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EMPIRICAL VALUATION OF PRAIRIE POTHOLES: FIVE CASE STUDIES

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Abstract. *Dollar values were estimated for four prairie potholes and a wetland complex in North Dakota. Assessing these values required careful consideration of the ecological values and the societal values on a site-specific basis. Assessments of value were made from four perspectives—owner, user, regional, and social. Values of specific outputs and total values varied among the five study sites. Annual per hectare values varied from the $10 owner value for the Nome wetland to the $921 regional value for the Alice wetland. The greatest analytical obstacle to obtaining more refined estimates was the physical and biological data needed to technically quantify wetland functions (e.g., groundwater recharge rates, groundwater flow paths and flow rates, runoff water storage capacity, impacts of runoff timing on flood synchronization, and sedimentation rates).*

The perceived worth of wetlands has increased rapidly over the past two decades (Heimlich 1991) as society, "educated" by special interest groups, has come to consider that wetlands provide a wide range of social benefits. These social benefits include floodwater retention, sediment entrapment, nutrient assimilation, aquatic habitat, and terrestrial habitat (U.S. Department of Transportation 1983; U.S. Fish and Wildlife Service 1984; Amacher et al. 1989; Stavins 1990). Increasingly aware of these social benefits and of continued wetland conversions, many emphasize carefully considering the fate of remaining wetlands. Such consideration includes objective assessments of their economic worth to society, especially when there are competing uses for the space they occupy, such as for agriculture or roads.

Less than half of the wetlands existing a hundred years ago in the Prairie Pothole Region remain today (Dahl 1990). A majority of the remaining prairie pothole wetlands in the United States are in North Dakota. The state has been involved in the controversy about wetland management for nearly three decades. Most public concern has been fueled by reactions to the Food Security Act of 1985 (P.L. 99-198), the 1990 Farm Bill's (P.L. 101-624) swampbuster provision, and the Clean Water Act's (P.L. 95-217,91) 404 permitting process (Leitch and Baltezore 1992). Although progress toward resolution has been made, disagreement remains over the relative values of wetlands when making public policy choices among wetlands or between wetlands and alternatives. This disagreement stems mostly from the lack of credible economic valuation estimates for the outputs of wetlands at the margin (i.e., one more or one less).

Published wetland value estimates have ranged from $299 per hectare for South Dakota seasonal wetlands (Hubbard 1989), to $6,669 per hectare per year for Louisiana coastal wetlands (Gosselink et al. 1974), and to $23,465 per hectare for Charles River wetlands (Ostro and Thibodeau 1981). Ferguson et al. (1989) used an opportunity cost assessment to estimate that the annual value of the Cowichan Estuary in British Columbia was $9,139 per hectare. Grigalunas et al. (1992) estimated the annual worth of Louisiana coastal wetlands was at least $766 per hectare. Most estimates, although attracting attention to the issue, are not well suited for policymaking. Policymakers need values that are measured similarly (i.e., conceptually consistent) to alternative use values (Chappelle and Webster 1993).

Common shortcomings of wetland value estimates include

(1) estimating total or average values, and not values of the marginal unit of wetland;
(2) assuming all the value of a wetland output is attributable to the wetland (e.g., wetland hay, fish and shellfish) without considering values of other inputs (i.e., fuel, labor, or other life cycle supports);
(3) including values not included in evaluating alternative uses (e.g., option, bequest, or existence values);
(4) measuring value using a nontraditional denominator, such as energy or biomass, and converting to currency values using market prices;

(5) assuming only one value perspective, when there are at least four; and
(6) simply not adhering to economic principles and concepts.

These shortcomings do not make estimated values necessarily incorrect, but do make them inconsistent with valuations of alternatives and therefore inappropriate for policy making (at least until alternatives are evaluated similarly).

Purpose

The purpose of this paper is twofold: (1) to report empirical dollar estimates of five specific wetlands and (2) to draw attention to critical data shortfalls in the valuation process. This was not meant to be a sample representative of the values of any set of wetlands other than just the five specific cases. A conceptually sound process of economic valuation was followed to estimate the dollar worth of selected pothole wetland outputs. The initial results of applying this process to five case study wetlands is presented. This valuation exercise highlights areas where additional data would be necessary to conduct credible, site specific economic valuations.

Procedure

The overall procedure was an application of off-the-shelf economic evaluation methods to assess the worth of wetland outputs to various stakeholders (Fig. 1). Those methods included

(1) next best alternative,
(2) costs avoided or damages prevented,
(3) estimating consumers' and producers' surplus, and
(4) input-output (multiplier) analysis (Table 1).

Assigning dollar values was straightforward, the difficult part was quantifying outputs in technical units to which monetary values could be assigned.

Numerous explicit assumptions had to be made regarding the characteristics of wetland outputs, these included:

- groundwater (1) is recharged by wetlands (the extent was estimated based on watershed size, average annual precipitation, and

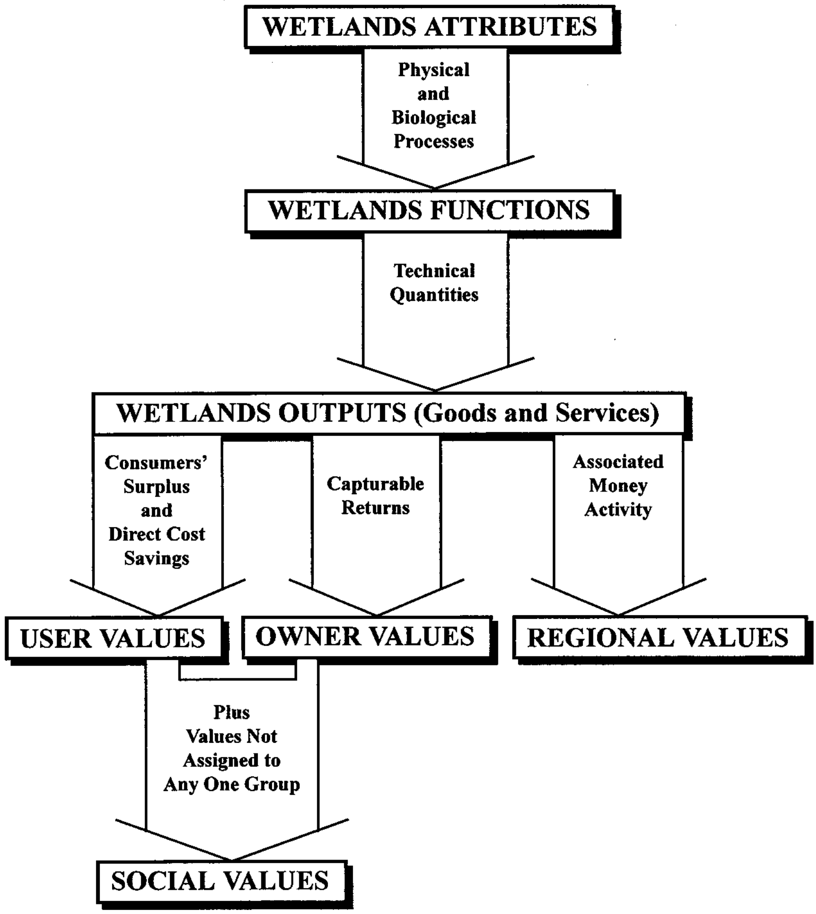

Figure 1. Wetlands evaluation process.

secondary infiltration estimates), (2) is potable without treatment, (3) is available at a functional well operating at zero cost, and (4) is locally scarce;

- flood control values were zero when downstream flood protection measures had excess capacity, otherwise they were assumed to be proportional to their volumes, assuming depth-damage functions were linear and timing was such that the detained water would have coincided with the flood peak;

TABLE 1
VALUATION METHODS USED TO VALUE THE OUTPUTS OF SPECIFIC PRAIRIE POTHOLE WETLANDS

Value/Output	Valuation Method
USER Value	
Groundwater Recharge	Cost of next best alternative (rural water system)
Flood control	Damages prevented by flood water retention
Wildlife habitat (consumptive and nonconsumptive)	Estimate of consumers' surplus[a] (from the literature)
Aquatic habitat	Producers' surplus[b] (bait sales)
Sediment entrapment	Damages prevented downstream
Nutrient assimilation	Water treatment costs avoided
OWNER Value	
Wildlife habitat	Producers' surplus (hunting leases)
Agriculture	Producers' surplus (commodity sales)
REGIONAL Value	Input-output analysis (multipliers)
SOCIETAL Value	Aggregate appropriate user and owner values
Bequest/Option/Amenity/ Aesthetics/Education/Research	Insignificant at the margin due to nonunique nature of study sites

[a] Consumers' surplus is the benefit individuals receive from consumption over and above their costs.

[b] Producers' surplus is the return to producers over and above their input costs.

- wildlife habitat (1) is provided in part by 2.49 million acres of wetland in North Dakota, (2) value estimates are made at the margin, *ceteris paribus*, (3) value estimates can be developed from published estimated relationships between expenditures and consumers' surplus, and (4) wetlands are responsible for 44% of the total habitat requirements for waterfowl, 11% for upland game, 40% for furbearers, 9% for big game, 15% for nonconsumptive wildlife;

- sediment entrapment values of wetlands are approximated by estimating (1) site specific soil erosion factors, (2) volumes retained by the wetland, (3) downstream water uses, and (4) costs to remove sediment downstream;

- agricultural use values were developed from existing farm budgets; and

- aesthetic and education/research values were assumed small at the margin for the study wetlands (they are in relatively isolated areas with an abundance of nearby wetlands) and were not included.

These assumptions, and others, were based on the best available information and were either potential upper bound estimates or lower bound, as appropriate, resulting in a generous estimate of the wetland's contribution.

Five study wetlands were selected with the help of a panel of "wetland experts" from the state. Four "generic" prairie potholes and one prairie pothole wetland complex served as study sites. Wetlands without notable special characteristics were selected. The four wetlands are like tens of thousands of others in the Prairie Pothole Region, while the wetland complex represents perhaps a few hundred similar areas in the Prairie Pothole Region.

Hovde (1993) empirically estimated values for a semi-permanent and a saturated wetland. Hovde and Leitch (1994) replicated Hovde's (1993) procedure to estimate values for two more individual wetlands and for the wetland complex.

Site visits and information from secondary sources, including discussions with experts, were used to characterize the attributes, functions, and outputs of each wetland. Technical and economic assessments were used to quantify each of the identified wetland outputs. Telephone interviews with wetland owners provided information to estimate owner values. User values were estimated by assuming consumers' surplus was equal to a percent of expenditures as reported in the literature (Anderson et al. 1985; Jacquemot and Filion 1987). For example, hunters in North Dakota were found to value a day of hunting at 140% of its cost to them. Input-output analyses (Coon and Leitch 1990) of user and owner money flows provided the estimation of regional values. Aggregating the estimated dollar values for each of the identified wetland outputs resulted in an approximation of social values.

Initial estimates of values were circulated to a state-level panel of wetland experts for their comments and ideas on how to achieve a more accurate (i.e., more narrow confidence interval) final estimate. Agreement was difficult to reach on the many assumptions made to fill in where the literature fell short.

Study Wetlands

The **Nome wetland** is approximately 3 kilometers southwest of Nome, North Dakota (Fig. 2). It formed in a local depression in what is now section 23 in Thordenskjold Township, Barnes County. The Nome wetland, a Type III (Shaw and Fredine 1971)/PEMC (palustrine emergent semi-permanently flooded, ala Cowardin et al. 1979) covers 1.2 hectares of its 8-hectare drainage basin. Emergent vegetation, primarily cattail (*Typha spp.*), has completely covered the wetland for at least the past five years. In 1987, the first year of available recorded ecological information about this wetland, vegetation covered 80 percent of the wetland and the water level was at about 50 percent of capacity. Since then, the wetland has dried out and has become fully vegetated (Hoisted 1993). A border of native grasses surrounds the wetland and a farmstead and fields surround the grass border.

The **Buchanan wetland** is 19 kilometers east of Buchanan, North Dakota in Round Top Township, Stutsman County. It is a Type IV (Shaw and Fredine 1971)/P(EM/AB)F (palustrine emergent aquatic bed saturated) wetland that covers approximately 7 hectares of its 99-hectare drainage basin. An elevation difference of 1.5 meters separates this wetland from its overland drain to the wetland below. Vegetation, primarily bulrush (*Scirpus spp.*), covers about 70 percent of the wetland. A 130-hectare U.S. Fish and Wildlife Service Waterfowl Production Area abuts two sides of the study wetland; agricultural uses dominate the other sides.

The **Alice wetland**, 10 kilometers west of Alice, North Dakota was formed in a local depression in Clifton township, Cass County. This wetland was chosen for study partly because information about the soils, hydrology, and landscape was available (Malo 1974). Malo (1974) called it a Type IV flow-through wetland. The National Wetland Inventory map lists it as a palustrine emergent temporarily flooded (PEMA) or Type III. Agricultural Stabilization and Conservation Service aerial photographs from 1985, 1990, and 1993 show that the Alice wetland was cropped those years. Hanson (1994) confirmed the wetland had been farmed from 1988 through 1993 when runoff from above-average summer rainfall inundated the crop. The drainage basin is approximately 7 hectares, and the wetland is approximately 3 hectares.

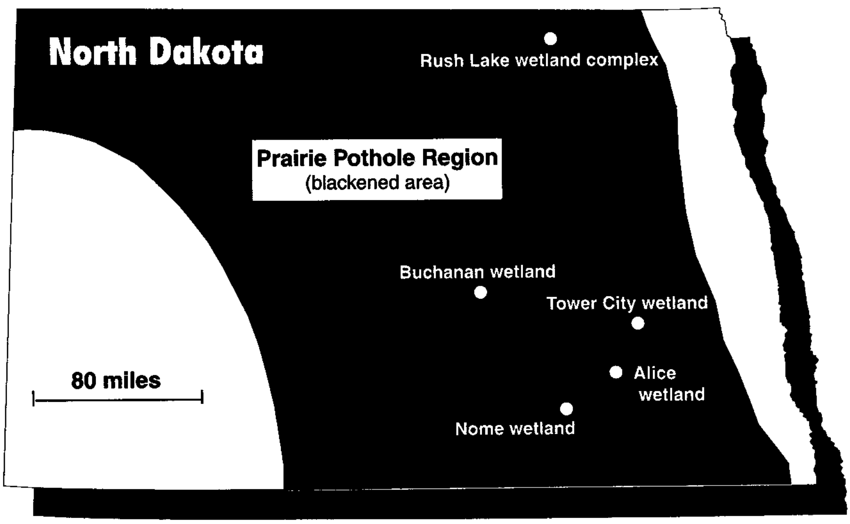

Figure 2. Location of case study wetlands.

The **Tower City wetland** is in Oriska township, Barnes County, 5 kilometers north of Tower City. This 1.6 hectare Type III/PEMC (palustrine emergent semi-permanently flooded) wetland is fully vegetated with cattail and prairie grass (*Juncaceae spp.*). The Maple River is only 6 kilometers to the east of the Tower City wetland, but any water overtopping the basin would meander approximately 19 kilometers southward before joining the Maple River.

The **Rush Lake wetland complex** is approximately 890 hectares of wetland and 970 hectares of associated upland in the Rush Lake Restoration and Flood Control Project, including the 280-hectare Rush Lake proper. Wetlands in this area consist of Types I, III, and IV (PEMA, PEMC, P(EM/AB)F, PABF, and others). The wetland complex surrounding and including Rush Lake has been described as ideal waterfowl production habitat and essential in the Central and Mississippi flyways. Groundwater in the local area is highly mineralized with high levels of dissolved solids.

Value Perspective

For many items, especially wetland outputs, value is not a singular, unique attribute. Thus, an often overlooked issue that must be explicitly addressed when valuing wetlands is to identify who the outputs benefit. Value depends on perspective and context. The disciplinary methods do not vary with perspective, but the values used for costs, benefits, and returns may vary considerably. The worth of wetlands can be estimated from at least four separate perspectives: user, owner, regional, and social (Leitch 1981). Money flows and nonmonetary benefits vary according to the type of value being estimated. Most other technical evaluation issues are beyond the limited scope of this paper; however, understanding value perspectives is crucial to efficient and equitable wetland policy.

User values. User values stem from the human consumption of wetland-related activities or products. Consumers (users) of normal products or services receive personal satisfaction equal to or greater than the prices paid for products or services. The net value of a wetland (or any good or service) is the value of the personal satisfaction over and above the price paid for a wetland-related product or service (consumers' surplus). The direct cash price paid, if any, for consuming wetland-related products or services goes to pay the costs of market inputs (e.g., fuel, film, waders). Therefore, none of a user's cash outlays can be attributed to the wetland, although a portion of the price paid, (i.e., rents or leases) may be attributed to wetland as owner value.

Owner values. The inflow of money resulting from the sale of wetland outputs and the owner's use values (owner satisfaction) make up the owner value of a wetland. Wetland owners may receive rents and/or fees for the use of their wetlands. People may rent wetland to harvest hay, or they may pay a fee for hunting access. These rents/fees, less ownership costs (i.e., taxes and insurance), are part of the net owner value of the wetland. The value of the owner's personal use of wetland outputs (the owner's user values) comprises the other part of owner value.

Regional values. Regional business activity values of wetlands are the financial activity in the area resulting from the use (consumptive or nonconsumptive) of the wetland's outputs. Gross business volumes can be estimated by using a regional input-output model (I-O Model) (Coon and Leitch 1990). North Dakota's I-O Model is an empirically-based model of the flows of inputs and outputs among the state's 18 economic sectors which include, for example, agriculture, retail trade, households, and recreation and tourism. This type of model may also estimate changes in employment and/or tax revenues supported by changed business volumes. Gross business volume shows how money passes among economic sectors and "multiplies." The number of jobs business activity supports is based on the volume of money spent in each sector. Regional values are important from an income distribution perspective, but not for national efficiency criteria, since they represent shifts in spending patterns and not additions to spending.

Social values. Social values represent the value of the wetland to "society," *present* and *future*. Social value is not the same as the sum of the value of all the ecological functions, but is the value society realizes from outputs resulting from these functions' outputs. This can be measured by combining compatible user values, owner values, and the values of benefits, such as sediment entrapment and nutrient assimilation, which benefit society in general. While the value of the regional impacts from a wetland should not be included in aggregate social value, regional values are appropriate as "tiebreakers" in social decision making.

Results

The purpose of this work was to estimate values by applying available techniques and to assess the viability of the overall process to provide credible values. Thus, one result was the dollar estimates of value for the five study sites. A second result was the identification of needed information to improve the precision of the estimates.

Annual per hectare values of the five wetlands varied from the $10 owner value for the Nome wetland to a $921 regional value for the Alice wetland (Table 2). These estimated values resulted from the different combinations, intensities, and juxtapositions of the attributes of the individual wetlands. For example, waterfowl contributed most to the values of the Buchanan wetland, as a result of stable water quantities. The values of the Tower City wetland, a Type III, resulted primarily from the characteristic drying of the wetland, which allowed the harvest of hay. The values of the Alice wetland were largely a result of the economic activity associated with production of an agricultural commodity in the wetland and the lease payment made to its owner. Rush Lake's value stems from flood control and waterfowl habitat, while the value of the Nome wetland comes from agriculture with some flood control and habitat. Thus, if those five are an indication, prairie potholes are not homogenous in the mixes of valued outputs they provide society.

TABLE 2
ANNUAL AND CAPITALIZED PER HECTARE VALUES
OF FIVE PRAIRIE POTHOLES, 1993

	ANNUAL Per Hectare	CAPITALIZED[a] Per Hectare
USER VALUES	······· dollars	········
Nome	30	494
Buchanan	15	329
Alice	77	1,334
Tower City	47	800
Rush Lake	50	1,102
OWNER VALUES		
Nome	10	163
Buchanan	12	252
Alice	86	1,494
Tower City	22	385
Rush Lake	17	378
REGIONAL ACTIVITY (GBV[b])		
Nome	279	n/a
Buchanan	146	n/a
Alice	921	n/a
Tower City	618	n/a
Rush Lake	361	n/a
SOCIAL VALUES		
Nome	40	667
Buchanan	27	618
Alice	163	2,818
Tower City	69	1,186
Rush Lake[c]	67	1,480
NEGATIVE VALUES[d]	······ not estimated	······

[a] Capitalized at four percent; 30 years for the Nome, Alice, and Tower City wetlands, 60 years for the Buchanan wetland and the Rush Lake wetland complex.
[b] Figures shown are gross business volumes.
[c] Rush Lake estimate represents minimum lower bound because all social values were not estimated.
[d] A comprehensive analysis of absolute values would incorporate negative values (e.g., crop depredation, mosquito control, and other nuisance factors).

Source: Hovde and Leitch 1994.

These values are for these wetlands only, assuming all other wetlands remain intact and there are no wetlands created or restored. If other wetlands are converted to other uses, the value of each remaining wetland rises. As the total amount and/or number of wetlands decreases, the marginal value (i.e., the value of the next wetland) increases, thus accounting for any "cumulative impact" that may occur. The value of all potholes as a group is larger than the sum of all marginal values of individual potholes if they are valued as if there would be no other changes. Similarly, the value of some or all of the functions of a single wetland may decrease if the total amount of wetlands is increased through creation or restoration.

Public decision making regarding any resource (such as wetland) should compare the resource's social values in one use to conceptually equivalent social values of alternative uses. If the social values do not clearly indicate a best option, regional values may be used as a supplementary input to help make choices. For example, if an alternative use of the Nome wetland had a social value of $50 per hectare annually, then society should encourage that alternative use—wetland preservation would be inefficient because the social value as wetland is only $40 per hectare. However, policymakers must be aware of the impacts to users, the owner, and the region and may choose to compensate for, or mitigate, those impacts. On the other hand, if there are no alternative uses of the Buchanan wetland valued higher than the wetland's $27 per hectare annual value, then society would be rational to protect it as wetland. As with any social decision, policymakers cannot ignore the possible adverse impacts on the other three value perspectives.

Conclusions

The greatest analytical obstacles to more refined estimates of the value of wetland are the physical and biological data needed to technically quantify wetland functions. Specifically, interdisciplinary cooperative research is needed to elaborate on

- groundwater recharge rates of individual wetlands,
- groundwater flow paths and flow rates,
- runoff water storage capacity of individual wetlands,
- impacts of runoff timing on flood synchronization,
- dependency of wildlife on wetland habitat,
- sedimentation rates of individual wetlands, and
- effectiveness of individual wetlands for removing nutrients.

The "natural" values of these five wetlands will likely increase as time passes, but so may the value of the alternative uses. The challenge to policy-makers is to make the right choices to maximize society's well-being over the long-run.

With the help of studies such as this one, reasonable and credible ranges of the values of prairie potholes can begin to emerge. These estimates would be suitable for comparisons among wetlands or between wetlands and their alternative uses. For example, on a per hectare basis, the current use of the Tower City wetland is worth more to society than the Buchanan wetland.

Estimated values for these five prairie potholes appear to differ widely from estimated values of wetlands in the literature. This may be due to these being marginal and not average values, the abundance of prairie pothole wetlands in the study areas, or one or more of the other reasons cited above.

Although a number of assumptions were made to estimate these values, each of the study wetlands now has a single value assigned to it. Even though deviation between the estimated value and the actual value may be large, each study wetland has a value that can be used as a starting point.

Improved data in several technical areas will reduce the reliance on assumptions used in the valuation process. Fewer assumptions will lead to more reliable and more precise value estimates. Until these natural and physical science data become available, additional work to refine economic valuation methods will yield low returns.

Acknowledgments

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