emphasize controlling pollution at the source provide the basis for a sustained proactive approach to NPSP abatement. Agricultural best management practices (BMPs) as described in USDA (1989), and elsewhere, as well as urban controls, as described in USEPA (1993) can and should be used to control NPSP at or near the source. Once NPSP has left its original source NPSP load reduction becomes important.

Hydraulic and pollutant mass loadings associated with NPSP are extremely variable. Most treatment systems designed for point source discharges are ineffective for NPSP because they cannot handle wide fluctuations in hydraulic loadings and perform poorly when there are large fluctuations in pollutant loadings. Wetlands, on the other hand, dampen extremes in flow and pollutant loadings by storing water. Wetlands trap sediments and have the ability to retain, transform, and degrade a wide spectrum of waterborne pollutants (Mitsch and Gosselink, 1986; Hammer 1989).

Constructed wetlands located to intercept runoff may, therefore, be an

alternative for reducing entry of NPSP into streams, rivers, lakes and estuaries. In some landscapes, it may be advantageous to consider constructed pollution abatement wetlands systems (CPAWS) as an integral part of an overall water quality improvement objective.

CONSTRUCTED WETLAND DESIGN, CONSTRUCTION, AND OPERATION

Constructed Pollution Abatement Wetlands Systems (CPAWS) are vegetated water treatment facilities designed, constructed, and operated to remove pollutants using physical, chemical, and biological processes intrinsic to wetlands. Two basic designs are utilized: free water surface wetlands and subsurface flow wetlands (Reed and Brown 1992). CPAWS designed as free water surface wetlands are similar to natural wetlands, having a soil bottom, emergent vegetation, and a water surface exposed to the atmosphere. This design is common for treatment of domestic wastewater. Subsurface flow wetlands are designed to maintain water levels below the surface of some type of porous media (rock, gravel, sand) (Reed 1993). The subsurface media also supports the roots structure of emergent vegetation. Subsurface flow systems are used to treat domestic wastewater and acid mine drainage.

Successful CPAWS design for NPS pollution abatement differs from CPAWS design for point source pollution in that average flows and pollutant concentrations do not provide a sound basis for design. The basic problem is to capture and spread high flow, high contaminant concentration runoff in a wetland and retain the water long enough for wetland physical and biogeochemical processes to degrade or remove pollutants.

Conceptual Design Sequence

A conceptual design sequence for constructed pollution abatement wetlands systems for NPSP is shown in Fig. 3. The three key elements in the design sequence are (a) identification of NPS pollutants for treatment and selection of a design storm or flow event, (b) estimation of chemical pollutant process kinetics and coefficients, and (c) calculation of the hydraulic retention time needed to remove the pollutants of interest. The conceptual design sequence is discussed below with emphasis on these three key design elements. Other components of the design sequence are further addressed elsewhere (Miller and Tate 1993, Richards 1993a, Richards 1993b, Downer 1993, Allen 1993, Dortch 1993, and Palermo 1992).

Pollutants: Successful design of CPAWS requires development of the proper physical and biogeochemical conditions to remove pollutants of concern. Therefore, one of the first steps in the design process is identification of pollutants and pollutant concentrations to be treated. Pollutants can be identified by sampling runoff, review of available data on water quality problems in the receiving water body, or evaluation of land uses and probable constituents in runoff. Identification of target pollutants for removal is important because different pollutants require different designs for effective removal. Treatment of acid mine drainage, for example, is probably best accomplished in subsurface flow wetlands due to pH adjustment typical of oxidation-reduction reactions in mildly reducing conditions (Ponnampetuma, Martinez, and Loy 1966). Nitrate removal may also be easier to accomplish in subsurface flow wetlands than free

water surface systems since denitrification is an anaerobic process. Ammonia removal, on the other hand, requires oxidizing conditions and may therefore be easier in free water surface wetlands.

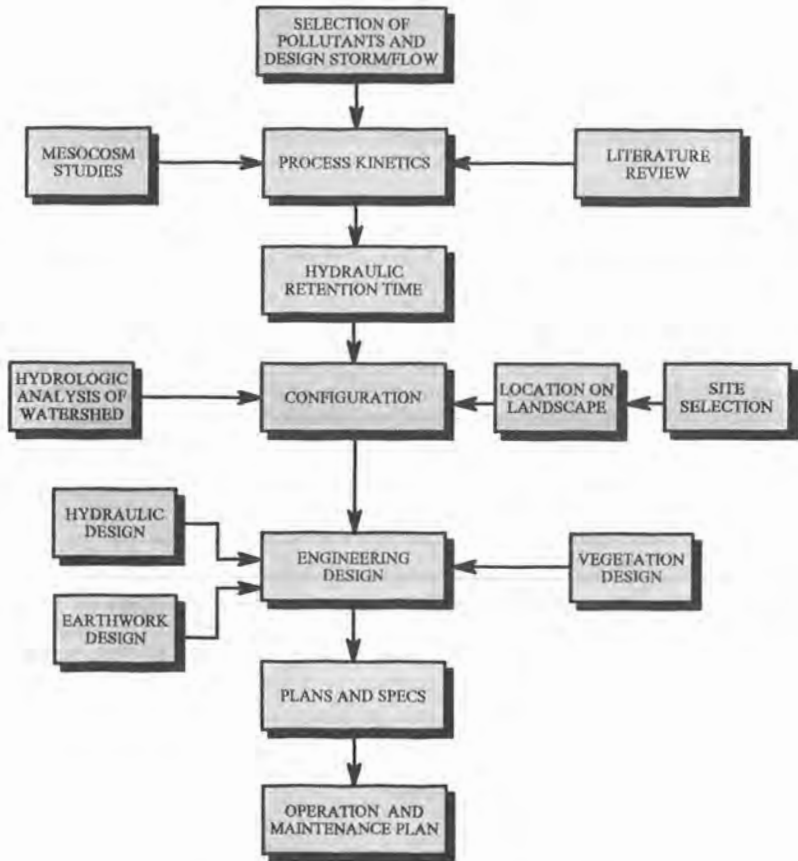


Fig. 3 CPAWS Conceptual Design Sequence

Hydrologic Analysis: To properly size a wetland for NPSP processing, a design storm event is needed. Two types of events are important, the maximum event to be treated and the extreme event the wetland must survive. The maximum event determines the size of the wetland and associated control structures. The extreme event determines the size of emergency flow structures.

The maximum event to be treated should be based on water quality objectives for the receiving water body and watershed pollutant loading characteristics. Land

and chemical use patterns will significantly affect watershed characteristics and hence, the maximum treatment event. Because selection of the maximum treatment event can be complicated, uncertain, and expensive, other factors are sometimes used to size wetlands. These include cost and land availability.

Storm events generate surface flows that wetlands must be designed to handle. Determining design flows from storm events involves hydrologic analysis of the watershed or catchment. The Watershed Modeling System (Brigham Young University 1995), can be employed to develop the hydrology of a watershed using a variety of standard techniques used by the USACE and the SCS. Hydrologic analysis should provide storm hydrographs for routing water, establishing stage-storage relationships, sizing inlet and outlet structures, and sizing the wetlands (Richards 1993a).

The extreme event to design for may be obtained from local or state codes for drainage design, or in situations where local or state codes are not applicable the judgment of an experienced hydrologist may be used. Selection of the appropriate event in some cases will depend on the project. Protection of downstream property and people and available land are some the factors that affect selection of extreme storm events.

Chemical Pollutant Processing: Design approaches for CPAWS range from "seat-of-the-pants" approaches to more rational approaches based on treatment process kinetics (Reed and Brown 1992). In "seat-of-the-pants" designs, judgment, land availability, or fiscal limitations are used to size wetlands for pollutant processing. A more rational approach based on a treatment capacity concept has also been widely used. In the treatment capacity approach, wetlands are sized using a treatment capability factor (number of acres needed per mass of pollutant) and the expected loading (the number of animals in the barnyard, quantity of biochemical oxygen demand, etc.). In this approach, CPAWS surface areas are determined by multiplying expecting loadings by treatment capacity factors. The treatment capacity factor approach implies zero order process kinetics, that is, residence time is not explicitly accounted for.

More realistic is an approach based on first order reaction kinetics and plug flow suggested as a first generation design technique (Reed 1990; Rogers and Dunn 1992; and Dortch 1993). Application of a plug flow model with first order reaction kinetics to wetlands involves an overall disappearance coefficient as indicated in the following process equation:

$$M_e = M_o e^{-kt}$$

where: M_e = mass of chemical released in effluent, kg, M_o = mass of chemical input, kg, k = overall disappearance coefficient, days⁻¹, and τ = mean chemical mass residence time, days.

The chemical mass terms, M_e and M_o , in the above equation refer to the total mass pollutant load in a single runoff event. M_o is obtained from the pollutant and hydrologic analysis. The overall disappearance coefficient, k , represents the composite effects of volatilization, sorption to bottom sediments, biodegradation, and plant uptake on effluent quality. Sedimentation and

volatilization are first order disappearance processes. Biodegradation is routinely modeled as a first order process, although the underlying reactions are probably mixed order. Sorption is usually modeled as a first or higher order process. Plant uptake is the one process incorporated into k that is probably zero order.

Although flow and pollutant concentrations vary during a runoff event, a steady state (flow and pollutant concentrations are constant) equation is often used for the initial sizing of wetlands. The steady state equation for plug flow with first order reaction is (Dortch 1993):

$$C_e = C_o e^{-kt}$$

where C_e = chemical concentration in effluent, mg/l, and C_o = chemical concentration in influent, mg/l.

One of the most difficult tasks in CPAWS design for NPSP is estimation of the overall disappearance coefficient applicable to wetlands. This coefficient is chemical dependent and is anticipated to vary with wetlands characteristics, such as extent of vegetative cover, vegetation type, climatological conditions, and other factors.

First order disappearance coefficients are commonly expressed as chemical half-lives. Half-life is the time required for half of the chemical introduced to a system to be eliminated from the system. From this definition and rearrangement of the first order process equation given above, the overall disappearance coefficient is given by

$$k = \left(\frac{\ln (0.5)}{\tau_{1/2}} \right)$$

where $\tau_{1/2}$ = chemical half life, days⁻¹.

Literature values for chemical half-lives can be unreliable for CPAWS design because few of the available data were developed from wetlands studies. Wetlands specific removal efficiencies are available for nutrients, metals, and some other water quality parameters (Phillips et al. 1993). In lieu of field data, experimental wetlands mesocosm studies can provide half-lives for specific chemicals and wetlands characteristics (Doyle, Myers, and Adrian 1993). When the corresponding hydraulic retention time is given along with removal efficiency, the disappearance coefficient can be calculated as follows:

$$k = \left(\frac{\ln \left(1 - \frac{RE}{100} \right)}{HRT} \right)$$

where HRT = hydraulic retention time, days⁻¹, and RE = removal efficiency, percent.

The overall disappearance coefficient (chemical half-life) determines the hydraulic retention time required to meet a target level of treatment. Once the required HRT is estimated, HRT then becomes the basis for hydraulic design and sizing wetlands. Hydraulic retention time is the average time required for a parcel of water to pass through a wetland. The theoretical HRT of an idealized system is defined as

$$HRT = \frac{V}{Q}$$

where V = wetland volume, m³, and Q = flow, m³/day. Q is obtained from the hydrologic analysis.

This definition implies that the entire cross-sectional area is included in the flow and each parcel of water remains in the system for the same amount of time. This is seldom true or even approximately true for wetlands. Irregularly shaped, vegetated wetlands subjected to a variety of flow conditions tend to form channels that reduce effective HRTs to values substantially less than theoretical HRTs. This is commonly referred to as "short-circuiting".

Combining the HRT equation for treatment and the HRT equation for flow yields

$$\frac{V}{Q} = \left(\frac{\ln \left(1 - \frac{RE}{100} \right)}{k} \right)$$

Since wetlands are shallow, usually one meter or less, total wetlands area is usually the design parameter adjusted to provide the needed HRT. Substituting area times depth for volume, rearranging the above equation, and adding a safety factor to account for the non-ideal flow conditions yields

$$A = F \left(\frac{Q}{d} \right) \left(\frac{\ln \left(1 - \frac{RE}{100} \right)}{k} \right)$$

where: A = area, m², d = depth, m, and F = non-ideal flow factor, dimensionless. Factors for non-ideal flow must be based on engineering judgment. Presently, there is no guidance on estimating this factor.

The above equation contains the important parameters affecting pollutant processing in wetlands -- flow, depth, and a chemical specific reaction coefficient.

Operation and Management for Water Quality Improvement

The effective use of constructed wetlands for NPSP abatement and sediment control depends on proper siting, and design. However, the treatment effectiveness of properly constructed wetlands can be enhanced by operational and management techniques. In addition to operational and management techniques that may increase removal efficiency, general maintenance programs are needed to keep the wetlands functioning properly. Management options and maintenance plans are discussed below.

Water Level Manipulation: One of the most effective management tools for controlling sedimentation and chemical pollutant retention/processing in wetlands is water level manipulation. In order to manipulate water level, some type of outlet control structure that allows for drawdown must be in place. Gated pipes or culverts, adjustable outlet pipes, and adjustable weirs are suitable for this purpose. Water level manipulation adjusts storage volume and as a consequence, HRT, a key parameter for optimizing pollutant processing in wetlands. To increase the HRT and pollutant removal efficiency for the wetland, storage in wetlands should be maximized in wetlands before significant rainfall events by drawing down the wetland before the event occurs.

Wetland storage volume should be maximized for those events that deliver the greatest pollutant loadings. In agricultural landscapes, the runoff events to capture are those taking place during the season of most intense chemical application and soil erosion. Baker (1985) noted that for agricultural areas flows that occur less than 10 percent of the time, carry about 90 percent of the NPSP load. In many agricultural landscapes, this occurs in the spring. Thurman et al. (1991) found that late spring and early summer stream concentrations of herbicides applied to Midwestern crops were up to an order of magnitude greater than preplanting and late summer levels. If possible, water level manipulation should be coordinated with farming activities. This requires that plans for water level manipulation be flexible. To capture the right events, draw down and filling should be conducted around storm events carrying heavy chemical/solids loads.

Flow Control: In addition to manipulating water levels to provide sufficient HRT, quiescent flow conditions are needed for effective sedimentation and removal of sediment bound pollutants. High velocities tend to keep particles in suspension. Thus, wetlands should be managed to minimize flow velocities. Once sediments

have been deposited they must also be retained. It is important that flow velocities be kept low during unusually large events or deposited materials will be scoured from the wetland. Velocities can be controlled by adjusting flow area (water level manipulation) and replacing inadequate emergency control structures.

One key in maintaining high HRTs and low velocity in CPAWS is eliminating well defined channels, which tend to concentrate flow, short-circuiting the wetland and increasing flow velocities. Channels should be filled or blocked and the reasons for channel development should be determined and eliminated. Dispersing inflows and outflows also helps assure more of the wetland volume will be involved in conveyance of water, increasing the HRT and reducing flow velocities. Dispersing flows helps to eliminate channel formation and helps establish quiescent flow conditions. Flows can be dispersed by providing multiple inlet and/or outlet locations or by having a distributed inflow and outflow. The establishment of dense emergent vegetation will also help to disperse flows and discourage channel development.

Vegetation Management: One of the most important factors influencing NPS processing in wetlands is the presence of aquatic vegetation. Vegetation provides resistance to flow, slows down water flow, encourages the settling of suspended particles, and supports periphyton development. Rooted aquatic vegetation is best for providing these functions. Emergent vegetation is better suited for this purpose than submergent vegetation because at high flows the water can flow over submergent vegetation and reduce its effectiveness in resisting flow.

Rooted vegetation also helps bind substrates, reducing the potential for resuspension and erosion of deposited materials. In addition to flow resistance and binding of deposited materials, vegetation provides a source of organic matter to form organic sediments. This buildup of organic sediments is important in the removal of many dissolved pollutants.

Because vegetation requires trace nutrients, particularly phosphorous and nitrogen, for survival and growth, the nutrient assimilative capacity of a wetland may be increased by vegetation management. Most constructed treatment wetlands experience a brief period of increased nutrient removal during startup. This increased capacity is due to nutrient uptake by the expanding plant community. Once the vegetation reaches a steady state biomass level, this added capacity is lost. Under steady state conditions, nutrients taken up by plants in spring and summer will, in large, be released after winter die-off, providing only temporary storage of these nutrients.

However, this short term benefit can be turned in to a lasting benefit by harvesting the vegetation at the end of the growing season, before winter die-off occurs. Nutrients, tied up in plant tissues, will be removed along with the plants. Harvesting on a yearly basis may or not be necessary, depending on the types of vegetation present. Utilizing vegetation that has a high nutrient assimilative capacity, such as cattails, will increase the effectiveness of this management option. Also, encouraging dense growths of vegetation will increase the effectiveness of harvesting. Such measures may not be compatible with habitat functions in multiple use wetlands. The economic feasibility of plant harvesting will depend on the wetland location, configuration, and access to

harvesting equipment.

Pretreatment: The NPSP treatment effectiveness of any constructed wetlands may be enhanced by combining the wetlands with pretreatment. Measures such as detention basins or vegetation filter strips may be used. Such treatment mechanisms located upstream of wetlands will remove larger size suspended particles from inflows. Pretreating inflows allows wetlands to retain their storage volume and better treat pollutants other than suspended solids. Such pretreatment measures can usually achieve the same treatment level as wetlands, in a much smaller area.

Maintenance: All wetlands constructed for NPSP abatement will require a maintenance plan. One of the most common reasons for failure of treatment wetlands is the lack of required maintenance. Inspection of dikes and hydraulic structures on a regular basis is a critical element in the maintenance plan. Gated pipes or culverts and adjustable weirs will require the greatest amount of maintenance to retain the ability to manipulate water levels in the wetlands. Pipes or culverts can become filled with sediments or other debris. Such structures should not be installed without planned maintenance. Even passive control structures, such as flumes and weirs, require some maintenance. Flumes and weirs should be kept free of sediments and debris. This is especially important if the flow control device is also used for flow measurements. Other maintenance measures will depend on the type, construction and uses of the particular wetland, and may include such measures as removal of undesirable plants and animals.

CASE HISTORY - SPRING CREEK, BOWMAN, ND

Bowman-Haley Reservoir, a USACE water supply and flood control reservoir located along the North Dakota-South Dakota Border in the western section of the states, provides a good case study that illustrates many of the issues discussed above. Initially, water quality in the reservoir was good and recreational use was high. As the reservoir aged, water quality deteriorated and recreational use declined. Located within a largely agricultural watershed, the lake suffers from eutrophication and experiences intense chronic summer algae blooms, resulting turbidity, and low winter dissolved oxygen problems (USACE 1984).

Because of the water quality problems in the reservoir, the Soil Conservation Service developed a watershed management plan to improve water quality in Bowman-Haley Reservoir (Soil Conservation Service 1990). Extensive on-the-ground implementation of BMPs including strip farming, vegetative filter strips, conservation tillage, deferred grazing, grassed waterways, and improved watering systems for livestock has been initiated in the watershed. In addition, a 24 acre wetland was constructed by the Bowman-Slope Soil Conservation District and Ducks Unlimited on one of the streams (Spring Creek) entering Bowman-Haley Reservoir (Fig. 4). The Spring Creek wetland is an off-channel wetland constructed on USACE land located within the flood pool of the reservoir. The wetland has the dual purpose of providing waterfowl nesting habitat and water quality improvement.

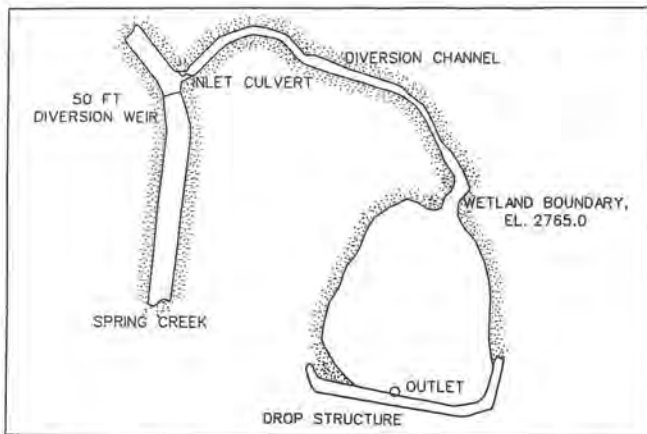


Fig. 4 Spring Creek wetland project (Downer and Myers 1995)

Although a hydrologic analysis of the watershed was not performed, hydraulic design of the wetlands was based on the extensive wetlands construction experience of Ducks Unlimited hydrologists. Water is diverted from Spring Creek into the wetland and then returned to Spring Creek after transiting the wetland. Gated inlet structures allow the water level in the wetland to be manipulated. Inlet and outlet control structures are at equal elevations.

Runoff events were monitored during spring and summer of 1992 and 1993 for suspended solids, nitrogen, and phosphorus and herbicide removal. The wetland removed 62 to 82 percent of the total suspended solids load, 36 to 42 percent of the total phosphorus load, and no nitrogen. Fertilizer applied to the inlet channel slopes resulted in outlet nitrogen concentrations that were approximately the same as nitrogen concentrations at the diversion weir. Concentrations of herbicides in the wetlands were too low to calculate mass removal efficiencies. Specific details on the project, monitoring and results are presented in Downer and Myers (1995).

While the removal efficiencies of the key pollutants phosphorous and suspended solids were similar for each year, the total amount of pollutants removed from Spring Creek, as a percentage of total load, varied greatly between the two years. Because the wetland was initially dry, and runoff was low, an estimated 26 percent of the flow in Spring Creek was diverted into the wetland during the 1992 sampling period (Downer and Myers 1995). In 1993, the wetland was filled by spring snow melt and the water retained for waterfowl production. This starting condition and higher flows in the creek, resulted in only 2 percent of storm flows being diverted into the wetland for treatment (Downer and Myers 1995). Design and operation of the wetland for waterfowl production, instead of water quality improvements, lead to a less than maximum amount of NPSP removal.

Based on experience at the Spring Creek wetland and objectives of the

watershed management plan, the Bowman-Slope Soil Conservation District and Ducks Unlimited are developing plans for another NPSP abatement/waterfowl nesting habitat wetland on another stream entering Bowman-Haley Reservoir.

Other key points about the project which illustrate important points in this paper and may prove important to other similar efforts include:

- Although the wetland was constructed on USACE land, a local group with interest in controlling NPSP (Bowman-Slope Soil Conservation District) provided part of the funds for construction. Ducks Unlimited provided engineering services and funds for construction.
- The wetland was constructed by Ducks Unlimited and is managed by the North Dakota Game and Fish Department to maximize waterfowl usage. Although the wetlands construction is hydrologically sound, the construction and operation do not follow the guidelines contained within this paper for maximum water quality improvement. The performance of the wetland for this purpose could be enhanced by water level manipulations, specifically using draw and fill to maximize the amount of water diverted into the wetland and the HRT.
- Monitoring was conducted to provide quantitative data on pollutant loads coming in and going out during storm events, that is, data on flow and concentration were obtained for storm event runoff. Water quality monitoring was based on NPS pollutants expected to be found in an agricultural watershed, specifically suspended solids, nutrients and herbicides.
- The greatest amount of pollutants were encountered during the first one or two significant storm events after spring planting. For example, concentrations of specific herbicides exceeding federal water quality standards were encountered during the first large event of the first sampling season. Herbicides were found only in trace quantities after this event.
- For an average flow in the wetland of about 0.5 cfs, the calculated HRT of the wetland based on Eq. 5 is about 47 days. The actual HRT measured at the site was only 4.5 days, an order of magnitude lower than the calculated HRT. Flow tends to remain confined to a deep channel along the edge of the wetland, short-circuiting the wetland. Based on these values the non-idealized flow factor for this wetland is 10. Values for other wetlands may be greater or lesser, depending on conditions.
- Based on the actual HRT of the wetland the detention time of the wetland is thought to be sufficient for sediments and nutrients removal, yet inadequate for herbicide removal. To target specific pollutants the proper HRT must be designed into the system.
- The calculated decay rate for suspended sediments using Eq. 4 is -0.279 d^{-1} . The calculated decay rate for phosphorous is -0.113 d^{-1} . These values provide a single data point for helping to determine

exponential decay rates for pollutants in wetlands.

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SEDIMENTATION OF PRAIRIE POTHOLE WETLANDS:
THE NEED FOR INTEGRATED RESEARCH BY AGRICULTURAL AND
WILDLIFE INTERESTS

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ABSTRACT

The Prairie Pothole Region (PPR) of the northern Great Plains is a major producer of cereal grains and wildlife, especially migratory waterfowl. Both agriculture and wildlife are important resources of the PPR. The objectives of maintaining productive lands for agriculture and wildlife are not mutually exclusive; both benefit under sound resource management. We examined the influence of sedimentation on wildlife values in wetlands. Results from June-July 1993 indicate that sedimentation rates ($\text{g} \cdot \text{m}^{-2} \cdot \text{d}^{-1}$) in wetlands with watersheds in summer fallow were significantly greater than in wetlands in native prairie, or in Conservation Reserve Program (CRP) lands. Our work highlights the need for integrated research that combines expertise from agricultural and wildlife disciplines to develop sound conservation practices that simultaneously promote productivity of agricultural fields and wildlife habitats.

INTRODUCTION

Spatial position and morphology of prairie wetlands in agricultural fields make them highly vulnerable to sedimentation (Neely and Baker 1989). Sediment is the most important pollutant of surface waters in the United States and the greatest source of sediment is erosion of agricultural lands (Robinson 1971; Long 1991; Wayland 1993). Impacts of suspended sediment and accelerated sedimentation on fish and aquatic life in riverine systems have been intensively studied (Ritchie 1972; Newcombe and MacDonald 1991; Waters 1995), but the influence of sediment on prairie wetland ecosystems is largely unknown. Sediment input from agricultural fields on prairie wetlands is of particular

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concern because these wetlands provide critical habitat required by breeding, migrating, and resting waterfowl (Batt et al. 1989), shorebirds (Eldridge 1987), and other wetland-dependent wildlife (Duebber 1981). In addition to high wildlife values, wetlands are valued for flood control (Brun et al. 1981; Ludden et al. 1983), ground-water recharge (Winter 1989), and other societal values (Stevens et al. 1995).

A few studies have examined the influence of agricultural land-use on sedimentation of prairie wetlands (Adomaitis et al. 1967; Martin and Hartman 1987; Dieter 1991; Dryer et al. 1996), but impacts on water quality, primary productivity, and aquatic food webs are poorly understood (Gleason and Euliss 1996). Soil erosion is a primary concern of agricultural interests because erosion reduces the integrity, productivity, and sustainability of agricultural lands (Timmons 1980). Agricultural research and policy have been instrumental in developing and implementing agricultural conservation practices on private lands that reduce soil erosion, in order to maintain productivity and enhance soils and water quality. However, the success of conservation practices is normally evaluated from an agricultural perspective and generally does not include wildlife considerations (Miranowski and Bender 1982). Integration of goals from multiple interests and disciplines in conservation policies is in line with recent political emphasis on developing holistic agricultural programs (Gerard 1995). The amalgamation of pertinent interests and disciplines into research programs will ensure that appropriate information is available to policy makers.

Here we present an overview of research on the influence of agricultural land-use practices on sedimentation rates in prairie wetlands, and discuss potential effects of sedimentation on wetland ecology. We also discuss management strategies that reduce sediment inputs into prairie wetlands and the need to integrate research by wildlife and agricultural interests to develop holistic management strategies.

SOIL EROSION AND SEDIMENTATION OF PRAIRIE WETLANDS

During 1993-1995, we examined sedimentation rates in wetlands with watersheds (i.e., catchments) in native prairie with no prior history of tillage, land in CRP, and summer fallow land-use treatments (Gleason and Euliss 1996). Preliminary results from June-July 1993 indicated that sedimentation rates ($\text{g} \cdot \text{m}^{-2} \cdot \text{d}^{-1}$) were up to 70 times greater in summer fallow ($\bar{x}=269.88$) than in native prairie ($\bar{x}=15.74$) and CRP ($\bar{x}=3.81$) (Gleason 1996). Other investigators also have documented accelerated sedimentation of wetlands in agricultural landscapes. Adomaitis et al. (1967) demonstrated that the aeolian mixture of

snow and soil ("snirt") in wetlands surrounded by cultivated fields accumulated at twice the rate as in wetlands in vegetated fields. Similarly, Martin and Hartman (1987) and Dryer et al. (1996) found that prairie wetlands with cultivated watersheds accrued sediments at twice the rate of wetlands surrounded by grassland, and Dieter (1991) demonstrated that turbidity in tilled wetlands was significantly higher than in partially tilled (wetlands with a filterstrip of vegetation along their periphery) and non-tilled wetlands. Catastrophic sedimentation events also have been observed in the PPR in which wetlands have completely filled with sediment during a single episodic rainfall event (Gleason and Euliss, personal observations). Wetlands in cultivated fields are thus shorter lived than wetlands in grasslands landscapes and significant soil loss occurs in agricultural lands under conventional tillage practices.

POTENTIAL IMPACTS TO WETLAND ECOSYSTEMS

Wetland-dependent wildlife values are greatly diminished after wetlands are filled with sediment. At a less catastrophic scale, prairie wetlands in agricultural landscapes receive short spates of sediment input during precipitation events. Sediments alter water quality, primary productivity, and aquatic invertebrates in aquatic ecosystems (Waters 1995). Suspended sediment reduces light penetration and reduces the rate of photosynthesis (Ellis 1936; Dieter 1991) and the concomitant fallout of sediment covers substrates critical to the production of periphytic algae and macrophytes. *In vitro* experiments have shown that sediment depths as little as 0.25 cm can significantly reduce species richness, emergence, and germination of wetland macrophytes (Jurik 1994; Wang 1994). Filling of wetlands also reduces historic water depths and alters the structure of vegetative communities. A common result of wetlands losing water depth from sedimentation is the development of monotypic stands of vegetation (e.g., cattails) that provide little biological diversity and exacerbate problems with farmers because they provide roost sites for blackbirds that depredate sunflowers and other agricultural crops.

Sediment effects on primary production translate into impacts on organisms at higher trophic levels through the aquatic food chain. Aquatic invertebrates are primarily collector-gatherers and grazers that consume periphytic algae associated with detrital food chains and vegetative substrates. Declines in algal production, loss of standing vegetative structure (Krecker 1939; Krull 1970), and covering of organic matter (Murkin 1989) make wetlands less productive of invertebrates through the indirect loss of forage and habitat. Direct effects include covering of invertebrates and their eggs, and clogging of filtering

apparatuses. High levels of silt and clay also are toxic to zooplankton and/or reduce feeding rate and assimilation, thus reducing energy available for reproduction (Robinson 1957; McCabe and O'Brien 1983; Newcombe and MacDonald 1991). Aquatic invertebrates play critical roles in wetlands to facilitate nutrient cycling (Merritt et al. 1984) and are required foods for wildlife (Reeder 1951; Krapu 1974a, 1974b; Swanson et al. 1974, 1985; Fritzell et al. 1979; Euliss and Harris 1987).

MANAGEMENT STRATEGIES

The potential for soil erosion to degrade wetlands and reduce the productivity of agricultural lands is great. Only for the past several decades has concern over soil erosion focussed on the effects of sediment in aquatic environments. However, most work has been conducted on reservoirs, lakes, and streams, which typically receive sediment from nonpoint sources. In contrast, prairie wetlands have only recently received attention although they are located in small catchments where sources of sediment input are easily identified. Lakes and streams can be protected by implementing large-scale control measures (e.g., CRP, bufferstrips, grassways) and soil conservation practices (e.g., no-till, minimum till), whereas wetland protection can be implemented using site-specific techniques.

Efforts to reduce sedimentation of wetlands by establishing perennial cover (e.g., CRP) and using bufferstrips are effective. Benefits of CRP to wildlife in the northern Great Plains have been documented by Johnson and Schwartz (1993a, 1993b), Kantrud (1993), and Reynolds et al. (1994), but this program is confined to certain types of agricultural lands and its long-term future is uncertain. Also, there are private land programs under which wildlife agencies pay farmers to take land out of production or use certain conservation tillage practices (Payne and Wentz 1992), but these programs are often of short duration. Land-use practices such as conservation tillage and zero-tillage are becoming more common in the PPR. In 1991, minimum tillage and organic farms comprised approximately 260,000 ha in North Dakota (Conservation Technology Information Center 1992). Both practices are long-term, reduce soil erosion, enhance wildlife benefits (Cowan 1982; Duebbert 1987; Youngberg et al. 1984; Lokemoen and Beiser 1995), and promote a highly productive and sustainable agriculture.

NEED FOR INTEGRATED RESEARCH

Future research should examine the influence of agricultural land-use practices on wetlands and wildlife in the PPR. It is not possible to sustain continental waterfowl and other wildlife populations on limited public lands. However, enhancing productivity of private lands for agricultural purposes and wildlife is possible. To insure the integration of long-term goals for agriculture and wildlife, research needs to develop management strategies that simultaneously provide for sustainable agriculture and wetlands.

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OXIDATION-REDUCTION AND GROUNDWATER CONTAMINATION IN THE PRAIRIE POTHOLE REGION OF THE NORTHERN GREAT PLAINS

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and J. A. Daniel³

ABSTRACT

The prairie pothole region (PPR) of the northern Great Plains, often intensely used for production of wheat (*Triticum aestivum* L.), maize, (*Zea mays* L.) and soybean (*Glycine max* L.), is characterized by numerous shallow, glacially-derived depressions. These depressions collect surface runoff of snowmelt and rainfall from nearby fields which infiltrates to shallow groundwater as focused recharge. While only 2 to 5 % of the total precipitation is recharge to groundwater, depressionally focused recharge allows point-source recharge of rainfall and snow melt as frost melts during spring thaw. Nitrate levels increase over winter (5- to 20-fold), but spring recharge dilutes these increased concentrations. Relative measures of aeration made with platinum electrodes during the thawed period show that potentials in well drained portions of the soil profile remain above + 400 mV throughout most of the crop year. Similar potential measures made in the base of a previously drained pothole were negative and well below the critical aeration potential for denitrification for most of the year. Therefore, it is unlikely that nitrates contained in rainfall-induced surface runoff move through prairie potholes to groundwater. However, some bound pesticides such as atrazine and alachlor are solubilized under anaerobiosis. Anaerobiosis effectively doubled the amounts of resin extractable atrazine and alachlor from a wide range of soils. Thus, contamination of prairie potholes with pesticides may contribute to groundwater pollution when both anaerobiosis and leaching occurs.

INTRODUCTION

A large portion of the Northern Great Plains are referred to as the Prairie Pothole Region (PPR). This region includes most of North Dakota, east and central South Dakota, parts of western Minnesota and western Iowa in the United States and the southern provinces of Saskatchewan and Alberta in Canada (van der Valk, 1989).

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The region is characterized by shallow surface depressions which collect snowmelt and occasional rainfall runoff. Large parts of the PPR are intensively cultivated for crop production. The western and northern portion of the PPR is devoted mainly to wheat production and the eastern and southern portion is intensively cultivated for maize (*Zea mays* L.), soybean (*Glycine max* L.), wheat (*Triticum aestivum* L.) and a variety of other crops (Table 1).

Table 1. Average annual acreages of wheat, maize, and soybean production in Iowa, Minnesota, North Dakota and South Dakota during 1991 through 1993.[†]

State	Crop			
	Wheat	Maize	Soybean	Sunflower
-----million acres-----				
North Dakota	10.71	0.51	0.62	1.00
South Dakota	3.45	3.03	2.07	0.49
Iowa	0.05	12.05	8.37	-----
Minnesota	2.42	5.70	5.25	0.21

[†] Source: Powers and Petrone, eds. 1995.

Most of the crop production area is treated annually with nitrogen- (N), phosphorus-, and potassium-fertilizers (Table 2) and two to three pesticides (Table 3). Nearly all of the crop land is being fertilized with N. Most of the crop land is receiving two to three different herbicides. Generally, as the toxicity of the

Table 2. Fertilizers applied to crops grown in the Prairie Pothole Region[†].

State	Crop	Applied Fertilizer		
		N	P	K
-----lbs ac ⁻¹ -----				
North Dakota	Durum Wheat	70	26	9
North Dakota	Spring Wheat	76	38	27
South Dakota	“ ”	52	23	14
Minnesota	“ ”	94	38	27
South Dakota	Maize	90	39	28
Minnesota	“	108	51	65
Iowa	“	121	58	71
Minnesota	Soybean	19	39	66
Iowa	“	27	43	56

[†] Data source: USDA-NASS-ERS. Agricultural Chemical Usage: 1994 Field Crops Summary. Washington, DC. 106 pp.

herbicide increases, the application rate decreases. As a result, most wetlands in the region would seem to be at risk of contamination with agricultural chemicals.

Table 3. Pesticides commonly applied to crops in the Prairie Pothole Region¹.

Pesticide	Crop			Rate	States				
	W	M	S ²		ND	SD	MN	IA	
	----- lbs ac ⁻¹ -----								
Herbicides									
2,4-D	x	x	x	0.31 to 0.49	x	x	x	x	
Acetochlor	-- ³	x	--	1.50 to 1.98	--	x	x	x	
Acifluorfen	--	--	x	0.15	--	--	x	x	
Alachlor	--	x	x	1.84 to 2.01	--	--	x	x	
Atrazine	--	x	--	0.72 to 0.87	--	x	x	x	
Bentazon	--	x	x	0.55 to 0.69	--	--	x	x	
Bromoxynil	x	x	--	0.22 to 0.25	x	x	x	x	
Clethodim	--	--	x	0.08 to 0.10	--	--	x	x	
Clomazone	--	--	x	0.56 to 0.73	--	--	x	x	
Clorimuron-ethyl	--	--	x	0.006	--	--	--	x	
Cyanazine	--	x	--	1.60 to 2.32	--	x	x	x	
Dicamba	x	x	--	0.07 to 0.35	x	x	x	x	
Diclofop-methyl	x	--	--	0.66	x	--	--	--	
Dimethenamid	--	x	--	1.13 to 1.41	--	x	x	x	
EPTC	--	x	--	3.71 to 4.59	--	x	x	x	
Ethylfluralin	--	--	x	0.79	--	--	x	--	
Fenoxaprop-ethyl	x	--	x	0.01 to 0.12	x	x	x	x	
Fluazifop-p-butyl	--	--	x	0.04 to 0.06	--	--	x	x	
Flumetsulam	--	x	x	0.06 to 0.07	--	--	x	x	
Glyphosate	--	x	x	0.43 to 0.65	--	x	x	x	
Imazamethabenz	x	--	--	0.34	--	--	x	--	
Imazaquin	--	--	x	0.06	--	--	--	x	
Imazethapyr	--	x	x	0.05 to 0.06	--	--	x	x	
Lactofen	--	--	x	0.07	--	--	x	--	
MCPA	x	--	--	0.34 to 0.38	x	x	x	--	
Metolachlor	--	x	--	1.28 to 2.21	--	x	x	--	
Metribuzin	--	x	x	0.32	--	--	--	x	
Metsulfuron-methyl	x	--	--	0.004	--	x	--	--	
Nicosulfuron	--	x	--	0.03	--	x	x	x	
Pendimethalin	--	x	x	0.98 to 1.22	--	--	x	x	
Primisulfuron	--	x	--	0.02	--	--	--	x	
Propachlor	--	x	--	2.39	--	--	x	--	
Quizalofop-ethyl	--	--	x	0.04 to 0.05	--	--	x	x	
Sethoxyden	--	--	x	0.19 to 0.21	--	--	x	x	

Table 3. (Cont.)

Pesticide	Crop			Rate	States			
	W	M	S [‡]		ND	SD	MN	IA
				----- lbs ac ⁻¹ -----				
Thifensulfuron	x	--	x	0.004 to 0.01	x	x	x	x
Triallate	x	--	--	1.04	x	--	--	--
Triasulfuron	x	--	--	0.01	--	x	--	--
Tribenuron-methyl	x	--	--	0.005 to 0.006	x	x	x	--
Trifluralin	x	--	x	0.34 to 0.85	x	--	x	x
Insecticides								
Clorpyrifos	--	x	--	1.04	--	--	x	x
Fonofos	--	x	--	1.24	--	--	--	x
Permethrin	--	x	--	0.12	--	--	--	x
Tefluthrin	--	x	--	0.11	--	--	--	x
Terbufos	--	x	--	1.04	--	--	--	x

[†] Data source: USDA-NASS-ERS. Agricultural Chemical Usage: 1994 Field Crops Summary. Washington, DC. 106 pp.

[‡] W = wheat, M = maize, and S = soybean.

[§] -- = insufficient data to record.

With the observed levels of crop production and chemical use, expressions of concern about the potential for ground water pollution are expected. Snowmelt and surface runoff aids movement of agriculturally applied chemicals such as fertilizer nitrates (NO₃-N) and pesticides to prairie potholes. Water often ponds, at least briefly, in these potholes and drains to the underlying groundwater reservoir or via interflow to adjacent potholes. The fate of these chemicals is directly affected by the relative aeration maintained in the soil profile. When dissolved oxygen (O₂) is depleted in the soil solution, soil microbial organisms extract it from a variety of soil oxides including NO₃-N, iron (Fe_nO_p) and manganese (Mn_nO_p) to name a few. Under oxidized conditions, NO₃-N is easily transported with water to the groundwater or other surface bodies of water. Most other oxides remain stable and form adsorptive surfaces for a variety of components, including pesticides.

Under reduced conditions, NO₃-N is converted to harmless gas (N₂) and the stable oxides of Fe and Mn become soluble and their associated adsorbates may be solubilized (Bohn, 1969; Schwab and Lindsay, 1983; Itô and Araki, 1984; van Cleemput and Patrick, 1984; Boyle and Lindsay, 1986). The driving force or cause of oxygen depletion in soil comes from microbial respiration. Under warm and wet conditions, O₂ diffusion is impeded and microbial populations consume O₂ at a rate greater than that supplied through diffusion.

Platinum electrodes are very sensitive to changes in O_2 concentrations in soil air and because of this they are useful as sensors of relative aeration (McIntyre, 1966 a and b, Grable and Siemer, 1968; Olness et al 1989).

Both inorganic and organic chemistries are affected by redox potential changes. When redox sensitive surfaces dissolve, their associated adsorbates are also solubilized (Olness et al, 1990). Thus, while some potential pollutants are rendered harmless under anaerobic conditions, some may become potentially more damaging.

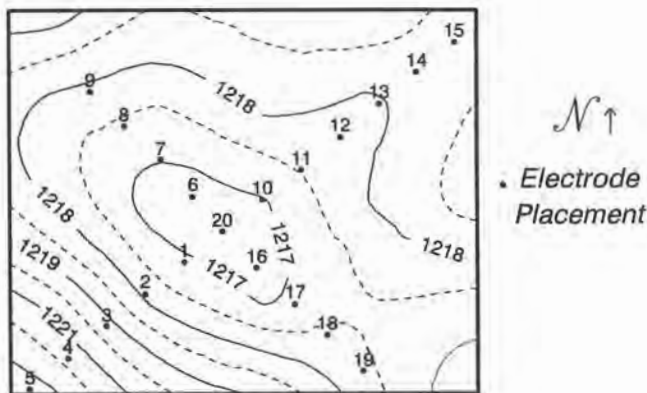


Fig. 1. Location of platinum electrode installations within the depression. Lines represent surface elevation (msl). Reprinted with permission, Minn. Acad. Sci. J. Olness, et al. 1994. 59:35-40.

We evaluated the relative aeration of a cultivated prairie pothole and leaching of nitrate and atrazine on an adjacent area.

MATERIALS AND METHODS

A shallow, < 6.5 ft (2 m), recharge depression on the Barnes-Aasted Research Farm located about 14 mi (23 km) northeast of Morris, Minnesota and about 9 mi (15 km) southeast of the continental divide (Gulf of Mexico--Hudson Bay) was

instrumented with 60 platinized platinum electrodes along two transects. Soil within the depression is a Parnell silty clay loam (fine, montmorillonitic, frigid, Typic argiaquoll) with Vallery silty clay loam (fine-loamy, frigid typic calciaquoll) on the north and east rim and Hamerly clay loam (fine-loamy, frigid, Aeric calciaquoll) on the south and west rim. A tile drain installed several

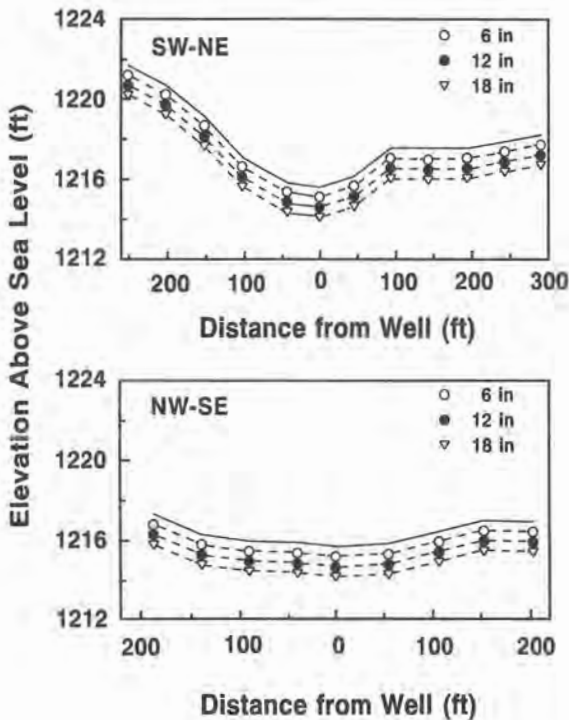


Fig. 2. Relative elevation of individual platinum electrodes in two transects through a cultivated shallow depression. The solid line without symbols represents the soil surface. Vertical axis has been exaggerated. Reprinted with permission, Minn. Acad. Sci. J., Olness et al. 1994. 59:35-40.

decades earlier was plugged during the study to prevent artificial drainage. A cased observation well was installed near the center of the depression; this installation had no apparent effect on drainage within the depression as water often ponded around the casing.

Electrodes were installed in sets of 3 (20 sets) along a southwest-northeast and northwest-southeast transects; relative elevations and distances are detailed in Fig. 1 and 2. Electrodes consisted of 2.5×10^{-3} inch (64- μ m) diameter, platinized platinum wire which extended 0.4 inches (1 cm) from the base of a 1-inch (2.5-cm) diameter PVC tube stoppered at both ends with a no. 2 rubber stopper. The electrode was fused to an insulated copper wire that extended about 6 inches (15 cm) beyond the opposite end of the PVC tube. Salt bridges were constructed from 2 ft (60-cm) lengths of PVC tubing and vented at 2, 8, and 14 inch (5, 20, and 35 cm) distances from the base (Veneman and Pickering, 1983).

Electrodes were inserted in mid-May after planting and removed at the end of October after harvest so early pre-plant data were not obtained. Electrodes were installed by withdrawing a 1-inch (2.5-cm) diameter core with a Hoffer tube and then inserting the electrode firmly into the soil. Clay from the subsoil was used to effect a seal between the soil and the PVC housings at the soil surface. Electrodes were placed in a circular pattern around a salt bridge at 6-, 12-, and 18-inch (15-, 30- and 45-cm) depths. Potential measurements were recorded at near-weekly intervals using a portable, battery-powered multimeter.

Groundwater samples were taken monthly from the observation well and immediately refrigerated. A single-check valve baler was constructed from a section of 1.5-inch (3.8-cm) diameter by 2 ft (60 cm) in length from schedule 40 PVC pipe. A field sample 17.6 oz (500 mL) was collected after bailing 2 well-volume equivalents of water. A 7 dram (20-mL) aliquot was filtered through a 7.9×10^{-5} inch (0.2 μ m) membrane filter, preserved with 0.7 dram (2 mL) of concentrated H_2SO_4 , and stored at 40 F (4 C) until analyzed. Additional details are given in Daniel and Staricka (1994).

Atrazine and nitrogen fertilizer was surface applied on a neighboring depression about 110 yds (100 m) from the depression rim on Hamerly clay loam and Parnell silty clay loam soils. wheat had been uniformly grown over the experimental site in the previous year. A split-split plot design with four replications was used; tillage was the plot treatment, N rate and atrazine were split plot treatments, and sampling position was the split-split plot variable. Tillage, moldboard plow or chisel plow was uniformly applied in the fall to 19.7 yds by 66.7 yds (18 m by 61 m) areas in a direction perpendicular to the contour. Nitrogen fertilizer was applied at rates, 116 or 232 lbs N ac^{-1} (130 or 260 kg N ha^{-1}) to subplots located midslope and parallel to a single contour line. Each year

13 lbs N ac⁻¹ (14.6 kg N ha⁻¹) were applied after spring thaw to the entire area and in 1992, 100 lbs N ac⁻¹ (112 kg N ha⁻¹) was side dressed over the entire area. Atrazine was applied at rates of either 0 or 3.0 lbs active ingredient ac⁻¹ (0 or 3.4 kg ha⁻¹). Both atrazine and N were randomized independently of each other.

Soil cores, 2-inch (5-cm) diameter, were taken to a depth of 5 ft (150 cm) within and at 10 and 30 ft (3 and 9 m) downslope of the application area during April and examined for NO₃-N and atrazine. Atrazine determined on 0.35 oz (10 g) air dried sub-samples using the method of Koskinen et al (1991). Determinations of atrazine were confirmed using dual column gas chromatography with DB-5 and DB-1701 capillary columns and a nitrogen-phosphorus thermoionic detector (Graves, 1989) in a Varian¹ model 3400 gas chromatograph (for additional details see Basta and Olness, 1992). Both soil and water samples were analyzed for ammonium- nitrate- and nitrite-N using an Alpkem⁴ auto analyzer (US EPA, 1979).

RESULTS AND DISCUSSION

All sites within the depression were initially aerobic (Figs. 3 a and b). However, during the months of April and May rainfall exceeded evapotranspiration and the center of the depression became increasingly anaerobic, first at the 18-inch (45-cm) depth and gradually throughout the upper 18-inch (45-cm) depth zone. The initial condition within the depression was probably due to the effects of long term tile drainage which allowed the bottom of the depression to drain more readily. The most reduced potentials, about -250 mV, were recorded at 18 inch (45 cm) and this value appears to be near the limit of biological reduction at this site. During the second year, potentials within the depression reached -250 mV at an earlier date and at shallower depths which suggests that, before the tile drain was plugged, even the soil profile within the basin had been well aerated. A cross sectional profile of the electrode potentials within the site are shown in Fig. 4. Soil within the very basin of the depression was sufficiently reduced eliminate virtually all nitrate over an area of about 0.37 ac (1500 m²).

A general tendency for the basin soil profiles to become more aerated as the soil cooled in the fall is consistent with a microbially driven system. As the soil cooled, microbial respiration decreases exponentially and at some point the rate of diffusion of oxygen into the system exceeds the rate of consumption. In depressions which have never been drained and in which the soil remains saturated most of the year, the relative oxidation of the profile during the cooler winter months should be less pronounced.

¹ Company and trade names are mentioned for the reader's benefit and do not imply preference by the USDA over products or companies not mentioned.

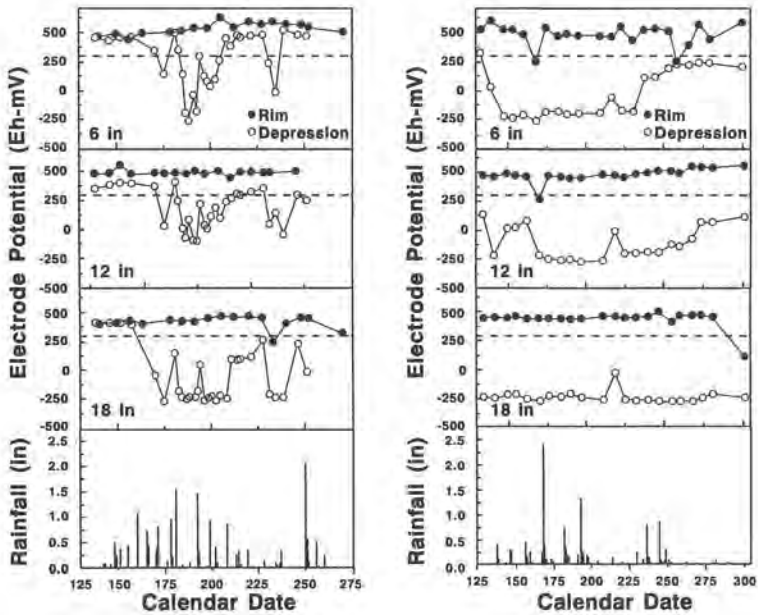


Fig. 3. Electrode potentials at locations 5 (rim) and 7 (within the depression) relative to the calomel electrode and rainfall throughout the growing seasons of 1991 and 1992. The dotted line at 300 mV represents the limit at which NO_3^- -N is found at pH 7.0. Reprinted with permission, Minn. Acad. Sci. J., Olness et al. 1994. 59:35-40.

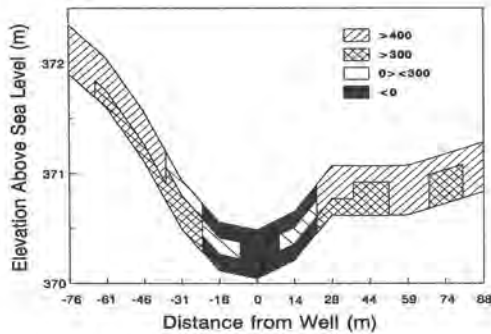


Fig. 4. A cross sectional representation of electrode potentials on 7/15/92 (Date 196) along the northeast-southwest transect. The vertical axis has been exaggerated. Reprinted with permission, MN. Acad. Sci. J., Olness et al. 1994. 59:35-40

In homogenous environments with a pH of 7.0, $\text{NO}_3\text{-N}$ is usually reduced to N_2 at electrode values of about 300 mV, Fe^{3+} to Fe^{2+} at about 200 mV and $\text{Mn}^{3,4+}$ to Mn^{2+} at 100 mV and SO_4^{2-} to S^{2-} at about -150 mV. Thus, it seems clear that movement of $\text{NO}_3\text{-N}$ through prairie pothole depressions to the groundwater is unlikely. At this site, Daniel and Staricka (1994) usually found only trace amounts of $\text{NO}_3\text{-N}$ entering groundwater during the growing season (Fig. 5) and this observation supports the conclusion that most $\text{NO}_3\text{-N}$ is denitrified in depressional environments.

Soil freezing is a common feature during the winter in the PPR. As the soil freezes, water to move to the freezing front and this permits accumulation of water in excess of the soil water holding (field) capacity. As this frost layer melts from the bottom surface in late winter, water in excess of the field capacity drains downward. Also, rapid loss of snow melt, which ponds briefly in the depression,

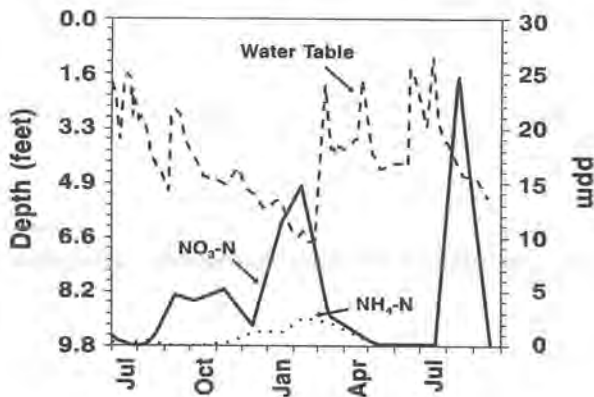


Fig. 5. Relative groundwater elevation and inorganic nitrogen concentrations during the 1991-1992 monitoring period for well number 4 located in the depression. Source: Daniel and Staricka. 1994. Proc. Focus Conf. Eastern Regional Groundwater Issues. pp. 663-754.

suggests that water is moving through fissures or channelized flow perhaps enhanced by frost. This allows excess water to reach the groundwater more rapidly with little interaction with the soil. An increase in the ammonium-N concentration in late winter is consistent with channelized flow of snowmelt and frost melt drainage (Fig. 5). Daniel and Staricka (1994) found $\text{NO}_3\text{-N}$ concentrations in groundwater beneath the depression increased during the winter months; this agrees with observations that the depression became more aerated as

the soil cooled. However, drainage during this period (late fall to early spring) is minimized in northern latitudes and throughout the PPR due to soil freezing.

In contrast to the depression basin, the rim of the depression remained well aerated throughout most of the year. Occasionally the potentials of the rim soils were reduced enough to enhance nitrate reduction but these occasions were very brief and episodic in nature. Potentials for electrodes on rim sites show the typical pattern of decreasing values with increasing soil depth; the mean change was about 160 mV over a 18-inch (45-cm) depth increment. Most of the decrease with depth is due to microbial respiration in the upper 6 to 8 inches (15 to 20 cm) of the soil profile, so further decreases in redox potential with depth below 18 inches (45 cm) should be small. Under these conditions, microbial populations continuously convert soil organic-N to $\text{NO}_3\text{-N}$ in the upper portion of the profile.

The climate of the PPR has probably been a major mitigating factor in minimizing ground and surface water contamination. Accumulation of $\text{NO}_3\text{-N}$ depends on soil temperature, soil moisture content, and the rate of plant withdrawal. For well aerated sites, transport of soil $\text{NO}_3\text{-N}$ to the groundwater is most likely to occur in the late fall as the soil profile re-hydrates and in the spring with frost melt drainage and early season rainfall. In the PPR, rainfall in excess of evapotranspiration occurs infrequently and usually in the spring (Fig. 6). During the summer, deficit conditions are incurred during which crop and grasslands are often in a state of drought stress. Under very dry or very wet conditions, microbial production of soil $\text{NO}_3\text{-N}$ is minimized (Skopp et al, 1990).

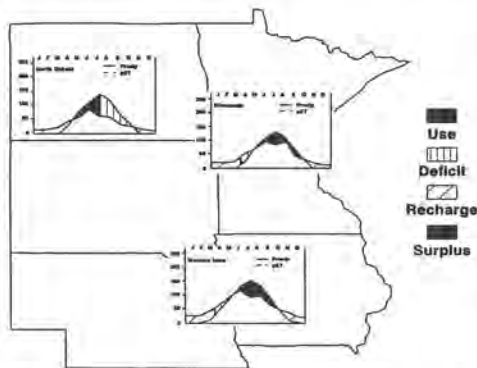


Fig. 6. Relative precipitation and evapotranspiration within the PPR of North Dakota, South Dakota, Minnesota and Iowa. Source: USDA-Soil Conservation Service. Agricultural Handbook, No. 436.

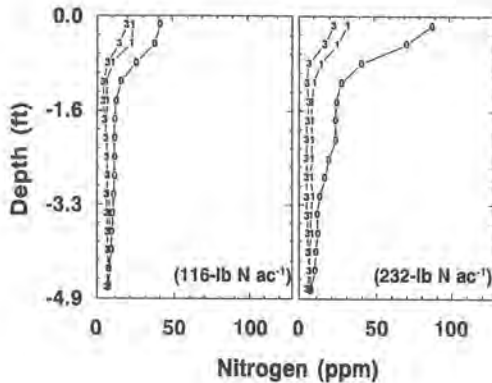


Fig. 7. Post-harvest distribution of nitrate nitrogen in a Hamerly-Parnell soil complex in 1993 after three annual treatments and two growing seasons. Symbols 0 = within treated area, 3 = 10 ft downslope of the treated area, and 9 = 30 ft downslope of the treated area. Source: Staricka et al. 1994. Proc. 2nd. Conf. Environ. Sound Agric. pp. 105-112.

The loss of fertilizer N to groundwater in the form of $\text{NO}_3\text{-N}$ depends then on the crop potential to accumulate N and the time and rate of N fertilization. For example, an 127 bu ac^{-1} (8,000 Mg ha^{-1}) maize grain yield will accumulate about 180 lbs N ac^{-1} (200 kg N ha^{-1}) in the vegetation (Olness et al. 1995); and the range of N derived from the soil may range from ≤ 36 to ≥ 90 lbs N ac^{-1} (≤ 40 to ≥ 100 kg N ha^{-1}) depending on the post harvest and early spring soil conditions. When the soil mineralized N and the applied fertilizer N exceed the crop requirement, the excess may move down the soil profile and eventually reach the groundwater. This fact is clearly expressed in the fertilizer N treatment study (Staricka, et al 1994; Fig. 7). Soil $\text{NO}_3\text{-N}$ concentrations ranged from about 20 ppm (40 mg N kg^{-1}) or 80 lbs N ac^{-1} 6-in $^{-1}$ (80 kg N ha^{-1} 15-cm $^{-1}$) at the surface to about 45 ppm (90 mg N kg^{-1}) within the fertilized area when fertilizer rates increased from 113 to 226 lbs N ac^{-1} (130 to 260 kg N ha^{-1}); at the same time, soil $\text{NO}_3\text{-N}$ concentrations for untreated areas were only about 20 ppm (20 mg N kg^{-1}).

More alarming, however, are the increased soil $\text{NO}_3\text{-N}$ concentrations at the 2 ft (60-cm depth): < 5 ppm (5 mg N kg^{-1}) in untreated areas, about 10 ppm (10 mg N g^{-1}) with the 113 lbs N ac^{-1} (130 kg N ha^{-1}) rate and > 20 ppm (20 mg N kg^{-1}) with the 232 lbs N ac^{-1} (260 kg N ha^{-1}) rate. Clearly, excess $\text{NO}_3\text{-N}$ can and is being leached below the rooting zone even in fine textured soils in climatic areas with little excess precipitation.

Equally serious is the observation that applied pesticides are transported downward in the soil profile (Staricka et al, prev. unpub. data; Fig. 8) Because of analytical limits of detection, atrazine was found in only a fraction of the samples analyzed. By applying statistical theory (Somsen et al 1994), however, mean concentrations of atrazine in the soil were estimated. Mean concentrations of atrazine in the treated plots were > 500 ppb ($500 \mu\text{g kg}^{-1}$) at the surface and > 8

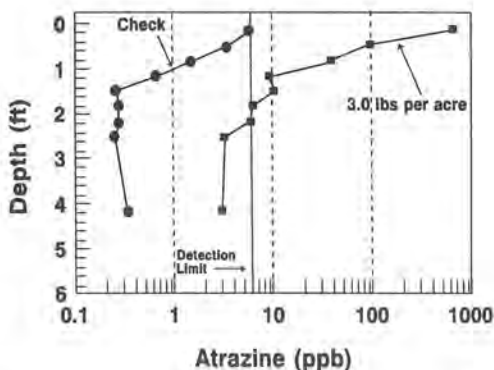


Fig. 8. Post-harvest distribution of atrazine in a Hamerly-Parnell soil complex in 1992. Source: J. A. Staricka (Previously unpublished). For depths of ≤ 16 inches, $n = 120$. For depths > 16 inches, $n = 40$

ppb ($8 \mu\text{g kg}^{-1}$) at a depth of 1 ft (30 cm) even though normal tillage depths were ≤ 8 inches (20 cm)! In untreated areas, atrazine concentrations were ≤ 5 ppb ($5 \mu\text{g kg}^{-1}$; probably drift contamination) at the soil surface and < 1 ppb ($1 \mu\text{g kg}^{-1}$) at depths > 1 ft (30 cm).

Unlike oxygen sensitive constituents, atrazine and many other pesticides are unaffected in the range of naturally produced redox potentials. Because the surfaces upon which atrazine adsorbs are affected by redox potential, the distribution of atrazine between the adsorbed and solution phase is affected by changes in soil aeration (Olness, Basta and Rinke, prev. unpub.; Fig. 9). Pesticides which are transported to prairie potholes and adsorbed on redox sensitive surfaces are at risk for transport to groundwater if the pothole serves as a focused recharge site for groundwater.

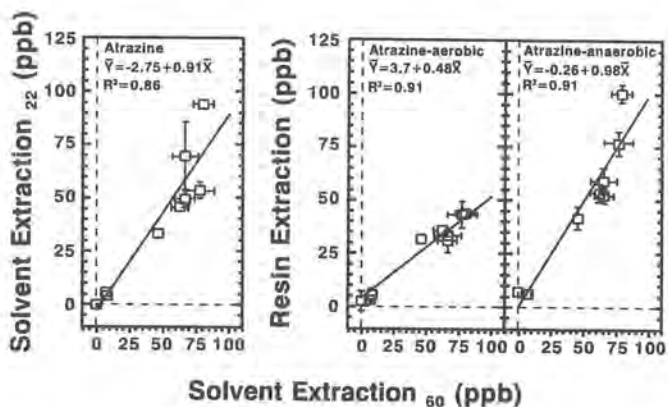


Fig. 9. Effect of aeration on extraction of atrazine from soils previously treated with atrazine. Source: Olness, Basta, and Rinke, 1996. (Previously unpublished).

ACKNOWLEDGEMENT

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- Fig. 1. Location of platinum electrode installations within the depression. Lines represent surface elevation (msl). Reprinted with permission, Minn. Acad. Sci. J., Olness et al. 1994. 59:35-40.
- Fig. 2. Relative elevation of individual platinum electrodes in two transects through a cultivated shallow depression. The solid line without symbols represents the soil surface. Vertical axis has been exaggerated. Reprinted with permission, Minn. Acad. Sci. J., Olness et al. 1994. 59:35-40.
- Fig. 3. Electrode potentials at locations 5 (rim) and 7 (within the depression) relative to the calomel electrode and rainfall throughout the growing seasons of 1991 and 1992. The dotted line at 300 mV represents the limit at which $\text{NO}_3\text{-N}$ is found at pH 7.0. Reprinted with permission, Minn. Acad. Sci. J., Olness et al. 1994. 59:35-40.
- Fig. 4. A cross sectional representation of electrode potentials on July 15, 1992 (Calendar date 196) along the northeast-southwest transect. The vertical axis has been exaggerated. Reprinted with permission, Minn. Acad. Sci. J., Olness et al. 1994. 59:35-40.
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EFFECT OF N FERTILITY RATE ON INTERNAL DRAINAGE UNDER
IRRIGATED CORN IN CENTRAL NORTH DAKOTA

Brian J. Wienhold¹

Todd P. Trooien²

ABSTRACT

Wetlands present in irrigated areas may be subject to groundwater discharge. The potential exists for contamination if these water inputs contain agricultural chemicals. Irrigation scheduling and fertilizer management are two aspects of irrigated crop management that influence the potential for nitrate (NO_3) contamination of groundwater. Meteorological methods of scheduling irrigation are becoming more accessible to producers. These methods utilize weather data to estimate potential evapotranspiration (ET) and incorporate a crop coefficient to adjust for the water requirements of different crops and growth stages. Nitrogen fertilizer is the agricultural chemical used in the greatest quantities and is also the most commonly detected contaminant in ground waters. Efficient fertilizer management involves applying sufficient fertilizer to meet a yield goal with adjustments in the fertilizer rate for residual fertilizer N in the soil and additions in crop residue, manure, and irrigation water. We have been measuring corn yield, internal drainage, and determining the fate of applied N in lysimeters at two sites in central North Dakota. Lysimeters were fertilized to 90 or 180 lbs N a⁻¹ (100 or 200 kg N ha⁻¹) with the higher rate being the rate recommended for an optimum crop yield. Irrigation was applied such that precipitation plus irrigation equalled the calculated ET rate. Averaged over years, corn receiving 180 lbs N a⁻¹ yielded 30% more dry matter; had a 40% greater N content; and derived 40% more N from fertilizer than corn receiving 90 lbs N a⁻¹. The meteorological method estimated water use by the corn crop receiving 180 lbs N a⁻¹ well as only 6% of the applied water drained out of the root zone. In contrast, over 20% of the applied water drained out of the root zone of lysimeters receiving 90 lbs N a⁻¹. Reduced growth of the under fertilized crop resulted in poor utilization of applied

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irrigation. Inadequate fertilization not only reduced yield but resulted in an increase in leaching potential of agricultural chemicals.

INTRODUCTION

Water is the factor most limiting to crops in the semi-arid Northern Great Plains. Precipitation is highly variable both in total amount and temporal distribution throughout the growing season. Supplemental irrigation is a management practice that can be used by producers to meet crop moisture needs during periods of below-normal precipitation or to grow crops that require more water than is normally available. Supplemental irrigation has been demonstrated to be economically feasible in areas of North Dakota (Leitch et al., 1991) but remains underutilized by producers. Construction of a potato processing plant in Jamestown, ND and a corn processing plant in Wahpeton, ND are increasing the demand for stable sources of potatoes and corn. Irrigation is likely to expand as producers implement management practices that will help them meet contract obligations to these processing plants.

As irrigation increases, best management practices (BMP) will need to be developed and implemented to insure economic returns are realized and environmental impacts are minimized. Irrigation scheduling and fertilizer management are two areas where a number of BMP's exist. Irrigation scheduling can be used to provide water to meet crop needs and for salinity management in the root zone. Fertilizer management includes: soil sampling and testing; adjusting fertilizer inputs to account for nutrients added in crop residue, manure, and cover crops; and applying fertilizer in the proper form and at the proper time to optimize utilization by the crop and minimize losses due to leaching or surface runoff. However, interactions between management practices need to be determined in order to develop improved management practices for efficient water use. Information concerning the effect of changes made in one management practice on efficacy of another management practice is lacking.

Meteorological methods of scheduling irrigation are becoming more accessible to producers. These methods utilize weather data collected at or near the irrigation site to calculate crop ET (e.g. Jensen et al., 1970). An adjustment is usually made to account for different crops and growth stages (e.g. Lundstrom and Stegman, 1983). Adjustments for other management practices (e.g. fertility, residue management) are generally not available. The objective of the present paper is to evaluate the effect of N fertility on internal drainage, the downward movement of water out of the root zone, from soils supporting corn grown under irrigation at two sites in central North Dakota.

METHODS

The study was conducted at two sites in central North Dakota; the Menoken township site (T139N, R78W, Sec. 19, SE 1/4) (Doering et al., 1986) and the Naughton township site (T140N, R79W, Sec. 35, SW 1/4) (Trooien and Reichman, 1990). Soils at the Menoken site are Lihen sandy loam (sandy, mixed Entic Haploboroll), Roseglen loam (fine-loamy, mixed Pachic Haploboroll), and Parshall (coarse-loamy, mixed Pachic Haploboroll). These soils developed on aeolian-lacustrine sediments deposited over fine lacustrine sediments. Soil structure at the Menoken site is massive or single-grained and is similar throughout the sampled profile. Soils at the Naughton site are Falkirk loam (fine-loamy, mixed Pachic Haploboroll) and Bowbells loam (fine-loamy, mixed Pachic Argiboroll). These soils developed on slope-worked alluvium deposited on glacial till. Soil structure at the Naughton site is weak to moderate coarse subangular blocky or prismatic in the surface layers and moderate to strong coarse subangular blocky to prismatic at lower depths. Soils at both sites are well drained.

Data collected from six nonweighing lysimeters at each site will be presented in this paper. Each lysimeter measured eight feet by eight feet (2.5 by 2.5 m) and extended seven feet (2.3 m) below the surface. A vertical plastic barrier was placed around each lysimeter to minimize water loss from the plot due to horizontal flow. The undisturbed lysimeters retained the natural drainage characteristics of the soil profile (Doering et al., 1986; Trooien and Reichman, 1990). A neutron access tube was installed in the center of each lysimeter to facilitate water content measurements. Tensiometers were installed at depths of 3 (0.9 m), 4.4 (1.35 m), and 6.6 feet (2.00 m). The tensiometers were used to measure soil matric potentials and hydraulic gradients. Hydraulic conductivity was calculated using soil water potential at 6.6 feet and data from previous hydraulic calibrations (Doering et al., 1986; Trooien and Reichman, 1990). Drainage was calculated with Darcy's Law using the measured gradient between 4.4 and 6.6 feet (Trooien and Reichman, 1990).

Each lysimeter was planted to corn and irrigated such that precipitation plus irrigation equalled the calculated Jensen-Haise corn evapotranspiration (Jensen et al., 1970; Lundstrom and Stegman, 1983). Water from the Heart River (a tributary of the Missouri River) was used for irrigation. Nitrogen fertility treatments were 90 and 180 lbs a⁻¹ (100 and 200 kg ha⁻¹). Nitrogen was applied such that fertilizer N plus soil inorganic N in the upper 2 feet (0.6 m) of the soil profile equalled the treatment rate. Nitrogen was applied as ammonium nitrate. Corn was harvested shortly after the first killing frost each fall. The plants were separated into leaves, stalks, and grain, oven dried, and weighed.

A study was conducted at the Menoken site from 1984-1989 to determine corn fertilizer N use efficiency, percent N derived from fertilizer, and fertilizer remaining in the root zone at the end of the growing season. Corn was grown in cylinders adjacent to the lysimeters which received irrigation and N fertility treatments identical to the lysimeters except that fertilizer N was enriched with ^{15}N (Wienhold et al., 1995). Soil and plant samples were digested for total Kjeldahl N (Bremner and Mulvaney, 1982) and subsamples sent to Isotope Services in Los Alamos, NM (1984, 1985) and to the Nitrogen Isotope Laboratory, University of Nebraska, in Lincoln (1986-1988) for ^{15}N analysis.

RESULTS

Water inputs during the growing season varied from year-to-year at both sites (Fig. 1). Irrigation inputs were greatest in 1984, 1988, and 1990, years of below normal precipitation and above normal temperatures, and lowest in 1992 and 1993, years of above normal precipitation and below normal temperatures. Averaged over the study, water inputs were 11.6 inches at the Menoken site and 12.2 inches at the Naughton site. Precipitation during the growing season provided 60% of the total input at both sites during the study.

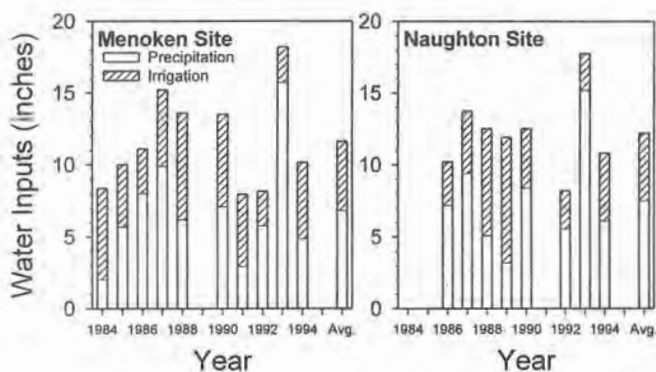


Fig. 1. Water Inputs for Lysimeters at Two Sites in Central North Dakota.

Corn grain yield varied from year-to-year, likely a response to growing season temperatures (Reichman and Trooien, 1993). Grain yields were greatest during years when growing season temperatures were above the long-term average (1986, 1987, and 1994) and were lowest during 1993 when cool, wet conditions occurred during the growing season. Average corn grain yields were 40% greater

when adequate N was provided (2.5 tons a^{-1}) than when N fertility was less than optimum (1.6 ton a^{-1}) (Fig. 2). Corn grain yields were similar and the response of corn grain yield to N-fertility was similar between the two sites.

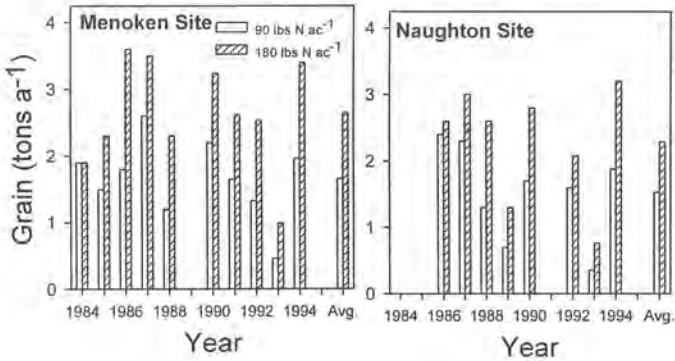


Fig. 2. Annual Corn Grain Yield at Two N Fertility Levels at Two sites in Central North Dakota.

Aboveground corn dry matter varied from year-to-year, likely a response to growing season temperatures (Reichman and Trooien, 1993). Above ground dry matter was nearly 30% greater when adequate N was provided (6.6 ton a^{-1}) than

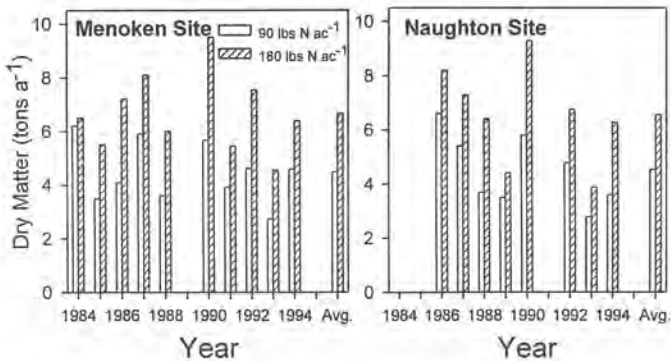


Fig. 3. Annual Above Ground Dry Matter Production at Two N Fertility Levels at Two Sites in Central North Dakota.

when N fertility was less than optimum (4.5 ton a^{-1}) (Fig. 3). Above ground dry matter production and the response of corn dry matter production to N-fertility was similar between the two sites.

Nitrogen content in the grain increased as N-fertility level increased (Fig. 4). While there was year-to-year variation in N-content, grain grown under an adequate level of N fertility averaged 40% more N (73 lbs a^{-1}) than did grain grown under an inadequate level of N fertility (44 lbs a^{-1}) (Wienhold et al., 1995). Grain N-content was greatest during years when temperatures during the growing season were above the long-term average (1986 and 1987). Extremely high temperatures early in the 1988 growing season stunted the crop. Nitrogen content in above ground dry matter exhibited a pattern similar to that of grain. Dry matter N-content grown under adequate N fertility averaged 110 lbs a^{-1} while that in dry matter grown under less than optimum N fertility was 68 lbs a^{-1} . Sixty percent of the N in the crop was present in the grain.

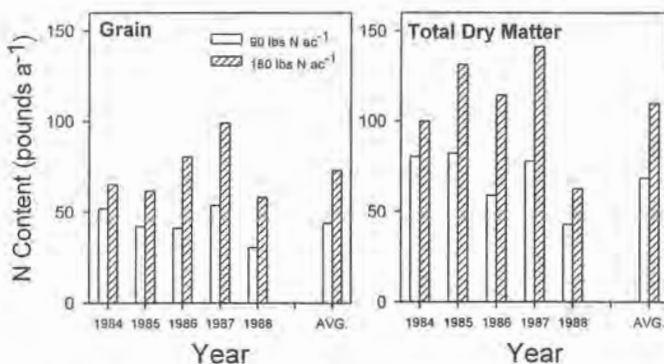


Fig. 4. Nitrogen Content of Grain and Above Ground Dry Matter Grown at Two N Fertility Levels at the Menoken Site.

Determining the percentage of N derived from fertilizer provides a measure of the amount of N being supplied by the soil. There was less year-to-year variation in percentage N derived from fertilizer than in yield or N-content. The percentage of N derived from fertilizer at the Menoken site was similar for grain and above ground dry matter (Wienhold et al., 1995) (Fig. 5). Percentage of N derived from fertilizer increased as level of N fertility increased. Corn grown under an adequate level of N fertility derived 30% more N from fertilizer than did underfertilized corn. Just over one-half of the N contained in the adequately fertilized crop was derived from fertilizer while only 40% of the N contained in

corn grown in under fertilized lysimeters was derived from fertilizer. These results suggest that mineralization of soil organic N and residual N fertilizer from previous years supply nearly one-half of the crops N needs.

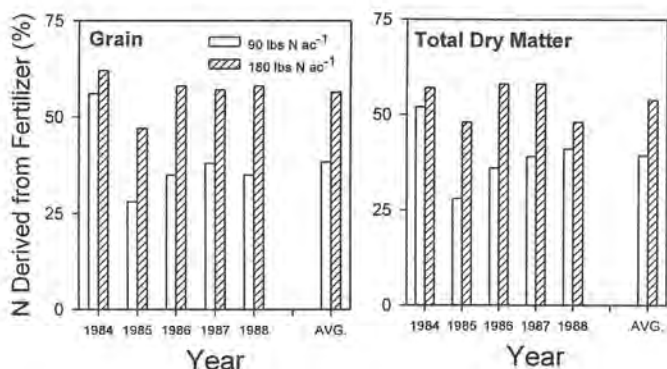


Fig. 5. Annual Percentage of Grain and Total Above Ground Dry Matter N Derived From Fertilizer at Two Levels of N Fertility at the Menoken Site.

Nitrogen fertilizer-use efficiency varied from year-to-year (Fig. 6). Level of N-fertility did not influence fertilizer utilization with 35% of the applied fertilizer being utilized by the grain and 50% being utilized by the total above ground crop (Wienhold et al., 1995).

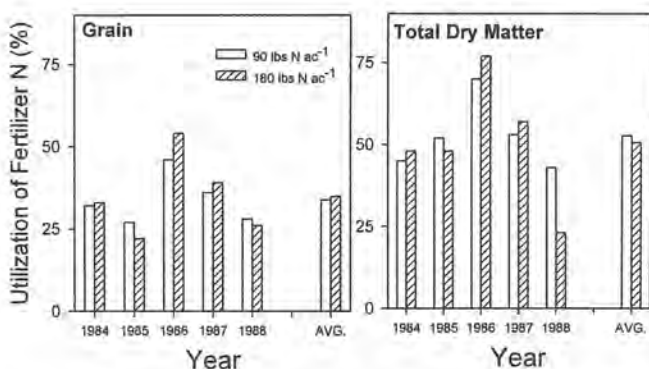


Fig. 6. Annual Utilization of Fertilizer N by Grain and Above Ground Dry Matter at Two Levels of N Fertility at the Menoken Site.

Nitrate-N present in the 0-to-2 foot layer of the soil varied from year-to-year (Fig. 7). Trends in residual soil $\text{NO}_3\text{-N}$ were similar for both levels of N fertility. Residual soil $\text{NO}_3\text{-N}$ was slightly higher at the Naughton site (65 lbs ac^{-1}) than at the Menoken site (50 lbs ac^{-1}). Residual soil $\text{NO}_3\text{-N}$ is not solely unused fertilizer. Soil samples collected following the ^{15}N study at the Menoken site showed that 30% of the applied N fertilizer remained in the 0-to-2 ft soil layer (data not shown); 20% of the applied fertilizer could not be accounted for, lost to leaching or denitrification; and these percentages were similar between the two N fertility levels (Wienhold et al., 1995). Residual N fertilizer was found throughout the root zone (0-5 ft) demonstrating that leaching of the chemical had occurred. A trend common to both sites was for a large increase in $\text{NO}_3\text{-N}$ following years when no crop was planted (no fertilizer added). This increase was likely due to N-mineralization combined with no N uptake by a crop.

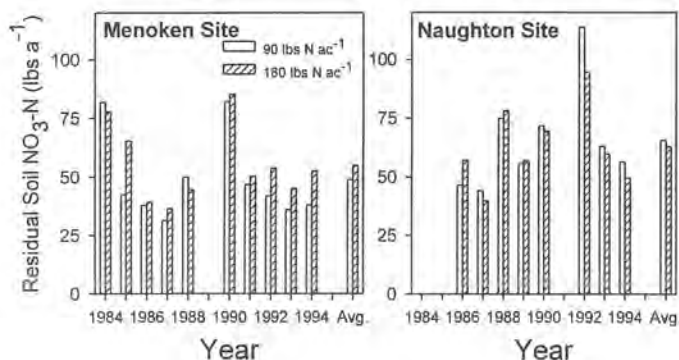


Fig. 7. Nitrate-N Remaining in the 0-to-2 Foot Soil Layer at the End of the Growing Season.

Internal drainage during the growing season varied from year-to-year (Troien and Reichman, 1993) (Fig. 8). During years where temperatures were above average (1984, 1985, 1988, and 1989) little drainage occurred. Drainage tended to be greater from lysimeters with corn crops fertilized with a suboptimal level of N. At the Menoken site, lysimeters receiving 90 lbs N a^{-1} averaged 2.6 inches of drainage and lysimeters receiving 180 lbs N a^{-1} averaged 0.9 inches of drainage. At the Naughton site, lysimeters receiving 90 lbs N a^{-1} averaged 2.5 inches of drainage and lysimeters receiving 180 lbs N a^{-1} averaged 0.5 inches of drainage.

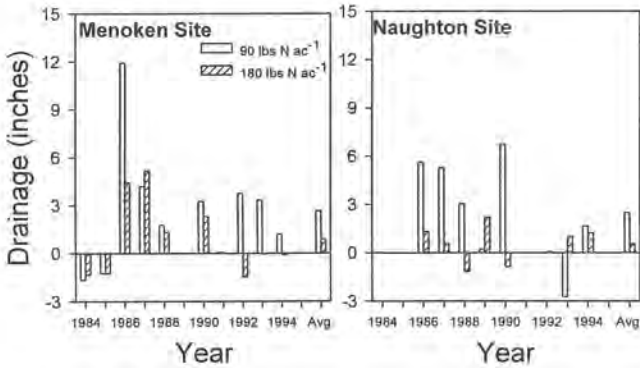


Fig. 8. Internal Drainage From Lysimeters Growing Corn at Two Levels of N Fertility in Central North Dakota.

DISCUSSION

Inadequate fertilization resulted in a reduction in dry matter production (Fig. 3). While evapotranspiration was not measured directly in this study it seems likely that evapotranspiration was less in underfertilized crop where less biomass was produced. This reduction in evapotranspiration resulted in increased internal drainage in soils supporting underfertilized crops (Fig. 8). The leaching fraction in lysimeters fertilized for an optimum yield averaged 8% at the Menoken site and 4% at the Naughton site. The leaching fraction in lysimeters that were under fertilized averaged 23% at the Menoken site and 20% at the Naughton site.

These results suggest that the meteorological method of scheduling irrigation works quite well for a crop fertilized for an optimum yield. If ET were calculated exactly, no drainage would have occurred. The observed drainage in lysimeters receiving adequate fertilizer was the result of precipitation being received at the site after an irrigation event. The observed drainage in underfertilized lysimeters was the result of precipitation plus water not utilized by the crop. The measured leaching fractions in adequately fertilized lysimeters were about what is needed to prevent salinity problems from developing in the root zone. Reichman and Trooien (1993) demonstrated that the increase in salinity observed in the lysimeters did not effect yields and that the leaching fraction was sufficient for salinity control. The results suggest that the meteorological method did not work well for an underfertilized crop as the leaching fraction from lysimeters that were

under fertilized exceeded what is needed for salinity control.

The leaching fraction in lysimeters that were under fertilized was nearly three times that of optimally fertilized lysimeters at the Menoken site and five times that of optimally fertilized lysimeters at the Naughton site. This excess leaching represents an economic cost and a potential environmental problem. The economic cost arises from the cost of the water and pumping costs (i.e. electricity or fuel). The environmental problems arise from the potential for leaching of agricultural chemicals out of the root zone. In this study, the residual soil $\text{NO}_3\text{-N}$ content was determined for the 0-to-2 foot increment and internal drainage was measured between 4.4 and 6.6 feet. The residual $\text{NO}_3\text{-N}$ remained within the root zone of subsequent crops and the potential exists for utilization of this N by the next crop. The drainage measured is below the root zone and this water can not be utilized by subsequent crops. Any agricultural chemicals present in this drainage water would also be unavailable to subsequent crops. Such leaching could potentially transport these chemicals to groundwater or surface waters if this groundwater were to discharge into wetlands, streams, rivers, or lakes.

Results presented in this paper suggest a need for more information concerning the interactive effects of various management practices on crop water use efficiency and the need to incorporate these interactions into irrigation scheduling programs. While this paper has emphasized fertilizer management there are other management practices that should be evaluated as well. Crop residue management could influence crop water use, especially early in the growing season. Presence of surface crop residue reduces evaporation from the soil surface by creating a boundary layer through which water must diffuse from the soil surface to the atmosphere. Surface residue may also maintain a cooler soil temperature thereby reducing evaporation. In addition, cooler soil temperatures may slow germination and seedling development resulting in reduced evapotranspiration early in the growing season. Weed infestations have the potential for altering crop water use. Timing of weed suppression practices could exert a strong influence on crop water use.

ACKNOWLEDGEMENTS

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A PROCEDURE FOR HYDROLOGIC ANALYSES OF CONSTRUCTED
WETLANDS FOR COMBINED ENVIRONMENTAL ENHANCEMENT AND
FLOOD CONTROL

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Robert Houghtalen²
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ABSTRACT

Benefits from constructed or restored wetlands for environmental enhancement and flood control are well documented. Proper wetland design should combine adequate wetland functionality and also ensure that the wetland can handle a range of conditions and flows. Sizing wetlands for flood control usually involves developing an inflow hydrograph based on one discrete hypothetical flood event, whereas evaluating the environmental functionality of wetlands requires a continuous simulation of the local hydrologic budget. This paper presents a method to utilize the major advantages of both types of models: distributed, physically-based kinematic wave runoff simulation associated with event modeling for flood control, and continuous hydrologic budget modeling for environmental enhancement. If a wetland is designed primarily for environmental enhancement or restoration, hydrologic investigations are essential to determine adequacy of natural waters or quantity of supplied waters to support wetland conditions. A water budget is most often used to determine this hydrologic adequacy and a continuous water moisture accounting procedure based on historical, physical data is arguably the most accurate method of water budget determination. The Wetland Hydrologic Analysis Model (WHAM) is an example of a water budget model that continuously simulates inflows, outflows and fluctuations in storage for a given historic period. The U.S. Army Corps of Engineers HEC-1 program, a well-documented rainfall-runoff model for event simulation, is used to determine flood control design hydrographs. Runoff hydrographs are synthesized using a combination of other models (HECIFH, HECDSS, DSSMATH) and used to simulate inflows in the WHAM. A case study of synthesized wetland modeling at Ellsworth Air Force Base, South Dakota is discussed that merges hypothetical event, continuous simulation, and water budget analyses into a comprehensive wetland design procedure.

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Background

A Base Wide Wetlands Mitigation Plan (BWWMP) for Ellsworth Air Force Base (RUST, February 1996) describes Installation Restoration Program (IRP) efforts to manage impacted wetlands on the Base. Included in the BWWMP is the conceptual design of an in-channel wetland, Site MB4, which is designed to return local drainage to its original meandering pattern and to develop a marsh habitat. Development of a wetland at Site MB4 will also assist in hydrologic modification, erosion control and water quality enhancement of the drainageway and downstream ponds.

Ellsworth AFB is located on gently sloping tablelands and plateau rangeland immediately east of Rapid City, South Dakota. The main base drainageway, which bisects the north-eastern portion of the base, is a left-bank tributary of Box Elder Creek with a total drainage area of approximately 6 square miles. The tributary upstream of the proposed wetland is approximately 3 miles long, and drains just less than a square mile of rangeland and rolling hills with mean slopes of twenty feet per mile. The lower portion of the drainage area, punctuated with Base buildings and facilities, has slopes of approximately 16 feet per mile. Multi-use channels, several small detention ponds and assorted conduits control runoff through the area before it reaches the wetland. The semi-arid region has an annual average precipitation of 14 inches and is characterized by high intensity and short duration thunderstorms.

The task of evaluating Wetland Site MB4 for hydrologic design was twofold: 1) determine surface runoff peak discharges, volumes and timing of peaks for flood control purposes, and 2) evaluate hydrologic sufficiency for wetland function. By integrating existing wetland analyses tools, a procedure was developed to combine surface runoff determination with continuous simulation of the local hydrologic budget.

Surface runoff determination was performed using the Corps of Engineers' (COE) HEC-1 program, which transforms hypothetical precipitation events to distributed runoff. The result of the HEC-1 modeling process is the computation of hypothetical streamflow hydrographs, and subsequently discharge/frequency relationships, at desired locations in the basin. Wetland structural design based on peak discharge, timing of flows and runoff volumes can be assessed using the hypothetical hydrographs. Having determined the streamflow hydrographs, an HEC-1 procedure was also used to optimize Clark Unit Hydrograph Coefficients, the first phase in the process of simulating daily inflows to the wetland for the

hydrologic budget analysis. Hourly historical precipitation data was input to the COE Interior Flood Hydrology Program (HECIFH), which, using a Unit Hydrograph procedure with the predicted Clarks Coefficients, developed simulated hourly runoff to the wetland. Finally, the COE DSSMATH program was used to convert hourly runoff to mean daily inflows, a primary component of the total data needed for the determination of the daily historical hydrologic budget. A schematic of the HEC-1 procedure is shown in Fig. 1.

Simulation of the daily hydrologic budget was accomplished using the Wetland Hydrologic Analysis Model (WHAM), a continuous simulation model that uses a simplified mass-balance equation to account for inflow, outflow and change in storage of an impoundment. Results of the historic simulation suggest average wetland pool fluctuations and seasonal changes in surface area and capacity. Frequency of exceedence relationships were developed to determine the percentage of time that various pool levels were exceeded over the historic simulation, the assessment of which were useful in determination of wetland planting schemes. A schematic of the WHAM procedure is shown in Fig. 2.

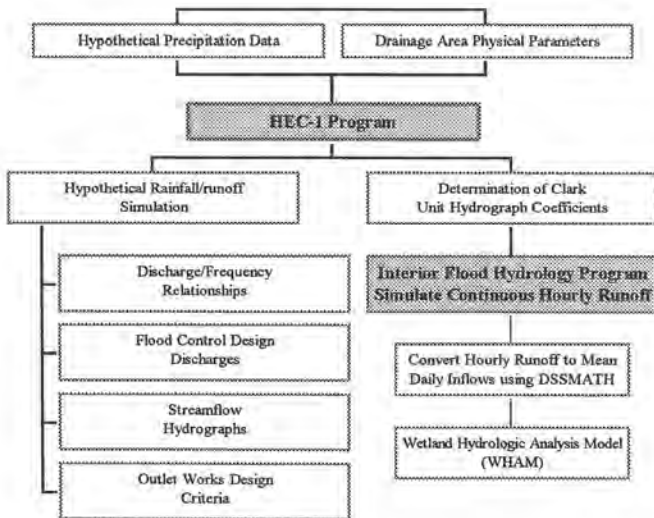


Fig. 1. Schematic of HEC-1 for determination of surface runoff to Wetland MB4.

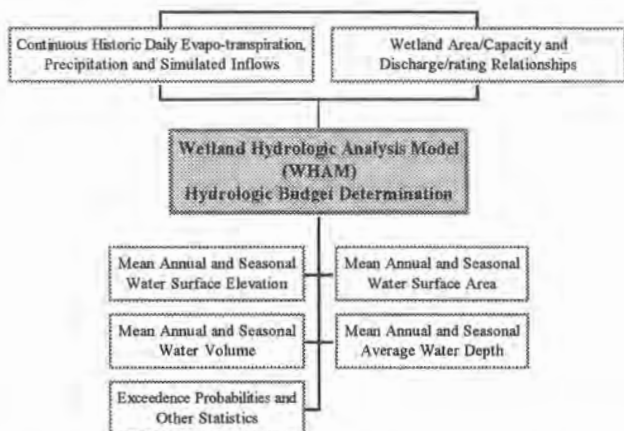


Figure 2. Schematic of the hydrologic budget determination using WHAM.

SURFACE RUNOFF DETERMINATION USING HEC-1

HEC-1 Modeling Techniques

Distributed outflow from a subbasin was obtained by utilizing combinations of three conceptual elements: overland flow planes, collector channels, and main channels. The kinematic wave method was used for modeling overland flow, where each subbasin used two overland flow elements separately representing the impervious and pervious areas of the subbasin. The Muskingum-Cunge routing technique was used to model collector and main channel flows using trapezoid channel sections for general flow routing. Routing flows through detention areas was accomplished using the Modified-Puls technique.

The Kinematic wave method is a non-linear technique that relates basin and flow characteristics directly to routing parameters, such as basin area, boundary roughness, flow lengths, and overland flow slope, each of which can be directly

measured. Residential areas were modeled with roofs, driveways, walkways, parking lots, and streets contributing to the impervious component of overland flow, and with lawns, parks and range contributing to the pervious component. The Muskingum-Cunge channel routing technique is also non-linear and accounts for hydrograph diffusion based on physical channel properties. The advantages of the Muskingum-Cunge method over other hydrologic methods are that the model parameters are physically based and the method has been shown to compare well against the full unsteady flow equations. The Modified-Puls storage routing method functions by receiving upstream inflows and routing these flows through a detention pond according to defined storage versus outflow relationships.

Rainfall

Hypothetical precipitation data from Technical Paper No. 40 (U.S. Weather Bureau, 1961) and Technical Memorandum Hydro-35 (NOAA, 1977) were used to model various hypothetical storms. Median accumulated point precipitation values of 5-minute, 15-minute, 1-hour, 2-hour, 3-hour, and 6-hour durations were determined for the 2-, 5-, 10-, 50-, 100-, and 500-year return periods. Point rainfall amounts used in the analysis were smoothed graphically and reflect the partial-duration-adjusted values in TP-40. No depth-area adjustments were made due to the size of the basin. Rainfall amounts used in the analysis are shown in Table 1.

Table 1. Accumulated point rainfall values, Ellsworth AFB.

Return Period	Accumulated Point Rainfall (inches)					
	5-min	15-min	1-hour	2-hour	3-hour	6-hour
2-year	0.36	0.69	1.05	1.19	1.25	1.45
5-year	0.46	0.90	1.45	1.62	1.73	2.00
10-year	0.54	1.05	1.75	1.92	2.05	2.35
50-year	0.72	1.42	2.40	2.67	2.82	3.20
100-year	0.80	1.58	2.70	3.00	3.20	3.55
500-year	1.02	2.17	3.50	3.80	4.00	4.50

Model Calibration/Verification

The HEC-1 model was calibrated using discharge/frequency relationships from two regional regression studies: the United States Geological Society Regional Regression Equations (USGS, 1974) for South Dakota and a Black Hills regional regression equation study (COE, 1991). The USGS equations were developed from peak-discharge records for 162 continuous and partial-record stations having 10 or more years of records, and correlate drainage area and mean basin elevation with discharge/frequency. The Black Hills study was developed using a best fit curve that correlated mean discharge and standard deviation with drainage area.

Results

Table 2 shows the existing 6-hour peak inflows to the wetland. The 100-year event was chosen as the design discharge and various outlet systems such as stoplog structures, conduit gating and low level outlets were considered for design. Fig. 3 shows the 6-hour, 100-year inflow and outflow hydrographs at the wetland.

Table 2. Existing 6-hour peak inflows to Wetland MB4

Parameter	Peak Discharge (cfs)					
	2-yr	5-yr	10-yr	50-yr	100-yr	500-yr
Computed, partial duration-adjusted peak discharges	90	240	350	830	1050	1720

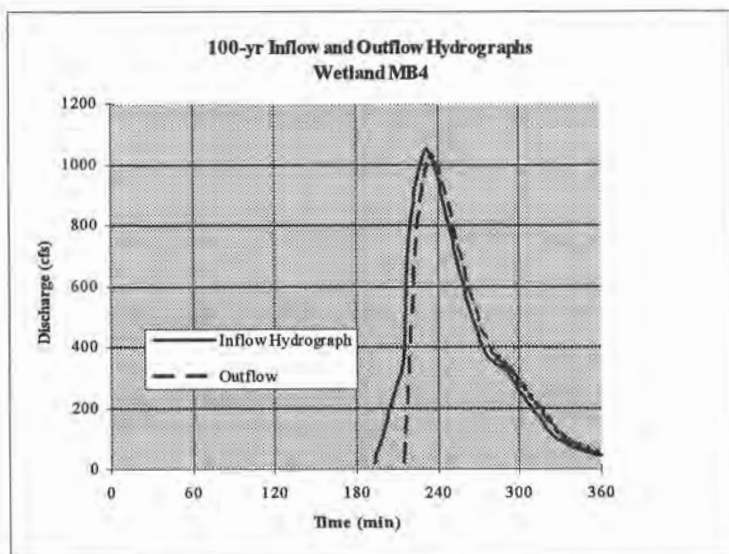


Fig. 3. 6-hour, 100-year inflow and outflow hydrographs at Wetland MB4.

SIMULATION OF A DAILY HYDROLOGIC BUDGET USING WHAM

Methodology

Simulation of the daily hydrologic budget of the wetland was performed using WHAM to ascertain whether the wetland's hydrologic conditions were adequate to support natural plant colonization and succession. The results of the budget analysis demonstrates how the wetlands will respond given identical historic hydrological conditions that have occurred in the past. The budget analysis allows for an optimum design of excavation and outlet works design which control the hydrologic conditions of the site. WHAM evaluates inflow, outflow, precipitation, evaporation, seepage, and change in storage of individual wetlands sites. Input for WHAM include: elevation-area-capacity-outflow relationships for the wetlands site, monthly seepage rates, daily historic precipitation amounts, daily historic evaporation, and daily inflows. Historic data for water years 1950 through 1993 were used in the daily simulation.

Input Data Determination

Various data input to WHAM was determined from historical records, 2-foot contour mapping, site inspection and from similar wetland environments.

Surface area: Surface area was digitized from 2 foot contour mapping.

Elevation/area/capacity relationships: Volumes were calculated using the conic method.

Precipitation: Mean daily precipitation values for 1950 through 1993 from the Rapid City Airport WSO weather station were used.

Evaporation: Values for 1950 through 1955 from the Pactola weather station and for 1956 through 1993 from the Rapid City weather station were used. An evaporation pan coefficient of 0.70 obtained from Technical Report NWS 33 (TR33) was used to convert pan evaporation data to free water surface evaporation. Average mean evaporation rates from TR33 were used to complete missing data.

Discharge rating: Outflow rates from the wetland were based on weir flow at elevation 3195 ft-msl.

Seepage losses: Estimated seepage rates were based on measured seepage rates from various midwest lakes with similar clay-loam and sandy-loam complexes. A seepage rate of 0.90 inches per day was adopted, although a sensitivity analysis using a range of loss rates showed seepage to be the most uncertain input parameter to WHAM. Because of this uncertainty and the fact that seepage rates are critical to wetland functionality, it is recommended that the wetland bottom be lined with clays or other impervious soils where possible.

Inflows

Daily inflows for the wetlands area were simulated using a combination of the COE HEC-1, HECIFH, HEC2SS, and DSSMATH programs. HEC-1 was used to transform precipitation into runoff for the 0.92 square mile drainage basin upstream of the wetlands area and optimized Clark unit hydrograph coefficients were developed from the kinematic wave solution. The Interior Flood Hydrology (HECIFH) program applied the Clark coefficients to determine hourly unit hydrograph. Hourly runoff was simulated because the basin response to intense precipitation rates is fairly quick due to

the relative small size of the watershed. The DSSMATH and HECDSS programs were used to aggregate the 44 years of hourly runoff values into mean daily runoff values required by WHAM for continuous simulation.

Results of Hydrologic Budget Simulation

For the wet and average years, the pool remains fairly consistently at the normal pool elevation, with an occasional loss of 0.5 to 1.0 feet of elevation several times throughout the year. A statistical analysis was performed on the pool level results from the WHAM simulation to determine the percentage of time various pool levels were exceeded over the historic simulation period. The results show that the pool level was within one foot of the maximum pool level of 3195 ft-msl approximately 90% of the time during a full year, 98% of the time during the main planting season from May through July, and 74% of the time during the month of October, when maintenance can be performed prior to the snow season. Fig. 4 shows duration curves for water surface elevation during three target time periods.

Because Fig. 4 can be used as a tool for evaluation of alternative water surface elevations, wetland species can be included in the design (i.e., cattails in wetter zones or grasses in drier zones). Output is also available to reveal the response of the wetland to typical dry, average or wet years. Pond water surface elevation, surface area, water depth and water volume can be correlated with precipitation for any part or all of the period of record.

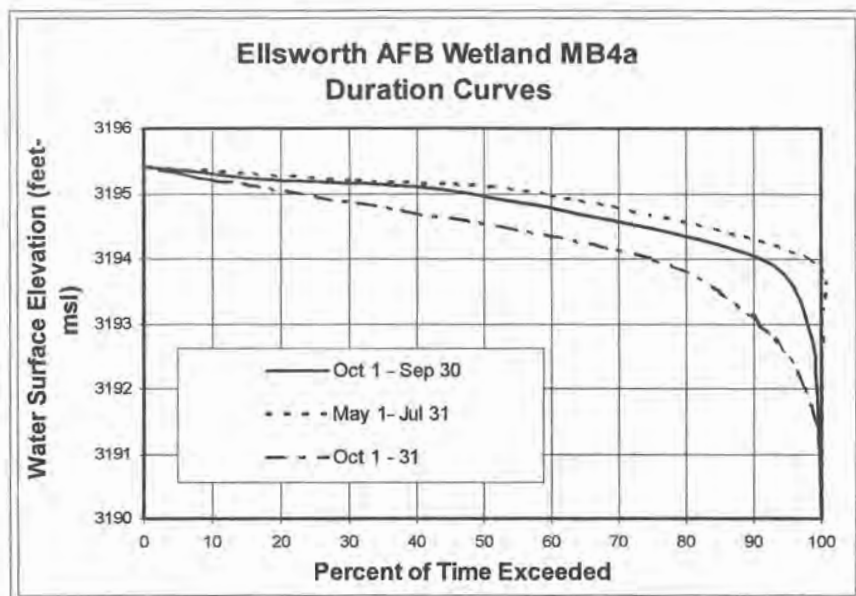


Fig. 4. Water surface elevation duration curves during three target time periods.

Conclusions, Discussion

As modeled, the wetland appears to have relatively little impact for flood control when the 100-year event is used as the design storm (See Fig. 3). Consequently, embankment and spillway structures should be designed primarily to withstand and pass high intensity and short duration discharges that develop in the basin. Results of the water budget analysis demonstrate that the wetland has adequate hydrologic recharge given similar meteorological conditions that occurred during the historic simulation period.

The Environmental Protection Agency's (EPA's) Storm Water Management Model (SWMM) appears to be a powerful alternative to the procedures presented in this paper. SWMM can function as an event-based model, can perform continuous

simulations and dry period simulation can be made more efficient by lengthening the model time interval. Statistical analysis of the results can also be performed within the model. Therefore, it is possible that the multiple models implemented in this procedure can be significantly simplified.

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THE SOUTHERN CALIFORNIA COMPREHENSIVE WATER RECLAMATION
AND REUSE STUDY: BALANCING NEEDS OF PEOPLE AND WETLANDS
IN THE DESERT

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Rebecca Redhorse²

John Hanlon³

ABSTRACT

The Bureau of Reclamation is conducting the Southern California Comprehensive Water Reclamation and Reuse Study (Study), which reviews and evaluates the potential for using water more than one time before discharging it to the Pacific Ocean. Agricultural and landscape irrigation, other urban demands, and environmental enhancement are uses being considered for reclaimed water. An integral step in the process has been coordination with the U.S. Fish and Wildlife Service (Service) to identify environmental projects which could be supported by reclaimed water.

Southern California has a population of over 18 million and is one of the largest economies in the United States. An economy of this size and the population it supports could not exist without adequate resources, the most important of which is water. Yet southern California is a desert. To explain how an economy the size of southern California's could exist in a desert, one can think of it as a garden. A garden is an artificial environment sustained by a garden hose. Without the garden hose, the garden would not have come into existence, and if the garden hose goes away, so will the garden. Southern California has three garden hoses: the Colorado River Aqueduct, the California Aqueduct, and the Los Angeles Aqueduct, the latter of which is temporarily operating at less than full

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capacity to restore and protect the environment of Mono Lake and the Owens Valley, the sources of its water.

Despite its importance to southern California, however, water imported into the area is dwindling. The Colorado River Aqueduct may have as much as 50 percent of its flows reduced, due to new demands on Colorado River flows from the recently-completed Central Arizona Project. Reduced deliveries to the California Aqueduct from the State Water Project could result from changes to Project operations to protect the Sacramento-San Joaquin Delta environment, the source of its water. Water resources are dwindling and the population of southern California is expected to increase and the economy is expected to expand. How can we reconcile this apparent incongruity and resolve the problem it poses? About two million acre-feet of potentially reclaimable water are presently produced, of which approximately 1.6 million are discharged to the Pacific Ocean. By putting reclaimed water to beneficial use, the economy can continue to grow and the ecosystems of southern California can be sustained. At the very least, residents will be able to preserve the water resources upon which they now depend.

INTRODUCTION

The Bureau of Reclamation is conducting the Southern California Comprehensive Water Reclamation and Reuse Study (Study) that reviews and evaluates the potential to reuse or reclaim water before discharging it into the Pacific Ocean. An integral step in the Study process has been coordinating with the Service to identify environmental projects which could be supported by reclaimed water.

Southern California's continued growth requires large amounts of water, yet the primary supply, imported water, is becoming less reliable. The intent of the Study is to identify and solve water supply and demand problems, and in the process, balance competing needs for water. The Study will document water supply and demands and demonstrate the need for, and availability of, reclaimed water on a large scale, including that which could be used for potential environmental

enhancement projects. During the next several years, potential solutions will be explored, and based on preliminary findings by the Service, specific environmental areas will be identified that may receive water. This paper discusses the Study and its preliminary findings, including those of the Service.

About the Study

Congress authorized the Study as a means to increase the use of reclaimed water in southern California and to encourage a region-wide approach. The Study was authorized in the Reclamation Projects Authorization and Adjustment Act of 1992 (P.L. 102-575, Title XVI). Seven major water agencies and municipalities, the California State Department of Water Resources, and the Bureau of Reclamation are charged with implementing the Study in an area covering nearly all of Ventura, Los Angeles, Orange, Riverside, San Diego, and Imperial Counties, as well as roughly the southern half of San Bernardino County.

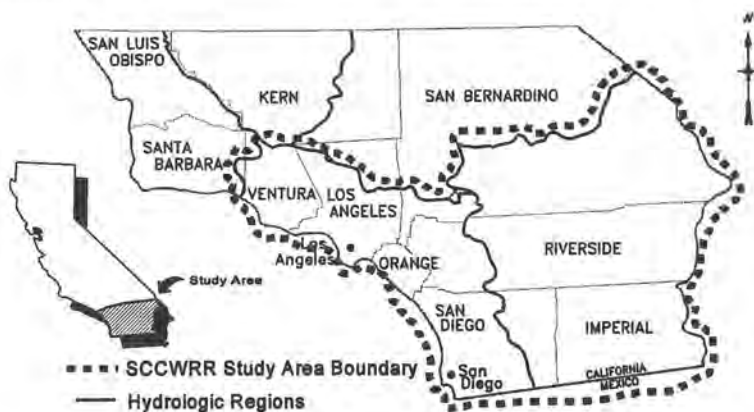


Figure 1. Southern California Comprehensive Water Reclamation and Reuse Study Area

The first of three Study phases is complete. Results of the first phase, water supply and demand

information, were documented in the "Phase IA Interim Report." Currently, Study sponsors have started Phase IB, which will identify potential reclamation projects that would deliver reclaimed water supplies to various areas for varying uses. The final phase of the Study, Phase II, will focus primarily on analyzing and documenting the feasibility of implementing the potential reclamation projects identified during Phase IB. The final Study report will result in specific water reclamation project recommendations. The list of potential water reclamation projects generated by this Study is expected to constitute the best possible solutions to the water supply and demand problem in southern California.

WATER SUPPLY AND DEMAND

Despite Congressional legislation to initiate the Study, the seriousness of water demand and supply problems in southern California is not always fully realized, especially since droughts generally recur only over long periods of time. Water resource managers have found that educating people about the widening gap between water demand and supplies has been challenging, and the Study addresses this problem. In addition, the negative side-effects of water scarcity are often overlooked, such as a possible slowing of the economy. For these reasons, the Study began by addressing the water shortage question in southern California.

The Current Water Demand and Supply Situation in Southern California

High water demand is expected to continue as southern California's population of over 18 million residents increases by about 250,000 people each year, and as the state hosts many visitors. Population levels are an important factor, given that an average person uses about 81,000 gallons (or a quarter of an acre-foot) of water each year. The current population expansion translates to an estimated water demand of about 20.2 trillion gallons, or 62,500 acre-feet of water. However, the Study's Phase IA Interim Report found that

in 1990, there was an estimated shortage of 80,000 acre-feet of water, and by 2010, the shortage could reach about 740,000 acre-feet.

On the water supply side, it is important to note that two-thirds of southern California's total water supply is imported. The area has, in essence, three garden hoses: The Colorado River, the California Aqueduct (State Water Project), and the Los Angeles Aqueduct. Environmental protection in the originating sources of the imported water, as well as other restrictions, are limiting all three sources in the short- and long-term. The Los Angeles Aqueduct is temporarily operating at less than full capacity in order to protect the environment of Mono Lake and the Owens Valley, the sources of its water. Additionally, now that the Central Arizona Project has been completed, new demands on the Colorado River may reduce flows in the Colorado Aqueduct by as much as 50 percent. Reduced deliveries from the State Water Project could result from changes to its operation to protect the Sacramento-San Joaquin Delta environment, the source of its water. Furthermore, groundwater supplies have dwindled over time with heavy agricultural use, and groundwater quality is often poor.

An unchecked gap between water demand and supply could cause water shortages even in normal years that would hamper the growth of one of the most important economies in the nation. Southern California's primary industries constitute about 61 percent of the total sales and dollar values of products and services in the State of California. Southern California's primary industries -- manufacturing, agriculture, trade, and services, most of which require large, reliable water supplies -- constituted nearly \$5.6 trillion (1987 dollars) in sales and dollar values. As an example specifically tied to water use, a Los Angeles Area Chamber of Commerce study showed that a 30 percent reduction in the water supplies going to large industries could result in a loss of about \$8 billion in revenues and 26,000 jobs.

Reclaimed Water Sources and Markets

In view of water demand and supply problems in southern California, the Study seeks to provide a solution by identifying supplies of reclaimed water as well as potential markets, including environmental enhancement projects. According to preliminary Study findings, there is an abundant potential supply of nearly 2 million acre-feet of potentially reclaimable water that will increase annually by an average of about 40,000 acre-feet through the year 2040. However, currently, only about 350,000 acre-feet of recycled water is used each year leaving most of the reclaimed water, about 1.6 million acre-feet, to be discharged to the ocean. On the other hand, the potential reclaimed water supply will increase by half by the year 2010, and will reach about 4 million acre-feet per year by 2040.

In terms of markets for reclaimed water, the Study has identified areas of high or concentrated reclaimed water demand, which will be the focus of the Study during Phase IB and Phase II. Demand projections were based on anticipated population growth and corresponding water use. Geographic areas of demand for reclaimed water were based on current reclaimed water uses, which are highest for groundwater recharge (53%) and landscaping (19%), followed by sea water intrusion barriers (11%), environmental (8%), and agriculture (7%). Current reclaimed water demand shortages are largest for groundwater recharge and landscape uses, which together comprise 83% of the potential uses. Longer-term demands for reclaimed water will continue to be largest for landscaping and groundwater recharge, comprising about 75% of the total, while agriculture and industry will each need about 6 percent, and environmental demand is projected to be minimal at 2%.

ENVIRONMENTAL ENHANCEMENT AREAS

By identifying potential reclaimed water markets and sources, specific projects and water transport systems will be planned that could provide reclaimed water to municipalities, agriculture, or industry, with largely incidental delivery to environmental enhancement areas.

The Service, as part of the Study, identified and ranked environmental enhancement opportunities that, in most cases, would be related to restoration. The selection and ranking process included research; consultations with local, state, and federal specialists; telephone surveys; and the use of advisory committees. The process resulted in a total of 80 environmental areas identified for potentially receiving reclaimed water, of which 17 are existing environmental sites and 16 are potential environmental enhancement projects. The remaining 47 locations are general habitat enhancement refuges, reserves, or wildlife areas. Most of the enhancement projects and habitat areas are considered to be wetlands of various types.

Functions of Wetlands

Southern California is unique in that it contains most types of wetlands and has historically been a significant habitat area. Wetlands are transitional lands between terrestrial and aquatic environments which may take several different forms that support certain plant, fish and wildlife species. There are five major classifications of wetlands: marine (ocean coastline areas), estuarine (inlet along ocean coastline), riverine (on or near the banks of a river), lacustrine (lakes and lake-sides), and palustrine (marshes). California has lost about 91 percent of its historical wetlands between about 1780 and the mid-1980s, with most of the loss in riparian wetlands.

In addition to supporting wildlife, wetlands benefit human needs directly through flood control, water storage, water treatment, and recreation and educational opportunities for adults and children. Relatively recent legal authorities and policies have placed a national and local priority on protecting and creating wetlands. The environmental enhancement projects and wetlands selected by the Study for potentially receiving reclaimed water include the five main categories of wetlands, most of which offer recreation and education opportunities.

Existing Environmental Enhancement Projects

Of the 17 existing enhancement areas within the Study area that could benefit from reclaimed water supplies, several of the most important are in the Sepulveda Basin, which contains a wildlife pond, a lake, and a Japanese Garden. The three freshwater wetlands sites, are in Los Angeles, and are no more than a mile apart. Although they currently use some reclaimed water, they could be enhanced with more water. Although the primary uses are education and recreation with incidental wildlife use, there are several threatened or endangered species that use the basin. The peregrine falcon and loggerhead shrike use the wildlife pond, and the American coot, several species of grebes, starlings, and cowbirds have been seen at the lake.

Potential Environmental Enhancement Projects

Sixteen potential enhancement areas that could possibly benefit from deliveries of reclaimed water were identified. One of these is a 19.2-mile reach of the Los Angeles River near downtown Los Angeles. The river has both palustrine and riverine type wetlands. Although there are numerous obstacles that may make it infeasible to create a habitat restoration project along the Los Angeles River, the Study identified an area covering up to 60 acres along three segments of the river that potentially could be restored, provided sufficient flood control protection can be maintained. If sufficient habitat is developed, Bell's vireo may be reappear in the area.

Habitat Enhancement Areas

Some of the largest habitat areas, particularly for endangered species, are the 47 wildlife refuges, reserves, and wildlife areas identified for potentially receiving reclaimed water. One of the most important areas is the Cibola National Wildlife Refuge. The refuge is primarily a riverine wetland with some palustrine areas, and spans about 16,667 acres as it extends down a large segment of the Colorado River. The Cibola refuge is an important habitat area

primarily because of its location in the desert and its proximity to the North American flyway. In addition, the refuge is used for recreation and educational purposes with interpretive trails and picnic sites provided, and with fishing, boating, and hunting activities. The wetland is important for several species of threatened or endangered birds.

CONCLUSION

The Study is important for enabling southern California to continue to be a garden in the desert for people and the environment. A growing water demand and shrinking supplies have been documented by the Study, and the result could be a damaged or limited economy in the future. In addition, environmental needs for water could continue to suffer without an alternative source of supply. The Study has also identified areas of large reclaimed water supply and demand.

The next step in the Study will be to solve water supply and demand problems by connecting reclaimed water supplies with potential market demands. Potential uses for the reclaimed water include landscape and agricultural irrigation, groundwater recharge, and other urban uses, and environmental projects including wetlands. Identifying candidate environmental projects for reclaimed water has been an integral step in the Study. By locating large reclaimed water supplies and potential markets, the Study will attempt to ensure that there will be enough water in the future for the needs of municipalities, industry, agriculture, and the environment.

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THE WETLAND DEVELOPMENT PROGRAM IN THE
GREAT PLAINS REGION OF THE BUREAU OF RECLAMATION -
ENVIRONMENTAL ENHANCEMENT
IN THE GREAT PLAINS ECOSYSTEM

Gary Davis¹

ABSTRACT

The Wetland Development Program (WDP) is an ambitious effort to restore, enhance, and develop wetlands and riparian areas throughout a nine-state region stretching east from the continental divide in Montana, Wyoming, and Colorado through the Dakotas south to the Gulf of Mexico. The concept for such a wetland program in the Great Plains Region (Region) developed in 1989 in response to the Nation's escalating concern over avoidable and unmitigated impacts to wetlands and to contribute Reclamation's expertise in support of the no net loss of wetlands goal. The WDP has been largely successful in meeting these goals throughout the Great Plains ecosystem and continues to generate support from throughout Reclamation, the Administration, and the public. Our WDP is frequently cited as an example of Reclamation's commitment to undertake programs emphasizing resource management and enhanced environmental sensitivity in the transition towards becoming a water management agency. Public and private partnerships developed through the WDP have been responsible for construction of wetland impoundments and moist soil management units in North Dakota, South Dakota, Montana, Nebraska, and Oklahoma; wetland and riparian habitat enhancement in Colorado, Wyoming, and Texas; environmental education projects in Wyoming and Texas; and North American Waterfowl Management Plan joint venture activities in North Dakota, Montana, Nebraska, Wyoming, and Texas. This paper focuses upon the Cottonwood Drain wetland enhancement project in Wyoming and the Nikolaisen wetland restoration and development project in North Dakota.

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INTRODUCTION

Reclamation's WDP originated in the Great Plains Region (Region) in response to the Nation's escalating concern over avoidable and unmitigated impacts to wetlands and to contribute Reclamation's expertise towards the Administration's goal of no net loss of wetlands. The Region reinforced its justification for Congressional appropriations for wetland restoration, enhancement, and development by focusing upon the agency's historic association with projects effecting wetland drainage and inundation throughout the major drainages of the western United States.

Reclamation's mission is ". . . to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public." In pursuing this mission, Reclamation's goal is to become the "premier water management agency" in the world. This Region strongly supports both the mission statement and goal. To further the agency's mission and goal, the Region embarked upon the WDP to restore, enhance, and develop wetlands and riparian areas in the interest of wildlife habitat, water quality, flood flow attenuation, recreation, and environmental education.

Regional Setting

The Region encompasses all, or parts of, nine western states stretching from the continental divide in Montana, Wyoming, and Colorado east to North Dakota and south to the Rio Grande in Texas. The Regional Office is located in Billings, Montana, and provides administrative and technical support to area and field offices. Within the Region are landforms and ecosystems ranging from the central and northern Rocky Mountains, to the Great Plains, to the cold deserts of Wyoming, to the Gulf Coast and subtropical environment of the lower Rio Grande valley. Average annual precipitation over the Region ranges from as low as three inches in central Wyoming to over forty inches in eastern Oklahoma and Texas.

Superimposed upon the Region are portions of the Central, Mississippi, and Rocky Mountain flyways that are important for waterfowl, shorebirds, and neotropical migrants; the hour-glass migration

route of most of North America's greater sandhill (*Grus canadensis*) and whooping cranes (*Grus americana*); and six joint venture areas sanctioned by the North America Waterfowl Management Plan (NAWMP). These natural patterns and relationships offer the Region a unique perspective in contributing to the life cycle requirements of migratory and resident wildlife utilizing the length of the Great Plains ecosystem. No other resource management agency shares the extent of this land base.

Program Development

The WDP is the Region's most ambitious effort to contribute to the Administration's wetland goals, the public's desires, and the Regional wetland initiative. The WDP was conceived in 1989 and initiated with the submittal of a budget request to Congress for line-item funding in 1992. Congress approved this request with an initial line-item appropriation of \$1,129,000. Prior to receiving the initial Congressional appropriation, the Region obtained limited funding from Reclamation's Denver Office to begin planning and construction. Annual Congressional appropriations have averaged more than \$1,000,000 since fiscal year 1992. Since its inception, the WDP has participated in dozens of cooperative projects throughout the Region involving thousands of acres of wetlands.

The WDP is funded through the Drainage and Minor Construction Program of the Construction Fund. It is well known that Reclamation's construction program was responsible for design and construction oversight of major dams, irrigation projects, and other water resource development projects that resulted in significant wetland impacts throughout the major drainages of the western United States. Today, the construction program is charged with completing unfinished Reclamation projects and overseeing projects supplying potable water to rural areas and Native American reservations.

Program Goals

The original intent of the WDP was to restore, enhance, and develop wetlands and riparian areas on Reclamation lands throughout the Region. Opportunities developed which suggested that the scope of the WDP be expanded to include all De-

partment of the Interior (Interior) lands. This expansion includes national wildlife refuges lands administered by the U.S. Fish and Wildlife Service (Service), national recreation areas managed by the National Park Service, Bureau of Land Management (BLM) lands, and reservations and other Native American lands held in trust by the United States through Interior's Bureau of Indian Affairs (BIA). Additional authority was recently acquired to improve fish and wildlife habitat associated with water systems or water supplies affected by Reclamation projects. This authority will allow Reclamation to approach habitat and water quality issues from a broader watershed/ecosystem perspective.

The WDP has been an important vehicle for the development of partnerships with other Federal agencies, state wildlife management agencies, local municipalities, conservation organizations, water conservancy districts, and agricultural groups. In addition to promoting cooperation, partnerships significantly enhance the Region's funding capabilities. Following considerable effort, the development of successful partnerships which focus upon wetland and riparian enhancement has largely been accomplished. Partnerships have been developed with the Environmental Protection Agency, the Service, the BLM, the BIA, state wildlife management agencies throughout the Region, North Dakota Wildlife Trust, National Audubon Society, The Nature Conservancy, Defenders of Wildlife, Ducks Unlimited, universities, and irrigation and municipal water contractors. Coordination efforts continue with other agencies and conservation groups to build upon existing partnership development.

A principal goal of the WDP is to restore, enhance, and develop a variety of wetland and riparian area types through active involvement of all of our area offices. Working within a region which extends from Canada to Mexico facilitates realistic achievement of that goal. Moist soil management units have been developed for migratory waterfowl and shorebirds in Oklahoma and Nebraska; emergent marshes have been developed in Montana, Wyoming, and North Dakota; prairie potholes have been restored in North Dakota; riparian areas have been enhanced and developed in Wyoming and Texas; and ephemeral prairie wetlands and associated

grasslands are being enhanced in Montana. This paper focuses upon two wetland projects which provide obvious physical benefits as well as biological benefits. These projects include the Cottonwood Drain enhancement project in central Wyoming and the Nikolaisen restoration and development project in the Devils Lake basin in northern North Dakota.

COTTONWOOD DRAIN WETLAND ENHANCEMENT

Cottonwood Drain was constructed on the Boysen Unit in central Wyoming as part of a system to convey excess irrigation waters to surface storage impoundments. Most of the excess irrigation water from the irrigation district flows through the drain prior to its entering Lake Cameahwait. Reclamation constructed Lake Cameahwait to impound and regulate excess irrigation water prior to its entering Boysen Reservoir on the Wind River. Lake Cameahwait supports a record-producing smallmouth bass population (*Micropterus dolomieu*) and has developed into a heavily-used regional fishery resource.

Since the drain was constructed in the 1960's, the addition of a perennial source of water has caused the drain channel to degrade vertically into the surrounding unconsolidated sands and silts. Some locations within the drain have eroded as much as ten vertical feet. In some locations, the drain also suffers from horizontal degradation and side-slope instability. Much of the displaced parent material was being transported directly into Lake Cameahwait affecting water quality, habitat values, and recreational opportunities.

Realizing the benefits of stabilizing the drain, the Wyoming Area Office initiated an agreement with the Wyoming Game and Fish Department (WGFD) and Midvale Irrigation District (MID) to stabilize the drain channel, reduce erosion, and minimize entrainment of suspended particulates flowing into Lake Cameahwait. This cooperative effort resulted in the construction of eight grade control structures at strategic locations throughout the eight-mile long channel. Reclamation completed environmental and cultural resource compliance, purchased much of the materials necessary to construct the drop structures, and provided funds for salaries necessary for construction with the MID and WGFD

providing construction equipment and maintenance. Grade control structures elevated local surface profiles, decreased channel gradient, and reduced flow velocity. As a result, the potential for erosion has been significantly reduced and emergent and riparian wetlands have expanded significantly in the vicinity of all of the grade control structures. Water quality and habitat values in Lake Cameahwait have improved and stabilized. Water quality in the drain has improved to a level which now supports a limited brook trout (*Salvelinus fontinalis*) population. This aquatic and wetland resource is extremely important for migratory and resident wildlife in an area of Wyoming which averages three to five inches of precipitation a year.

NIKOLAISEN WETLAND RESTORATION AND DEVELOPMENT

The Nikolaisen wetland restoration and development project is located in the Devils Lake basin in northeastern North Dakota. The Devils Lake basin lies in the heart of the prairie potholes region and encompasses nearly 2,500,000 acres. Much of the basin's native grasslands and wetlands have been converted for agricultural production. With average precipitation, the Devils Lake basin has no natural outlet. However, during periods of extraordinarily abnormal precipitation, Devils Lake can enlarge and ultimately leave the basin and flow into the Sheyenne River. Significant economic and natural resource damage would result from such a scenario.

Some of the ramifications of wetland drainage in the basin include reduced water storage capability in the upper reaches of the basin, increased surface runoff into Devils Lake, and degradation of water quality. Drainage activities, coupled with recent abnormal levels of precipitation, have caused significant flooding and associated impacts in the vicinity of Devils Lake.

It has been recognized that drainage activities in the upper basin have adversely affected wetland habitats, flood flow attenuation, and water quality values. In an effort to reduce the adverse effects associated with these activities, Reclamation entered into a cooperative agreement with the U.S. Fish and Wildlife Service and Ducks Unlimited to restore and develop wetlands on the Nikolaisen

Waterfowl Production Area north of Devils Lake. This cooperative project resulted in the restoration of a previously drained 15-acre prairie pot-hole by filling a portion of an existing drainage ditch and the development of approximately 43 acres of open water and emergent wetlands through construction of two small impoundments on ephemeral drainages. These wetlands attracted migratory waterfowl and other wetland-dependent wildlife in the first year following construction and will continue to enhance water quality and contribute to flood flow attenuation in the basin. It is anticipated that a number of similar cooperative projects will be pursued to contribute to the enhancement of environmental values in the basin.

CONCLUSION

The Region supports participation in cost-sharing partnerships to restore, enhance, and develop wetlands and riparian areas throughout the Great Plains ecosystem. Many of these projects focused on the enhancement of habitat values for migratory and resident wildlife and those listed as threatened or endangered. However, successful partnerships have been developed for a variety of projects which focused upon wetland values other wildlife habitat. These projects have resulted in measurable benefits for water quality, flood flow attenuation, primary productivity, and environmental education in addition to providing habitat values.

We are optimistic about the future of the Region's WDP and will continue to explore opportunities to participate in cost-sharing partnerships to enhance environmental values throughout the Great Plains ecosystem.

GARRISON AGRICULTURAL/WILDLIFE ENHANCEMENT PROJECTS
(CANADIAN CLUB)

Allyn J. Sapa¹

ABSTRACT

A partnership between the Garrison Diversion Conservancy District, Bureau of Reclamation, North Dakota Game and Fish Department, U. S. Fish and Wildlife Service, and private landowners resulted in a productive use of water from the McClusky Canal for enhancement of prairie wetlands for waterfowl and livestock water supplies. This partnership resulted from a trip to Alberta, Canada, in 1989, sponsored by the Garrison Diversion Conservancy District, that brought together irrigation and wildlife interests to view cooperative projects developed in conjunction with the Eastern Irrigation District.

The State and Federal agencies pooled their resources and expertise entering into a formal partnership with private cattlemen to fill drought-stricken wetlands located in native prairie pastures so that waterfowl would be able to complete their breeding cycle and cattlemen would have water available in the wetlands for their cattle.

This paper describes the characteristics of a partnership approach, and how it can be used to accomplish mutually beneficial projects.

INTRODUCTION

I want to talk to you today about a partnership process that has been used in North Dakota to bring together divergent interests to work toward a common goal. The interests in this case are irrigation development through the Garrison Diversion Unit, a Bureau of Reclamation project, and wetland conservation interests. Our goal was to use irrigation water for beneficial

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agricultural and wildlife uses. This paper is not so much about what we did, but how it was accomplished.

The Garrison Agricultural/Wildlife Enhancement Project is the bureaucratic title for a partnership approach to using Garrison Diversion McClusky Canal water to serve both wetland and private livestock interests. The long title was simply an effort to give credibility to the more casual Canadian Club title, an informal name we adopted out of circumstance. The Canadian Club was formed by staff from the Garrison Diversion Conservancy District, N.D. Game and Fish Department, Bureau of Reclamation, and the U.S. Fish and Wildlife Service. The impetus for this collaboration was a trip to Alberta, Canada, organized by the Conservancy District to examine a number of cooperative projects between irrigation interests, private landowners, and Ducks Unlimited. During the late 1980s and early 1990s, North Dakota was experiencing a severe drought. Duck sloughs were dry, and so were livestock pastures and watering holes. At the same time, the McClusky Canal, the primary delivery canal for the partially completed Garrison Diversion Project, was full of water but largely unused. By working together, our group was able to identify common goals for the productive use of the water, pool their resources, and develop a number of cooperative projects. Water was provided to livestock operators adjacent to the McClusky Canal by filling dry wetlands from the canal using siphons, pumps, and irrigation pipe. This provided water for cattle in the drought-stricken pastures and provided an area for breeding waterfowl. Each of the partners contributed equipment, manpower, expertise, or funding to make these projects work. It brought together irrigation development and wetland conservation interests in a forum that allowed these projects to get done.

In all, six projects were produced that enhanced 16 wetlands and five stock water dugouts. Prior to our water management, 41 duck pairs were counted at the enhancement sites. In the 3 preceding years, pairs averaged 179, or over a four-fold increase. These observations also showed that these duck pairs were productive, as numerous broods were observed. Both agriculture and wildlife benefited from these projects. When the drought ended in 1993, the wetlands and pastures no longer needed this McClusky Canal water. That's the short version of what happened.

Now, a little digression. As wildlife biologists, I have to say that we have not always seen eye to eye with agricultural development when trying to conserve wetlands in North Dakota. We have had our share of battles. So when we were approached to go look at some cooperative projects involving wetlands in Canada, I was a little bit skeptical. If I were to use that skeptical attitude of working with irrigation developers to conserve wetlands as a setup for this discussion, a better title for this talk might have been "Marching into Hell For a Heavenly Cause." Now as biologists, we would view positive wetlands projects as a worthy endeavor, a heavenly cause so to speak, but as this new title would imply, the march to get there may be an arduous task.

Cooperative projects are not new, but the process we used and the doors it has opened are worthy of note. By shedding some light on what we accomplished, I hope to provide some food for thought that can be used elsewhere.

First let me say, cooperation is defined by Webster as "to associate with another or others for mutual benefit." Okay, so far! By definition then, the cooperative agricultural/wetland projects would have wetland conservationists working with irrigation developers for mutual benefit - now here is where it gets shaky. We had not done much of this. Some folks might think that working with the irrigation developers is like working with the Devil. Here is where the marching into Hell comes into play. After all, Hell is defined by theologians as a place of the Devil and those that enter will suffer everlasting punishment. Some would say that is a just result for those that abandon the traditional approaches to wetland conservation. I guess I might agree, there may be a punishment for those working cooperatively with irrigation developers, but it won't be for trying, it will be for not trying hard enough.

Wetland conservation has been a struggle from the beginning. There's a story that goes:

A young up-start wetland biologist went to a fortune teller to get advice on how to protect wetlands. The fortune teller looked into her crystal ball, pondered the mystical glass, and finally said "You will be frustrated with wetland conservation efforts

until you are 45." Disappointed with the prediction, but always hopeful, the biologist asked "then what will happen?" Then, the fortune teller said "you will get used to it." And so it seems that's how wetland conservation has gone.

To no ones surprise, wetland conservation has been frustrating here in North Dakota as well as elsewhere in the country. There have been successes, but there always seems to be barriers to achieve wetland conservation as an accepted public policy. Wetland benefits have been routinely relegated to a low priority or ignored altogether. Society quickly opts for short-term economic gain instead of long-term sustainability. Wetland issues and wetland supporters have been a convenient political whipping boy for those that don't understand or oppose environmental protection, government regulation, and public values. The fortune teller's prediction in the story would suggest that wetland conservation will be frustrating forever - that we will accept the status quo. I don't believe we can or should accept that prediction. We are all challenged as professional wetland managers and agricultural developers as well to find and work toward better ways of doing business, to not accept getting used to frustration, but getting beyond it, and working out solutions. Cooperative approaches, like the Canadian Club process, can be a model of a better way to do business.

This paper then is about process - the process of cooperation. What I'd like to do in the next few minutes is provide a brief background on where we have been with wetlands, and why cooperation in this agricultural-dominated economy has been so hard to get going.

I've worked for the conservation of wetlands for over 20 years. During that time, a lot of water has passed under the bridge - wetlands drained for development no doubt. The process has always been very contentious. We have generally worked in our own camps, without a lot of meaningful dialog with the agricultural community. The result is that wetland resources have continued to deteriorate, slower than they used to - but deteriorate none the less.

Since the first settlers came to North Dakota, agriculture has been the economic energy of the State. Because this State had an abundant wetland resource, conflicts were common. Wetland drainage began with the Bonanza Farms of the late 1880s and were still being reported in the 1960-80s at nearly 20,000 acres a year. There are people who advocate development of every wetland in the prairie ecosystem; and generally, there was political support for those conversions.

When Congress took action with the 1985 and 90 Farm Bills, Swampbuster provisions slowed conversion rates, although some still occur. The recent drought of the late 80s and early 90s also temporarily removed the stimulus to convert wetlands, since many of the wetlands prior to the rains in '93 could be farmed anyway. With the return of moisture the past 3 years and the strength of crop prices, the old arguments to get rid of wetlands have begun to resurface.

This country was born out of exploitation. Wetlands are often considered wasteland by those that want to convert them, with little thought to the values they provide. With wetland conservation, we are trying to change the momentum of nearly a century of conversion, passed on from one generation to the next. Attempts at wetland conservation have been met with conflict, bad feelings, and political resistance. With such a one-sided history, it's no wonder that projects that included wetland conservation were difficult to achieve.

Wetland conservationists throughout this time continued to actively try different strategies to protect wetland resources. What resulted was sometimes referred to as the "wetland wars". These conservationists testified at public hearings and before Congress, wrote letters to the editor, initiated lawsuits, lobbied agencies, and raised money; but in many cases, these efforts just increased the price of wetland destruction - they didn't stop it, and turned off a lot of folks as a result. The developers, of course, were doing the same, and with more success. They did not want to hear the wetland side of the story. It did not fit their paradigm. That lack of communication has been the major roadblock to wetland conservation solutions.

So with all this prohibitive history, how were developers and conservationists able to work together? Leverage - I think. Cooperative wetland projects require that all parties come to the table and negotiate in a fair and open-minded manner. This was not occurring on wetland issues because the wetland developers who had the upper hand did not see the need politically to negotiate.

That changed in the 1980s. Two major reasons created the atmosphere that allowed cooperative approaches to work: one, the reformulation of the GDU Project legislation; and two, the interest of then Governor Sinner to bring sides together to resolve problems. The difficulties surrounding the Garrison project persuaded the water development interests to come to the table and see what wetland folks would support. This brought many of the water development interests into the discussion since GDU was and is woven into most State water issues. Governor Sinner provided leadership and credibility to create an atmosphere that facilitated this kind of process. Now in a perfect world, the outside stimulus or leverage would not be necessary, but we don't live in a perfect world so sometimes a little push helps.

So what really does it take to have a cooperative approach? I think I know some of the characteristics. For example:

- o It means meeting face-to-face so you know the folks you're talking to and develop a rapport with them. That leads to understanding their point of view.
- o It means clearly identifying your position and flexibility to resolve issues. It has been my experience that there is almost always middle ground, but we rarely talk about it. All too often, we are sure we know what the other side means or where their flexibility is or should be, and when they don't reflect that in letters or formal meetings, the issues get quickly polarized. Some think middle ground is giving away half. I think middle ground means identifying a solution both sides can agree to and support.
- o It means that we need to act with credibility and develop well thought out and practical solutions. This requires taking

chances. It requires you to expose your ideas to others who may not hold these ideas, and

- o It means commitment to working to jointly implement solutions. This is the bottom line. Did you really mean what you said?

I don't mean to imply the cooperation as illustrated in the Canadian Club projects is new - we all cooperate in lots of areas - these are common skills we practice every day with our peers, our spouses, our children, and our neighbors. But some issues seem to be held to a lower standard and in this case we didn't have a long track record cooperating on joint wetland and agricultural projects, and that's why the Canadian Club projects are worthy of mention.

There is also the influence of outside interests. Some groups have watched from the sidelines or participated in the conflicts in the past. I think in some cases that some of these groups don't want the wetland projects to succeed because that would ratify the notion that wetlands have value and can be compatible with other uses. As a result, I think there is some mistrust of what cooperative wetland approaches can be. One thing for sure, they are a change from the traditional way of doing business. It's not the type of process that a lot of folks have been directly involved in. That fact has also led to some suspicions - thinking the worst. I can only say the safety net for these people is that projects built through this process must stand the test of policy or regulations.

Wetlands conservation has lived and died on political decisions. Since the wetland resource is a relatively fixed resource, failure to resolve problems almost always results in fewer wetlands. Decisions need to be made that are supported by the widest base possible to insure long-term survival from the changing political winds. Otherwise, the project guarantee is only till the next political change. What I have seen as the best deal for wetlands are those decisions that received broadest support and participation. Cooperative wetland/agricultural approaches can do that because they recognize both sides of an issue and look for stability. It allows people to get together for the common good, to build constituencies, to defeat misinformation, and promote solid

public policy. It allows people from all sides of the issue to support the project.

Cooperative approaches also do not mean that you must agree on everything. Quite the opposite is more likely. What it does mean is that you identify those areas where agreement can be reached and not let areas of disagreement stymie cooperation and implementation of the project.

Another point I want to make is that some conservationists think there is a "right" policy for wetlands and that people that don't support wetlands don't think right. We've all heard or used the phrase he or she "thinks right." I can tell you with great confidence that the development interests think just as strongly that they are right in pursuing development. We should not let this provincial ideology override good judgement. The cooperative process is not for people that think right, it is for people that think.

Cooperative approaches are really then a communication process. Both sides have perpetuated the wetland controversy by laying back in the weeds and sniping, "send in the scuds," for effect, often perpetuating the letter-writing war. Invariably, things are not as bad as one side says or as good as the other side says. What it takes to start cooperation is initiative by one or both sides to meet and talk - clearly identifying the need to find the middle ground. This is a key point. Somehow, someone has to make the first move. If that initiative is real, it can energize the process. As with the Canadian Club efforts that spawned out of the Garrison Diversion project, people saw an opportunity, identified what they could agree upon, and that was enough to go forward. The process is infectious. Turns out, it's much more pleasant to work toward a common goal than tear each other down. Through the cooperative process, we can overcome conflict and are able to work on solutions.

The Canadian Club projects are a simple concept. Take water where it is to where it is needed. That was not accomplished without its difficulties, but we found through pooling our resources that projects that would have been difficult for each of us to accomplish individually were very doable together.

I would be negligent if I didn't mention the role of the private landowners where the projects took place. They got a good deal. The agencies worked hard to put water in the dry pastures for the cattle. In exchange, the livestock operators shared their resources as well. To facilitate the projects, they agreed to a grazing management plan so that the breeding waterfowl could take advantage of the wetlands.

So what can we say the Canadian Club process has done to improve working relationships. It was a small effort, but it has brought irrigation development and conservation interests to the negotiations table and created a forum, a working model that can result in a constructive process to resolve issues. We found that we had a lot more in common than we thought.

Once the process is started, familiarity builds credibility with the partners and further opens the discussion and possibility for resolutions of issues. With the Canadian Club projects, it is important not to miss the point that our experience gained in cooperation will likely be more important for both agriculture and wetlands than the waterfowl/livestock watering benefits we produced. This is our future!

In conclusion, it would be a mistake to accept the fortune teller's prediction that we will get used to frustration with wetland conservation. What it often takes is personal initiative to get the ball rolling. That initiative can and should come from both sides. It is our responsibility as wetland conservationists, as well as it is the responsibility of agricultural developers, to recognize that there are a variety of public resource values. Cooperative approaches (like Canadian Club) that develop and conserve the public resources are worth pursuing. The cooperative approach is a way to seek the middle ground, a way to advance both wetland conservation and agricultural development in the future.

CREATING MULTIPLE PURPOSE WETLANDS TO ENHANCE
LIVESTOCK GRAZING DISTRIBUTION, RANGE CONDITION
AND WATERFOWL PRODUCTION IN WESTERN SOUTH DAKOTA

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ABSTRACT

Creating multiple purpose wetlands on large unfragmented tracts of western grasslands affords a unique opportunity to serve both ranching and wildlife interests by simultaneously enhancing livestock performance, range condition, and waterfowl production. While surface water developments on western grasslands have long been recognized as an effective technique for improving grazing distribution, more recent data suggest that such developments also have high potential for waterfowl production. Dabbling duck productivity rates per surface acre of water in these systems are often 2-4 times higher than in more traditional habitats of the Prairie Pothole Region where waterfowl managers have traditionally focused their efforts. Throughout the Prairie Pothole Region dabbling duck recruitment appears to be severely limited by the combined influences of nesting habitat fragmentation and artificially high predator densities supported by anthropogenic landscape changes. Conversely, western grasslands are characterized by relatively large tracts of nesting cover, low density predator communities, and as a result, high duck productivity when adequate surface water is available.

Recognizing the multiple benefits of created wetlands, beginning in 1992 the U.S. Fish and Wildlife Service initiated a unique statewide partnership in South Dakota to create multiple purpose wetlands on private and tribal grasslands. Emphasis was placed on creating multiple purpose wetlands on large unfragmented tracts of grassland, including for the first time, sites outside of the traditional Prairie Pothole Region. Primary partners in this program include the North American Wetlands Conservation Council, Ducks Unlimited

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Incorporated, Native American Tribes, the South Dakota Association of Conservation Districts, the South Dakota Department of Game, Fish and Parks, county Conservation Districts and individual landowners. Through this partnership over 450 wetlands have been created, with 30% occurring on western grasslands outside of the Prairie Pothole Region.

As expected, tangible benefits noted from wetlands created through this partnership include improved grazing distribution and livestock performance, enhanced range condition and localized increases in waterfowl production. More importantly, as a result of this program many participating landowners have expressed a renewed enthusiasm for the intangible benefits of wildlife conservation. Interest in this program continues to grow providing an example of a true working partnership between agriculture and wildlife.

**SURFACE WATER DEVELOPMENTS ON WESTERN GRASSLANDS:
AN OLD TOOL FOR RANCHERS, A NEW OPPORTUNITY FOR DUCKS**

Benefits to ranchers

Ranchers across the arid mixed-grass prairies have long utilized surface water developments for livestock watering needs. Bue et al. (1964) estimated that 260,000 such developments for livestock watering have been constructed in North Dakota, South Dakota, Montana and western Minnesota. Eng et al. (1979) described the three most common designs of livestock surface water developments: (1) pit reservoirs that are steep sided rectangular excavations, (2) retention reservoirs which are created by building earthen dams across natural waterways, and (3) pit-retention reservoirs which are a combination of pit and retention reservoir designs. All three designs are constructed to intercept groundwater runoff from the immediate watershed. In general, the retention and pit-retention designs are most commonly used in the western United States. In South Dakota, Ruwaldt et al. (1979) estimated there are over 88,000 retention and pit-retention reservoirs with over 80% occurring in the western portion of the state.

While surface water developments are often an essential prerequisite for any livestock production on arid grasslands, they also facilitate improved range condition and enhanced livestock performance. Holecheck et al. (1989) generally noted that inadequate water distribution is the primary cause of poor

livestock distribution and range utilization. Specifically, Valentine (1947) documented on a New Mexico range that forage production was most severely reduced within .8 km of watering sites. Poor distribution of water can also lead to reduced livestock performance. Holechek et al. (1989) generally noted that increased travel distance between available forage and water can influence livestock productivity. The importance of travel on cattle energy budgets was illustrated by Havstad and Malechek (1982) who showed that free ranging cattle expended 46% more energy than did cattle fed in stalls. With these factors in mind, it is readily apparent why ranchers across the western United States continue to view surface water developments as an essential tool for proper range management and optimal livestock performance.

Benefits to ducks

While ranching interests have long understood the utility of surface water developments for range management and livestock production, more recently waterfowl managers have noted that if located in the right landscapes these same developments may also present a very unique and much needed opportunity to enhance duck production. The opportunities for duck production on western surface water developments are best illustrated by current biological explanations for the severely limited duck production noted in more easterly breeding areas.

One hypothesis for declines in duck populations is that throughout much of the Prairie Pothole Region, which historically accounted for 50% of continental duck production (Smith et al. 1964), the combined influences of nesting habitat fragmentation and high predator densities, primarily mammals, are suppressing recruitment rates below levels suggested for population maintenance. Recent investigations of nest success, a primary determinant of recruitment rates (Cowardin and Johnson 1979), support this contention. Many studies in the Prairie Pothole Region are currently reporting Mayfield (1961) nest success rates below the 15% population maintenance threshold suggested by Cowardin et al. (1985) for mallards *Anas platyrhynchos* in central North Dakota. For example, Klett et al. (1988) summarized data from 1966-1984 for more than 15,000 nests found throughout the Prairie Pothole Region of North Dakota, South Dakota and Minnesota to calculate nest success for 50 unique combinations of species, year, and region. Nest success in 40 of the 50 data

combinations was below levels suggested for population maintenance and mammalian predation was the primary cause of nest failure in all habitats studied. More recent studies across the Prairie Pothole Region continue to document predation as a proximate cause of low nest success. Fleskes and Klass (1991) documented 11.9% nest success on an Iowa study area and attributed mammalian predation to 82% of the nest failures. Sargeant et al. (1995) noted a 5.6% average nest success and attributed 96% of nest failures to predation on 12 study areas in North Dakota and Minnesota. Greenwood et al. (1987) estimated an average mallard nest success of 12.0% and attributed nearly 75% of nest failures to predation during 1982-1985 on 17 studies in Alberta, Saskatchewan, and Manitoba.

Working under the premise that fragmented nesting habitat and high predator densities suppress nest success and recruitment, certain waterfowl managers and researchers have begun to focus attention on regions where these suggested factors of decline are less prevalent. The mixed-grass prairies of western North Dakota, western South Dakota and eastern Montana exhibit many of the landscape scale features suggested for high nest success and recruitment. This region is characterized by large unfragmented blocks of nesting cover and relatively low predator densities. Although wetland densities in this region are very low relative to the Prairie Pothole Region, when adequate surface water is available, breeding pair densities and overall duck productivity rates per individual wetland can be high. Ball et al. (1995) used breeding pair/brood ratios to infer a dabbling duck nest success of 45-60% on large tracts of grassland across north-central Montana. This level of productivity is approximately 2-4 times higher than in most duck populations recently studied throughout the Prairie Pothole Region

Cowardin et al. (1995) forwarded two distinct techniques for waterfowl managers to enhance dabbling duck production; managers can either (1) attempt to raise recruitment rates in landscapes where they are inadequate to maintain stable populations or (2) increase carrying capacity and attract additional breeding pairs to landscapes that have high recruitment rates. Creating wetlands to attract additional breeding pairs to the mixed-grass prairies of western North Dakota, western South Dakota, and eastern Montana appears to constitute an encouraging opportunity for waterfowl managers to implement the latter technique.

A SOUTH DAKOTA CASE HISTORY: BRING TOGETHER
RANCHING AND WILDLIFE INTERESTS FOR WETLAND CREATIONS

It is apparent that ranchers and waterfowl managers have a mutual interest in securing funding mechanisms for surface water developments on western grasslands. Ranchers need livestock water and waterfowl managers need a workable technique to enhance duck production. Recognizing a unique opportunity to forge a working alliance between agricultural and wildlife interests the U.S. Fish and Wildlife Service (USFWS) through it's Partners For Wildlife Program initiated a new program in 1992 for the creation of multiple purpose wetlands on private and tribal lands across South Dakota.

From it's inception this partnership was designed to serve both ranching and wildlife needs. To facilitate duck production while simultaneously improving livestock grazing distribution and range condition, wetlands were selectively created in large tracts of grassland, including sites in the western portion of the state. Within South Dakota, this represented the first significant endeavor of the USFWS Partners For Wildlife program outside of the Prairie Pothole Region. Wetland creations were usually designed as retention or pit-retention reservoirs (Eng et al. 1979) and selectively located on the landscape to provide an optimum combination of deeper water (3-5m) that is needed for livestock watering purposes and shallower water (<.5m) that provides emergent wetland vegetation for waterfowl habitat.

A defining characteristic of this program is an extremely broad and diverse base of partners comprised of private, local, county, state, federal and tribal entities. Primary partners joining the USFWS in this ongoing program include the North American Wetlands Conservation Council, the South Dakota Department of Game, Fish and Parks, Ducks Unlimited Inc., the South Dakota Association of Conservation Districts, the U.S. Department of Agriculture Natural Resource Conservation Service, the Federal Emergency Management Agency, 50 county Conservation Districts, the Yankton, Crow Creek, Lower Brule, Cheyenne River, and Sisseton-Whapeton Sioux Tribes, Wildlife Forever, the Izaak Walton League, the Delta Waterfowl Foundation, the South Dakota Division of Resource Conservation and Forestry, local water development districts, and most importantly over 300 private landowners.

CURRENT ACCOMPLISHMENTS AND FUTURE GOALS

The multiple purpose wetland creation program has allowed the USFWS to expand it's wetland conservation efforts throughout South Dakota and to capitalize on potentially high duck recruitment in large grasslands throughout the western portion of the state. During 1992-1996 over 450 multiple purpose wetlands have been created with 30% occurring in the western portion of the state outside of the Prairie Pothole Region where the USFWS has traditionally focused wetland conservation efforts.

Popularity of the wetland creation program among South Dakota landowners continues to rapidly grow with the level of interest exceeding funding levels in many portions of the state. Within South Dakota the USFWS Partners For Wildlife Program continues to work among all existing partners to secure additional funds. Currently, the USFWS Partners For Wildlife program has initiated similar partnership for multiple purpose wetland creations in North Dakota and Montana. The North American Waterfowl Management Plan (NAWMP), an international plan devoted to the recovery of North American waterfowl populations has recognized the unique biological opportunities of wetland creations on the mixed-grass prairies outside of the Prairie Pothole Region. The NAWMP has designated portions of western South Dakota, western North Dakota, and eastern Montana as the "Northern Great Plains" Waterfowl Habitat Area of Major Concern (NAWMP 1994). This designation may provide additional opportunities to secure future funding for wetland creations across this region.

While improved range management and waterfowl production were initial goals of the South Dakota multiple purpose wetland creation partnership, other less tangible benefits will likely make a larger lasting impact on resource conservation in South Dakota. As a result of this program, agricultural and wildlife interests that historically operated independently from each other have now joined in a uniquely productive partnership to effectively address land and water conservation matters of mutual concern. The South Dakota multiple purpose wetland creation project provides an example of a true working partnership between agriculture and wildlife.

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JORDANELLE WETLANDS: A Mitigation Site to Benefit Wildlife
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ABSTRACT

The Jordanelle Wetland mitigation site was developed on a 100+ acre parcel below Jordanelle Dam near Park City, Utah. Originally agricultural field with irrigation induced wetlands on site, the mitigation area was designed to avoid disturbance to these wetlands and to create irregularly shaped, variously sized flow-through ponds. Many features were incorporated to both discourage nuisance species and predators and to enhance wildlife habitat.

INTRODUCTION

Although Federal agencies must comply with a variety of laws and regulations, these actions can exceed compliance to provide multiple-resource benefits. Opportunities exist in nearly all land management activities. Additionally, mitigation actions for losses to one resource, such as wetlands can provide, through thoughtful design, benefits to wildlife, including rare and threatened species.

A primary benefit to wildlife is the provision of habitat. Every animal requires a particular habitat without which it cannot survive. The four basic components of habitat are water, food, cover, and space for animals to conduct activities such as feeding, resting, and breeding. Habitat is physically defined by climate and substrate. Habitat is dynamic and changes with time and alterations, either by direct manipulation or natural events. Although species differ in their habitat requirements, creating a variety of habitats will benefit more species than a single habitat type.

Diversity is key. Habitat diversity can be created by structural diversity. Specifically, the edge between two habitat types affords more variety. Many animals frequent these areas more commonly than, say, the adjacent field or forest. Associated with edge is interspersed and irregularity. A single linear edge provides less diversity than many meandering ones. Spatially irregular mosaics of habitat types afford the most variety and will support the greatest diversity of wildlife. With these principles in mind, a wetland mitigation site was designed to benefit a variety of wildlife species.

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The Bureau of Reclamation completed Jordanelle Dam, near Park City, Utah in 1993. The dam and reservoir are part of the municipal and industrial system of the Bonneville Unit of the Central Utah Project. As a condition of the permit to construct the dam, the U.S. Army Corps of Engineers (Corps) under Section 404 of the Clean Water Act required Reclamation to mitigate for 175 acres of wetlands lost to inundation and highway relocation. To satisfy a major portion of this commitment, Reclamation purchased approximately 355 acres of hay fields below the dam.

The site selected for development consisted of two parcels (the 162 acre Jordan property to the north and the 190-acre Condie property to the south). The Jordan River runs through the property. Dikes and berms were constructed along the river in the 1950s to provide flood protection. The parcels contained riparian communities, wetlands, and was used largely for largely irrigated hay meadows, for crops and cattle and sheep grazing. Alfalfa and pasture was being produced on most of the irrigated land.

PLANNING

Many agencies were involved early in the process, including the Utah Division of Wildlife Resources (UDWR), the U.S. Fish and Wildlife Service (FWS) and the Corps of Engineers. Additional groups became interested over time. In response, Reclamation formed a Technical Advisory committee (TAC) to involve all interested parties. The TAC identified key issues, lent expertise to the planning process, and developed goals and objectives for the project.

The following goals were established:

1. Meet 404 permit requirements
2. Minimize impacts to existing wetlands and riparian areas
3. Create and maintain maximum habitat diversity within operating limits and funding constraints
4. Facilitate low-cost, long-term maintenance and management
5. Enhance development of western spotted frog habitat
6. Accommodate educational and research uses of the wetland

Reclamation's challenge was to meet these goals. The 404 permit required approximately 100 acres of wet meadow wetland complex with 4 to 10 acres of open water while preserving and/or enhancing the existing wetlands and riparian communities. Thus, the first step in the design effort was to identify existing wetlands so they could be incorporated into the design. The wet meadows were seasonally saturated, flooded by snowmelt and flooded by irrigation water.

A wetland delineation was conducted in 1991 and approximately 45 acres of jurisdictional wetlands were on the site, primarily wet meadow palustrine emergent wetlands, with some palustrine scrub/shrub wetlands. Forested riparian communities covered about 63.5 acres.

Soils were identified as Kovich loams, deep soils formed on floodplains and stream terraces and on the hydric soils list for Utah, and Fluventic Haploborolls, an intermixed soil complex along stream bottoms located in valleys and narrow canyons. The subsoils were clay or clay loams, underlain by gravelly and cobbley glacial materials. Seepage and permeability studies were conducted and monitoring wells were installed. Results from these studies indicated a high ground water table over most of the site.

A vegetation survey also was conducted. Common species were redtop (*Agrostis alba* - FW); Nebraska sedge (*Carex nebraskensis* - OB); Baltic rush (*Juncus balticus* - OB); and reed canary grass (*Phalaris arundinaceae* - FW). Grasses and forbs lined old irrigation ditches and drainage ways. Shrubs consisted of red-osier dogwood (*Cornus stolonifera* - FW); thin-leaved alder (*Alnus incana* - FW) and willow (*Salix* sp - FW or OB). The meadows were mowed and heavily grazed. The forested riparian community was dominated by narrowleaf cottonwood (*Populus angustifolia*) which was also associated with former river meanders. Approximately 133 acres of irrigated hay meadow was available for developing new wetlands to mitigate the impacts from Jordanelle Dam and Reservoir.

WETLAND DESIGN

Reclamation's design consisted of a series of low profile earthen dikes constructed on the agricultural fields. The site has a north-south gradient. The complex is divided into two sections. Designed to avoid existing wetlands on site, the northern section contains 18 berms, the southern section has 16. The dikes impound water to create a series of ponds that match the contours and blend with existing wetlands. A 6800 foot meandering screen ditch separates the wetland cells from the highway.

Water within each pond is regulated independently and can be released to downstream ponds or can be turned out to adjacent wetlands. Overflow spillways on each dike allow for alternate release locations. Stoplogs regulate the depth in each pond. Reclamation secured water rights from land purchased within the reservoir boundary and is currently seeking additional storage rights for late summer releases. Water requirements were expected to be 5.9 ft³/s. Water is diverted below the dam into the first pond and to the screen ditch. The delivery

system is designed to be operated during non-freezing temperatures and is drained each fall.

With the help of the TAC, a revegetation plan was designed and implemented over several years. It included mixtures of primarily native grasses and forbs on the dikes. Woody vegetation, both trees and shrubs, was planted along the screen ditch. An intensive monitoring program to measure the progress of wetland development is in its third year.

WILDLIFE HABITAT

The project incorporated many features to benefit wildlife. The dikes were designed on natural land contours and with a gradual slope to ensure a gradation in water depth from flooded areas (4 feet) to upland. The upstream slope was 5 to 1 and the downstream slope was a 3 to 1 ratio. The flatter upstream slope was to reduce muskrat burrowing. The dikes ranged from 2 to 6 feet in height with a crest width of 10 feet (to accommodate maintenance vehicles) The dikes are made from soil that allows water to slowly seep through the dikes. This diversity in topography correlates with various soil moisture regimes which in turn supports a gradation of vegetative communities.

Islands, peninsulas, and isthmuses were constructed to provide landscape diversity and will contribute to soil substrate and water depth diversity. Islands were irregularly shaped to increase edge and were placed a minimum of 30 feet from the shoreline to discourage predators. Peninsulas were planted with willow and cottonwood trees to provide cover and perch sites. Some areas were scarified to allow more rapid establishment of aquatic plants.

Vegetative diversity to benefit local species was achieved by planting primarily native vegetation. Topsoil removed during construction was stockpiled for later placement on the dikes, to increase success of locally adapted varieties.

Obstacles to habitat diversity include browse damage of young plantings and invasion of exotic species, particularly weedy species. Planting of trees and shrubs was accompanied by placing black mulch at the base to discourage competition from more aggressive herbaceous species that would compete better for available water. Some trees and shrubs were also fitted with a plastic mesh to discourage browsing by deer and elk. These techniques have met with varying success. In some cases natural regeneration of willows and cottonwoods has been more effective than plantings. Deer and elk browse has been heavy in some locations, less in others.

Aggressive noxious weeds on the wetland site include scotch and musk thistle, white top, and to a lesser degree leafy spurge. Infestations of the species allowed to go unchecked will result in an expanding monoculture, devoid of vegetative diversity. The Central Utah Water Conservancy District currently has weed management responsibilities at the site. Selective spraying with herbicides has had some success. Reclamation also released biocontrol organisms - *Rhinocyllus conicus* to combat musk thistle and *Aphthona lacertiosa* for leafy spurge. Water management techniques have also reduced infestations. A former paddock on the property was heavily infested with thistle. Spraying marginally reduced populations. This year, a spring has developed upgradient from this area and has flooded this population of thistle.

Beaver activity has increased water in the riparian area separating the northern ponds from the southern and water has overflowed the road at times. The spotted frog (*Rana pretiosa*) was listed as a candidate species (Category 1) under the Endangered Species Act by the FWS. This frog is usually found in cool, clear spring-fed water with emergent and submergent vegetation. A population of spotted frogs was located in the reservoir basin in 1990 and during 1991 106 adults, 36 tadpoles and 70 egg masses were translocated from six locations within the reservoir basin and released at six sites on the wetland mitigation site. The sites on Reclamation land included Condie's pond and wire pond.

Reclamation also excavated a small pond to provide habitat for these frogs. It is located between the northern and southern pond areas. Follow up monitoring showed that translocated egg masses successfully hatched. Since then DWR has conducted annual surveys. Last year was dry and some egg masses desiccated. This spring, several egg masses were located in several of the northern ponds. DWR biologists think winter water would provide more habitat and increase the population. The current design does not allow year-round water flow, but options are being considered.

An additional objective of the wetlands was to promote education and research. Utah State University is conducting a long-term experiment on site to evaluate various cultivars of ryegrass and the correlation to exposure and soil moisture. They have also used experimental mulches, Kiwi Green, a semipermeable inorganic membrane that is sprayed over new plantings. The membrane allows moisture to enter the soil, but provide a barrier to evaporation. It biodegrades over three to five years. Results of this research will provide benefits to vegetation efforts throughout the west.

The Utah Division of Wildlife Resources is conducting a multi-year neotropical migratory bird study in riparian areas statewide. One of the sites is the riparian area in the Jordanelle wetlands. Ninety-six species of birds have been identified within the riparian zone. Federally permitted individuals are mist netting and

banding individual birds to establish return rates. Riparian zones are essential to nearly 80% of these species (Howe 1996).

LONG-TERM MANAGEMENT

An intensive monitoring program to evaluate the success of the wetlands, including structures, operations, and revegetation has been in place the last three years. Revegetation efforts have been highly successful. The monitoring plan has focused on several areas. Key to transitioning to a less labor intensive monitoring plan is establishing clear goals.

The challenge will be to integrate the interests of several agencies and organizations, meeting multiple objectives. Another ongoing study that may serve to provide clashing objectives is the Provo River Sinuosity Study. A goal of the fisheries mitigation for the Central Utah Project is to reestablish the sinuosity of the Provo river. Portions of the river under consideration for this effort include the area in the Jordanelle Wetlands.

Recreationists would like to use the wetlands for hunting, fishing and wildlife viewing. Reclamation has established that hunting is inconsistent with the goals of the site. However, fishing will be a part of the overall management plan. An interpretive center will be designed to provide school groups and the public with information about the wetlands and its wildlife.

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PHANTOM LAKE SPRINGS: ENDANGERED FISH HABITAT AND
IRRIGATION WATER FOR AGRICULTURE

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ABSTRACT

Phantom Lake Springs, near Balmorhea, Texas is home to many aquatic species. In particular, two of these species are endangered fish, the Comanche Springs pupfish (*Cyprindon elegans*) and the Pecos gambusia (*Gambusia nobilis*). These species are native to southwestern Texas, with the gambusia's range extending into southeastern New Mexico. Both species have experienced a decline in population due to the failure of springs such as Comanche Springs which was home to approximately one-half of the total population of the Comanche Springs pupfish. Water withdrawals and dam construction for irrigation purposes have depleted natural flows. As a result of reduced flows, dispersal routes between tributary springs and streams have been lost. These habitat losses have resulted in the fish becoming isolated and dependant on permanent springs and spring flow for survival.

INTRODUCTION

In 1945, Phantom Lake Springs was acquired by the Bureau of Reclamation (Reclamation) to supply water to local water users and the Reeves County Irrigation District, (RCWID) after construction of

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the water conveyance system. Several species of fish and other aquatic life have continued to inhabit the spring and adjacent water channels, from construction through the present. However, in recent years, the endangered fish at Phantom have declined in numbers to dangerously low levels.

In 1992, a design was derived after consultation with the Rio Grande Fishes Recovery team, State and federal agencies, and the water users for the development of a refugium to provide native habitat for the propagation of the endangered fish. Construction of the refugium was completed in Summer 1993, with the introduction of the pupfish and gambusia in October 1993. Both species presently thrive in the habitat at this location. The design of this refugium has also ensured that the flow of water from the spring will continue to be made available for the water users along the irrigation canal.

The immediate area surrounding Phantom Lake Springs is home to a large number of plant and wildlife species and many migratory species of birds. The area around the spring is also a unique archaeological site, with human habitation in this area dating to 9,000 B.C.

This project is an excellent example of the manner by which endangered species "and others concerned," Reclamation projects and water users may all benefit.

Phantom Lake Springs: Endangered Fish Habitat and
Irrigation Water for Agriculture.

Location and History

Phantom Lake Springs is an archaeologically rich site, which may date to 9000 B.P. for human occupation. Phantom Lake Springs is located in West Texas, approximately 6 miles from the town of Balmorhea and 40 miles south and west of Pecos, Texas. This site is in the Trans-Pecos section of Texas between the Pecos River and the Rio Grande. The spring is west of the Reeves/Jeff Davis County Line, located in Jeff Davis County.

Phantom Spring is an artesian spring, issuing from a cave in a depression known as, " Phantom Lake Springs." The spring has been a perennial source of water, dating from the Pleistocene. The lake formed has been a favorite recreation spot in recent times.

In the late 1800's, landowner Joe Kingston modified the lake. By plugging several bedrock drain holes and confining the spring water, he provided a permanent watering hole for his cattle.

In 1945, Reclamation purchased from the J. O. Kingston family the spring and surrounding lands. The Kingston family retained 3,262 acre feet of water for irrigation, and the Splittgarber family retained a right to 60 acre feet of water per year for irrigation. The Federal Government holds the remainder of the water right to the spring, which, by contract, is provided to Reeves County Water Improvement District (RCWID).

In August 1945, the Bureau of Reclamation (Reclamation) was asked to improve the water supply to surrounding lands. Reclamation constructed a concrete-lined irrigation ditch from the mouth of Phantom Spring to the District Main Canal at San Solomon Springs and an inlet Feeder Canal from the Main Canal to the Lower Parks Reservoir in

Balморhea.

In 1946, Reclamation, under authority of the Water Conservation Act of 1939, rehabilitated the RCWID project facilities. Subsequently, on June 12, 1947, the project was placed in operation; and the project was returned to the district on June 22, 1951. Upon completion of the project, the Federal Government maintained ownership of the 17.56 acres surrounding Phantom Springs, as well as an operation and maintenance easement on the remainder of the project.

In 1986, final repayment for construction costs to Reclamation was made by the District, at which time the RCWID believed they were entitled to ownership of the 17.56 acre parcel at Phantom Lake Springs. The District, upon learning that this parcel would remain in Reclamation ownership, pursued Congressional channels to obtain the land. Through Section 7 consultation, under the Endangered Species Act, the U.S. Fish and Wildlife Service has objected to the acquisition of this land by private interests, due to concern for the welfare of the two endangered fish species listed above. Reclamation's policy stated that it could not abrogate its responsibility for protection of these endangered fish. The situation was explained to the RCWID's board, no further proposals from RCWID were brought forward on this issue.

The Balморhea project irrigates some 10,608 acres. This includes 59 farms with principal crops of cotton alfalfa, pasture, oats, and barley. Other crops raised at various times on project water include hegira, a grains sorghum, maize, or Indian corn, pecans, and cantaloupes (Bogener 1993). Work on the project consisted of the following: 1) Construction of inlet feeder canals ; 2) concrete lining of several miles of canal; and 3) repair of the Madera Diversion Dam.

Irrigation and Endangered Fish

The Comanche Springs pupfish (*Cyprinodon elegans*) was listed as an endangered species, as defined by the Endangered Species Act of 1973, in the Federal Register, on March 11, 1967. The Pecos gambusia (*Gambusia nobilis*) was designated an endangered species, in the Federal Register, October 13, 1970. Recovery plans for these two species were completed in 1981 and 1983, respectively. Each plan was approved by the U.S. Fish and Wildlife Service, following completion by the Rio Grande Fishes Recovery Team.

By the late 1980's, populations of these two fish were in decline in the Phantom Springs location. In 1988, Tony Echelle, fisheries biologist, Dexter National Fish Hatchery, Dexter New Mexico, reported that between August 25-29, 1988, Jim Brooks, Alice Echelle (also Dexter fisheries biologists), surveyed the system of irrigation canals in the Balmorehea area of Reeves and Jeff Davis Counties, Texas. This survey found that *C. elegans* at Phantom Lake Springs were not present, except in the isolated pool adjacent to the cave mouth, from which the spring flows, and in a lateral canal. The total was a very few individuals.

The population of another spring in the system, East Sandia Spring, had been eradicated. In East Sandia Spring, hybridization had occurred with sheepshead minnow (*Cyprinodon variegatus*) and may be the cause of the loss of *C. elegans*, through competition or hybridization. Published data demonstrates that, morphologically and electrophoretically, the Phantom Lake Springs population of *C. elegans* is the most distinctive extant.

The loss of other populations through loss of habitat had occurred when Comanche Springs, Fort Stockton, Texas, went dry in 1955. This was a loss of approximately one-half of the historic habitat

for C. elegans. Many large springs of West Texas have failed, or are failing. Wells drilled into underground aquifers to supply municipal and agricultural needs have depleted water levels and reduced spring flows. Construction of canals to divert water to irrigate fields in the Balmorhea area has caused drying of the marshes and rapidly removed water from the spring areas, depleting habitat. Elimination of habitat has undoubtedly been a major cause in the reduction in the pupfish population.

G. nobilis is endemic to the Pecos river basin in southeastern New Mexico and western Texas. The species occurred at least as far south as Fort Stockton, Texas and as far north as Fort Sumner, New Mexico. Extensive ground water pumping of the aquifers surrounding the Pecos River caused cessation of flows from Comanche Springs and North Springs River and reduced the flows, with loss of habitat in other areas. The fish have become isolated in permanent springs and are totally dependent on spring flows for their survival.

G. nobilis cannot compete with several common non-native species. Specifically, G. nobilis is disappearing, due to the expansion of Gambusia geiseri, a non-native species introduced into the springs in the 1930's. Negative effects caused by these introductions include predation, hybridization, and introduced diseases. The effects of competition from other fish are well known. Available data shows G. nobilis to be disappearing in the Balmorhea area, due to the expansion of G. geiseri.

Construction of the Refugium

I first viewed Phantom Lake Springs in late Fall 1990, shortly after my transfer from the Bureau of Land Management, to the El Paso office of the Bureau of Reclamation. The shallow valley was flooded, due to the unusually heavy rain; and the walls of the canal leading from the cave mouth were

barely visible above the high water level. It was at this time that 73 pupfish individuals were captured from Phantom Lake Springs, by members of the Rio Grande Fishes Recovery Team. These fish were taken to the Uvalde Fish Hatchery, Uvalde, Texas for propagation and preservation and as stock for reintroduction to suitable habitat. Additionally, a stock of C. elegans is being maintained at Dexter National Fish Hatchery, Dexter, New Mexico. These fish were taken from an irrigation ditch fed by Giffen Springs, approximately 6 miles northeast of Balmorhea.

The Bureau of Reclamation's canal construction at Phantom Lake Springs in the mid-1940's funneled all waters from the spring into a bench flume. The bench flume is a concrete-lined, channel (7 ft. wide and 6 ft. deep), which provides minimum habitat for both of these fish species. The bench flume is inhabited by several other fish species, such as: Mexican Tetra (Astyanax mexicanus); black bullhead catfish (Ictalurus melas); mosquitofish (Gambusia affinis); green sunfish (Lepomis cyanellus); and roundness minnow (Dionda episcopa). These fish also inhabit a small area at the mouth, and just inside the cave, from which the spring issues.

In 1990, I attended several Rio Grande Fishes Recovery Team meetings and began to learn of endangered fish in the area, especially the two species at Phantom Lake Springs. The team discussed the need for improved habitat for propagation of the species and the limited opportunity in the existing bench flume at Phantom Lake Springs. The canal system in place for delivery of irrigation water at Balmorhea was poor habitat for the endangered fish species, due to swift currents and walls scrubbed bare of vegetative cover.

The initial step in protection of the Phantom Lake Springs property was the protection from livestock grazing and damage, through construction of a five

strand fence (Top and bottom strands smooth, middle three strands barbed). A pipe gate was installed, and signs were posted to restrict entry.

As part of this fencing, a cultural survey of the extensive cultural resources found within the 17.56 acres was accomplished in compliance with the National Environmental Policy Act (NEPA). A map and report of the cultural resources was prepared and nomination was proposed for listing the site as a National Historic Place.

Through continuing coordination with the Rio Grande Fishes Recovery Team (RGFRT), the U.S. Fish and Wildlife Service (FWS), and the Texas Parks and Wildlife Department (TPWD), the design for the endangered fish refugium continued to develop during 1990-1992. During this coordination, the TPWD and Reclamation developed a Memorandum of Understanding for the operation and maintenance of the refugium and the natural resources within the Phantom Lake Springs property. In addition to these coordinating agencies, the water users of RCWID, as well as the current holders of the Kingston (the Roy Byrd family) and Splittgarber (McAlpine and McWilliams families) properties were kept informed as the project developed.

A key to accomplishing the construction of this refugium was the agreement of the Reeves County Water Improvement District. Meetings between the District and Reclamation clarified the reasons for the refugium and the details of the design. The fact that both the irrigators and the endangered species would benefit made this a "win-win" project. Significant elements to the district were the use of a special lining material to reduce water loss and the reduction of the flow rate within the refugium, thereby reducing the evaporation to less than that of the old bench flume. It was explained that if the project were successful, the chance of extinction of the endangered fish would be lessened.

Texas Parks and Wildlife Department's responsibilities followed the completion of construction of the boundary fence, completed April 7, 1992. Their monitoring efforts include unauthorized entrance, vandalism, disturbance of cultural remains, and general resource observation and protection. From the beginning of this monitoring effort, the work of TPWD has been of great benefit in protecting the endangered fish and other resources on this property.

Access to the Phantom Lake Springs property is through the Kingston property, now owned by the Roy Byrd Family. The Byrd family has been instrumental in providing security for the refugium and the resources of this property. Without their help and cooperation, this project would not have been possible.

The consensus from all the contributing agencies and RGFRT was that the refugium design should be a canal and would extend only within the fenced property boundaries, thereby minimizing water losses to downstream users. The endangered fish would continue to receive first use of the water emerging from Phantom Lake Springs. As the water flowed from the refugium system, it would be delivered to the canal system and downstream to the water users.

The finalized design for this project consists of a terraced excavation, parallel to the existing bench flume. The upper refugium consists of a diversion structure across the bench flume, an opening into the refugium, and an overflow structure to the adjacent cienega (marshy area). The refugium channel consists of a series of steps to provide lateral areas of similar depth and four back bay pools. This design will combine deep water areas, with shallow water areas and provide a variety of flow velocities. The refugium channel is approximately 300 feet in length and is 12 feet wide, underlain by a low density polyethylene membrane, to prevent percolation into the soil.

This type of membrane is flexible and long-lived. The liner is covered by a lift of soil, placed on top of the liner, for habitat and the establishment of aquatic vegetation. The refugium design provides for the needs of the fish, through changes in water velocity. It would be a controlled environment, excluding most predator fish and fish species which interbreed with the endangered fish populations.

Except for periods of high flows, all water is diverted from the upper end of the bench flume, through the refugium, and re-enters the canal through the weir at the end of the refugium channel. The waterfall from the weir into the canal would also serve to exclude larger fish (e.g., centrachids which may prey upon pupfish and gambusia) from entering the refugium.

After the initial archaeological survey for construction of the fence it was determined that a more complete archaeological survey would be necessary before construction of the refugium could begin. Due to the significance of archaeological deposits, trenching and grid type excavation were necessary for thorough investigation of the site. Work began in June 1992 (involving approximately 20 days) for the primary goal of evaluating the impact of construction of a refugium for the two endangered fish species. When completed, the data collected would be a part of NEPA compliance.

In June 1992, Reclamation requested Endangered Species Act, Section 7 consultation for the construction of the refugium for the endangered species. The biological opinion for the project was received from the FWS, in agreement with the project and commending Reclamation for its efforts.

At that time, Reclamation received verification from the U.S. Army Corps of Engineers that this project would have no effect on waters of the United States.

In December 1992, I completed an analysis of the impacts from construction to the applicable resources; thus, NEPA compliance was achieved. With this completed, input from biologists was again analyzed in finalizing the refugium design. The contract for construction was awarded January 13, 1992, and construction began February 8, 1992.

Phantom Lake Springs' flows were estimated to be approximately 4 cubic feet per second at the time water was diverted from the bench flume to the refugium, June 7, 1993. Water was slowly diverted to the refugium by placing sandbags in the bench flume. A screen was installed at the entry to the refugium, to exclude non-target species, while the lower end of the refugium was protected from fish migration, by the weir-created waterfall. Despite attempts to exclude all fish species at this time, numerous Astyanax mexicanus (Mexican tetra) had gained access to the facility. June 8, 1993, sandbags were placed in the lower bench flume, above the weir, to restrict flows throughout the bench flume. This action isolated all organisms within the bench flume. On June 9, 1993, pumps began de-watering the isolated bench flume section, to allow permanent installation of stop log water diversion structures. In parallel fashion, biologists began working in the isolated bench flume section, attempting to remove endangered fish, plus invertebrate species identified by Fish & Wildlife Service (Service) personnel as unique to the Balmorhea area. Aquatic vegetation and rocks, containing representative unique invertebrates, were transferred from the bench flume into the new refugium.

A total of seven (7) seining passes were completed. The following fish species were captured in the bench flume:

Gambusia nobilis
G. affinis
G. geiseri
A. mexicanus
Lepomis cyanellus

Ictalurus sp.Dionda episcopa

Cyprinodon elegans were not observed or collected in the bench flume, although two (2) young-of-the-year pupfish were noted in the turnout below the refugium weir.

A total of 11 G. nobilis were transferred successfully into the isolated pool near the spring head. A total of 19 Gambusia species were retained during collection activities near the spring head, including two G. nobilis which did not survive the transfer (Biological Opinion 2-15-92-F-240 allows "take" of up to 30 G. nobilis by Reclamation during these activities.). All retained Gambusia species are catalogued and maintained in the University of New Mexico Museum of Southwestern Biology.

October 14, 1993, representatives from the Rio Grande Fishes Recovery Team introduced 110 C. elegans, which were collected at the Uvalde Federal Hatchery and transferred to the Bureau of Reclamation Phantom Lake Springs Refuge. One (1) fish died in transit. The fish were divided into three (3) groups and stocked into three (3) of the side pools. Upon entering the water, most of the fish moved into the current and seemed to smoothly adjust to the new habitat. A short time thereafter, personnel from Texas A & M initiated a two-year monitoring effort at the facility.

After completion of construction and establishment of flows, a group of A. mexicanus was found in the refugium, having been able to "swim-up" the waterfall, from the old channel, through the weir. This discovery was by personnel from TPWD&W, and it was decided to trap as many of these fish as possible from the refugium. The Mexican tetra, being predators of pupfish and gambusia, needed to be removed to the greatest extent possible, to give the pupfish and gambusia the opportunity to occupy the refugium. The attempts at trapping captured 107 tetras and two (2) roundnose minnows (Dionda sp.). Many designs were considered for blocking

the tetra from swimming up the waterfall. Ultimately, I designed a screen constructed of PVC pipe, which broke the column of the waterfall and did not allow the tetras to enter. This screen "floats" on the surface, due to its air-tight, four-sided configuration, with small PVC bars in the center of the screen.

Habitat inside the refugium was created with assistance from biologists from Reclamation's Upper Colorado Regional Office and personnel from Texas Parks and Wildlife Department, at Balmorhea State Park. Aquatic vegetation and rocks were removed from the old channel and placed in the refugium. Along with the rocks and vegetation, amphipods and other microorganisms have populated the refugium and have created the habitat necessary for the endangered fish to propagate and increase their populations.

By late October 1993, approximately 55 Mexican tetras remained within the refugium. The pupfish were observed in all areas of the refugium and were observed in large numbers. A refugium, such as this, should include members of species present in the ecosystem; therefore, this small number of tetras were allowed to remain.

After construction, the area around the refugium was rehabilitated. The disturbed surface was re-seeded; and gravel was used to cover the berm of the refugium, until vegetation established itself, and erosion was prevented. To prevent vehicle impacts, a parking area was established a short distance from the refugium.

Post Construction

At this writing, the refugium continues to provide the needed habitat for the Pecos gambusia and the Comanche Springs pupfish. Both species are again occupying the irrigation channel, as they have in the past, by exiting the refugium through the weir. These fish have continued to be prolific in the

refugium habitat, as young fish of both species are readily observed throughout. No introduction of any predatory species has occurred, other than the invasion of tetras, which seem to be present only in reduced numbers.

Currently, the most troubling aspect of the refugium is the reduction in flows from the spring. Late 1993, Reclamation re-established a recording station downstream from the refugium. 1994 Summer flows (June, July, and August) averaged 2.1 cubic feet per second (cfs); and 1995 Summer flows for the same months averaged 1.6 cfs. The 1996 Summer could have an even lower average, due to the drought which West Texas is experiencing. Other uses have reduced this spring from an average of 12 to 14 cfs in the 1930's, to between 5 and 6 cfs in the 1970's.

The refugium has successfully become a natural system and accomplishes the two purposes for which it was designed: The delivery of water to the irrigation users on the irrigation channel and habitat for the endangered fish. As long as this spring flows, this facility will continue to fulfill these two purposes.

Acknowledgments

- Dr. Clark Hubbs
Personal communication, 1991-1993
- Dr. Gary Garrett
Personal communication, 1991-1996
- Ms Christine Karas
Personal communication, 1991-1996
- Mr. Doug Young
Personal communication, 1991-1994

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Phantom Lake Spring, Jeff Davis County Texas

Prepared by Mona C. Charles, Powderhorn Research,
by CASA

Prepared for the Cultural Resources Program; Bureau
of Reclamation Upper Colorado Region Salt Lake
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"WHO DECIDED WILDLIFE AND AGRICULTURE CAN'T WORK TOGETHER?"

David G. Potter¹

Most of us haven't thought much about it . . . But there are a whole lot of similarities between farming and wildlife management. Farmers and wildlife managers have a whale of a lot of common ground.

Farmers work hard raising crops from the land. Wildlife managers similarly work hard raising a different kind of crop from the land. Farmers face drought, diseases, soil problems, weeds and pest animals. Wildlife managers face most of these same problems as they work to produce high quality wildlife habitat.

Both farmers and wildlife managers have a broad range of outside factors they must deal with such as health, safety and environmental protection laws.

I could continue these comparisons at length. But the bottom line is this: there are many similarities and much common ground to be found between the farmer working on one side of the road and the wildlife refuge manager working on the other side.

. . . So, I ask again: who decided wildlife and agriculture can't work together?

In my experience, I don't think anyone in particular decided that we can't work together. It seems to boil down to more of a mind set. It sometimes seems sort of like a Hatfields and McCoys deal.

But it doesn't need to be this way!

Today, I want to talk about what can be achieved when farmers and wildlife managers are willing to get together to talk about ideas, work out details and get past the negatives. In my experience over the last 17 years as a wildlife refuge manager, its not so tough to make good things happen for both wildlife and agriculture if we will just take the time to visit with each other - to open and maintain a friendly

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relationship.

I'm not presenting the theoretical today. I'm not talking about what might be accomplished sometime in the future. I'm talking about concrete, dollars-and-cents things I and my staff have accomplished on-the-ground in cooperation and partnership with our farmer neighbors.

II. Audubon National Wildlife Refuge is about 65 miles straight north of here. The Refuge is superimposed on about half of a large US Army Corps of Engineers reservoir, Lake Audubon. It's the eastern lobe of the over 180 mile long reservoir named Lake Sakakawea - which is backed up by the Garrison Dam across the Missouri River.

The Refuge water levels - Lake Audubon - are managed, in consultation with the Refuge and several other agencies, by the US Bureau of Reclamation. Lake Audubon is pumped full each spring to serve as the supply pool for Reclamation's Garrison Diversion Irrigation Project. The Project's water supply canal, the McClusky Canal, exits Lake Audubon through Audubon Refuge.

As McClusky Canal water flows east, within the first twenty miles it passes through or beside six large wildlife areas managed by the US Fish and Wildlife Service.

Opportunities to release water from the Canal to improve wildlife habitat are numerous. Better yet, there are many opportunities to release water from the Canal through these wildlife areas to benefit both neighboring farmers and wildlife on privately owned land. All that has been needed is a vision, a dream of what might be possible.

Today, I want to talk about three of these opportunities: three case histories of common sense, discussions and mutual trust between neighbors who just happen to farm for different crops. How these neighbors are pulling off some great cooperative projects for both farming and wildlife.

III. Case History #1: About six years ago, a neighbor farming immediately east of the Refuge brought up the idea of developing a pivot irrigation system for alfalfa and other crops. His was good irrigable land. But he had no access to nearby Lake Audubon across Refuge land.

We talked over the idea. What might be done? Details began to shake out. He worked through permits, water rights and such. He envisioned a short ditch across Refuge land to flow water into a pond on his land. From there an electric pump would supply his irrigation pivots. The Refuge land where the ditch would go was an abandoned gravel pit where the native prairie had been destroyed and minimal grass had regrown. Converting a dry, ex-gravel pit to a wetland - even in the form of a ditch - significantly improved habitat for waterfowl and other wildlife on the Refuge.

To the north of the planned pump station, the Refuge contained two small wetlands formed by an abandoned road grade. They held water only during wet springs and only for short periods of time. So their value to waterfowl was minimal.

To further the wildlife benefits from this project, the farmer agreed to annually fill these two wetlands using his irrigation pump. This produced larger, longer lived wetlands in an area of the Refuge short on wetlands - a big benefit to wildlife.

In addition to access across the Refuge, a couple additional arrangements were worked out with the neighbor. To allow optimum installation of one pivot, a Refuge boundary fence was opened so the outer wheel could complete a full circle. One wheel travels about 30 yards across Refuge grasslands - providing free water on Refuge duck nesting grass with each pass.

A second arrangement involved allowing the placement each spring of a short length of irrigation supply pipe on Refuge land, just inside the boundary fence. There were no other reasonable places to put it. So, what would be the harm with irrigation pipe laying next to the boundary fence? It allowed the farmer the best route to his fields and made no significant impact on Refuge values. So, we allowed it.

This irrigation project has been in operation for about four years. Wildlife habitat has been improved and irrigated crops have been grown each year. A good, neighborly arrangement. Drive by today: Refuge to the west, irrigated farmland to the east, a good deal for all.

. . . I want to clarify one thing: Audubon National Wildlife Refuge is managed by the US Fish and Wildlife Service - my outfit. But the land is owned by the US Army Corps of Engineers. All of the above agreements were approved and facilitated by the Corps. They too

have been good partners in this project.

Case History #2: Here in the grasslands of North Dakota, waterfowl management means, in most cases, grassland management. Over the years our Refuge Biologist has learned from neighboring farmers, researchers and his own observations that short-duration cattle grazing can be used to improve both native and tame grasslands and wetlands. Plant species diversity and vigor can be improved with proper grazing sequences.

We use cattle grazing to clip off or trample grass plants simulating the effects of bison grazing, one of the major conditions under which our native grasses evolved.

We also use cattle to improve wetlands. Eating and trampling cattails and other marsh plants opens dense, choked areas, improving them for water birds. Also, the manure fertilizes the wetland increasing aquatic insect life upon which waterfowl and other water birds feed. Grazing wetland vegetation to create openings is a much improved technique compared to spraying herbicides - both by reducing costs and by not introducing chemicals into the environment.

Neighboring farmers pay to graze Refuge grasslands and wetlands according to specifications in annual grazing contracts. Refuge grazing supplements their own pastures making business more profitable for the farmer.

During dry years, many of our grazing units lack water. The solution has been simple but very effective. The Refuge loans the rancher a tractor driven pump so he can pump Lake Audubon water into dry wetlands for his cows to drink. During the recent drought years these wetlands provided some of the Refuge's best wildlife habitat. Ducks, grebes, deer, pheasants, song birds and many other wildlife species found these wetlands very attractive.

Pumping wetlands full for cow water also improved the surrounding upland grass habitat by allowing planned grazing to be conducted. This invigorated the grasslands which are so important to nesting ducks as well as many other wildlife species.

Pretty simple concept but somewhat unusual: refuge tractor, dry refuge wetlands, refuge water, rancher's cattle and rancher's labor. It all fit together. Improves wildlife habitat - both wetlands and uplands -

and improves the rancher's bottom line, especially in drought years when his own pastures may be short.

Case History #3: This last case history again involves a simple arrangement. . . but a mutually profitable one: releasing water from the McClusky Canal onto Fish and Wildlife Service lands to be passed through to flood irrigate a neighbor's hay land.

For years, a neighboring farmer has received water early in the spring, as soon as the Canal turnouts can be freed from lingering ice. This early water is flowed out into large, flat hay meadows up to a depth of about one foot. Migrating ducks, geese, shorebirds and other wildlife find these early flooded hay meadows extremely valuable for feeding or resting. Nearly all deep wetlands are still ice covered while the shallow wetlands are often dry, yet to be filled by spring run-off if any occurs.

During our recent drought years nearly all wetlands were dry for several years. These early flooded hay meadows provided outstanding feeding and resting areas for flocks of waterfowl numbering in the tens of thousands. It was truly a sight to gladden winter-weary eyes.

The early flooding isn't required to produce a hay crop. But it doesn't hurt hay production either and it certainly produces major benefits to waterfowl. As spring comes on the water sinks in and the grass grows lush and tall. In early July a control gate is opened and the remaining water released downstream. Typically, the hay is cut in mid to late September. This irrigation arrangement always improves hay production. And in the drought years, the abundant hay crop is doubly valuable.

As a bonus, many newly hatched waterfowl and shorebirds find the shallow waters of the drying hay meadow to be prime feeding habitat before they move on to adjacent, deeper wetlands.

. . . So, not really an earth shattering procedure or concept. Just some good common sense and down to earth working together for the benefit of both parties.

IV. To wrap this up; I reiterate, Who decided wildlife and agriculture can't work together?

When we give up our preconceived notions and listen to the other guy, the neighboring farmer on the other side of the fence, we can find many ways to improve both operations.

A key factor is to listen. We often are good talkers but not so strong on the listening. . .

There are many ways and possibilities in which agriculture and wildlife can and should work together. I've presented three case histories. They range from a complicated, expensive pivot irrigation venture to the simple loaning of refuge equipment to a rancher to improve both his grazing and our wetland habitat. Both commercial farming and wildlife farming benefit significantly by these partnerships.

My neighbors and I do it. Simple, common sense, trust building, down-to-earth dialogue, problem solving and challenge grabbing.

We can do it more!

NORTH DAKOTA'S ENDANGERED SPECIES MANAGEMENT PLAN SETTING THE COURSE FOR THE FUTURE

Michael Olson¹

Kenneth Junkert²

ABSTRACT

The North Dakota Endangered Species-Pesticide Management Plan was developed in response to the Environmental Protection Agency's (EPA) request for assistance in designing an effective federally-listed endangered and threatened species protection program. The purpose of this program is to protect threatened and endangered species in North Dakota from harm of pesticides. The program was developed cooperatively by the North Dakota Game and Fish Department, the North Dakota Department of Agriculture, the North Dakota State Extension Service, and the U.S. Fish and Wildlife Service. The program has been designed to fulfill endangered species protection requirements as determined by the EPA in accordance with the Endangered Species Act and the Federal Insecticide Fungicide and Rodenticide Act (FIFRA). While the program recognizes the need to provide adequate protection for endangered and threatened species, it also acknowledges a need to protect the agricultural producer from unnecessary hardship and unreasonable procedures. The ultimate goal of the program is to protect endangered and threatened species and at the same time allow the agricultural producer to continue operating in an economical and practical manner.

INTRODUCTION

A 1988 review of the Nation's endangered and threatened species indicated that approximately 20 percent were listed, in part, because of pesticide use. Notable examples of species adversely

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affected by pesticides include the brown pelican, Houston toad, and the bald eagle. About that same time in North and South Dakota, wildlife and agriculture officials were investigating the deaths of seven bald eagles as a result of poisoning with the pesticide phorate, known by the trade name Thimet.

An Environmental Protection Agency (EPA) analysis of recent pesticide studies and mortality rates estimates that the use of the pesticide carbofuran (Furadan) alone results in 1 to 2 million bird deaths annually, including some endangered and threatened birds. Even if a pesticide does not directly contribute to the decline of a species, the potential exists for a pesticide to further stress or delay recovery, the ultimate goal, of the endangered species.

Why do we work so hard to save endangered species? Besides the need to preserve genetic diversity, the species direct uses, and their usefulness as environmental monitors, there are ecological reasons to protect endangered species as well. The Lakota Indians, perhaps North America's first ecologists, use to call it "Makoche", a Lakota Indian word that acknowledges our earth's relationship and interdependency among all living things great and small, numerous and rare.

Today, hundreds of years after the Lakota Indians recognized the need for these species, the Endangered Species Act states that the Secretary of Interior shall determine species as endangered or threatened based on manmade factors affecting their continued existence. One of those manmade factors affecting endangered species is the use of pesticides.

We first need to understand the definition of endangered and threatened to further discuss this topic. Species listed as endangered are in danger of extinction throughout all or a significant portion of their range. Species listed as threatened are species which are likely to become endangered within the foreseeable future.

DISCUSSION

The North Dakota Endangered Species-Pesticide Management Program was developed in response to the EPA's request for assistance in

designing an effective federally-listed endangered and threatened species protection plan. The purpose of this program is to protect resident threatened and endangered species in North Dakota from harm resulting from pesticides. The program was developed cooperatively by the North Dakota Department of Agriculture, the North Dakota Game and Fish Department, the North Dakota State Extension Service, and the U.S. Fish and Wildlife Service.

The program is designed to fulfill endangered species protection requirements as determined by the EPA in accordance with the Endangered Species Act and FIFRA. The Fish and Wildlife Service, in 1995, issued a nonjeopardy biological opinion on the implementation of the program. The final authorization of the program by EPA marked the first successful endangered species pesticide program to be handed down to the state level.

While the program recognizes the need to provide adequate protection for endangered and threatened species, it also acknowledges a need to protect the agricultural producer from unnecessary hardship and unreasonable or over burdensome regulations. The ultimate goal of the program is to protect endangered and threatened species and at the same time allow the agricultural producer to continue operating in an economical and practical manner.

All pesticides that are legally used in the United States must be registered by EPA under FIFRA. Part of this registration process involves consideration of what impact the pesticide may have on wildlife. The impacted wildlife may include endangered species, such as with the phorate and bald eagle incident previously discussed. Wildlife deaths from pesticide use, particularly the endangered species impacts, were the driving force behind the EPA's proposed rules in 1987 urging a Federal endangered species/pesticide management program.

The EPA's original program as proposed in 1988 would have eliminated the use of 37 pesticides in 31 counties in North Dakota. This initial program was met with much resistance by both agricultural and wildlife interest. Both sides agreed to attempt to resolve the issue via a more pragmatic approach than originally proposed by EPA using county boarders as limits to some pesticide applications.

In 1988, the North Dakota Game and Fish Department, the North Dakota State University Extension Service, the North Dakota Farm Bureau, North Dakota Farmers Union, North Dakota Stockman's Association, North Dakota Durum and Wheat Growers Association, and the North Dakota Parks and Recreation Department, met to develop the framework for an initial plan to protect endangered species from pesticide application. Without the support from the agricultural interests at the beginning of the planning phase, this program would not have been successful.

Instead of banning the use of pesticides in 31 counties as originally proposed, the program now only impacts relatively small portions of 23 counties, yet provides protection for certain threatened and endangered species across North Dakota. The ban is in effect only if the endangered species is present.

North Dakota currently has seven endangered species including the pallid sturgeon (Scaphirhynchus albus), least tern (Sterna antillarum), grey wolf (Canis lupus), whooping crane (Grus americana), peregrine falcon (Falco peregrinus anatum), black-footed ferret (Mustela nigripes), and the eskimo curlew (Numenius borealis). North Dakota also has four threatened species including the bald eagle (Haliaeetus leucocephalus), piping plover (Charadrius melodus), western prairie fringed orchid (Platanthera praecleara), and mountain plover (Eupoda montana).

Of the eleven endangered and threatened species just mentioned, the State's Endangered Species Pesticide Management Plan currently provides protection to the following four species. The bald eagle which is found primarily along the Missouri River yet can be found throughout the State during migration, the pallid sturgeon which is only found in the Missouri and Yellowstone Rivers, the piping plover is found on the sparsely vegetated sandbars on the Missouri River and bare gravel shorelines of saline wetlands found throughout the Coteau Region of North Dakota and the least tern which nests along the Missouri and Yellowstone Rivers. Work is continuing to include the western prairie fringed orchid to this plan.

North Dakota's Coteau Region contains a large share of North America's population of piping plovers and subsequently the focus of the program. The bald eagle, least tern, and pallid

sturgeon protection provided by the program is limited to one-half mile either side of the Missouri and Yellowstone Rivers and Lakes Oahe and Sakakawea. Piping plover protection includes one-half mile buffer from the edge of alkali beaches known to be used by piping plovers for nesting habitat.

How does the program work? In the spring of 1991, all county agents and commercially-certified persons in North Dakota received a copy of an endangered species bulletin for the county in which they reside. When a private applicator purchases a pesticide, the label must be reviewed. The label of affected pesticides will have an endangered species precaution statement. This is found under the precautionary statements section of the label under environmental hazards. If the label does not contain the endangered species precaution statement, the pesticide can be used according to label directions with no limitations regarding endangered species.

If the label does have endangered species limitations, the pesticide user must then review the bulletin that the dealer or county agent has available. Bulletins have also been distributed during mandatory recertification of restricted use pesticide applicators. The following table shows the active ingredients for the pesticides that are currently affected by the program. Common trade names are included to help producers identify the pesticides included in the program.

Table 1. Federally Labeled Pesticides With Endangered Species Use Limitations.

<u>Chemical name</u>	<u>Trade name</u>	<u>Chemical name</u>	<u>Trade name</u>
4-AP	(Avitrol)	Fenamiphos	(Nemacur)
Acephate	(Orthene)	Fensulfothion	(Dasanit)
Aldicarb	(Temik)	Fenthion	(Baytex)
Azinphos-Methyl	(Guthion)	Fluchloralin	(Basalin)
Carbofuran	(Furadan)	Fonofos	(Dyfonate)
Chlorpyrifos	(Lorsban/ Dursban)	Isofenphos	(Oftanol, Amaze)
Cloethocarb	(Lance)	Malathion	(Cythion)
DDVP	(Vapona)	Mevinphos	(Phosdrin)
Diazinon		Methyl parathion	(PennCap-M)
Dicofol	(Kelthane)	Oxamyl	(Vydate)
Dicrotophos	(Bidrin)	Oxyfluorfen	(Goal)
Dinoseb	(Premerge)	Paraquat	(Gramoxone)
Endosulfan- nongrain	(Thiodan)	Temephos	(Abate)
Endrin-granular		Phorate	(Thimet)
Endrin-nongranular		Sodium Cyanide	(Rodenticide)
EPN-nongranular		Strychnine	
Ethoprop	(Mocap)	Toxaphene- nongranular	
Ethyl parathion		Trichlorfon	(Dylox/ Neguron)
Zinc Phosphide			

It's important to recognize the dynamics of this program and that pesticides can be added or removed from the list as pesticides go through the required reregulation procedures. Also, areas under protection are also updated annually. Fish and Wildlife Service and the ND Game and Fish Department personnel review endangered species surveys to ensure data used for publication of county maps is accurate. If no endangered species have been observed in a given area for 5 years, the area is removed from the protected list.

The list of pesticides with endangered species use limitations currently contains mostly insecticides, some of which are no longer available to producers yet producers may still have in their possession. The list contains one herbicide (Gramoxone or Paraquat). The list of herbicides would grow if and when

protection for the western prairie fringed orchid is added to the program.

The county bulletins contain a map with an area enlarged showing the area or areas of a county affected by the program. If the pesticide applicator finds the affected pesticide will not be applied within the mapped area, the pesticide can be applied according to the label directions. If the applicator finds the pesticide will be applied within the mapped area, the applicator must contact either the Extension Service, Department of Agriculture, or the ND Game and Fish Department. This will set the site review team in motion.

A group comprised of the aforementioned agencies and the U.S. Fish and Wildlife Service will review the application site to determine if the pesticide can be used. The review team looks to see whether the application will have an adverse impact on the endangered species. The team addresses specific site situations: such as, the actual presence of the endangered species in the mapped area that year.

The program includes protection for areas where piping plover have been observed for the last 5 years, however, wetland conditions change from year to year and plovers may not be located in areas protected by the program. The type of pesticide application or the timing of the pesticide application is also considered. Topography or individual site settings may also play a role in protection. The precise location of the endangered species nesting or feeding areas and how close this area is to the area to be treated is also considered. Are alternative or less toxic pesticides available? Are there alternate management practices that could be used to control the pest? All information to determine if the pesticide will impact the endangered species will be reviewed.

If it is determined that the use of the pesticide will impact the endangered species, the pesticide will not be allowed to be used. However, the review group will try to determine alternate methods of control, or any other potential solutions. To date, all reviews have been handled to the producer's satisfaction.

However, it may be determined by consensus of the review team, that the application will not pose a threat to endangered

species then the pesticide will be allowed to be used according to label directions or according to prescribed directions. Either way, a timely decision will be made.

Timely decisions are an important aspect of the program. When dealing with a pest, the most effective and economical solutions usually involve early treatment once an economic threshold has been surpassed.

North Dakota's Endangered Species Pesticide Management Program is based on a simple concept. Site specific pesticide protection for endangered species and agricultural production do not need to be mutually exclusive. North Dakota's program shows through cooperation, teamwork, and the will to tackle a potentially difficult issue, a program such as this can be run at the State level and provide decisions that are in the best interests of the producer and the endangered species.

CONCLUSION

Americans are becoming increasingly concerned about how businesses and agriculture are affecting the health of our environment. In the same atmosphere, this endangered species issue has symbolized a potential national environmental concern about pesticides. Congress has responded to this concern by placing new demands on Federal and State agencies to design programs that combine safe, effective pest management with the conservation of endangered species. Almost 10 years ago, a few farsighted North Dakotas took it upon themselves to do just that, protect endangered species and protect agriculture from overly-burdensome regulations. With the continuing development of this program, we are setting a positive course for the future for both agriculture and wildlife.

BUILDING DIVERSITY: WETLANDS PARTNERSHIPS IN THE PN REGION

Robert C. Christensen¹

David M. Walsh²

ABSTRACT

For the last 5 years the Bureau of Reclamation's (Reclamation) Pacific Northwest (PN) Region has been actively involved in a wetlands initiative program. Under PN Region's wetlands program many cooperative projects have been constructed through partnerships and cost sharing with other state and Federal resource management agencies, irrigation districts, and conservation groups. This poster session paper describes three examples of wetland projects, each with unique characteristics.

The Alpine Wetland was developed and constructed through partnershiping with other Federal agencies. The primary purpose was to benefit wildlife. Drought relief funds were used to construct the project.

H Drain wetlands were constructed as a demonstration project working closely with the A&B Irrigation District and other state and Federal partners. The primary purpose was to improve the quality of agricultural return flows. Wetland initiative and drought relief funds were used to construct the project.

The Cascade Reservoir wetlands were constructed partially by contract and by force account. Cooperators were primarily state agencies and local volunteers. The purpose was to improve water quality in the reservoir and provide a more diverse wetland habitat for fish and wildlife. Funds for the program were derived from Reclamation's wetland initiative account, drainage and minor construction account, and from cost share reimbursements.

INTRODUCTION

For the last 5 years Reclamation's PN Region has been actively involved in a wetlands initiative program. Under PN Region's wetlands program many cooperative projects have been constructed through partnerships and cost sharing

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with other state and Federal resource management agencies, irrigation districts, and conservation groups. These projects have been designed to benefit wildlife and water quality at Reclamation reservoirs and other facilities and to support the North American Waterfowl Management Plan and Reclamation's new direction as a leader in water resource management. Each project is being monitored to determine specific benefits.

SPECIFIC WETLAND PROJECTS

Wetland projects which were featured in the poster session include the following three examples. Each project presents unique characteristics regarding purpose and effect, partnership, and funding.

Alpine Wetland

The 300-acre Alpine Wetland is located on the upper end of Palisades Reservoir along the Idaho/Wyoming border. This wetland enhancement project created 115 acres of new wetland habitat. Low dikes and water conveyance channels were constructed to form nine ponded areas to provide a year-round wetland complex. When water levels of Palisades Reservoir drop, diversions are made from the Salt River to water the wetland complex.

The Natural Resources Conservation Service (NRCS), formerly named the Soil Conservation Service, developed the designs and managed the construction of the Alpine Wetland project under an interagency agreement with Reclamation. Other cooperators in the project were the U.S. Fish and Wildlife Service, U.S. Forest Service, and the Wyoming Game and Fish Department. Due to the cooperative effort and the significant benefits derived from the project, the U.S. Department of Agriculture awarded the Alpine Wetland project the 1994 "Taking Wing Award" in the category: "Partnership." Alpine Wetland provides diverse habitats for a variety of waterfowl, furbearers, amphibians, and neotropical birds.

Reclamation provided full funding for the project from monies appropriated through the Drought Relief Act.

H Drain Wetlands

The H Drain wetland is a research and demonstration project located within the A&B Irrigation District on Reclamation's Minidoka Project in eastern Idaho. H Drain collects return water from over 10,000 acres of farmland. The water collected by H Drain and other drainage facilities within the district is injected back into the Snake River aquifer which is a source of drinking water for individual farms and communities in the area. The objective of this wetlands

project is to evaluate the effectiveness of separate and combined wetland components in removing silt, nutrients, and other contaminants from irrigation return water before it re-enters the Snake River aquifer. If this demonstration project proves successful and cost effective, it is hoped that the same methods can be used to treat irrigation return flows throughout the A&B Irrigation District.

The project includes construction of a sediment basin and several ponded areas within the drain. Also, unique to this project is the planting of drought-resistant and winter-hardy wetland plant species which are able to survive the low- to no-flow conditions during the nonirrigation season and still act as nutrient filters when drain water is present. In addition to the water quality benefits derived from the demonstration project, the wetland areas created in the drain provide habitat for a variety of wetland and upland wildlife species.

Reclamation designed the H Drain project and provided a grant to the A&B Irrigation District to construct the sediment basin and ponds. Wetland plants were provided through NRCS's plant laboratory. Other cooperators in the project were Reclamation's Denver Service Center, U.S. Fish and Wildlife Service, and Idaho Department of Fish and Game. This project was paid for by Reclamation's wetlands initiative funds and drought relief funds.

Cascade Wetlands

The Cascade wetlands project consists of constructing a series of wetland impoundments on several small tributaries of Cascade Reservoir in western Idaho. These wetlands projects are designed to benefit water quality in Cascade Reservoir by reducing sediment and phosphorus inflow into the reservoir and to enhance fish and wildlife habitats. Cascade Reservoir experiences excessive algae blooms during the warm summer months. Phosphorus concentrations in runoff water and in the associated sediments are the leading cause of algae production in the reservoir.

On Hembry Creek, located on the east side of Cascade Reservoir, three small contiguous ponds totaling about 15 acres were constructed to catch sediment. Local volunteers planted 14,000 native wetland plants which will help remove phosphorus from the creek water before it enters the reservoir. At the old state highway bridge, also on the east side of the reservoir, a 6½ ton concrete wall was installed on the upstream side of the bridge to create a 12-acre impoundment and associated wetland complex. In the Duck Creek and Mallard Bay areas on the west side of the reservoir, small dikes have been constructed on several small tributaries to impound runoff water and provide sufficient retention time to settle out sediments and allow uptake of nutrients by wetland plants. In some streams, log weirs were installed to act as sediment traps. In Willow Creek on the south end of the reservoir, the log weirs were notched to allow for fish passage, and willow slips

were planted by volunteers to provide shade, bankline stability, and to take up phosphorus. Thus, a variety of methods are being used to improve water quality in Cascade Reservoir and provide a more diverse wetland community for fish and wildlife populations. It is estimated that water draining from more than 20,000 acres will eventually be filtered by one of the six constructed wetlands. The size of each wetland area ranges from 2 to 20 acres.

Cooperators in the project are Idaho Division of Environmental Quality, Idaho Department of Fish and Game, and local organizations and volunteers. Construction of the Hembry Creek ponds was contracted, while other construction efforts were accomplished inhouse by Reclamation's drill crew personnel. Initial funding was provided through Reclamation's wetlands initiative program along with cost sharing from the cooperating agencies. Followup funding is being provided through Reclamation's drainage and minor construction account, a portion of which will be reimbursed by project cooperators.

CONCLUSIONS

Reclamation's PN Region has found many avenues by which its wetlands initiative program can be promoted and carried out. Construction, development, renovation, and conservation of wetlands can enhance many resources even though one purpose (i.e. water quality) may be the primary objective. There is a variety of partnerships that can be formed on the local, state, tribal, and Federal levels. Partnerships is greatly dependent on finding a common ground or goal. Once this is accomplished, the synergism established carries the project forward. Up front programming of funds is important along with the ability to find obscure sources and tag onto cost share funds made available, sometimes unexpectedly and suddenly, through specific state or Federal programs or legislation. Cost effectiveness is also a prime concern, i.e. how do we get the most benefits per dollar expended. For this reason, it is important to monitor project effects as well as to identify and quantify resource values that are enhanced or otherwise affected.



Recreational Values of Wetland in a Rural, Agricultural State

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Purpose: (1) to identify and demonstrate procedures for estimating economic value of wetland-based recreation, and (2) to "scope out" a plausible range of economic values for in situ wetland-based recreation activities in North Dakota.

Poster prepared for presentation at *Water for Agricultural and Wildlife and the Environment—Win-Win Opportunities* seminar sponsored by U.S. Committee on Irrigation and Drainage and U.S. Bureau of Reclamation, Bismarck, North Dakota, June 27-29, 1996

Definitions

Economics - the study of how individuals, firms, and societies allocate their scarce resources among alternative uses to satisfy unlimited wants.

Economic Value - what someone is willing to give up to have something else, usually specified in terms of a common denominator such as dollars; implies both a willingness and an ability to give something up.

Marginal Value - the value of the next (or the previous) unit of something

Average Value - the total value of a set of like items divided by the number of items

Ecological Value - the value of something to its ecosystem, not an economic value

Intangible Value - a value that cannot be quantified, not very useful for making choices!

Nonmarket Value - the value of something that is not traded in a market where prices are the medium of exchange.

Valuation Perspectives/Philosophies

Anthropocentric/utilitarian -
values are from the perspective of humans

Legitimate philosophies, but NOT appropriate for public sector choice making today:

Environmentalism - humans are part of the environment, dollar values cannot (should not) be assigned to everything.

Ecocentric - humans are just a part of the environment, environment has value in and of itself

Deep Ecology - humans are part of the environment, and humans should not adversely affect any other parts of the environment, the world can support fewer than a million humans

Ecofeminism

Ecosocialism

Animal Rights

and many more . . .



Wetland

Attributes

- size
- depth
- location
- hydrology
- vegetation
- water chemistry
- substrate texture
- landscape diversity
- ecological diversity...

Functions

- aquatic habitat
- wildlife habitat
- flood control
- groundwater recharge/discharge
- nutrient assimilation
- aesthetics...

Outputs (goods and services)

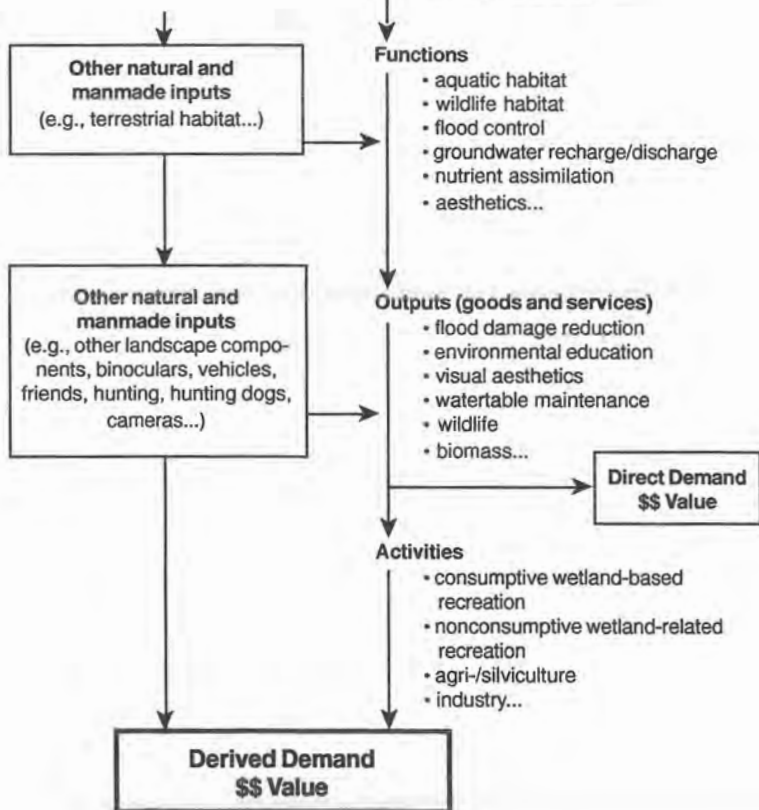
- flood damage reduction
- environmental education
- visual aesthetics
- watertable maintenance
- wildlife
- biomass...

**Direct Demand
\$\$ Value**

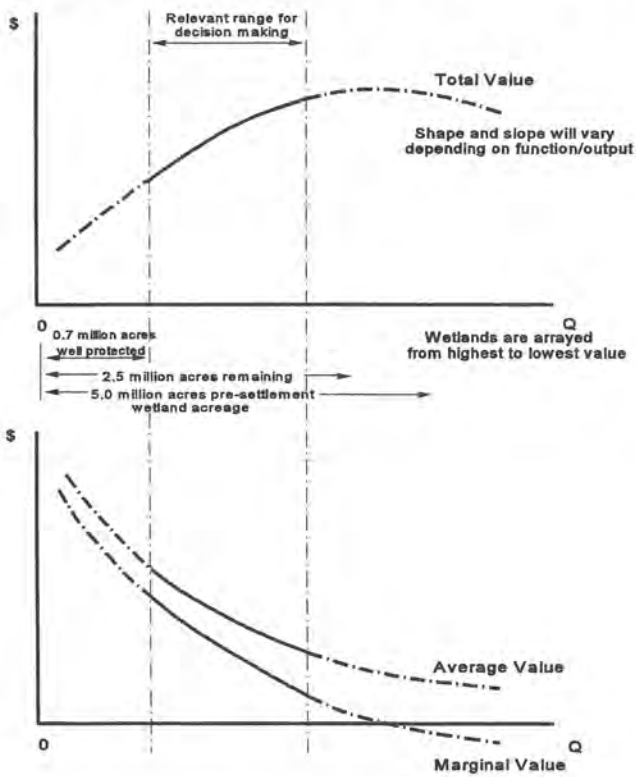
Activities

- consumptive wetland-based recreation
- nonconsumptive wetland-related recreation
- agri-/silviculture
- industry...

**Derived Demand
\$\$ Value**



Economic Value of North Dakota's Wetlands



Economic Value of Wetland for Selected Recreational Activities in North Dakota, 1995

Activity	Lower Bound ^a		Upper Bound ^b	
	Wetland-Base Activity Value	Wetland Contribution	Wetland-Base Activity Value	Wetland Contribution
	dollars			
Hunting ^c	1,357,898	253,597	12,711,785	2,540,557
Furbearer Hunting & trapping	541,985	162,596	3,376,000	1,012,800
Fishing	2,873,565	287,356	43,422,566	4,342,256
Canoeing	25,498	12,748	87,611	43,830
Crafts	--	--	--	19430
Totals	4,798,437	716,297	59,617,442	7,939,443
Per Acre ^d	1.92	0.29	23.85	3.18
Capitalized ^e	--	7.25	--	79.50

^a Estimated using day values.

^b Estimated using expenditure-based consumers' surplus.

^c Includes waterfowl, upland, game and big game.

^d Assumes 2.5 million acres.

^e Capitalization rate of 4% in perpetuity.

**Example
Waterfowl Hunting
Unit Day Values**



Value of a day of waterfowl hunting	\$5.55
Value of a day x number of days	\$1,833,881
Contribution of North Dakota wetland to waterfowl production	.44
Contribution of wetland to a day of waterfowl hunting	.20
<i>(Other inputs include: other landscape amenities, variety of equipment companionship of dogs and other hunters, other hunting trip amenities.)</i>	
Overall contribution of wetland to waterfowl hunting activity	\$161,381
Average per acre value of wetlands for waterfowl hunting in North Dakota	\$0.06
<i>(Assuming 2.5 million acres of wetlands in North Dakota.)</i>	



Example Waterfowl Hunting

Expenditure-Based Consumers' Surplus Values

Total waterfowl hunting expenditures	\$39,603,129
Consumers' Surplus	\$15,871,200
<i>(Hunters realize a nonmarket benefit that is 40% over and above what they have spent.)</i>	
Contribution of North Dakota wetland to waterfowl production	.44
<i>(Other inputs include: upland habitat, wintering habitat, and other ex situ life support inputs.)</i>	
Contribution of wetland to a day of waterfowl hunting.	.20
<i>(Other inputs include: other landscape amenities, variety of equipment, companionship of dogs and other hunters, other hunting trip amenities.)</i>	
Overall contribution of wetland to waterfowl hunting activity	\$1,394,030
Average per acre value of wetlands for waterfowl hunting in North Dakota	\$0.56
<i>(Assuming 2.5 million acres.)</i>	


Prairie Pothole Wetland Values




Recreation:

in situ - consumptive	\$0.29 to \$3.18	
- nonconsumptive	_____	
ex situ	_____	
Flood Peak attenuation	_____	
Water quality enhancement	_____	
Nutrient assimilation	_____	
Sediment trap	_____	
Aesthetics	_____	
Gene pool	_____	
...	_____	
...	_____	
...	_____	
Existence	} Apply to one-of-a-kind irreplaceable resources	{ Not Applicable
Option		
Bequest		
TOTAL (sum of compatible uses)	Topic of further research!	

Point:

 Wetlands are a necessary (but not sufficient) input for some recreational activities. Recreational activities require other inputs as well. The total value of the activity must be appropriately distributed across all inputs.

Conclusion:

 The average per acre value contribution of wetlands to selected recreational activities in North Dakota is in the range from \$0.29 to \$3.18 per acre

Reference: Donald A. Kaiser. (1996). "The Recreational Value of North Dakota Wetlands." M.S. Thesis, North Dakota State University, Fargo (forthcoming).

WETS - CLIMATE ANALYSIS FOR WETLANDS

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J.K. Marron²

ABSTRACT

Wetlands have been identified as an important component to healthy ecosystems. Climate and topography are the primary determining factors in the genesis and identification of wetlands. With increased population, demands on the wetlands will also increase. This paper identifies the science and technology used to identify the climatic component of a wetland.

INTRODUCTION

Wetlands have been identified as an important component to healthy ecosystems. Climate plays an important role in the genesis and identification of wetlands. With increased population, demands on the wetlands will also increase. Therefore, to identify the physical characteristics of wetlands adequately, specific tools and procedures are needed.

OBJECTIVE

The objective of the WETS Table is to define the normal range for monthly precipitation and normal range for growing season required to assess the climatic characteristics for a geographic area over a representative time period.

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SOURCE OF DATA USED IN WETS TABLE

The data used in the WETS Table are observed by the National Weather Service (NWS) Cooperative Network. This nationwide network currently consists of nearly 8,000 active climatic stations. Observations at cooperative stations are performed by private citizens, institutions (such as utilities and television stations), or state and federal agencies.

The digital record of these observations is called the Summary of Day (TD-3200). The Climatic Data Access Facility (CDAF) obtained this digital dataset from the National Climatic Data Center (NCDC) in Asheville, North Carolina. Quality control procedures have been performed on the dataset by NCDC as part of

the ValHidd project (Reek et al., 1991). The ValHidd project identified extreme data errors, such as a maximum temperature of -99 degrees in the summer or a precipitation amount of 40.00 inches instead of 0.40. ValHidd also suggested replacement values where appropriate.

Extreme data errors were corrected or marked as missing and in the Natural Resources Conservation Service's Centralized Database System (CDBS) located in Portland, Oregon. The entire U.S. Summary of the Day historical climate record consists of nearly 17,000 stations.

Of the nearly 17,000 NWS climate stations in CDBS, approximately 6,700 contain sufficient observation record length (greater than 20 years during the most recent normal period, 1961 - 1990, or no more than 5 consecutive years of missing data) to provide representative averages and probability information.

A brief description of each climate element used in the WETS Table is included in the following sections.

Air Temperature Measurement

Air temperature measurements are made five feet above the ground with a liquid-in-glass maximum and minimum thermometer mounted in a Cotton Region Shelter or with an electronic thermistor-based Maximum, Minimum Temperature System mounted in a small "beehive" like structure. Maximum and minimum air temperatures are taken and recorded daily.

Precipitation Measurement

Precipitation is measured with either a non-recording gage (standard NWS 8 inch), a recording weighing-type gage (either Universal or Belfort), or both. Precipitation amounts are taken and recorded daily. Snowfall is the incremental depth of snow that has fallen since the last snow depth measurement, usually 24 hours. It is traditionally measured with a stiff stick graduated in inches.

PROBABILITY CATEGORY DEFINITIONS

Five categories of temperature and precipitation departures have been defined and are in widespread use. These categories were defined by the National Climatic Data Center (NCDC). The five quantitatively-defined categories (Table 1) are qualitatively referred to as MUCH ABOVE NORMAL, ABOVE NORMAL, NORMAL, BELOW NORMAL, AND MUCH BELOW NORMAL (NCDC, 1984a).

Table 1. Class limits for the Z-score categories.

CATEGORY	Z-SCORE
Much Above Normal	$Z > 1.282$
Above Normal	$.524 < Z \leq 1.282$
Normal	$-0.524 \leq Z \leq 0.524$
Below Normal	$-1.282 \leq Z < -0.524$
Much Below Normal	$Z < -1.282$

Temperature Categories Used for Growing Season Calculations

Monthly and annual temperatures are usually well represented by the normal distribution; therefore, the Z-score (or standardized departure from average) was used to classify, by category, the growing season length. The growing season Z-score is calculated as $z(i) = (T(i) - T(\text{avg}))/s$, where $T(i)$ is the growing season length associated with a given Z-score, $z(i)$, $T(\text{avg})$ is the mean annual growing season length over the selected period (e.g. 1961-1990), and s is the standard deviation of the annual growing season lengths over the selected period (e.g. 1961-1990).

For example, MUCH ABOVE NORMAL would represent any amount greater than a 1.282 standard departure above the mean. In a normal distribution, the NORMAL category will contain 40% of the values. The ABOVE NORMAL and BELOW NORMAL categories will each contain 20% of the values, and the MUCH ABOVE and the MUCH BELOW categories will each contain 10% of the values.

The 30% category shown in the WETS Table represents the class limit values associated with the NORMAL category Z-values of -0.524 and 0.524.

Precipitation Category Definitions

The same Z-score categories apply to precipitation, however, monthly and annual precipitation exceedance probabilities are calculated from fitting the observed monthly data to a two-parameter gamma distribution.

The two-parameter gamma distribution is asymmetrical and is used with continuous random variables such as precipitation. Its probability density function has a lower limit of 0 and an upper limit of infinity. The distribution was fit using the method outlined by the Soil Conservation Service (1985).

WETS TABLE DEFINITIONS

The WETS program was created from several existing computer programs available at CDAF that summarize temperature and precipitation, growing season lengths, and last and first freezing dates. The summaries of precipitation, temperature, growing season length and dates produced by the WETS Table provide representative climatic information for the stations selected.

The WETS Table, shown in Table 2, summarizes monthly and annual climatic information in a concise format. The table provides the normal range for monthly and annual precipitation and growing season dates required to assess the climatic characteristics for a geographic area over a representative time period.

The table can be generated from any NWS Cooperative Climate Station with 20 or more years of data. The user has control over the starting and ending year and growing season threshold temperatures.

Average Daily Maximum Temperature for a Month and Yearly Average (Column #2)

The WETS table uses daily maximum (TMAX) and minimum (TMIN) observations to calculate average daily maximum and minimum temperatures for each month.

Average daily maximum temperatures are calculated by summing the daily maximum temperatures for an individual month and dividing by the number of values used in the summation for that month. The monthly averages are then summed and divided by the number of months used in the period (years) selected.

The yearly average is calculated by summing the monthly average maximums and dividing by 12. The value represents the average over the period selected.

Table 2. WETS Table Example

WETS Station : DE SMET, SD2302
 Latitude: 4423 Longitude: 09733 Elevation: 01750
 State FIPS/County (FIPS): 46077 County Name: Kingsbury
 Start yr. - 1961 End yr. - 1990
 Temperature: 30 years available out of 30 requested in this analysis
 Precipitation: 30 years available out of 30 requested in this analysis

Month	Temperature (Degrees F.)			Precipitation (Inches)				
	avg daily max	avg daily min	avg	avg	30% chance will have		avg	avg
					less than	more than	# of days w/.1 or more	total snow fall
COL #1	COL #2	COL #3	COL #4	COL #5	COL #6	COL #7	#8	#9
January	23.0	2.4	12.7	0.60	0.31	0.78	2	6.6
February	29.3	9.0	19.2	0.68	0.41	0.89	2	7.0
March	41.3	21.1	31.2	1.60	0.87	1.95	3	8.9
April	58.7	34.2	46.5	2.26	1.28	2.75	4	1.6
May	71.1	45.8	58.5	3.05	1.82	3.69	5	0.0
June	80.3	55.8	68.0	4.02	2.59	4.84	6	0.0
July	86.2	61.1	73.7	3.25	1.96	3.93	4	0.0
August	83.9	58.6	71.3	2.44	1.51	2.95	4	0.0
September	73.7	48.7	61.2	2.14	1.03	2.61	4	0.0
October	61.0	36.8	48.9	1.78	0.83	2.25	3	0.8
November	41.7	22.5	32.1	0.92	0.34	1.11	2	5.4
December	26.7	8.1	17.4	0.58	0.32	0.73	1	6.0
Annual					19.83	26.03		
Average	56.4	33.7	45.1					
Total				23.30			40	36.3

GROWING SEASON DATES

Requested years of data: 30 Available years of data: 30
 Years with missing data 24 deg = 0, 28 deg = 0, 32 deg = 0
 Years with no occurrence 24 deg = 0, 28 deg = 0, 32 deg = 0
 Data years used 24 deg = 30, 28 deg = 30, 32 deg = 30

Probability	Temperature		
	24 F or higher	28 F or higher	32 F or higher
COL #10	COL #11	COL #12	COL #13
Beginning and Ending Dates			
Growing Season Length			
50 percent *	4/16 to 10/22 189 days	4/27 to 10/ 9 165 days	5/ 4 to 9/29 148 days
70 percent *	4/12 to 10/27 198 days	4/22 to 10/13 174 days	5/ 1 to 10/ 3 155 days

* Percent chance of the growing season occurring between the Beginning and Ending dates.

Average Daily Minimum Temperature for a Month and Yearly Average (Column #3)

Average daily minimum temperatures are calculated by summing the daily minimum temperatures for an individual month and dividing by the number of values used in the summation for that month. The monthly averages are then summed and divided by the number of months used in the period (years) selected.

The yearly average is calculated by summing the monthly average minimums and dividing by 12. The value represents the average over the period selected.

Average Daily Temperature for a Month and Yearly Average (Column #4)

Average daily temperature for a month is calculated by adding the individual monthly average daily maximum temperatures and average daily minimum temperatures shown in columns 2 and 3 and dividing by two.

Average yearly temperature is calculated by summing the monthly averages shown in Column 4 and dividing by 12. The value represents the average over the period selected.

Average Monthly and Annual Precipitation (Column #5)

The WETS Table uses daily precipitation to determine average monthly precipitation. Monthly precipitation is calculated by summing the daily precipitation for each month. All monthly amounts are then summed and divided by the number of months used in the period (years) selected. The Yearly Total is the sum of the averages for individual months shown in Column 5.

The "30% Chance Less Than" Values for Monthly Precipitation and Annual Precipitation (Column #6)

This value represents the threshold for which 30 percent of precipitation amounts will be less than or equal to the value shown. Viewed inversely, 70 percent of all precipitation amounts can be expected to exceed this value. These thresholds are calculated from the fitted two-parameter gamma distributions (NRCS, 1985).

It should be noted that the annual threshold shown in Column 6 is not the sum of the individual monthly thresholds. Individual monthly, (e.g. all January totals) and annual precipitation totals possess different statistical distributions which must be modeled separately with the gamma distribution. Accordingly, monthly totals are used to calculate the monthly threshold values and annual totals are used to calculate the annual threshold values.

The "30% Chance More Than" Values for Monthly Precipitation and Annual Precipitation (Column #7)

This value represents the threshold for which 30 percent of precipitation amounts will be greater than or equal to the value shown. Viewed inversely, 70 percent

of all precipitation amounts can be expected to be less than this value. These thresholds are calculated from the fitted two-parameter gamma distributions.

The monthly and annual thresholds are calculated in the same manner as described in the "30% Chance Less Than" (Column #6).

Average and Total Number of Days With .10 Inch or More of Precipitation (Column #8)

The monthly average value is calculated by summing the number of days with precipitation greater or equal to .10 inches for a individual month over the period (years) selected and dividing by the number of months used in summation. The yearly average is calculated by summing the 12 monthly average values.

Average Total Snowfall (Column #9)

Snowfall is the incremental depth of snow that has fallen since the last snow depth observation. The time between snowfall observations is usually 24 hours for the NWS Cooperative Network. The monthly average value is calculated by summing the observed daily snowfall values greater than or equal to 0.1 inch for an individual month and dividing that sum by the number of months used in the selected period (e.g. 1961-1990). The yearly average is calculated by summing the 12 monthly average values.

ACCOMMODATING MISSING TEMPERATURE AND PRECIPITATION DATA

Nearly all climate observations in the U.S. are made by volunteers who are part of the NWS Cooperative Station Network. Events such as sickness, vacation, or equipment failure can create missing daily data values. Since missing data values do affect climate statistics, guidelines have been established to accommodate missing data and still provide representative statistics.

Missing Temperature Algorithm for Calculating Averages

To create representative averages and totals, the WETS program scans each month for missing temperature and precipitation values using the following logic:

To be included in a temperature analysis, a month must contain at least 21 maximum and minimum temperature values. Since temperature is a continuous function, previous research has shown that representative averages can be calculated using 21 or more temperature values for a particular month (Duchon, 1981).

Missing Precipitation Algorithm for Calculating Averages

To be included in a precipitation analysis, a month must contain at least 25 observed daily precipitation values. (Zero is considered a valid observation and not treated as missing.) Since precipitation occurs as distinct events rather than continuously, and significant amounts can occur in a single day, a more stringent criterion for missing days has been imposed than for temperature.

One exception to the 25 day rule is the calculation of average monthly snowfall. Since snowfall is observed less frequently than liquid precipitation (rain) and larger sample sizes ensure more stable estimates, no months are excluded from the calculation unless an entire month's snowfall dataset is reported as missing.

WETS GROWING SEASON DATES AND LENGTH

The growing season is defined as that part of the year when soil temperatures at 19.7 inches below the soil surface are higher than biologic zero (5 degrees C). As this quantitative determination requires in-ground instrumentation which is not usually available, growing season can be estimated by approximating the number of frost free days. The growing season can be approximated as the period of time between the average date of the last killing frost in the spring to the average date of the first killing frost in the fall. This represents a temperature threshold of 28 degrees F or lower at a frequency of 5 years in 10.

The growing season length is determined from daily minimum temperature values. Threshold surface temperatures of 32, 28, and 24 degrees Fahrenheit are generally used to determine the effects of air temperature on plants using the following commonly accepted classification (NCDC, 1984b):

- 32 to 29 degrees F. is a light freeze -- tender plants killed, with little destructive effect on other vegetation.
- 28 to 25 degrees F. is a moderate freeze -- widely destructive effect on most vegetation with heavy damage to fruit blossoms, tender and semi-hardy plants.
- 24 degrees F. and less is a severe freeze -- heavy damage to most plants. At these temperatures, the ground freezes solid, with the depth of the frozen ground dependent on the duration and severity of the freeze, soil moisture, and soil type.

It should be noted that temperatures near the ground may be significantly lower than temperatures measured at five feet, the normal height that air temperatures are observed. It is not unusual for surface temperature and air temperature to vary by four degrees or more. For this reason, the WETS program allows users to select the three threshold temperatures.

Growing Season Definitions

All freeze dates are based upon the season August 1 through July 31 for each threshold temperature. Last spring dates of occurrence for a given year are obtained from the period August 1 of the previous year through July 31 of the

given year (e.g., spring season for 1971 runs from August 1, 1970, through July 31, 1971, except for the selected starting year, which begins on January 1).

First fall dates of occurrence are obtained from the period August 1 of a given year through July 31 of the following year (e.g., fall season of 1971 runs from August 1, 1971, through July 31, 1972, except for the selected ending year, which ends on December 31).

Therefore, for purposes of calculating the "growing season" with the WETS program, the climatological year begins on August 1 of the previous year and ends on July 31 of the following year.

This season definition follows that of NCDC (1984b). It coincides more closely with previous definitions of the annual march of temperature, in which the warmest time of year occurs near August 1, and the cold season extends beyond December and into the following winter months. This allows for the first "fall" freeze to occur after December 31, which sometimes happens in warmer climates.

The estimation of freeze probabilities was based upon the work of Thom and Shaw (1958) and Thom (1959), which was later modified by Vestal (1970, 1971).

Growing Season Dates and Length Calculation

To determine the last occurrence of a temperature threshold in the spring, the WETS program begins on July 31 of a given year and progresses "back" toward August 1 of the previous year, comparing each daily minimum temperature with the user selected or default thresholds. The first date on which the temperature is less than or equal to a threshold for that year is stored. This then becomes the spring date.

To determine the first occurrence of a temperature threshold in the fall, the program then starts on August 1 of the given year and progresses "forward" toward July 31 of the following year comparing each daily minimum temperature with the user selected or default thresholds. The first date in which the temperature is less than or equal to a threshold for that year is stored. This then becomes the fall date.

During this search procedure, it is possible for a single date to fulfill all three user selected thresholds. For example, an observed minimum temperature of 20 degrees would fulfill thresholds of 24, 28, and 32 degrees.

Both the last spring and first fall dates are converted to Julian days for calculation of summary statistics. The growing season length is determined by counting the number of days from July 31 back to the threshold date in the spring and by counting the number of days from August 1 forward to the threshold date in the fall. The spring and fall counts are summed to determine the growing season length for an individual year. The growing season length for the period of selected (such as 1961-1990) is determined as the average of the growing season lengths calculated for the individual years.

Growing Season Dates and Length Probabilities

The average growing season length is shown in the WETS Table as the 50% probability value. Associated with this length are the average dates of the beginning and end of the growing season. The 70% value of growing season length represents the upper bound of the NORMAL category; 70% of years will have a growing season less than or equal to this length, and 30% will have a growing season greater than this length. Associated with the 70% probability value of growing season length are the average dates of the beginning and end of a growing season of this length.

Since average growing season length is determined first (in total days), starting and stopping dates must be calculated. The growing season length calculation does not include the ending date in the fall. Since minimum temperatures usually occur in the morning, the effective last day of the growing season would have been the previous day. Therefore the date of the threshold exceedance would not be included in the growing season calculations.

Starting and ending dates are derived by first determining the "midpoint date" (50% probability) for each growing season for each year in the selected period. An average "midpoint date" is then calculated for the selected period (e.g. 1961-1990). The average probability start and end dates are determined by dividing the average growing season length by two, rounding as appropriate, and then adding and subtracting the resulting number to the "midpoint date." These values are then converted to the calendar dates shown in the WETS Table. Due to the effects of rounding, leap years, and the use of a 366 day Julian calendar, growing season start and end dates shown in the WETS Table may differ by one day from the growing season lengths.

The 70% starting and ending dates are then determined by taking the difference (in days) between the 70% and the 50% probability growing season lengths, adding half the difference to the 50% probability ending date and subtracting half the difference from the 50% probability beginning date.

Since the minimum temperatures used to determine growing season lengths can be modeled using a normal distribution, the assumption of symmetry in both the 50% and 70% growing season length distributions is valid. Therefore, adding and subtracting the difference in days between the 70% and 50% growing season lengths will provide reasonable results. The 70% probability average beginning and ending dates are to be interpreted as the "normal" growing season for wetland determinations.

The growing season dates for specified temperatures and probabilities are shown in the bottom half of the WETS Table in Columns 2, 3, and 4.

Accommodating Missing Minimum Temperatures When Calculating the Growing Season Dates and Length

Previous research (Ashcroft et al., 1992) has shown that representative last and first frost dates can be calculated from time series that contain missing data. Based on this research and CDAF sensitivity tests (Pasteris, 1994), the WETS

program excludes a year from the calculation if a season (spring or fall) has 9 sequential or 18 random missing minimum temperatures. The number of years excluded for each temperature threshold is shown at the top of each WETS table. The WETS program requires a minimum of 20 valid data years to produce a representative WETS table.

Threshold Temperature Non-Occurrence

Certain areas of the country, Florida or Arizona for example, do not experience one or more of the threshold temperatures in some years. The WETS program adjusts for this situation by using a mixed distribution, binomial and normal, to calculate representative probabilities (Vestal, 1970, 1971). The number of years with non-occurrence are shown at the top of the WETS Table.

A growing season length will not be calculated if the probability of non-occurrence is greater than the preselected probability. If, for example, a temperature of 24 degrees or less was not recorded in 16 out of 30 valid years (probability of non-occurrence equal to 53 percent), a 50 percent probability value could not be calculated. This logic applies to all probabilities calculated by the WETS table.

Differences Between Last Spring and First Fall Frost Dates and Growing Season Length

The number of days between the last frost in the spring and the first frost in the fall derived from the dates for a selected probability level in the CDBS FROST table will not, in general, be equal to the growing season length for the same probability level given the WETS table or the CDBS GROWTH table. They will only be equal for the 50% (5 years in 10) probability level; otherwise, they will not be equal.

This is because the CDBS FROST program treats the spring and fall threshold date distributions as separate and independent. A growing season for a particular year, however, is a "coupled event," that is, it is the length of time between the spring and fall temperature threshold occurrences in that year. One cannot, therefore, determine the growing season lengths for selected probability levels from the two independent distributions in the FROST table. The WETS and GROWTH programs treat the growing season as a coupled event and should be used to obtain growing season lengths for different probability levels.

STATS TABLE

STATS, shown in Table 3, is a companion table to WETS. It displays monthly and annual totals summed from daily observed precipitation. Months with at least one missing daily observation are annotated with an "M". Months containing no daily observations are shown as a blank.

STATS tables have been generated for all WETS stations for the period 1961-1993. If a full 30 year period is unavailable, totals are shown for the period that matches the period selected in the WETS Table.

Table 3. STATS - Monthly and Annual Precipitation Totals

Station : SD2302, DE SMET													
total 1961-1993 prcp, Unit = inches													
yr	jan	feb	mar	apr	may	jun	jul	aug	sep	oct	nov	dec	annl
61	0.20	M0.57	0.86	1.34	4.51	5.48	2.75	0.36	1.94	4.39	0.43	0.84	23.67
62	M0.32	1.58	2.03	2.25	8.17	4.73	7.09	2.59	1.43	0.48	0.23	0.15	31.05
63	0.80	0.72	1.12	2.61	2.14	2.14	5.82	0.72	1.76	1.04	0.75	1.32	20.94
64	0.03	0.21	1.73	2.43	1.87	2.10	2.59	2.79	1.33	0.00	0.32	0.64	16.04
65	0.13	0.70	2.11	3.05	7.36	5.89	1.78	1.38	4.54	1.00	0.73	0.31	28.98
66	0.24	0.75	1.43	2.30	1.06	1.75	2.27	3.47	1.50	1.80	0.17	0.29	17.03
67	1.18	1.32	0.09	1.80	0.75	7.75	2.82	0.95	1.92	0.84	0.23	0.30	19.95
68	0.39	0.00	0.57	4.96	2.34	4.87	2.32	2.96	2.20	3.43	0.69	2.03	26.76
69	1.36	1.81	0.56	0.31	2.93	2.32	3.34	1.19	1.35	3.21	0.17	0.81	19.36
70	0.51	0.00	1.53	3.82	2.28	4.63	3.07	1.13	1.20	2.10	2.09	0.70	23.06
71	0.06	1.45	0.05	2.07	2.69	3.88	2.08	2.23	1.07	M4.63	3.41	0.60	24.22
72	0.51	0.49	1.42	4.13	6.28	3.37	6.00	0.94	1.23	2.06	1.73	1.42	29.58
73	0.52	0.63	1.90	M0.59	M2.82	1.21	2.77	2.43	M2.72	1.12	0.81	0.87	18.39
74	0.00	1.12	1.39	M0.79	4.24	2.16	1.83	2.97	0.05	M0.14	0.08	0.12	14.89
75	M2.22	0.23	M3.19	2.72	1.74	4.34	0.33	5.16	1.87	0.89	M1.68	0.15	24.32
76	1.41	0.58	1.45	1.50	M0.43	1.47	1.29	0.50	2.45	0.25	0.06	0.38	11.77
77	0.82	2.40	3.51	2.59	2.01	7.78	1.40	2.92	3.16	3.27	3.05	0.76	33.67
78	0.80	0.30	0.68	3.05	4.83	1.74	2.85	0.72	1.85	0.21	0.62	0.81	18.66
79	0.67	0.35	1.97	3.20	2.28	3.35	1.99	2.49	0.08	2.58	0.46	0.39	19.61
80	0.42	0.46	0.69	0.67	1.71	5.27	1.86	4.17	0.95	1.34	0.08	0.10	17.72
81	0.48	0.52	1.57	0.64	1.09	3.86	4.72	2.38	0.69	2.25	1.06	0.32	19.58
82	1.15	0.08	0.93	1.56	6.30	1.86	4.62	2.33	2.77	4.82	0.88	0.44	27.74
83	0.21	0.32	3.28	1.05	1.31	3.39	2.05	1.44	3.44	1.28	2.23	0.38	20.38
84	0.53	0.69	1.28	3.46	2.11	11.92	1.55	5.85	2.22	4.86	0.17	0.69	35.33
85	0.55	0.25	3.51	2.39	3.84	2.51	3.31	4.21	7.62	1.40	1.95	0.95	32.49
86	0.43	0.44	1.40	7.63	3.88	2.86	7.45	3.46	4.46	0.38	0.53	0.20	32.92
87	0.18	0.81	3.30	0.45	0.97	1.79	8.31	3.28	1.76	1.05	0.92	1.01	23.83
88	1.42	0.62	1.63	1.17	2.28	1.71	1.63	2.42	3.82	0.17	1.03	0.45	18.35
89	0.37	0.65	1.87	2.45	2.15	4.67	4.57	3.30	2.60	0.53	0.89	0.07	24.12
90	0.00	0.32	0.81	0.74	5.00	9.72	3.12	2.33	M0.17	2.02	0.05	M0.29	24.57
91	0.00	0.65	0.35	4.06	M6.54		1.51	1.50	2.13	0.63	1.31	M0.00	18.68
92	0.71	1.04	1.09	2.02	1.37	4.18	4.21	3.12	2.66	0.86	M0.89	0.61	22.76
93	0.50	0.46	1.25	3.11	3.64	8.74	5.34	3.24	2.07	0.00	M0.88	0.88	30.11

Notes: Data missing in any month have a 'M' flag
Data missing for all days in a month is blank

GUIDELINES FOR WETS TABLE USAGE

- A. Select climate stations that observe both temperature and precipitation. Precipitation only stations can be used if a neighboring station has the temperature information necessary to determine growing season. It should be noted that growing season dates are more important in the spring and fall and that determinations made in the middle of the growing season are more dependent on precipitation.
- B. Select stations with a minimum of 20 years of data.
- C. There may be a great variation in climate for an individual county, especially in the West. Therefore, it may necessary to review several climate stations and select one that represents the climate in the area under consideration.
- D. Some areas of the country seldom experience temperatures of 28 degrees or less. These areas include coastal South Carolina, coastal Georgia, Florida, southern Alabama, southern Mississippi, southern Louisiana, coastal Texas, southern and coastal California, coastal Oregon, coastal Washington, the

Pacific and Caribbean Islands. Thresholds temperatures of 34, 32, 28 degrees should be selected for these areas.

E. Additional guidelines will be added as implementation begins.

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THE BUREAU OF RECLAMATION'S WETLAND INITIATIVE IN MONTANA

Thomas J. Parks¹

The Montana Area Office has been involved since 1991 specifically in collaborative efforts to restore, enhance and create Northern Great Plains wetland ecosystems as one component of the wetland development program. Additional program components include technical assistance, outreach and educational opportunities, and support of research into wetland function as demonstrated by recently completed projects including:

Tiber Dike Wetland Project. This project, located at Tiber Reservoir near Cheser, Montana, captures and consolidates precipitation in an intermittently flooded pasture on withdrawn land associated with Reclamation's Lower Marias Project. Constructed in 1995, the 1,900-foot-long, 7-foot-high dike with 3:1 sideslopes maximizes the shallow water emergent vegetation habitat type and with a minimal deeper zone associated with excavation for the dike. Appropriate shrub and food plot plantings will take place on the surrounding uplands to produce a "living snowfence" effect in maximizing the accumulation of local runoff.

Anita Reservoir. Currently under construction, Anita Reservoir complex is located 35 miles north of Chinook, Montana. As set forth in the North American Waterfowl Management Act (NAWMA), this is a partnership between the Bureau of Land Management (BLM), Bureau of Reclamation (BOR), Ducks Unlimited, MTDFWP and local permittees. The project features a permanent 880 acre-foot (90 surface acres) reservoir averaging four-five feet deep with riparian, emergent and deep water habitat types. Eight to 15 satellite pair ponds, from one to five acre-feet each, will be built within one mile of the core project. The diversity of habitat types designed to be provided by the completed project in this generally mesic setting will contribute significantly to the goals of habitat and biological diversity.

Sleeping Buffalo. At Nelson Reservoir, Milk River Project, Reclamation provided NEPA water right permit compliance assistance to MTDFWP and Ducks Unlimited. Construction consisted of a 1,400-foot long, "L" shaped dike, pick up drains (pair ponds) on the perimeter and culvert installation and island construction to convert a monotypic cattail stand into a variety of wetland habitat types.

Yellowtail WHO. Located six miles east of Lovell, Wyoming, this unit provides quality habitat for and unique viewing opportunities of Wyoming's wildlife. Acquired by Reclamation for construction of Yellowtail Project, 14,100 acres are managed by

¹Bureau of Reclamation, Billings, Montana

Wyoming Department of Game and Fish through cooperative agreements with NPS, BLM and BOR.

Lee Maye Wildlife Viewing Blind. The Lee Maye Wildlife viewing blind was constructed in 1995 in a cooperative effort between Exxon Oil, Bureau of Reclamation and Wyoming Department of Game and Fish. The blind overlooks dominant old growth cottonwood stands with multi-structural age classes, and the associated Shoshone River floodplain understory. It provides for viewing and interpretation of waterfowl and associated wetland species in an undisturbed setting. Located on an alluvial floodplain of Shoshone River, it involved the construction of a dike, road and water control structure to create a 3.6-acre wetland on an existing beaver pond.

Outdoor Classroom Pond Project. Originally constructed by the Youth Conservation Corps, the project was rehabilitated to provide a more stable water supply and access for school buses. This project features ideal wood duck nesting habitat as well as trails and interpretive signs for school groups and the general public. It includes such functions as groundwater recharge, sediment toxicant stabilization, and floodflow attenuation in the more permanent wetland.

Additional wetland program activities include:

Management — Nelson Reservoir Plover Management Agreement

Research — Cottonwood Recruitment Research

Research — Intensive short-term livestock rest/rotation grazing to stimulate grass production

Research — Hydrogeomorphic Approach to Functional Assessment of Wetlands.

LIVESTOCK GRAZING: A TOOL FOR REMOVING PHOSPHORUS FROM IRRIGATED MEADOWS

G.E. Shewmaker¹

ABSTRACT

Elevated phosphorus (P) loading of wetlands, streams, lakes, and reservoirs can occur from nonpoint sources such as grazing of irrigated or naturally wet meadows and palustrine wetlands. The water entering Cascade Reservoir of west-central Idaho sometimes has elevated P concentrations (>0.050 ppm) and provides a P load of 54 tons P/yr. The use of best management practices such as rotational grazing, buffer strips next to wetlands, and proper irrigation management should reduce overland flow and streambank erosion. Livestock grazing should harvest and remove a significant amount of P from the ecosystem from incorporation into bone and tissue mass of growing animals and beef export from the basin. About 44,000 ac of mostly flood-irrigated pasture land exists in the Cascade Reservoir watershed. The Phosphorus Uptake and Removal from Grazed Ecosystem (PURGE) model uses three separate methods to estimate P retention in cattle and using limits of the input variables, predicted that from 4 to 57 tons P could be removed annually from the Cascade watershed. With proper grazing management, cattle should be part of a long term solution to P loading and improvement of water quality in Cascade Reservoir.

INTRODUCTION

Nonpoint source effects on water quality have become an important issue in recent years. Croplands and grazing lands are increasingly scrutinized for their contribution to nutrient loading of water bodies. While improvements in grazing management usually can reduce nutrient loading, the nutrient loading contribution by grazing animals may be overestimated and goals for reduction of nutrient loading may be unrealistic. Determining background levels is difficult but critical to setting realistic goals for nutrient loading.

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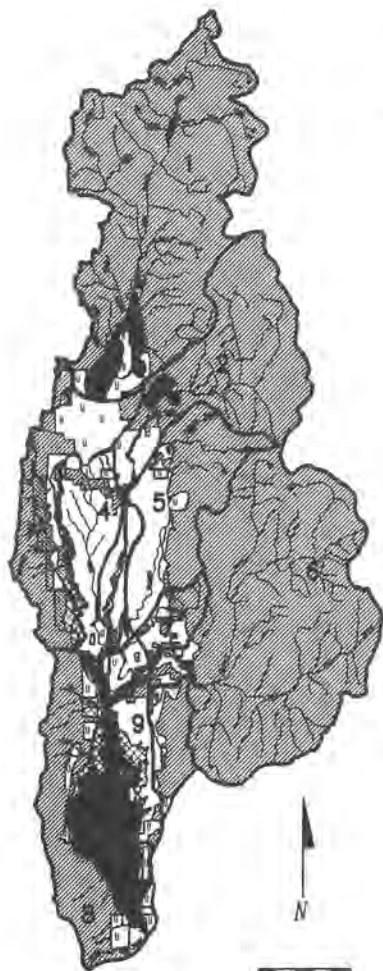
A case study of the Cascade Reservoir watershed (Fig. 1) will be used in the development and application of a conceptual simulation model of P export by cattle. Eutrophication of Cascade Reservoir in west-central Idaho is attributed to excess P and other nutrients entering the shallow reservoir through tributaries and irrigation return flows (Entranco Engineers 1991). Besides the point sources of pollution, large loadings have been measured from stream segments through croplands, pasture, and forest lands in the watersheds. Nonpoint sources are estimated to contribute 60% of the P load (VSCD 1991). However, the "natural" or background levels are unknown. Abrams and Jarrell (1995) concluded that the contribution of P from native soil sources needs to be evaluated as well as those from anthropogenic sources of stream P. They found that high native P levels and P adsorption characteristics of soils in a tributary watershed of the Willamette River were an important nonpoint source of P.

The fast-growing population of vacation home owners and recreationists has become convinced that the environmentally correct solution is the removal of livestock grazing from the watershed. However, their opinions may result from a flawed perception of the ecosystem dynamics of grazing.

Proper grazing management is essential to reducing nutrient loadings to streams. In Oklahoma, Olness et al. (1980) reported that total P concentrations in surface runoff from continuously-grazed watersheds ranged from 1 to 1.8 ppm, and they were about three times higher than those from rotation-grazed watersheds because of greater soil loss. Average annual losses in runoff from the same rotationally-grazed and continuously-grazed watersheds were 0.5 and 1.7 lb total P/ac, respectively (Menzel et al. 1978), over a four-year period. In northern Idaho, Jawson et al. (1982) reported annual total P losses in runoff from a grazed watershed over three years ranged from 0.09 to 1.2 lb/ac and from 0.09 to 0.15 lb/ac for the check watershed. However, the watershed effect may be confounded in the studies and comparisons are difficult because of differences in topography, vegetative cover, and intensity of precipitation.

Assuming best management practices (BMPs) for grazing pasture and rangelands are applied, a simple mass balance confirms that livestock grazing can remove significant amounts of P from the ecosystem. This is accomplished through cattle harvesting the forage and exporting P from the land in bone and soft tissue growth.

CASCADE
WATER QUALITY PROJECT
LAND USE



PRODUCED BY SCS
423 BOISE, IDAHO

SCALE IN MILES
0 1 2 3 4

LEGEND

SUBWATERSHED	
1	PAYETTE LAKE
2	LAKE FORK
3	N. FORK PAYETTE
4	MUD CREEK
5	BOULDER CREEK
6	GOLD FORK
7	WILLOW CREEK
8	WEST SIDE
9	CASCADE
LAND USE	
[White box]	IRRIGATED PASTURE
[White box]	NON-IRRIGATED PASTURE
[Diagonal lines /]	IRRIGATED CROPLAND
[Diagonal lines \]	NON-IRRIGATED CROPLAND
[White box with 'I']	RECREATION LAND
[Cross-hatch]	WILDLIFE-WETLAND
[Diagonal lines /]	FOREST LAND
[Diagonal lines \]	RANGE LAND
[White box with 'U']	URBAN OR RESIDENTIAL
[Black box]	WATER
[Dashed line]	SUBWATERSHED BOUNDARY
[Thin solid line]	RIVERS/STREAMS
[Thick solid line]	STATE HIGHWAY 55

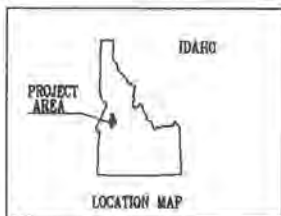


Fig. 1. Cascade Reservoir Watershed Land Use

Several monitoring studies on this site are an inappropriate basis from which to infer the effects of grazing management on P loadings. For example, the comparison of one grazed watershed with an ungrazed watershed has a confounding effect with no measure of experimental error. The confounding effect is that the watershed itself may be a larger source of variation than the treatment; i.e., different soils, aspects, slopes, vegetative cover, etc. In another case, the comparison of P concentration above and below grazed and nongrazed pastures is also not appropriate to infer management effects because of confounding by stream and soil differences. Monitoring studies are only useful in recording what happened, not why it happened. Critical studies are needed that test hypotheses of cause and effect in addition to monitoring.

Climate is the overriding variable in the process. Separating climatic effects from any treatment of the watershed is difficult. Much of the P enters the wetlands as a pulse during snow melt. Thus, it is dangerous to infer trends because of the yearly weather effects and probable interactions. For example, during water year 1993, the watershed received 115% of normal precipitation and produced a load of 60 tons of total P (DEQ 1995). During water year 1994, the watershed received 60% of normal precipitation and produced a load of 22 tons of total P (DEQ 1995).

The transport of P by overland flow depends on the desorption, dissolution, and extraction of P from soil, and mineralization of plant material and feces. Temperature, precipitation, presence of anaerobic soil conditions, and evapotranspiration rates further influence the process. Plant species composition and rate of decay affect the P leached from plant material. Soil loss of P is dependent on the capacity and charge of ion exchange sites on minerals and organic matter, pH, and the concentrations and interactions of other elements (Broberg and Pearson 1988).

Degraded water quality is not beneficial to recreationists, wildlife, homeowners, or agricultural producers. It behooves us to use BMPs and other tools-based on science rather than perceptions—to reduce P loading. Recreational and grazing activities that accelerate erosion will increase total P loadings because of P adsorption to soil particles. We should also recognize that properly managed livestock grazing operations will export P from the basin. The following conceptual model, with some constraints, estimates P removed from the ecosystem by grazing cattle.

METHODS

Site Description

The watershed of Cascade Reservoir is 390,000 acres and is located in the west-central mountains of Idaho. The watershed has forested mountains at the headwaters and wide flat valleys along the reservoir and stream channels. Soils are glacial tills of decaying granite from the Idaho Batholith. Irrigated pasture lands are sandy, mixed Humic Cryaquepts and fine-loamy, mixed Typic Cryumbrepts (Rasmussen 1981). Water table depths are generally > 6 ft and soils are generally well-drained; however, saturated conditions due to spring flooding or irrigation can produce anaerobic conditions and some soils with high clay along riparian areas are not well drained. The Donnel sandy loam and Archabal series--major components of the pasture lands--have soil reactions from 4.5 to 6 pH and water soluble P levels from 0.10 to 0.20 ppm (mg/L) in the surface horizon (McGeehan 1996). The P concentration and P sorption capacity decrease significantly with profile depth. The maximum P sorption of the surface horizon varies from 93 to 580 ppm (mg/kg) in the Donnel series and from 540 to 760 ppm (mg/kg) in the Archabal series (McGeehan 1996). In acid soils, inorganic P precipitates as Fe/Al-P secondary minerals and/or is adsorbed to surfaces of clay minerals and Fe/Al oxides (Tisdale et al. 1993).

The Cascade Basin has 44,000 acres of irrigated and 8,000 acres of nonirrigated pasture land. Pasture land is typically leased for summer grazing by cattle. There are an estimated 30,000 livestock in the basin during summer (VSWCD Board & Roach 1995 referenced in DEQ 1995). During spring, cattle are trucked into the basin and in the fall they are trucked out. Very little fertilization is done and most pastures are continuously grazed, resulting in heavy and selective utilization of forage. Sub-irrigation practices produce saturated soil conditions and when pastures are continuously grazed, soil compaction results. Carex and rushes have increased in abundance due to over-irrigation. Potential pasture yields support stocking rates of 4 to 7 animal unit months (AUMs) per acre with a high level of management (VSCD 1991). Production limitations are low soil pH, high water table and saturated conditions, and short-growing season of 70 frost-free days (Rasmussen 1981).

Many riparian areas suffer from accelerated streambank erosion. Overland erosion rates are estimated at 0.1 tons per acre annually (VSCD 1991). Approximately 54 miles of critically eroding stream-bank have been identified that are estimated to yield 4,850 tons of sediment annually to the reservoir. In addition to having been the number one fishery in the state of Idaho, the area supports wildlife resources like waterfowl, raptors, deer, moose, and elk.

Model Development

The Phosphorus Uptake and Removal from Grazed Ecosystems (PURGE) simulation model is developed to estimate P uptake by grass and P retention in bodies of grazing cattle. The variables include known, approximate, and assumed values based on measurements, the literature, and personal experience. Three methods within the model estimated P exported in cattle tissue. The PURGE model was developed in a Quattro Pro spreadsheet.

Method #1: The input variables are:

Net P absorption by animal (%)	Daily DM consumption (% body wt)
Cattle weight (lbs)	P concentration in the grass (%)
Stocking rate (hd-mon/ac)	Area grazed (ac)

The net P absorption by cattle is about 90% efficient in young calves and 55% efficient in cows (ARC 1980, Miller 1979). The P concentration of the forage can vary between 0.18 and 0.30% (Kincaid 1993) depending on soil series, temperature, interactions with other nutrients, fertilizer treatments, soil moisture, plant species, and phenological stage of the plants. The variables calculated are:

$$\text{Carrying capacity} = \text{stocking rate} \times \text{area grazed} \quad (1)$$

$$\text{Total weight gain per season} = \text{rate of gain} \times \text{carrying capacity} \times (30 \text{ days/mo}) \times (\text{ton}/2000 \text{ lbs}) \quad (2)$$

$$\text{Grass consumed per day} = \text{cattle weight} \times \text{daily DM consumption} \quad (3)$$

$$\text{P consumed per hd-day} = \text{P conc.} \times \text{grass consumed per day} \quad (4)$$

$$\text{P retained per hd-day} = \text{P digestibility} \times \text{P consumed per hd-day} \quad (5)$$

$$\text{P removed by cattle} = \text{P retained per hd-day} \times \text{carrying capacity} \quad (6)$$

Method #2: Input variables are forage production, P concentration of grass, and the ratio of *P mass removed by cattle / plant P uptake*. Forage production can be varied but values from 2,000 to 6,000 lbs/ac are in the moderate range for irrigated pasture in this area. The P concentration of forage may vary from 0.3% in early spring to 0.15% in tropical mature plants (McDowell et al. 1983). Cohen (1980) estimated the ratio of P retained in animal tissue removed to plant-P uptake at 3.6% for cattle grazing unsupplemented native range in Australia and 11.2% for range that had been seeded and fertilized with superphosphate. In contrast, Pieper (1974) reported the ratio at 23.3% on the arid southwest rangeland. The variables calculated are:

$$\text{P removed by cattle gain per acre} = \text{forage production} \times \text{P concentration} \times (\text{ratio of P removed/plant uptake}) \quad (7)$$

$$\text{P uptake in cattle} = \text{P removed by cattle gain} \times \text{acreage} \quad (8)$$

Method #3: This method was suggested by R.C. Bull, animal scientist at the University of Idaho (personal communication 1996). The P composition of bone and soft tissues in cattle is highly predictable and therefore the P export is easily calculated from cattle weight gain while on the pastures. The P content of wet bone tissue is from 4 to 4.5% (Church 1971) and from 75 to 80% of total body P is found in the skeleton and teeth. The acreage and weight gains used are those described in Method #1.

Model Constraints

No constraints are built into the model for these variables. Thus, user discretion is needed. Realistic values have been used in this example and recommended constraints are listed in Table 1.

Validation

The PURGE model has not been validated by predicting P export and subsequent measurement of P export. However, the values predicted seem reasonable and are corroborated to a degree by the literature (see Discussion). The main purpose of the model is to help land managers understand concepts of mineral cycling.

Table 1. Recommended Constraints for Input Variables Used in the PURGE Model.

Variable	Minimum	Moderate	Maximum
<u>Method #1</u>			
Net P absorption (%)	55	70	90
Cattle weight (lbs)	400	600	1000
Daily DM consumption (%)	2	2.5	3
P conc. in grass (%)	0.15	0.25	0.30
Stocking rate (hd-mon/ac)	1	2	4
Area grazed (ac)	0	--	infinity
Rate of gain (lb/hd-day)	0	1.5	4
<u>Method #2</u>			
Forage production (lb/ac)	0	4,000	10,000
P conc. in grass (%)	0.15	0.25	0.30
Ratio of P removed/plant uptake (%)	3.6	7.5	10

RESULTS

Three simulations of PURGE are shown in Table 2 representing low, moderate, and high P export scenarios.

Method #1

The simulations shown in Table 2 varied the net P absorption by cattle from 80 to 60%, which is inversely related to cattle weight as varied from 500 to 800 pounds. Daily dry matter consumption varied from 2.5 to 3%, the P concentration in grass from 0.25 to 0.30%, the stocking rate from 1.5 to 2 hd-mon/ac, and the rate of gain from 1.5 to 2 lb/hd-day. The area grazed was held constant at 43,640 acres. The simulation produced a range of estimated P export with cattle from 25 to 57 tons P annually. A moderate value was 39 tons P removed annually.

Table 2. Simulations of P Export Produced by the PURGE Model.

	A	B	C	D	E
1	PURGE.WB1	P Uptake and Removal from Grazed Ecosystems			
2					
3	Plant material on dry matter basis	Formula	Scenario		
4	Method #1		1	2	3
5	<i>Inputs (assumptions):</i>				
6	Net P absorption (%)		80%	70%	60%
7	Cattle wt (lb)		500	650	800
8	Daily DM consumption (%)		2.50%	2.75%	3.00%
9	P conc. in grass (%)		0.25%	0.28%	0.30%
10	Stocking rate (hd-mon/ac)		1.5	1.75	2
11	Area grazed (ac)		43,640	43,640	43,640
12	Rate of gain (lb/hd-day)		1.5	1.7	2
13	<i>Calculations:</i>				
14	Carrying capacity (hd-mon)	+B10*B11	65,460	76,370	87,280
15	Total weight gain (ton)	+B14*B12*30/2000	1,473	1,947	2,618
16	Grass consumed/hd-day (lb)	+B7*B8	12.50	17.875	24
17	P consumed/hd-day (lb)	+B16*B9	0.031	0.049	0.072
18	P retained/hd-day (lb)	+B17*B6	0.025	0.034	0.043
19	P removed with cattle (ton)	+B18*B14*30/2000	25	39	57
20					
21	Method #2				
22	<i>Inputs (assumptions):</i>				
23	Forage production (lb/ac)		2,000	4,000	6,000
24	P conc. in grass (%)		0.25%	0.28%	0.30%
25	Ratio of P removed/plant uptake		4.00%	8.00%	12.00%
26	<i>Calculations:</i>				
27	P uptake in cattle (lb/ac)	+B23*B24*B25	0.2	0.88	2.16
28	Exported P (ton)	+B11*B27/2000	4	19	47
29					
30	Method #3				
31	<i>Assumptions:</i>				
32	Same total weight gain as above		fresh bone contains 4.5% P		
33	Bone growth is about 20% of the animal growth		bone P = 80% of total body P		
34	<i>Calculations:</i>				
35	Weight gain as bone (ton)	+B15*0.2	295	389	524
36	P in bone growth (ton)	+B35*0.045	13	18	24
37	Non-bone P from gain (ton)	+B36/4	3	4	6
38	Total P from gain (ton)	+B36+B37	17	22	29

Method #2

The simulations held the area grazed constant but varied forage production from 2,000 to 6,000 lb/ac, P concentration in the grass from 0.25 to 0.30%, and the ratio of P removed/plant uptake from 4 to 12%. Estimates of P removed from the watershed were from 4 to 47 tons (Table 2). The moderate value was 19 tons P removed annually. Method #2 estimates were roughly half those using Method #1 for the moderate scenario.

Method #3

Results shown from Method #3 (Table 2) are produced by varying weight gain as in Method #1. This method produced estimates from 17 to 29 and a moderate value of 22 tons P removed by cattle from the ecosystem. Method #3 estimates were more stable across scenarios because P concentration is constant within the body and only increased tissue mass will increase the P export.

DISCUSSION

Nutrient Cycling

In a system without herbivores, the nutrients cycle from soil to soil water, to plants, to litter and back to soil (Fig. 2). Erosion of the soil or leaching through the ground water transports P to the streams and reservoirs. When herbivores are added to the ecosystem, P may be found in more chemical forms with varying solubility. Urine and feces return unabsorbed or unretained P to the soil surface to continue cycling.

However, patterns of dung and urine deposition are not uniform. Such patterns may be more distinct with sheep where from 1 to 2 lb P/ac annually were transported to raised levees where sheep camped at night (Haynes & Williams 1993). Theoretically a BMP of high-intensity and short-duration grazing should provide more uniform dung distribution. However, in a Florida study, soil P redistribution was not different among short-duration, long-duration, and continuous grazing systems on Bermuda grass, but accumulated in the third of the pastures closest to shade and water, probably a result of urine and feces deposition by cattle (Mathews et al. 1993).

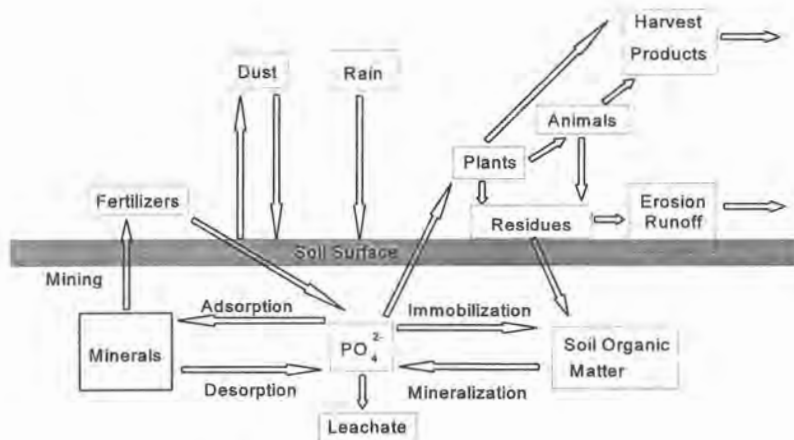


Fig. 2. The P Cycle on a Grazed Pasture

The effects of livestock grazing on nutrient loading is reported with mixed conclusions. Darling and Coltharp (1973) studied several watersheds in the Bear River Mountains of northern Utah and concluded that cattle and sheep grazing of mountain watersheds through which live streams pass increased the coliform bacteria counts but had no measurable effect on the phosphates, nitrates, temperature, turbidity, or pH in streams. Lavado and Taboada (1985) reported that grazing had no measurable impact on the N and P pools in soils of infrequently flooded, upland grasslands. Some nonrefereed papers report that grazing increases P in streams. However, these monitoring studies have inappropriate designs and are confounding. It is clear that any activity that accelerates erosion will increase the total P load. It isn't clear what effects grazing has on the soluble P loading to streams and reservoirs.

Export of P

Haynes and Williams (1993) reported that sheep removed 46 lb P/ac from P-fertilized perennial ryegrass (*Lolium perenne* L.) in association with white clover (*Trifolium repens* L.) pastures in New Zealand. Pieper (1974) estimated that sale of calves removed 0.6 lb P/ac from the arid range in New Mexico. Using moderate values calculated by Method #3,

the model produced an estimate of 22 tons P removed from the basin, or 1 lb P/ac removed. Linqian and Tingcheng (1993) reported that native range in northeastern China dominated by *Leymunes chinenses* could have 1.3 lb P/ac exported annually as forage (hay) which was 21% of the P balance.

The PURGE model clearly demonstrates that grazing livestock that are gaining weight in soft tissue and bone--either stocker calves or cows with developing fetuses--will export P from the ecosystem when the cattle are removed from the area. Hypothetically, the amount of P exported is significant and could be equal to the average load entering the reservoir. However, whether this export of P actually reduces P loadings to the reservoir depends on good grazing management to protect stream banks from erosion and to limit deposit of feces and urine in the water. Cattle can remove P from the ecosystem, but improperly managed grazing can simultaneously increase P loading to the tributaries of the reservoir. Even at the above-predicted rates of P export, erosion and large runoff events would produce big P loads because of the enormous mass of the P-pool in the soil and minerals. The P cycled through grazing cattle may also be more bioavailable than through decaying vegetation.

Recommendations of Best Management Practices

Grass buffer strips can be effective in reducing P transport from pastures (Lee et al. 1989) by increasing infiltration, sedimentation, and decreasing overland flow. Off-stream water development and fencing of riparian areas should reduce (1) streambank degradation, and (2) direct deposit of feces and urine in streams. High-intensity rotational grazing systems should provide for a healthier pasture.

Recommendations for Further Research

1. Determine the effect of grazing by using a design of randomized and replicated treatment areas within the same watershed, and multiple years and watersheds.
2. Measure the volume and nutrient concentration of overland flow and leachate on these plots as often as every other day during peak snow melt conditions, and as often as twice per week during the grazing season.
3. Monitor overland flow and leachate during high, medium, and low runoff years.

4. Measure total and soluble P concentration in the soil, forage, and feces in temporal and spatial scales.
5. Record cattle gains to verify the input variables used in this model. By using a mass balance approach, accounting for most of the P cycling in the ecosystem should be possible.
6. Use radioactive isotopes to trace P cycling in extracted soil cores. Knowing the cycling times and forms should provide insight into adjusting BMPs.

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EVALUATION OF SMALL CONSTRUCTED WETLANDS FOR IRRIGATION DRAINWATER MANAGEMENT IN THE UPPER SNAKE RIVER BASIN

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Chris Ketchum²

ABSTRACT

Constructed wetlands were considered as an alternative to manage irrigation return water in an area of the upper Snake River Basin in south-central Idaho. A four-year demonstration project was undertaken to examine practical issues and performance characteristics encountered to effectively integrate wetland features with irrigated agriculture operations. The project activities included sites studies to evaluate feasibility and potential environmental consequences, wetland design and construction, and follow-up monitoring of the water quality and habitat values associated with the site features. Early review of results appears positive, although additional monitoring is needed to assess conditions as the wetland become more fully established. The project results are intended to be applicable to other wetland sites in the area and generally contribute to sustainable water use and more effective watershed management approaches.

INTRODUCTION

The North Side Pumping Division (NSPD) of the Minidoka Irrigation Project was established by the U.S. Bureau of Reclamation (Reclamation) in the 1950's. The NSPD covers nearly 77,000 acres in south-central Idaho, north of the Snake River plain as shown in Figure 1. Water for the NSPD service area is supplied by pumping directly from the Snake River and from the underlying Snake Plain Aquifer system. Since 1966, the NSPD irrigation facilities have been operated by the A & B Irrigation District (ABID).

Return flows from the ABID irrigation area have historically been conveyed to passive drain wells that were constructed as part of the original irrigation project facilities. Conversion from flood irrigation systems to sprinkler has reduced return flows sufficiently to allow certain wells to be closed. A few additional wells have been closed due to concerns regarding poor water quality and their proximity to domestic water supply wells. Approximately 60 of the 78 drain wells originally constructed currently remain in operation.

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The State of Idaho, ABID, and Reclamation have undertaken several studies of the water quality and alternative drain water management methods (eg. IDWR, 1983; USBR, 1983; USBR, 1990). In 1991, the eastern Snake River Plain Aquifer was designated as a sole source of drinking water subject to the water quality protection provisions of the Safe Drinking Water Act (EPA, 1991). A Drainwater Management Framework Plan was prepared by Reclamation (1993) to propose a coordinated approach for implementing drain water management improvements. One alternative described in the framework plan involved the use of wetland and pond components that could be integrated to improve water quality and facilitate irrigation reuse systems.

The Minidoka Wetlands Demonstration Project was initiated to evaluate the feasibility and effectiveness of establishing wetland features and integrating wetlands within irrigation operations. The demonstration project facilities were constructed in the terminal reach of the "H-Drain" (named alphabetically) in the ABID drainage system. The H-Drain site was selected as a relatively small drainage that could be used as a practical representative of the typical drainage and site conditions found in the ABID service area.

BACKGROUND

The ABID service area ranges from about 2 to 7 miles wide and 30 miles in length. The ABID is divided into a Unit A service area of about 15,000 acres located contiguous to the Snake River, and Unit B which serves about 62,000 acres that are separated from the river by 3 to 8 miles. Unit A is supplied by water pumped directly from the Snake River, and Unit B utilizes ground water pumped from deep wells extended to the Snake Plain Aquifer. The land area located between Unit B and the Snake River is primarily irrigated agricultural land that is served by the Minidoka Irrigation District (MID).

Area Description

The project area is located in a moderately arid area that is characterized by gentle land slopes and broad flat areas overlying the basaltic rock formations that are common to southern Idaho. Native vegetation generally consists of drought tolerant species such as dryland prairie grasses and sagebrush.

Wildlife habitat is responsive to both the arid climate and agricultural land use that has altered the vegetative cover and hydrologic patterns. Larger trees and riparian cover are uncommon apart from local towns, farm residences, or along the Snake River channel. Aquatic and wetland habitat is sparse, and small drainage courses and vegetation zones near the edges of cultivated fields can provide valuable habitat corridors for resident and migratory wildlife.

Soils in the area are primarily silty loams that are low in total salts, metals, and trace element content. This fairly shallow soil mantle overlies fractured basalt which in turn overlies the Snake Plain Aquifer, a highly transmissive alluvial deposit that occurs at a nominal depth of about 200 feet. This aquifer, is one of the most productive groundwater sources in the world, that provides drinking water to an estimated 275,000 residents (EPA, 1991).

Historic Drainage Conditions

A lack of natural surface drainage outlets to the Snake River and constraints associated with drainage into the adjacent MID require most irrigation return flows and stormwater from Unit B to be disposed of through injection drain wells. These injection drain wells were drilled into highly porous zones of lava rock, passing return flows and stormwater directly into the underlying eastern Snake River plain aquifer. The drain wells were originally constructed to operate as passive, gravity-feed injection wells designed to accept normal irrigation return flows from localized depressions and accommodate minor storm runoff flows. Higher runoff is conveyed to larger catchment ponds and extreme flood flows tend to follow historic paths to the Snake River.

Water Quality

The ABID and the state have periodically monitored the quality of both the water supplies and return flows. The supply water quality from either surface or groundwater sources is generally very good. Irrigation drainwater samples have occasionally indicated elevated turbidity, nutrient, and bacteria content that are attributed to normal agricultural practices. No significant levels of synthetic organics (eg. pesticides) or trace elements (eg. from soil leaching) have been found to indicate toxic contamination problems.

The designation of the Snake Plain Aquifer as a sole source of drinking water requires the water quality to meet the provisions of the Safe Drinking Water Act, and the Underground Injection Control (UIC) program that specifically addresses injection well operations. Drain water monitoring by Reclamation and the ABID indicate that selected drain wells could exceed these standards for coliform bacteria and turbidity (Reclamation, 1993). The State of Idaho, the ABID, and Reclamation have since worked together to resolve these water quality issues in an appropriate manner.

Constructed wetland have been used effectively to remove various substances from water (eg. WPCF, 1990; Moshiri, 1993; Olsen, 1993). Wetland systems are particularly well suited to remove the sediment, nitrogen materials, and bacterial contaminants found in the ABID irrigation drain water.

DEMONSTRATION SITE WORK

The wetland demonstration project was intended to reflect typical activities expected to implement drainage improvement projects as a means to assess the practical feasibility of incorporating wetland and water reuse features into a drainage management program. The project included all site work activities ranging from the initial site investigations through design, construction, and subsequent site monitoring studies.

The H-Drain demonstration site extends about 1.5 miles along the final reach of the drainage system downstream of the contributing irrigated land. Before this project, the H-drain was a typical irrigation drainage course, built by cutting a narrow channel into the bottom of the natural drainage course. The drain channels are often confined by a berm access road on each side and are frequently maintained by clearing or burning bank vegetation and dredging of sediment. The H-Drain originally had two passive injection wells, of which one well is now closed. The other well at the terminal end of the drainage receives water only during extended high inflows. The overall site topography and features developed as part of this project are shown in Figure 2.

Preliminary Investigations

Initial project planning involved a variety of studies to evaluate the benefits and potential problems associated with the H-Drain site and anticipated types of site development features. These preliminary investigations centered on four major topics: (1) complete site surveying to prepare base mapping for use in site planning; (2) evaluate site conditions and potential to create wetland features to improve water quality and provide wildlife habitat; (3) assess the possible changes that the created wetlands could produce in either surface or groundwater hydrology; and (4) assess the potential to inadvertently create conditions harmful to wildlife or human health.

The first two questions were addressed through the initial site review and survey work. Base maps were prepared and field reviews were completed to assess the suitability to restore channels and establish meadow, marsh and pond features that would be consistent with water management objectives.

To evaluate the feasibility and suitability site soils for wetland creation, 16 exploratory test wells were drilled at selected locations throughout the site. These tests indicated that the soils in the area are moderately permeable, but would not necessarily preclude the ability to support wetlands. Subsurface flows were expected to follow the local water table along the natural stream course such that lateral seepage problems did not appear likely.

The question of toxic contamination potential involved more extensive studies undertaken by the U.S. Fish and Wildlife Service to examine the area soils and water chemistry which could indicate sources of contamination to the wetland systems. These investigations were conducted at the H-Drain site and at two other terminal drain catchment ponds that were constructed with the original irrigation facilities. These ponds have been in operation for over 30 years and were useful to provide insight into long-term trends that might be anticipated for constructed wetlands in the area.

These preliminary investigations indicated moderately elevated concentrations of cadmium believed to be a product of volcanic formations, but there was no evidence of significant accumulation of toxic trace elements (FWS, 1991). Periodic flushing by seasonal high flows was suggested as a mechanism that has maintained low levels of trace elements in these older ponds. No pesticide compounds (e.g., organochlorines) were found in either the water or sediment samples taken. Additional studies of the H-Drain site were undertaken during and after the site development work, and again, no significant contamination was reported (Mullins and Burch, 1993). Further studies were recommended to examine the potential for toxic accumulation over longer time.

Design Development Approach

Several criteria were applied in selecting site components and design features for the H-Drain site. The original irrigation development left little area to create large wetland components. The site was accordingly divided into linear stream reaches with specific features identified according to the characteristics of each reach. Design features considered included riparian restoration, small ponds, emergent marsh areas, and upland meadows.

Site features were intended to be low cost, sustainable, and low maintenance to be practical as drainwater management improvements. Site hydrology and soil conditions are largely fixed. This meant earthwork grading was the primary method to establish the desired size, shape, and slopes for features such as open pools, islands, and marsh areas. For example, grading work was utilized to form specific depth zones to encourage defined vegetation patterns in the features created. Water distribution and hydraulic conditions were considered as important factors for both water quality and to resist flood damage.

In addition to water quality objectives, wildlife habitat values were considered where possible. This included aquatic features such as islands and riparian bank zones, upland meadows for terrestrial food and cover, and separation of the higher maintenance areas from more habitat intensive areas. Mild slopes and wet meadow areas were used to provide shore and upland habitat zones.

Water quality improvement was evaluated with respect to important chemical constituents and known wetland functions. Sediment, nutrients, bacteria, and organic materials commonly found in the drain water are consistent with the wetland process mechanisms that are effective in reducing these constituents. The focus of water quality was on sediment removal due to the high loading of sediment in the drain water and the high efficiency for sediment removal mechanisms. Sediment removal can also effectively remove other constituents that are associated with the sediment materials. Sedimentation features were oriented to accommodate the 1 to 5 cubic feet per second base return flows.

The principal water quality component of the H-Drain project is an enhanced sedimentation pond located at the upstream end of the drainage. This pond is an unusual design in that a managed sediment pond is directly integrated with a vegetated marsh filter and willow transition as a means to enhance sediment removal and tolerate greater flood levels. The sediment pond is overexcavated at the upstream end of the pond to isolate sediment removal maintenance and increase the quality and longevity of downstream wetland features. The entire site is excavated below the grades of the overbank to minimize the hydraulic energy grade increase with greater storm flows. Marsh and willow vegetation zones are intended to increase the normal filtration effectiveness and reinforce the system functions against erosion damage during moderate flood events.

Construction and Planting

The design and construction of all the demonstration facilities was closely coordinated with the ABID. This arrangement was both cost effective and advantageous to produce desirable site configurations. Minor adjustments and repairs were according to conditions encountered without requiring expensive changes or more extensive site studies.

Construction work was initiated in the spring of 1992 and was substantially complete by the fall of 1995. Construction work proceeded from the upstream to downstream direction to establish the functional features of the enhanced sediment pond, and prevent disturbance of downstream features as staged construction proceeded. Site construction was primarily oriented toward the low flow channel, with the overbank areas remaining intact in most locations.

Limited planting was done in certain locations to establish desirable species and increase the rate of establishment. The sediment pond emergent marsh zone was planted by a planting contractor and the willow zone was planted by staff from the Natural Resources Conservation Service (NRCS) Plant Materials Center in Aberdeen, Idaho. The NRCS groups also provided assistance to start vegetation in other wetland and upland areas.

Site Monitoring

The demonstration project was monitored to evaluate the effectiveness of water quality improvements, wildlife habitat values and wetland creation techniques applied. As-built conditions were recorded after construction to track the practical attributes of what was actually constructed versus in comparison to the initial design objectives for each component. Wildlife values have only been qualitatively assessed to date due to the small size of the demonstration site and the relatively short time it has been established.

Water quality monitoring was initiated in 1992 and continues to date. Water samples are taken at each of 9 stations on a monthly basis. Analyses include biochemical oxygen demand, total suspended solids, various nitrogen species, total and dissolved phosphorus, turbidity, and coliform bacteria. In addition, the FWS has completed further studies of trace elements and synthetic organics to evaluate toxic hazard risks associated with newly created wetlands.

RESULTS AND DISCUSSION

The wetland demonstration site is rapidly becoming established, although it is evident that some additional time will be required to fully evaluate how things are changed and/or sustained over longer term. Still, the site is already being used effectively to eliminate disposal of irrigation wastewater through the drain injection wells. This may be partly attributed to the reduced water use due to drought conditions and more efficient irrigation practices as many farms are converting from flood irrigation to sprinkler systems. The site also provides additional wildlife habitat for waterfowl and other wetland birds and mammals. The enhanced wildlife values are evident in both wildlife observations and in the increased interest in wildlife related recreation.

The enhanced sediment pond is becoming fairly well-established and appears to be effective in filtering low and moderate flows and has held up well under normal runoff flows. Sediment removal is visually apparent in the increased clarity of the return pond downstream which was very turbid and now supports submerged aquatic vegetation.

Actual water quality data is not conclusive to date; however, there is some indication of net reduction in the downstream direction for samples taken in 1995 for nitrogen and turbidity. Total nitrogen was typically reduced from about 6.0 mg/L to 4.0 mg/L indicating approximately a 30 percent reduction in the downstream direction for samples taken in 1994 and 1995. Similar results were indicated for turbidity, but was not supported by total suspended solids data. Water quality analyses for the other constituents was inconsistent.

Water can be pumped for irrigation reuse from a pond downstream from the enhanced sediment pond. In the past, irrigators were reluctant to use reuse drainage water for irrigation because of large amounts of sediment which usually accompanied the drainage water. Increased reuse may further reduce the water volume conveyed downstream to the drain injection wells.

CONCLUSIONS and RECOMMENDATIONS

This project proved to be valuable to demonstrate the realistic expectations for wetland water management features and the practical considerations required to realize project objectives. The potential for direct application is apparent since there are about 11,000 acres of drainage area within this irrigation district that might be suitable for developing similar wetlands to treat or dispose of return flows. The project appears to be successful in incorporating wildlife habitat and water quality improvement with active agricultural operations.

This project illustrates practical and cost effective approaches to incorporate wetlands into watershed management plans. It is apparent that actual project performance depends on potential environmental consequences, site conditions, operational constraints, and the inherent limitations of wetland functions. Further monitoring is recommended to confirm these results and reveal longer term characteristics of the wetland facilities. Nevertheless, this project illustrates how water remediation and reuse can be effectively integrated with habitat objectives to sustain water and environmental resources.

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**APPLICATION OF NRWS - WETSCAPE
DECISION SUPPORT CAPABILITIES FOR WETLAND
AND WATERSHED MANAGEMENT PLANNING**

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ABSTRACT

WetScape is an interactive computer-assisted decision support system that provides resource analysis capabilities to facilitate water resource, watershed management, and wetland planning decisions. Initial efforts to support these capabilities are incorporated into the Natural Resources Workstation (NRWS) developed by the Bureau of Reclamation, Technical Services Center and the Integrated Decision Support Group at Colorado State University (IDS, 1993). Development completed to date has focused on terrain-based analyses that can be applied to examine local or basin-wide landform characteristics. A modular approach is employed to provide convenient application of different types of resource analysis tools. The system framework is flexible to allow resource characteristics and management alternatives to be examined based on readily available spatial data before proceeding with more detailed investigations or undertaking activities that could affect water quality, water use, and related natural resources. The overall system framework and the functionality of the currently available resource analysis modules are described.

INTRODUCTION

Resource managers are faced with difficult challenges when considering how to allocate resources and sustain vital ecological functions to optimize resources for competing uses. The need for integrated watershed management approaches (eg. NRC, 1992, NRLC, 1992) is often cited as important to more effective resource management. In practice, the term "watershed management" is somewhat of a misnomer because it implies greater predictive capability than is typically appropriate in most watershed situations. Even with the benefit of detailed resource information, rarely would land ownership, political boundaries, and natural characteristics allow for comprehensive management of a watershed area of any appreciable size. More often, distinct strategies are applied to focus on defined classes of resource problems or discrete projects are undertaken at specific locations in the watershed.

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Wetland ecosystems can be an important component in watershed management (NRC, 1992). Wetland functions are illustrative of the complex interactions commonly experienced in coordinated resource management. As transitional ecosystems connecting land and water, wetlands are inherently diverse and robust in nature. Due to their position in the landscape, wetlands are exposed to all manner of land and water use practices. As such, the conditions found in wetlands can reflect the properties of the adjoining ecosystems and in turn, can serve to attenuate or alter conditions downstream.

Wetlands are frequently described according to hydrologic and biotic indicators that are used to classify their ecological properties (Cowardin, et. al., 1979) or to delineate wetland areas (FICWD, 1989) for regulatory jurisdiction purposes. Functions such as wildlife habitat, water quality, and hydrologic modification are widely recognized (eg. Mitsch and Gosselink, 1993), and wetlands are also described in reference to their hydrogeomorphic setting (Brinson, 1993), and with respect to watershed functions ranging from ambient values of natural wetlands to the potential application of created wetlands as "Best Management Practices" (BMP's) for non-point water pollution control (Olsen, 1993).

These common wetland-related activities indicate a discrepancy regarding how essential information pertaining to wetland mechanisms is derived from studies of fairly small sites or local areas, and yet the important application of this information to predict the influences of relevant functions is required at the systematic or watershed level. The same problem applies to other strategies such as vegetative buffers, land use modifications, or aquatic restoration efforts that are spatially distributed throughout a watershed area. Uncertainty arises from attempting to interpret the characteristics found at local sites, transfer information to other locations or larger areas, and derive predictive models to evaluate the potential effects of these watershed characteristics in resource management alternatives. Detailed investigations are often prohibitively expensive to undertake over watershed areas, and yet attempting large scale or widely dispersed resource management actions without careful consideration of the potential consequences is risky.

WetScape was undertaken to develop integrated tools to assimilate spatial data across local and systematic scope, and to allow refinement of the analysis in response to the sophistication of information available. Specific objectives were identified for individual planning tools including; to evaluate local site landform conditions and site alternatives; to allow local results to be compiled to examine the implications over larger areas based on user-defined scenarios, and finally, to provide assistance in review of spatial information, alternative development, and correlation of measured or simulated conditions. The overall framework is intended to allow flexibility in how the analysis tools are applied and accommodate development of additional capabilities in the future.

SYSTEM INFORMATION

WetScape was developed as an interactive workstation that combines different operations in a readily accessible environment to allow flexibility in user expertise and application. WetScape tools are presented in a user-friendly Graphical User Interface (GUI) comprised of windows, icons, and pull down menus designed to guide users through various analysis tools and simulation routines. At the core of WetScape are a Geographic Information System (GIS) and data management utilities. GIS analyses utilize the Geographic Resource Analysis Support System (GRASS) version 4.1 (USACERL, 1993). The GUI currently operates under the SUN Microsystems UNIX-based operating system and X-Motif library. WetScape workstation capabilities were developed using the C programming language, TeleUSE by TeleSoft, Inc., and spatial analysis accommodated by the GRASS operations.

DATA USED BY WETSCAPE

System data requirements to support the basic GUI computer functions are not described here. As an appraisal-level GIS, WetScape functions are designed to examine spatial geographic data, incorporate additional data, and to allow interaction with external hydrologic, water quality, and watershed models. Digital elevation map coverage is the foundation of the terrain-based analysis tools. NRWS WetScape utilizes digital raster map data; however, spatial data coverage can be imported in either digital raster form or as point and linear format data and then spatially interpolating within the GRASS system.

WetScape can accept data types ranging from simple site survey information to more intensive GIS data layers. Actual data limitations may depend on system capacity and acceptable user pre-processing effort. WetScape also incorporates specific information that is associated with spatial coverage and other data that is used for tracking user-defined projects and operations. The GIS operations are not constrained to specific data types, so the desired level of resolution can be adjusted according to application needs or practical limitations.

A convenient way to access spatial information is by directly incorporating Digital Elevation Model (DEM) or Digital Line Graph (DLG) data that can be purchased at nominal cost. For example, depending on the area of interest, DEM and DLG files available from the U.S. Geological Survey (USGS, 1994) and other sources. Commercial data coverage of relatively coarse resolution might be appropriate for initial assessments, then as information becomes available, it could be incorporated to develop more detailed analysis. This allows the user to begin with a minimal investment, and still have the option of refining investigations later. A similar approach might be applied to

evaluate larger areas during early planning, and then to focus on promising areas identified during the initial review stages.

WETLAND ANALYSIS MODULES

WetScape is comprised of a series of separate, but interrelated data analysis modules that each contain a distinct set of tools designed to accomplish certain tasks. Each module has an associated GUI designed to facilitate use and to guide the user through the settings and functionality. The analysis module tools link spatial information analysis features with data manipulation, modeling interface, and user defined selections. This modular organization was implemented to anticipate the need to expand capabilities in the future, while still allowing the base system to remain intact and functional.

WetScape modules are accessed through the main NRWS interface which also supports generic operations such as: 1) estimating the water budget associated with a given area based on consumptive use variables; 2) editing of individual cells within a raster map, and 3) viewing elevation maps, or GIS products for comparison with digital aerial photos images.

Analysis modules were developed to explore topographic features, to identify areas based on defined criteria, examine surface hydrology characteristics and projected wetland conditions, and to develop and analyze potential watershed management strategies. Additional modules were considered to perform other functions, but have not been fully developed. Identified analysis modules and their respective development status are listed as follows:

- | | |
|------------------------------------|-----------------------------|
| • Basin Wide Siting (BWS) | initial phases complete |
| • Projected Wetland Analysis (PWA) | initial phases complete |
| • Basin Wide Analysis (BWA) | currently in progress |
| • Local Site Evaluation (LSE) | started, incomplete |
| • Case Study Analysis (CSA) | started, incomplete |
| • Case Data Base (CDB) | started, incomplete |
| • Water Quality Loading (WQL) | possible future development |
| • Hydrologic Loading (HYD) | possible future development |

ANALYSIS MODULE FUNCTIONS

Capabilities identified as incomplete or future development primarily concern analysis and correlation of existing site performance data and development of hydrologic and water quality loading functions that could be used in watershed simulation and evaluations. Only the functions of analysis modules currently complete or in progress are described in this section.

Basin Wide Siting (BWS)

This analysis module is generally designed to be utilized for the initial review of landform characteristics that influence selection of specific sites or areas of interest. The BWS module provides tools to assist users in defining criteria to apply spatial analysis to raster map information. This is accomplished through a model development interface called the Spatial Analysis Model Interface (SAMI). The SAMI is used to create script programs comprised of a sequence of GRASS operations that are applied to accomplish specific functions.

Spatial models are being evaluated that could be used to identify regions that have geomorphic features associated with different wetland characteristics such as: 1) Riparian; 2) On-Channel; 3) Off-Channel; and 4) Depressional. Selected model templates are currently under development to provide the user with a set of functional terrain-based models for use in testing. The SAMI is flexible to accommodate different types of spatial information data or to combine GRASS operations with other UNIX programs to develop more sophisticated models or to create models with more complicated multiple evaluation criteria.

Projected Wetland Analysis (PWA)

The PWA tool is designed to allow the user to evaluate a selected site area in greater detail. It is an important WetScape utility because it allows the user to evaluate the actual physical topography of an area with respect to projections of local surface flooding conditions. The user places an artificial control line, either open or closed, to define the area to be examined (Figure 1). A set of vertical elevations can then be selected to evaluate the water area and volume corresponding to flood stage. Three elevation zones can be specified to show the areal extent associated with each depth. These features might be employed to examine stage volume characteristics, or evaluate how a created wetland might respond to differing water surface elevations.

The open control line is generally used to evaluate branched riverine watershed drainages or local catchments. The closed control line is utilized in areas with depressional features (eg. prairie potholes area in central U.S.) or to isolate regions for evaluation of surface topography.

The results of the PWA analysis can be saved to a database according to the respective maps which can then be utilized for analyses at the watershed or basin-wide level. In this case, the attributes from individual site maps are combined to form a composite map. The composite map can then be utilized in the analysis of impacts of several wetlands throughout a basin

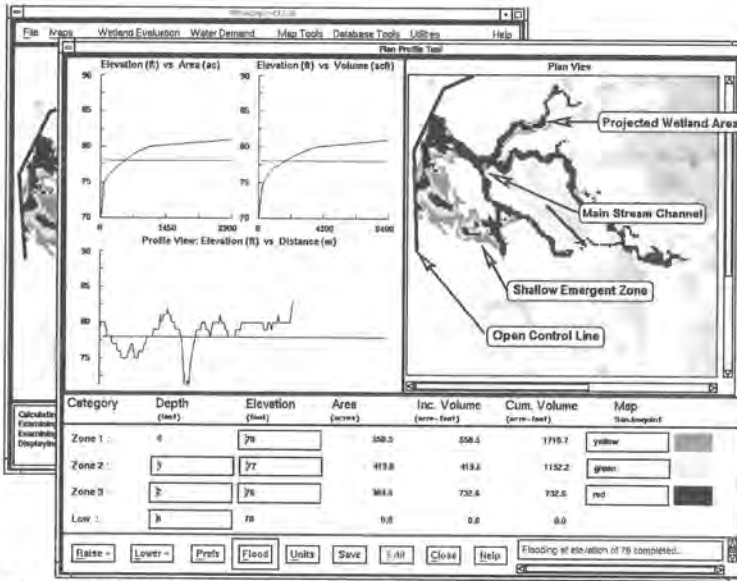


Figure 1: Terrain-Based Analysis using the PWA WAM

The PWA module uses the elevation map to develop the storage characteristics of a projected wetland. The user can adjust these controls to examine and optimize up to three depth zones in the wetland, representing emergent plants, floating plants, and open water. The zone depths are completely definable by the user. Total surface area, and volume of the flooded area is also displayed to the user in graphical and tabular forms.

Basin Wide Analysis (BWA)

The BWA analysis module consists of several models that develop totalizing reports for aggregating attributes assigned to the spatial data imported to the system or data generated by other analysis modules. For example, attributes associated with zone features defined in the PWA module could be compared for different hypothetical implementation strategies. In the most simple form, BWA supports totalizing spatial features according to area, volume, or linear attributes. BWA models can be designed to take advantage of the interactive environment of the WetScape interface to work with the other analysis tools, SAMI models or as preliminary stages for use of external resource models.

An example watershed basin showing potential wetland sites is shown in Figure 2. Support for interface with other external hydrologic and water quality models would be undertaken in subsequent development stages.

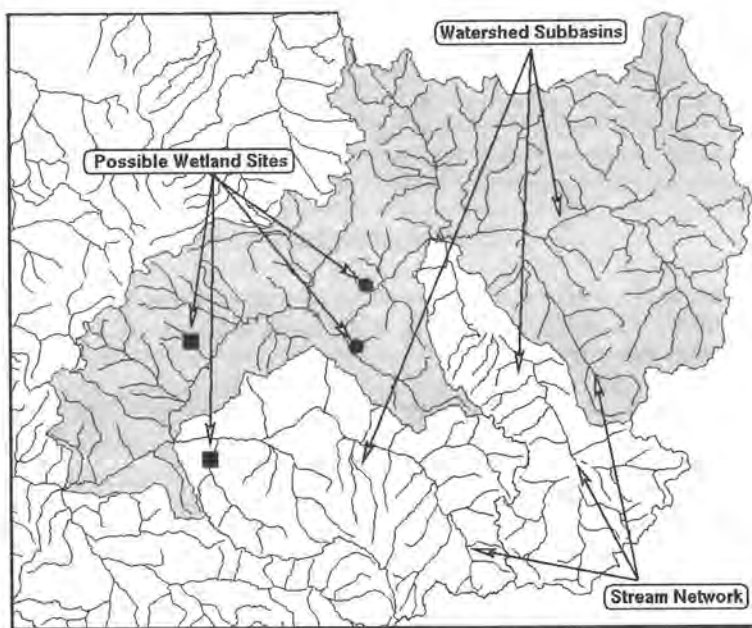


Figure 2: Watershed Basin Showing Potential Wetland Sites

RESULTS AND DISCUSSION

The capabilities provided within WetScape may be best illustrated through examples of how the analysis modules and tools might be used in practice. Modules may be used individually or applied in a sequence that is selected according to project objectives and analysis requirements. For quick review or simple tasks, a single module could be applied when project objectives can be accomplished by one type of analysis. Local tools may be used in iterative steps to develop a composite watershed map consisting of optimized sites and projected siting alternatives.

The interaction between spatial model user modes and tools can be powerful if applied with careful attention to interpretation stages. Sequence application may be desirable to extend project planning from initial development to more detailed analysis, or as a means to refine an evaluation through a series of transfers and interactive cycles between capabilities. Examples of possible sequences include BWS/PWA (regional screening followed by site selection and local optimization), or PWA/BWA (evaluation of local areas to prepare a composite map for analysis according to selected performance criteria).

The current development of WetScape allows a broad variety of terrain-based conditions to be examined and allows hierarchical refinement of the analysis as more detailed information is obtained. The approach bridges a basic gap between technology that is available for local (eg. CADD) and systematic (eg. DEM, DLG) data types, to create an appraisal-level GIS that is hierarchical in application. Additional capabilities have been considered that could be easily incorporated in to the modular framework described.

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ADDITIONAL PROJECT INFORMATION

IDS Group, 1996. *WetScape - User Manual*, Integrated Decision Support Group, Colorado State University, Fort Collins, Colorado, (in progress).

LAND APPLICATION OF ADIT WATER ON HISTORIC MINE TAILINGS AT STILLWATER MINE

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ABSTRACT

Land application disposal (LAD) systems have been used throughout the U.S. for several decades, but land application of wastewater in Montana has little documentation. More importantly is the lack of literature on the **performance** of LAD systems. As companies and municipalities, both public and private, plan for future expansion, wastewater treatment and disposal issues are of significant concern. The State of Montana's "non-degradation" rule places strictly regulated limitations on the discharge of wastewater into Montana's public waters. These regulations have many entities seeking new technological methods and economical solutions for wastewater treatment and disposal that meet current standards. Stillwater Mining Company (SMC) has upgraded LAD systems and developed a water quality monitoring plan to stabilize and reclaim approximately 42 acres (17 hectares) of partially reclaimed chromium tailings. Forage on the LAD area supports resident mule deer and serves as winter range for bighorn sheep. In 1993, SMC commissioned MSE-HKM, Inc. (formerly HKM Associates) to design a new LAD system and monitoring program for the partially reclaimed tailings site. After two years of operation and monitoring, results show high levels of nitrogen utilization and significant forage improvement on the LAD site. The design considerations, operation, monitoring, and results of two years of land application at SMC are presented. Wildlife ecosystem and habitat enhancements have been achieved by increasing natural food sources and cover. Results show that land application disposal systems can be utilized to improve reclamation efforts and can economically provide treatment and disposal solutions to improve water quality.

INTRODUCTION

Stillwater Mining Company (SMC) is a platinum and palladium mine near Nye, Montana. The only mine of its type outside the former USSR and South Africa, SMC provides precious metals required in the production of items used daily by most Americans, such as catalytic converters and computer chips. Located along a blue ribbon trout stream, the Stillwater River, and at the foot of the Beartooth

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Mountain Range, much of SMC's property supports resident mule deer and wintering bighorn sheep. SMC is continually improving methods of operation to protect and enhance the surrounding ecosystem and environment.

SMC uses nitrogen-based blasting agents to break ore in mine workings on the east and west sides of the Stillwater River. Natural groundwater inside the mine mixes with the nitrogen residues remaining after blasting and flows out of the mine. Most of the mine production water, referred to hereafter as adit water, has historically been diverted to percolation ponds, with a small portion applied to land by big gun sprinklers. Current SMC water and nitrogen disposal methods are well within the existing discharge limits of the permit issued by the State of Montana. However, in an effort to improve "disposal" methods, SMC has installed two state-of-the-art land application systems to spray irrigate a variety of grasses growing on partially reclaimed chromium tailings.

In 1993 SMC commissioned MSE-HKM, Inc. (formerly HKM Associates), a consulting engineering firm in Billings, Montana, to design the LAD system and to prepare a water quality monitoring program that would quantitatively document the nitrogen utilization of the LAD system. The design team used innovative, site-specific design concepts to help develop two center pivot sprinkler systems for the LAD site. The new center pivots are unique in that the spray irrigation system design maximizes the water and nitrogen utilization. To minimize costs of the LAD system, an existing pumping plant and pipeline were utilized to deliver adit water from a storage pond to the two LAD systems. This paper discusses the engineering considerations and design parameters used to develop the LAD system layout.

MSE-HKM developed a water quality monitoring plan to measure the performance of the LAD system. SMC has collected data for two years, 1994 and 1995. An overview of the water quality monitoring plan, including data collection and analyses, is presented. A summary of the LAD performance for 1994 and 1995 is also included.

BACKGROUND INFORMATION

Mine operations produce year-round adit water flows ranging from approximately 500 to 1,000 gallons per minute (32 to 63 liters/second). About 60% of this flow originates from the east side of the Stillwater River and 40% is produced from the west side. Typical nitrate plus nitrite (referred to herein as nitrogen) concentrations range from approximately 2 to 6 milligrams per liter (mg/l) on the east side to 15 to 20 mg/l on the west side.

Existing soils in the LAD area vary widely depending on location. The soil profile in the southern portion of the LAD area consists of varying depths of chromium

tailings, usually 5 to 10 feet (1.5 to 3.0 m), overlain by varying depths of gravelly loam topsoil, typically 2 to 12 inches (51 to 305 mm). Soils in the northern portion of the LAD area are generally deep gravelly loams overlain by 0 to 6 inches (0 to 152 mm) of chromium tailings. The small depth of chromium tailings over native soil in the northern portion of the LAD area is a result of wind erosion and deposition from the tailings to the south. The native soils and the chromium tailings have high permeabilities, ranging from 2 to 6 inches per hour (51 to 152 mm/hr). Baseline soil samples collected in 1993 and 1994 show very low nitrogen levels.

Site vegetation prior to LAD system operation varied in type and population depending upon topsoil quantities and past irrigation patterns. Vegetation under the portion of the site which had historically been irrigated with big gun sprinklers consisted primarily of alfalfa. The site also had scattered areas of bluegrass, fescue, and assorted wheatgrasses. Sparse vegetation existed over tailings with shallow topsoil. Some areas of exposed chromium sand tailings had no established vegetation. The surrounding areas are a mix of native grasses, brush, aspen, and conifers. Site vegetation is used as a year-round food source for a variety of wildlife.

ENGINEERING DESIGN CONSIDERATIONS

LAD System Design

The design of an optimum land application disposal system requires a variety of professional expertise. The design team, consisting of agricultural and civil engineers, environmental specialists, and a soil scientist evaluated water quality, soils, vegetation, climate and topography to design the LAD system. MSE-HKM worked closely with SMC personnel to identify the project objectives and to develop the details of the LAD system and monitoring plan. The LAD system plan and site enhancements were reviewed by a multi-disciplinary team from SMC, MSE-HKM, the Natural Resources Conservation Service (formerly SCS), and the State Department of Environmental Quality.

The shallow topsoil over chromium sands results in an effective root zone depth of approximately 1 foot (305 mm). The water holding capacity in the root zone of the existing vegetation is low, estimated at 0.5 to 1.5 inches (13 to 38mm). Soil fertility tests show little or no residual nutrients, particularly nitrogen, in the soil profile. Topographic characteristics on the site vary from relatively flat areas to steeper slopes (15 to 20 percent) along the base of the mountain. Based on the soils and topography, the use of a mobile, automated sprinkler system that would apply frequent, light applications of irrigation to the site with a high level of control was recommended. A high level of water management is necessary to

maximize crop water and nitrogen use which will result in vigorous plant growth. The goal is to develop the soil profile by increasing the organic matter in the root zone.

Vegetative conditions on the site varied from areas of thick grasses, where historic irrigation had occurred, to areas with limited foliage. Analysis of mine water quality (nitrogen concentration), climate, soils and vegetation indicated that inter-seeding a meadow grass with a high water and nitrogen uptake potential was most suitable for the LAD site. Garrison Creeping Foxtail (*Alopecurus arundinaceus*) was selected to inter-seed with the existing grasses for a variety of reasons: high water use potential, high nitrogen uptake potential, good sod building characteristics, lush growth in a wet environment, excellent forage qualities, and adaptability to a variety of soils. Garrison Creeping Foxtail is a hearty variety that will thrive with the existing species under irrigation. If irrigation ceases, the existing species more adapted to semi-arid conditions will dominate the site. Vegetation establishment in the chromium tailings has proven difficult in the past. Therefore, inter-seeding was completed by drill seeding with a no-till drill to insure minimum disturbance of the tailings.

Climatic conditions during the growing season, typically April through October, were evaluated. The majority of growing season precipitation occurs in April, May and June. Mid-summer and early-fall months (July, August, September, and October) are typically warm, dry and breezy with little rainfall. Climatic conditions of the site indicated that the crop water demand would be highest in the summer and fall, and lower in the spring.

A two-phase conceptual design layout for SMC's land application disposal system was prepared in 1993. The Phase I layout was designed to be a pilot study and included one center pivot sprinkler system that was installed in 1993. Successful results of the pilot study prompted the implementation of the Phase II design layout, which included a second center pivot sprinkler system that was installed in 1994. Center pivot sprinkler systems were selected over other potential methods of land application for several reasons:

- Center pivot irrigation systems provide uniform application distribution which maximizes the consumptive use of the crop and optimizes nitrogen uptake.
- Nozzles can be designed and located to maximize water and nitrogen utilization.
- Operation and management of a center pivot system can be modified throughout the growing season to match the climatic and vegetative demands of the crop.
- Design objectives could be achieved matching the existing pumps at SMC which operate at approximately 80 psi (552 kPa).

- Center pivots are easily automated with computer control panels and thus operate with a high level of management with minimal labor.
- Automated operation of this type of irrigation system provides a higher level of quality control than conventional stationary irrigation systems.
- Computer controls automate the water accounting of system operations.

Water Quality Monitoring Plan

An investigation was made of the data required to analyze the system's performance. Field data necessary to analyze the LAD system included: water delivered to the LAD system, rainfall, application depth, and deep percolation. From the field data, calculations of crop uptake and evaporation were made. The water quality monitoring plan to measure the water and nitrogen utilization performance of the LAD system was implemented in two phases. A pilot monitoring program under Pivot #1 began in 1994 and was expanded as Phase II in 1995 to include Pivot #2.

Bucket lysimeters and rain gages were installed to quantify water application, rainfall, deep percolation, and crop uptake. Samples from the lysimeters and rain gages allow quantification of water quantity and quality for both the water applied and the water deep percolated. SMC's monitoring data was summarized by MSE-HKM and presented in two reports (HKM Associates, 1994 and MSE-HKM, Inc., 1995).

Additional water quality monitoring components in place at Stillwater Mine include monitor wells, located down gradient of the LAD area. The monitoring plan also includes periodic soil sampling to assess the long-term effects of applying nitrogen to the soil.

LAND APPLICATION DISPOSAL (LAD) SYSTEM

LAD System Layout and Operation

SMC installed two center pivots, Pivot #1 and Pivot #2, in the fall of 1993 and the spring of 1994, respectively. Pivot #1 and Pivot #2 cover 19.5 and 22.0 acres (7.9 and 8.9 hectares), respectively. Pivot #1 operated on a limited basis in the fall of 1993, with full operation and monitoring beginning in 1994. Pivot #2 had limited operation in 1994, with full operation and monitoring beginning in 1995. Twelve lysimeters and rain gages, including three baseline units outside the irrigated area, were installed. Figure 1 shows the layout of the center pivots and monitoring components.

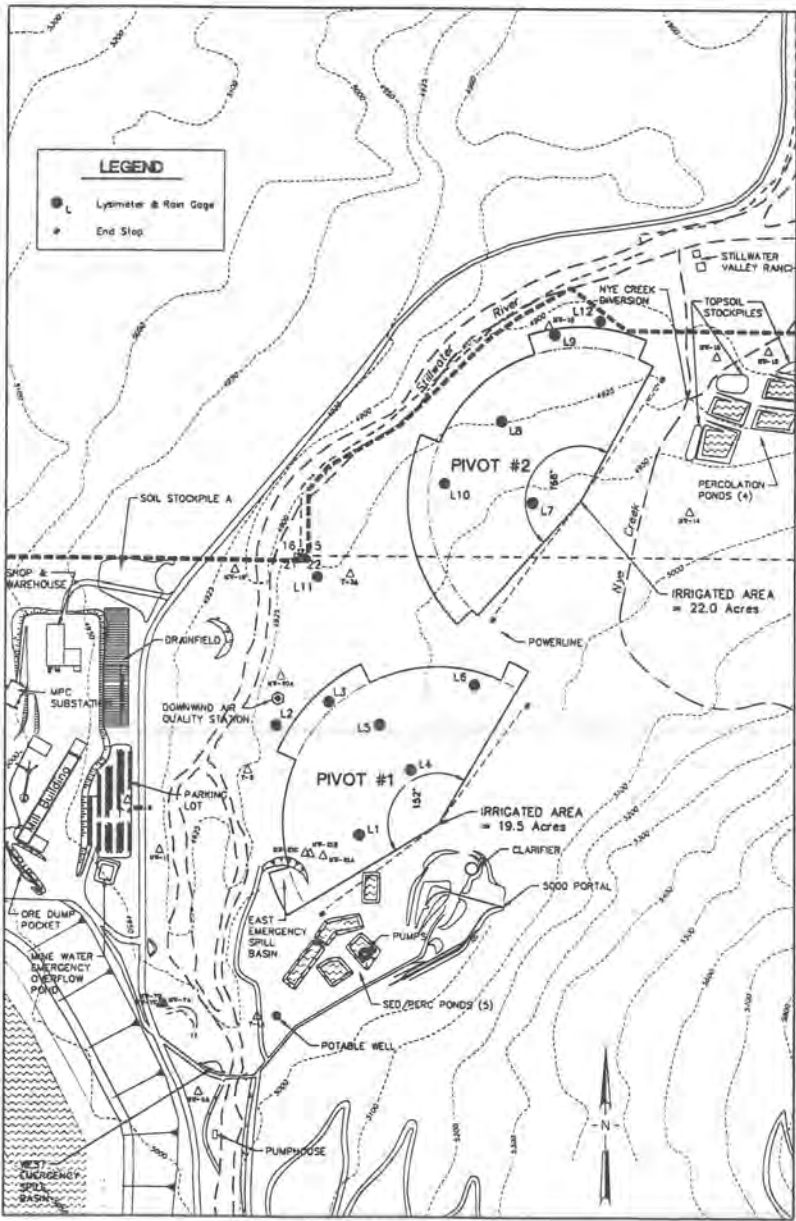


Fig. 1. LAD System Layout

Seasonal operation of the center pivots generally begins in May and ends in late October. During warm, dry autumn seasons, the pivots may operate well into November. Typically, the systems are operated 10 to 12 hours per day, Monday through Friday. During light rain showers, the systems generally continue operation. However, during regional storm fronts producing heavier rainfall, the LAD systems are usually shut off.

Water Quality Monitoring Plan

Adit water flows from clarifiers on the east and west sides are measured and sampled continuously, producing a daily composite sample from each side. Flows through the center pivots are measured by flow meters at each pivot's computerized control panel. Water delivered to the LAD system is sampled daily, and composited weekly. Precipitation and irrigation under the LAD system and in the baseline lysimeters are measured daily. Daily samples are combined into a weekly composite for each sampling site. Deep percolation samples are collected weekly from each lysimeter using a suction pump. Soil samples are collected twice per year, before and after the LAD season. Monitor wells are sampled quarterly by SMC personnel. All water quality monitoring samples are analyzed by a certified independent laboratory.

RESULTS

The overall performance of the LAD system can be defined by the amount of nitrogen deep percolating from the LAD area versus the amount of total nitrogen delivered to the system. In 1994 and 1995, the nitrogen utilization efficiencies of the LAD system were 98% and 83%, respectively. The LAD system performance was lower in 1995 than in 1994 due, in part, to a very wet spring season in 1995. The water utilization efficiencies in 1994 and 1995 were 62% and 43%, respectively. The performance of SMC's LAD system for 1994 and 1995 is summarized in Table 1. Figures 2-7 show graphical representations of the results for 1994 and 1995. Detailed results of this study are presented in two annual LAD performance reports (HKM Associates, 1994 and MSE-HKM, Inc., 1995).

The total annual water delivered to the LAD area exceeded the crop water use potential of the forage, resulting in deep percolation. However, annual nitrogen loads delivered to the LAD area were less than the nitrogen uptake potential of the crop. Therefore, nitrogen utilization efficiencies are significantly higher than the water utilization efficiencies. Total annual nitrogen loads delivered to the pivots averaged 122 lbs/ac (137 kg/ha) and 79 lbs/ac (89 kg/ha) in 1994 and 1995, respectively. An SCS trial at the Bridger, MT plant materials center found that Garrison Creeping Foxtail has increasing yields with nitrogen application up to 240 lbs/ac/yr (270 kg/ha/yr) (SCS, 1979).

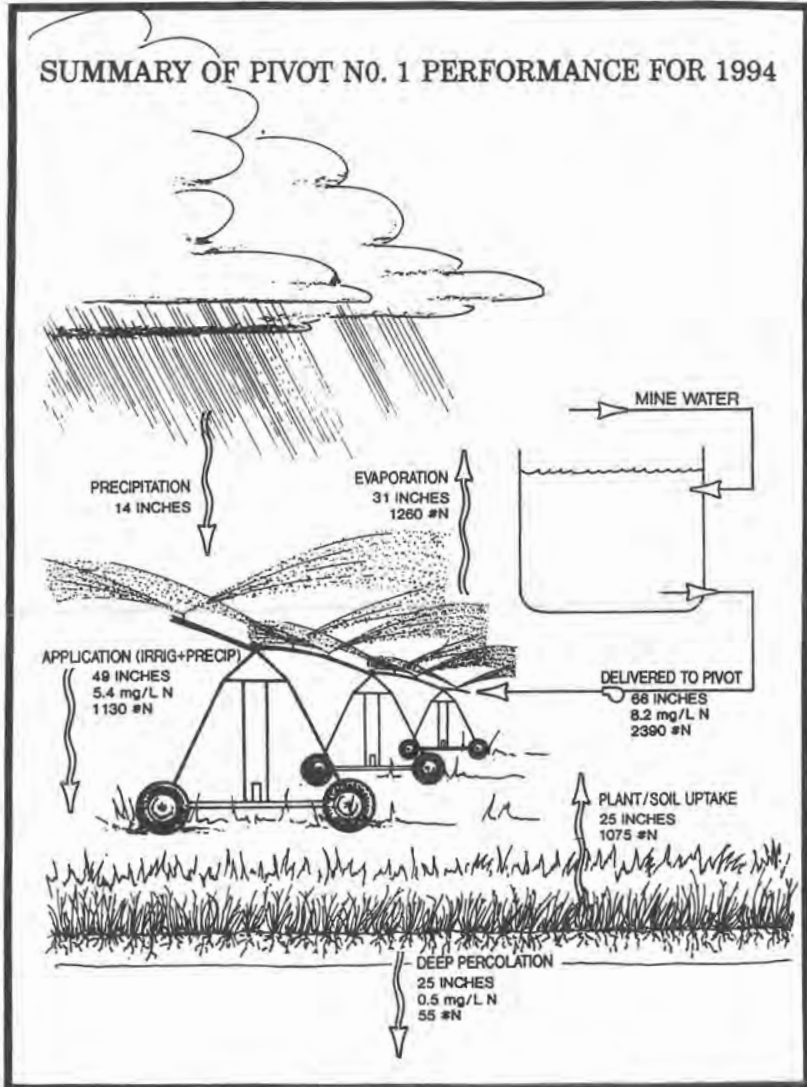


Fig. 2. 1994 LAD Performance

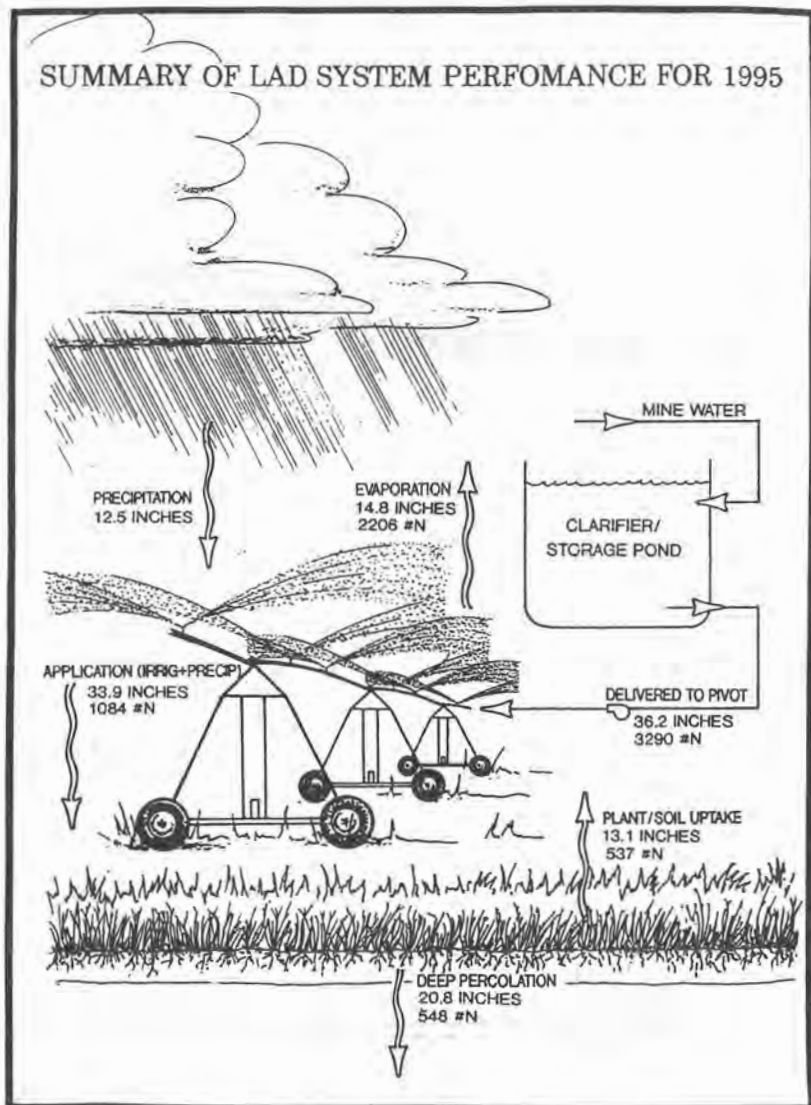


Fig. 3. 1995 LAD Performance

1994 WATER

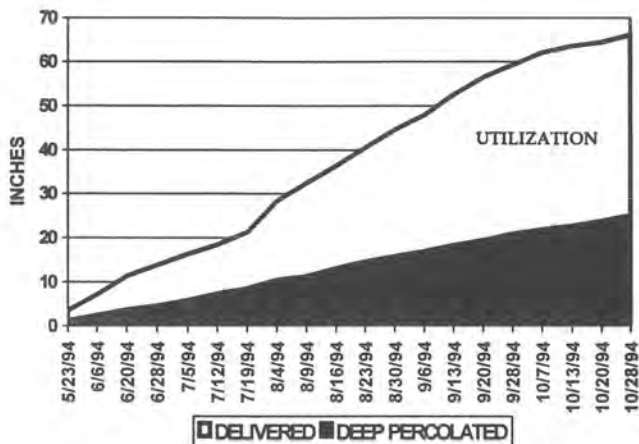


Fig. 4. 1994 Cumulative Water Utilization

1994 NITROGEN

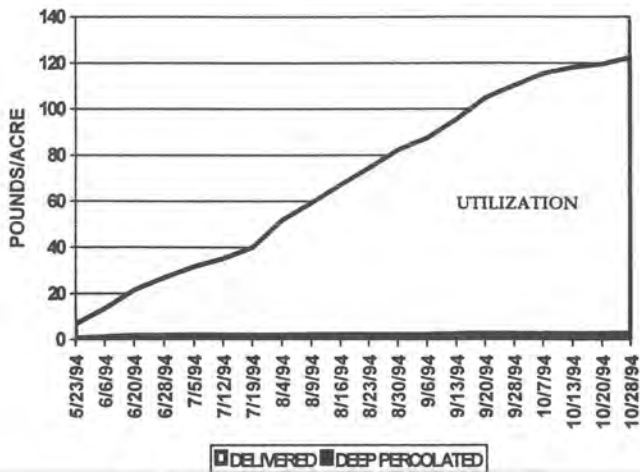


Fig. 5. 1994 Cumulative Nitrogen Utilization

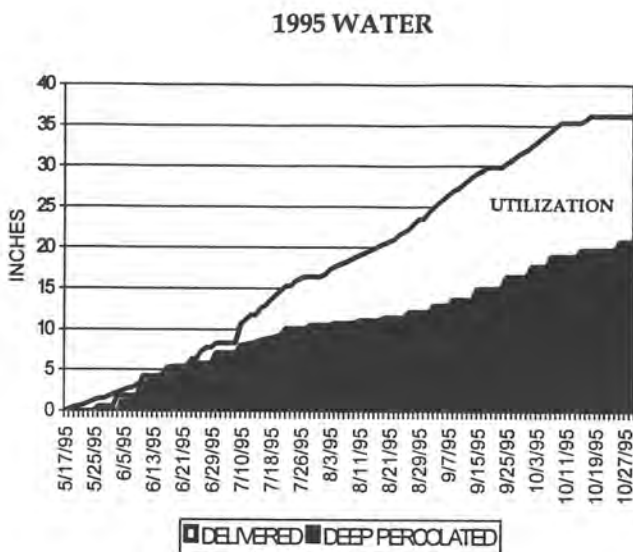


Fig. 6. 1995 Cumulative Water Utilization

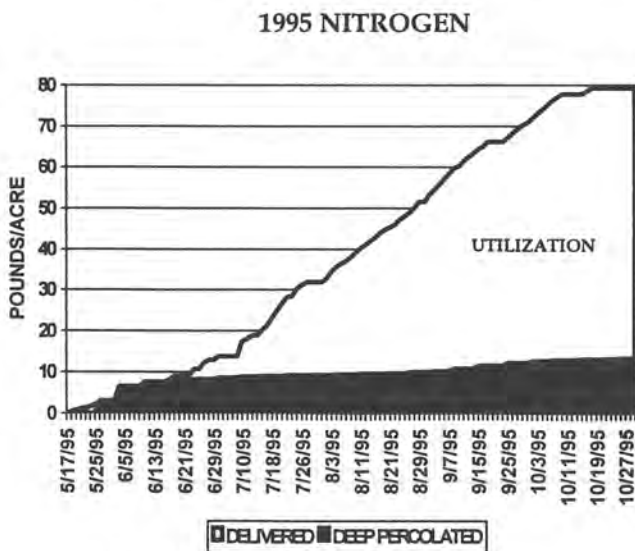


Fig. 7. 1995 Cumulative Nitrogen Utilization

TABLE I. LAD PERFORMANCE SUMMARY

WATER				
	1994	1995	1995	1995
	PIVOT #1	PIVOT #1	PIVOT #2	TOTAL
Delivered to LAD, af (ha-m)	107 (13.2)	78 (9.6)	47 (5.8)	125 (15.4)
Delivered to LAD, in (mm)	66.14 (1,680)	47.82 (1,215)	25.82 (656)	36.16 (918)
Applied to ground, af (ha-m)	80 (9.9)	65 (8.0)	46 (5.7)	111 (13.7)
Applied to ground, in (mm)	48.93 (1,243)	40.03 (1,017)	28.37 (721)	33.85 (860)
Precipitation, in (mm)	13.80 (351)	12.50 (318)	12.50 (318)	12.50 (318)
Deep percolation, in (mm)	25.13 (638)	29.06 (738)	13.39 (340)	20.76 (527)
Evaporation, in (mm) (Calculated)	31.01 (788)	20.30 (517)	9.95 (253)	14.81 (376)
Crop uptake, in (mm) (Calculated)	24.75 (629)	10.96 (278)	14.98 (380)	13.09 (332)
Water Utilization Eff (%)	62%	39%	48%	43%
NITROGEN				
	1994	1995	1995	1995
	PIVOT #1	PIVOT #1	PIVOT #2	TOTAL
Delivered to LAD, lbs (kg)	2,386 (1,085)	2,060 (936)	1,230 (559)	3,290 (1,496)
Delivered to LAD, lbs/ac (kg/ha)	122 (137)	106 (119)	56 (63)	79 (89)
Applied to ground, lbs (kg)	1,152 (524)	623 (283)	462 (210)	1,084 (493)
Applied to ground, lbs/ac (kg/ha)	59 (66)	32 (36)	21 (24)	26 (29)
Precipitation, lbs (kg)	0 (0)	0 (0)	0 (0)	0 (0)
Deep percolation, lbs (kg)	53 (24)	413 (188)	134 (61)	548 (249)
Evaporation, lbs (kg) (Calculated)	1,233 (560)	1,438 (654)	768 (349)	2,206 (1,003)
Crop uptake, lbs (kg) (Calculated)	1,099 (500)	209 (95)	328 (149)	537 (244)
Nitrogen Utilization Eff (%)	98%	80%	89%	83%

CONCLUSIONS

A successful, state-of-the-art land application disposal system and monitoring program was implemented at SMC to utilize nitrogen and to reclaim chromium tailings. The LAD systems at Stillwater Mining Company had very high nitrogen utilization efficiencies during 1994 and 1995. The surrounding environment has been enhanced by significant improvements in forage quantity and quality. This project illustrates that an inter-disciplinary team of engineers, environmental specialists, and state and federal regulatory personnel can successfully work together to protect and enhance the environment.

Montana's Department of Environmental Quality calls land application "a preferred method of ultimate wastewater disposal" (MDEQ, 1995). Land application systems, when designed, managed, and operated correctly, may be an important tool in wastewater treatment and disposal. LAD systems should be considered in future planning and for remediating existing water quality problems.

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HYDROLOGY TOOLS FOR WETLAND DETERMINATION HANDBOOK

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ABSTRACT

The Hydrology Tools for Wetland Determination Handbook is an outgrowth of a Natural Resources Conservation Service (NRCS) Water Management and Hydraulic Engineers Workshop in Wilmington, Delaware, in 1991. Existing analytical hydrologic and hydraulic procedures used to determine wetland hydrology are in a Chapter 19 of the National Engineering Field Handbook (NEFH). Chapter 19 is in the final step of the printing process. These analytical tools determine duration and frequency of inundation or saturation.

INTRODUCTION

The Hydrology Tools for Wetland Determination is Chapter 19 of the National Engineering Field Handbook, Part 650, Field Office Handbook. Chapter 19 is an outgrowth of a NRCS Water Management and Hydraulic Engineers Workshop in Wilmington, Delaware in 1991. These analytical tools determine the duration and frequency of inundation or saturation in a potential wetland. Chapter 19 is used by engineers as well as non-engineers. The chapter was reviewed by Representatives of the signatory agencies to the 1994 Memorandum of Agreement, Concerning the Delineation of Wetlands for Purposes of Section 404

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of the Clean Water Act and Subtitle B of the Food Security Act. The four signatory agencies are the Environmental Protection Agency (EPA), Fish and Wildlife Service FWS, Natural Resources Conservation Service (NRCS) and Corps of Engineers (COE).

Local state technical committees determine the applicability of each tool. The chapter can be supplemented at the state level.

Handbook

There are seven major sections in Chapter 19. Each section contains an analytical tool and explains the use of the tool, data requirements, sources of the data and limitations of the procedure. An example of the calculations is provided. In some cases, the section talks about the development of a tool for a particular area or county.

First Section: The first section describes the use of stream and lake gage data to determine duration, frequency and depth of inundation of water in riverine and freshwater wetlands. The procedure assumes the water is from out of bank sources rather than direct precipitation. The procedure requires at least 10 years of continuous gage data at or near the potential wetland being studied. The procedure describes the analytical and statistical techniques used to characterize the wetland.

Second Section: This section discusses how runoff volumes are used to determine the duration, frequency and depth of inundation of water in ponded wetlands. Four procedures are outlined in this section: (1) use of stream gage data, (2) use of computer models, (3) manual method of determining runoff volumes from daily rainfall records, (4) use of runoff volumes to develop a relationship of contributing drainage area to surface area of the pothole wetland. The fourth

procedure evaluates impact of storage terraces on the hydrology of wetlands. The information in this section can be used to determine the hydrology for wetland restoration. This section suggests that 30 years of precipitation data are required to determine the average runoff volume to the wetland.

Third Section: The third section describes the use of precipitation data to understand the signature on aerial photographs. The procedure is used to select the flights used in off site procedures as outlined in the National Food Security Act Manual (NFSAM). The current methodology suggests that an equal number of wet and dry year flights be used and this section indicates how to determine wetness. The chapter also indicates that 5 years of aerial photographs is the minimum number of flights. The flights must be during the growing season. This section does not describe how to interpret a wetland signature on a photograph. The procedure described is a way of normalizing a short-term record. The procedure is effective when at least 20 years of precipitation data are available.

Fourth Section: The next section discusses the use of the DRAINMOD computer program to establish the degree of saturation of a wetland under a wide range of drained and nondrained conditions. DRAINMOD also normalizes a short-term well record. Normally, DRAINMOD will not be run for every site; it should be used where the usual techniques do not provide an answer. This section does not provide instruction on use of the DRAINMOD computer program, but provides information on how to evaluate the output. DRAINMOD uses hourly precipitation data for at least 20 years.

Fifth Section: The fifth section describes the use of scope and effect equations to evaluate the effect of surface and subsurface drainage measures on wetland hydrology. Scope and effect equations also determine lateral extent of the modification. Currently, the ellipse equation is in the handbook;

however, other equations can be used. Scope and effect equations only represent the average condition.

Sixth Section: The next section discusses how information in drainage guides can be used to evaluate the effects of drainage systems and as input data for computer programs. An up-to-date state drainage guide is a preliminary screening tool to determine if the wetland hydrology has been removed. State guides also provide information on the hydraulic conductivity of soils in the area.

Seventh Section: The last section outlines how observation well data is analyzed to determine if the duration, frequency and depth criteria for saturation are met. This section does not describe how to install observation wells. It sets some length of record criteria and how to correlate well data with precipitation data to normalize the short periods of record.

FIELD TEST

The analytical procedures in the Chapter 19 have undergone field testing. The signatory agencies participated in the field test at various locations in 24 states. The locations were selected to be representative of a wide range of conditions and tools. Preliminary results indicate that the tools provide additional information about the duration and frequency of inundation and saturation. Any changes in the procedures as a result of the field test are being incorporated into the final version of the handbook. As part of the peer review, a final report of techniques described in the chapter is being prepared.

TRAINING SESSION

NRCS developed a training session to explain how each tool can be used to determine the duration and frequency of inundation and saturation. The training was developed for users of the handbook that are not experts in hydrology analytical techniques.

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DINNER ADDRESS

Lloyd A. Jones¹

We in North Dakota are national leaders. We lead the nation in duck production and we have more individual wetland basins than any other state. We also lead the nation in the production of barley, flax, oats, sunflowers, durum and spring wheat. We are third in potatoes and we may be gaining on that shortly.

You may notice the potential for conflict between conservation or wildlife interests and agriculture with this information. *Both* interests lead the nation in production of a precious commodity — wildlife and crops.

The theme of this seminar is a win-win in water, wildlife and agriculture. That's a noble goal, but I would offer that it should not only be a goal, but a mandate. It *has* to be a win-win; there is not other choice. If only one wins, that means the other has lost. Our state, our region, our country and our earth cannot afford to have only one win. We can't afford to see viable and essential food production decreased and we value the quality of life afforded by a healthy and sustainable wildlife population. We can't think of anything less than a total win-win solution. That must be a mandate.

Can that happen? Yes, as mentioned, there is no alternative; it must happen. How it will happen is a path less clear. It is known however, that all of the water, agricultural and wildlife interests need to challenge themselves to do business in ways different than ever done before. They need to change, adapt to a new way of business, if we are to see a win-win.

Is there any evidence that change is occurring? Yes, just look at the transformation in the direction of the Bureau of Reclamation. Seen any big dams built lately? Look at the transformation in the direction of the SCS, now called the NRCS. Seen any publicly funded wetland drainage projects lately? They even changed their name to reflect more of a resource perspective. By the way, I wish the U.S. Committee on Irrigation and Drainage would consider a similar change. "Drainage" generates a high level of concern with the loss of wetlands through drainage practices and projects. Look at the title of this conference. Seen a lot of irrigation conferences with wildlife and environment in the titles lately? I doubt it.

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These by name are not substantive issues, but they are an indication of change, a positive change in the right direction. A change that must occur and continue if there will be a win-win.

As for wildlife interests, of which I am one, so I am pointing to myself, there is a great need for change. And in honesty, I haven't seen the needed interest or commitment to change. We often see the nobility of fight or opposition to a project or initiative as a measure of success, losing sight of the outcome to the resource we are committed to protect. And, as a result of not looking for opportunities that may have benefited the environment within water or agriculture projects, we may have sold the resource short. I haven't seen the change needed to succeed in getting that long-term win-win.

Part of the reason for that, is that wildlife has much less than ever before. There is less wetlands, less grassland and less wildlife. All this less when there is more cropland, more land being converted to a different use as a result of development at the expense of habitat. A difficult reality to deal with, but one that must be addressed for wildlife interests to change and for there to be a win-win.

Let me leave this line of discussion with that clear direction. Regardless of what group you are associated with, you need to change. You need to progress to a more common goal, the win-win or result which benefits all.

It won't be easy, it won't be quick. It won't be without the urge to maintain that philosophical and purist attitude that your interests are right and theirs are wrong. However difficult that change is, it is essential. Without it there will be no win-win. And, anything less is not an option.

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