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Valuing Prairie Potholes: Five Case Studies

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Cover Photos: Top–the "Nome" wetland
Bottom–the "Buchanan" wetland

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HIGHLIGHTS

Dollar values were estimated for four individual prairie potholes and a wetland complex located in North Dakota. Assessing the values of these wetlands' outputs 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 acre values varied from the $4 owner value for the Nome wetland to the $373 regional value for the Alice wetland. The dearth of applicable physical-biological science information necessitated many assumptions, which represent areas of needed research. The social values estimated in this study are appropriate only for social decisions about the use or condition of the study's specific wetlands. The range of wetland values should not be generalized into the value of the other millions of acres of wetlands in the Prairie Pothole Region. With this type of empirical value information, wetland management policies and subsequent decisions can begin to be made based on objective criteria rather than subjective values.

VALUING PRAIRIE POTHOLES: FIVE CASE STUDIES

Brett Hovde and Jay A. Leitch*

INTRODUCTION

Perceived values of wetlands have increased rapidly over the past two decades (Heimlich 1991) as society, "educated" by special interest groups, has come to perceive that wetlands provide a range of social benefits. Many descriptions of these social benefits, which include water retention, sediment entrapment, nutrient assimilation, aquatic habitat, and terrestrial habitat, exist (U.S. Dept. 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 the importance of carefully considering the fate of remaining wetlands. Such consideration includes assessments of their economic worth to society.

Less than half of the wetlands existing a hundred years ago in the Prairie Pothole Region remain today (Dahl 1990). The majority of the remaining prairie pothole wetlands in the United States are in North Dakota. The state has been involved in 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.

Purpose

The purpose of this study 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. A conceptually sound process of economic valuation was developed to estimate the dollar worth of selected pothole wetlands. The initial results of applying this process to five case study wetlands are presented. Application of the valuation exercise highlighted areas where additional data would be necessary to improve credibility of the economic valuations. The pragmatic approach forced assumed or hypothesized technical relationships that were identified as areas of critical data needs.

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Previous Work

Published wetland value estimates have ranged from $2700 per acre per year for Louisiana coastal wetlands (Gosselink et al. 1974), to $9500 per acre per year for Charles River wetlands (Massachusetts) (Ostro and Thibodeau 1981), to $121 per acre per year for South Dakota seasonal wetlands (Hubbard 1989). Ferguson et al. (1989), using an opportunity cost assessment, estimated the annual value of the Cowichan Estuary in British Columbia to be $3700 per acre. Grigalunas et al. (1992) estimated Louisiana coastal wetlands to be worth at least $766 per acre annually.

Most past estimates, although attracting attention to the issue, are not well suited for policy-making. Most studies do not fully resolve wetland valuation issues because of one or more of the following four problems (Hovde 1993):

- economic principles are not strictly adhered to,
- studies are limited by not valuing all compatible functions or outputs,
- studies are highly site specific, or
- studies use uncommon denominators.

More importantly, there have been no comprehensive empirical studies of the economic value of prairie potholes. Policymakers need values that are measured similarly (i.e., conceptually consistent) to alternative use values (Chappelle and Webster 1993).

PROCEDURE

Hovde (1993) empirically estimated the values for a semipermanent wetland and a saturated wetland. This study replicates Hovde's (1993) procedure to estimate values for the additional two wetlands and for the wetland complex (Figure 1). The overall procedure was an application of economic evaluation tools to assess the worth of wetland outputs to various stakeholders. Numerous explicit assumptions had to be made regarding the characteristics of wetland outputs. These assumptions were based on the best available information and attempted to be neither optimistic nor pessimistic.

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. The four wetlands are like tens of thousands of others in the Prairie Pothole Region, while the wetland complex is representative of perhaps a few hundred similar areas in the Prairie Pothole Region.

Site visits and information from secondary sources, including discussions with experts, were used to characterize the attributes, functions, and outputs of each wetland (Table 1).

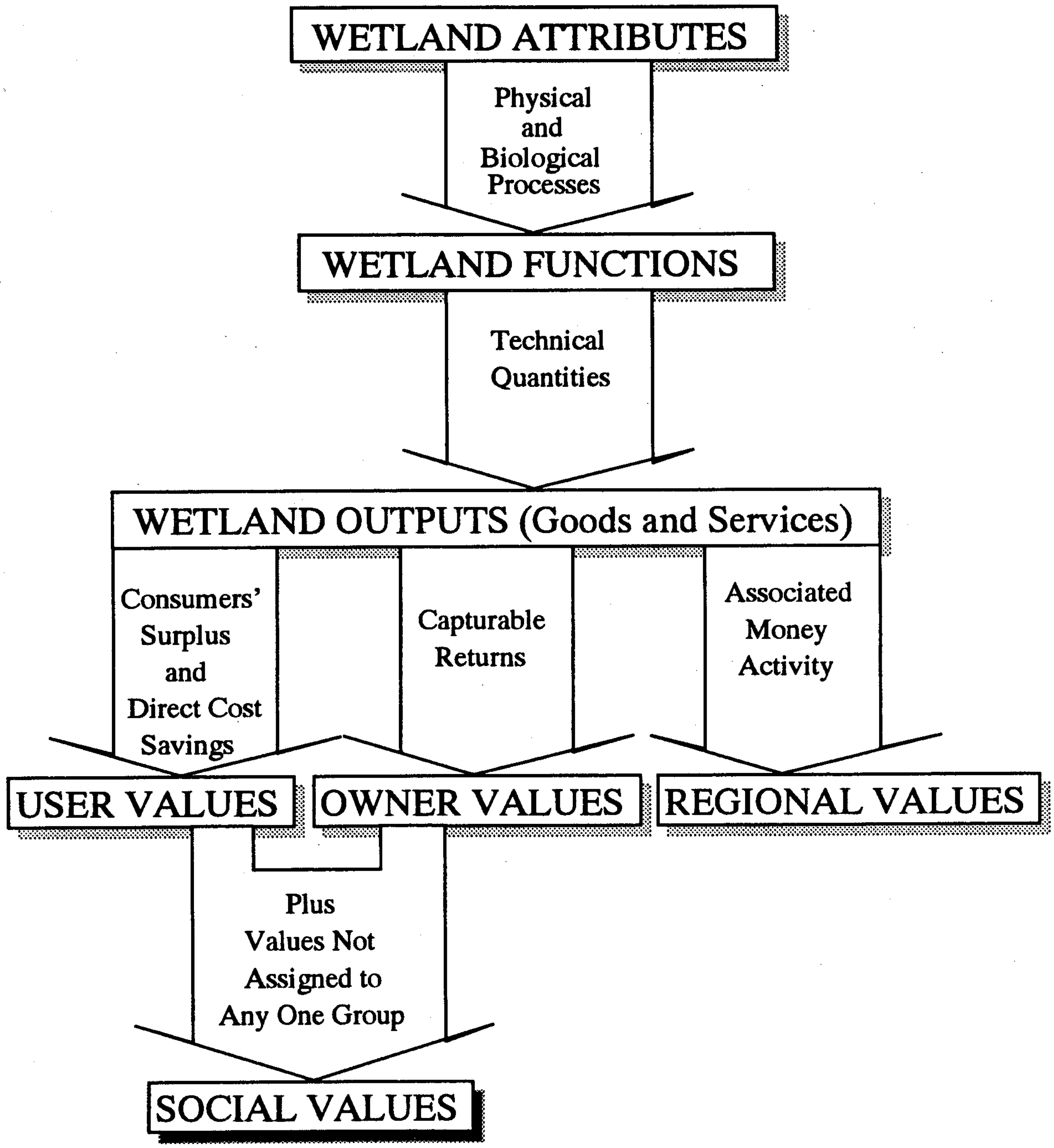

Figure 1. Wetlands evaluation process.

Table 1. Wetland Attributes, Functions, and Outputs

Attributes	Functions	Outputs
Vegetation species types	Terrestrial	
	Fauna	Gene Pool
Vegetation composition		Food Chain
		Nonconsumptive Uses
Substrate type		Consumptive Uses
Water level/temperature	Flora	Gene Pool
		Agricultural Uses
Location of site		
	Aquatic	
Turbidity	Fauna	Gene Pool
		Food Chain
Water quality indices		Nonconsumptive Uses
		Consumptive Uses
Biomass indicators		
	Flora	Gene Pool
	<u>Water Retention</u>	
Size	Altered Flood Hydrograph	Reduction in Peak Flow
Location in basin		
Substrate texture	Groundwater Recharge	Maintenance of Water Tables
Vegetation density and type		
Water permanence	Low Flow Augmentation	Aquatic Fauna
Types of outlets	(in-stream uses)	Water-based Recreation
Soil composition		
Soil storage capacity	Agricultural Uses	Irrigation
		Consumption by Livestock
	<u>Sediment Entrapment/ Nutrient Assimilation</u>	
Sediment deposition rates	Water Filtration	Water Quality Improvements
Particle size		Nutrient Level Reduction
Nutrient level		
Outlet size		
	<u>Aesthetics</u>	
Landscape Diversity	Open Space/ Parkland	Recreational Uses
		Increased Welfare
Ecological Diversity	<u>Education / Research</u>	Environmental Education

Technical and economic assessments quantified each of the identified outputs. Telephone interviews with wetland owners provided information to estimate owner values. A non-survey method of estimating nonmarket values aided the measurement of user values. An input-output analysis of user and owner money flows provided the estimation of regional values. Aggregating the dollar values given to each of the identified wetland outputs led to the social values.

Initial estimates of values were circulated through a state-level panel of wetland experts for their comments and ideas on how to achieve a more precise final estimate. Agreement was difficult to reach on the many assumptions that were made in instances of inadequate literature.

Marginal values (the value of the next or previous unit) of wetland outputs were estimated to arrive at the value of the marginal wetland, although average values (total value divided by the number of units) had to be used as proxies in some instances in the absence of marginal values. Using marginal values allows wetland decisions to be made on a wetland-by-wetland basis as opposed to a blanket policy covering all wetlands. A policy covering all wetlands does not account for the heterogeneous nature of wetlands.

Study Wetlands

The Nome wetland is approximately 2 miles southwest of Nome, North Dakota (Figure 2). It formed in a local depression in what is now section 23 in Thordenskjold Township, Barnes County. The Nome wetland, a Type III/PEMC (palustrine emergent seasonally flooded, as described by Cowardin 1979) covers 3 acres of its 20-acre drainage basin. Emergent vegetation, primarily cattails (*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; the water level was at approximately 50 percent of capacity. Since then, the wetland has dried out and has become fully vegetated (Hoistad 1993). A border of native grasses surrounds the wetland, and a farmstead and fields surround the grass border.

The Buchanan wetland is 12 miles east of Buchanan, North Dakota, in Round Top Township, Stutsman County. It is a Type IV/P(EM/AB)F (palustrine emergent aquatic bed semipermanently flooded) wetland that covers approximately 17 acres of its 245-acre drainage basin. An elevation difference of 5 feet separates this wetland from its overland drain to the wetland below. Vegetation, primarily bulrushes (*Scirpus spp.*), covers about 70 percent. A 320-acre U.S. Fish and Waterfowl Service Waterfowl Production Area abuts two sides of the study wetland, while agricultural uses dominate the other sides.

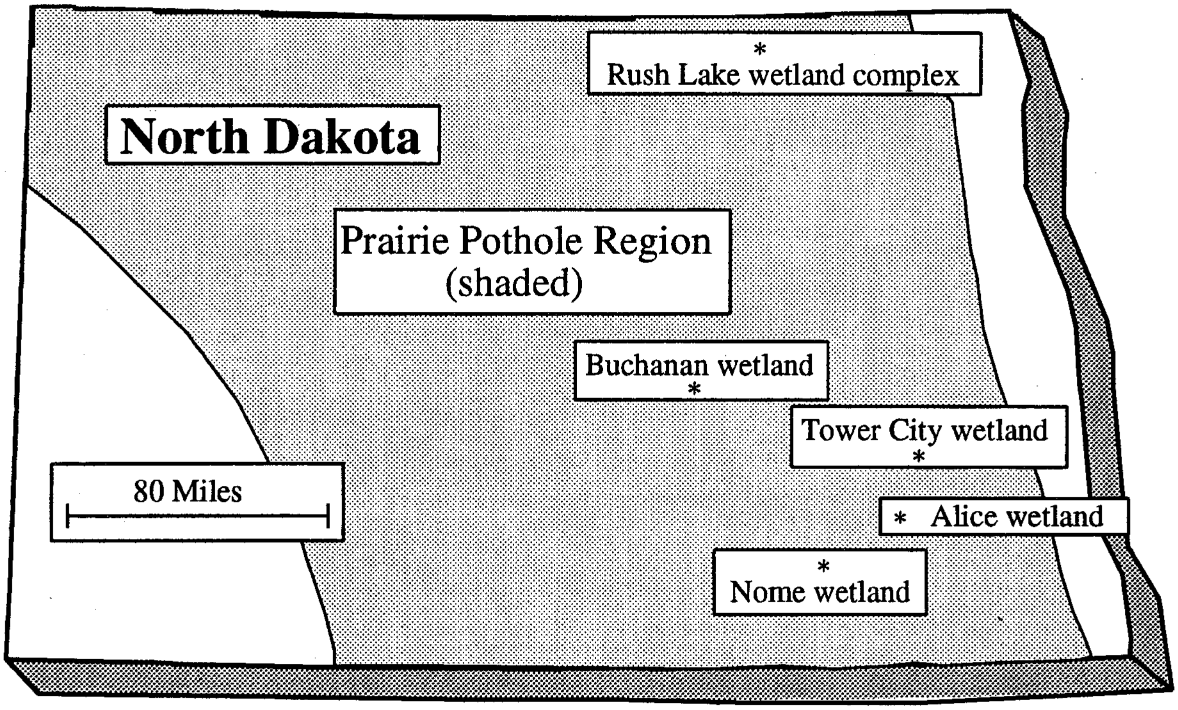

Figure 2. Location of study wetlands

The Alice wetland, 6 miles west and 2 miles north of Alice, North Dakota, was formed in a local depression in Clifton Township, Cass County. This wetland was chosen because information about the soils, hydrology, and landscape was available (Malo 1974). Malo (1974) calls 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. 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 18 acres, and the wetland is approximately 8 acres.

The Tower City wetland is in Oriska Township, Barnes County, 3 miles north of Tower City, North Dakota. This 4-acre Type III/PEMC (palustrine emergent semipermanently flooded) wetland is fully vegetated with cattails and prairie grass (*Juncaceae spp.*). The Maple River is only 4 miles to the east of the Tower City wetland, but any water overtopping the basin would meander about 12 miles southward before joining the Maple River.

The Rush Lake wetland complex is approximately 2,200 acres of wetlands and 2,400 acres of associated upland in the Rush Lake Restoration and Flood Control Project, including the 700-acre Rush Lake proper. Wetlands in this area consist of Types I, III, and IV wetlands (PEMA, PEMC, P(EM/AB)F, PABF, and others). The Rush Lake wetland complex has been described as ideal habitat for waterfowl production and as an essential component of the Central and Mississippi flyways. Groundwater in the local area is highly mineralized with high levels of dissolved solids.

Output Identification

Prairie potholes have been credited with a range of potentially useful functions (Amacher et al. 1989). These functions provide beneficial outputs such as:

-groundwater recharge,
-flood control,
-wildlife habitat,
-aquatic habitat,
-agricultural uses,
-sediment entrapment,
-nutrient assimilation,
-aesthetics, and
-education/research.

Each study site was assumed to supply some level of each output.

Output Evaluation

The wetland evaluation process starts with an initial quantification of the wetlands' outputs in technical and dollar terms. Wetland values are estimated from these quantities. The option, existence, and bequest values of the wetlands must be considered, along with the compatibility of individual outputs, when estimating a wetland's value. Technical quantities can be interpreted from at least four perspectives. Annual wetland values may be converted into capitalized values to facilitate comparisons to other land values (prices).

Output quantification. Each output was quantified for each wetland site to provide a starting point for the value estimates. If the wetland was determined to recharge groundwater, the quantity of water recharge and the local demand for that water was estimated. The flood control output was quantified by estimating the volume of water detained and by the location of the wetland. Quantification of the wildlife habitat output involved linking expenditures on wetland-dependent wildlife to the ability of each wetland to provide wildlife habitat. Aquatic habitat quantification followed the same process as wildlife habitat.

The type and amount of wetland forage (or crop, as was the case of the Alice wetland) and corresponding prices were identified as the starting point for valuing agricultural outputs. Sediment entrapment was quantified by estimating the amount of sediments each wetland could trap and estimating the demand for this function. An assessment of the demand for nutrient assimilation was the initial starting point in valuing this function. Aesthetics and education/research were not individually quantified, but a small positive value was applied to each wetland to account for these benefits. Wetland values may be estimated by applying economic concepts to these measured outputs.

Wetland values. The value of wetland outputs may be ecological or economic. Ecological value is a measure of the wetland's contribution to the ecosystem. Economic value is a measure of the utility (or satisfaction) people receive from the presence of a wetland. Wetland-produced outputs may or may not be linked to a market. The value of the outputs that can be linked to a market is the portion of consumers' surplus (a measure of the satisfaction consumers receive from the purchase of goods or services beyond the price they pay) from wetland-related goods and activities.

The accuracy of market-linked output values depends on how closely the market approximates a purely competitive market. Although the criteria to be considered a purely competitive market are never fully meet, purely competitive markets are assumed for wetland outputs with market links. Outputs without a clear market link may be valued by (1) estimating consumers' willingness to pay/sell or (2) considering the cost to replace a wetland output.

A wetland's value for market-linked outputs comes from consumers' surplus, which can be (should be) attributed to all of the inputs (factors of production) of the producing activity. The value of a wetland is the value of the consumers' surplus assigned the wetland for its contribution of production outputs.

In many cases, the wetland is merely an input for another input for a product or activity (output). Therefore, only a portion of consumers' surplus is attributable to the wetland. In the case of duck hunting, for example, the wetland is an input that contributes to the production of ducks. The ducks are an input that contributes to the production of duck hunting experience. This can be represented symbolically as:

Consumers' Surplus = f(ducks, shotguns, dogs, companionship,...),

where **Ducks = f(wetland, upland, weather, winter habitat,...)**.

The value of the wetland for duck habitat can be estimated, using a portion of hunters' consumers' surplus. The percentage contribution of the wetland to the duck hunting experience will be equal to the percentage of consumers' surplus that can be attributed to the wetland. Since this study does not divide consumers' surplus among all factors of production, but assigns it entirely to the wetland, the estimated values represent maximum upper bounds to the actual values.

Total payments (expenditures) for a wetland-dependent product cannot be interpreted as the value of the wetland for that product (Batie and Shabman 1982). Total payments are the sum of producers' surplus and costs of production. Producers' surplus, also called pure or economic profit, is returns to the entrepreneur as the risk taker and organizing force. Pure profit is not an economic cost, because it is not necessary for acquiring or retaining entrepreneurial ability. Pure profit should be considered the return on risk, not as part of a wetland's value.

Option, existence, and bequest values. Option values arise because people who do not use a good may still be willing to pay for the option to use that good at some future time (Randall 1987). Some people who do not use or ever intend to use a specific good may receive utility or well-being from simply knowing the good exists. This value is called existence value. Bequest values are existence values in which the people value the existence of a good because they want to secure its availability for future generations. Since individual wetlands have many substitutes and wetlands are not scarce [2.49 million acres in North Dakota alone (Dahl 1990)], option, existence, or bequest values for the marginal wetland, under current conditions, are assumed to be zero.

Compatibility of functions/outputs. Compatibility of wetland functions/outputs is considered in the aggregation process to ensure one function's contribution is not precluded by another's. Wetlands cannot simultaneously perform all listed wetland functions because of the incompatibility of some functions. A function is fully compatible when its functioning does not negatively affect other outputs. In other words, as the value of one output increases over time, the values of the incompatible outputs decrease. For example, if a wetland effectively traps sediments, it will not recharge groundwater as efficiently as compared to its possible capability without trapping sediments.

Compatibility of functions (and therefore outputs) is not a concern when measuring the contemporary outputs from a selected wetland. Wetland functions simultaneously produce outputs from a common source of attributes (the wetland). The compatibility of functions is accounted for when each wetland function uses the given attributes to their full extent, but produces only a specific, measurable, level of each output. Estimates of value based on the actual wetland output levels have indirectly considered output compatibility.

Value perspectives. For many items, especially wetland outputs, value is not a singular, unique attribute. Thus, when valuing wetlands, the beneficiaries of the outputs must be identified. Value depends on perspective and context. The worth of wetlands can be evaluated from at least four perspectives: user, owner, regional, and social (Leitch 1981). Money flows and nonmonetary benefits vary according to the type of value being estimated. Most technical evaluation issues are beyond the scope of this paper; however, value perspective 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 any normal products or services receive personal satisfaction equal to or greater than the price paid for those products or services. The net worth of a wetland is the value of the personal satisfaction above the price paid for a wetland-related product or service (consumers' surplus). The direct cash 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 the users' cash outlays can be attributed to the wetland (although a portion of the price paid, i.e., rents or leases, may be attributed to the 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 rent 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 from the use (consumptive or nonconsumptive) of the wetland's outputs. Gross business volume can be estimated by using a regional input-output model (Coon and Leitch 1990). This model also estimates changes in employment supported by changed business volumes. Gross business volume shows how money passes from 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 equal to the value of all the ecological functions but is the value society realizes from these functions' outputs. This can be measured by combining compatible user values, owner values, and the value 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 values, regional values are appropriate as "tiebreakers" in social decision making.

Negative values. This study has focused on valuing the positive or beneficial functions of wetlands. Wetlands may have negative or adverse functions in addition to their beneficial ones. Adverse functions include

- mosquito production,
- blackbird habitat,
- contribution to flooding,
- aesthetics, and
- farming nuisance.

The shallow, stagnant water of pothole wetlands provides ideal habitat for mosquito production. Society's negative value for mosquitoes could be estimated from the expenditures made to control their populations and the cost of mosquito-related ailments. The dense stands of cattails in pothole wetlands provide nesting cover for blackbirds that often feed on surrounding agricultural crops (Linz et al. 1992). The lost yield to farmers and the blackbirds' dependency on wetlands could be used to estimate the negative value of wetlands for blackbird production.

If wetlands are full of water before spring thaw or rainstorms, flooding could be worse than if the wetland area was another land use. The aesthetic value of a wetland may be positive or negative, depending on the people who view the particular wetland. Many potholes are only visible to the farmer who does not like wetland because it is "unproductive" land. Wetland which falls into this category would have a negative aesthetic value. Some wetlands have negative value because they interfere with farming operations. Farming around potholes is more costly than farming through them (Baltezore et al. 1987). Negative values should be considered along with the positive values when deciding the use of any wetland.

Capitalized value. Each value perspective was quantified as an average annual value, which can be converted to an estimate of capitalized value by using a social discount rate. Randall (1987) suggested using a discount rate from 2 to 4 percent for social projects. Four percent was chosen for this study because it is close to the private sector market-determined rate so private sector and public sector opportunities will have similarly derived capitalized values. Comparable value estimates for private and public sector opportunities help to determine the best resource use. Based on expected wetland life (smaller wetlands naturally evolve into non-wetlands faster than larger wetlands), the Nome, Alice, and Tower City wetlands were capitalized for a 30-year period, while the Buchanan wetland and the Rush Lake complex were capitalized for a 60-year period.

RESULTS

The process developed in Hovde (1993) was used to estimate values for the Nome, Buchanan, Alice, Tower City, and Rush Lake wetlands. Wetland output quantifications lead to output values, which were aggregated into the value of each wetland. A second result was the identification of needed information to improve the precision of the estimates.

Nome Wetland

The Nome wetland is valued from the perspectives of the user, owner, region, and society. The process used to estimate each perspective, which is explained in this section, represents the process used to arrive at each wetland's value.

User value. The Nome wetland provides users with flood control benefits, wildlife habitat benefits, agricultural uses, aesthetics, and education/research benefits. The average annual cost savings from prevented flooding is $2.68 per acre, based on an estimate of flood control for a water retention project in the same watershed (Gulf South Research Institute 1980). The Nome wetland can be expected to retain 3 acre-feet of runoff water. The average annual user value for flood control is $8.05 ($2.68 per acre). The users, in this case, would be anybody residing in the watershed downstream of the Nome wetland, most notably those residing in or near the floodplain.

State-wide average recreational expenditures on waterfowl, upland game, furbearers, big game, and nongame species were adjusted for species' dependency on wetlands. Annual wildlife habitat-related expenditures for the Nome wetland are $17. Consumers' surplus for recreational activities in North Dakota has been estimated at 40 percent of the expenditure (Anderson et al. 1985), or $2.22 per acre in this case.

Cattails and other forage could be harvested in dry years (one year in five is assumed to be dry enough), with an average production of five tons per acre. An average of three tons of hay per year (5 tons/acre X 3 acres X 20 percent chance of harvest), with an estimated annual market value of $25.50 per ton, could be harvested from the Nome wetland. The price elasticity of demand has some implications for consumers' surplus amounts. Price elasticity estimates for agricultural products with many substitutes are generally highly elastic. Wetland hay (used as forage for livestock) has many substitutes; therefore, the demand for wetland hay is highly elastic. Assuming a linear demand function and an elasticity of -2 leads to 25 percent consumers' surplus. The annual average agricultural user value is $6.38 per acre.

The user value for aesthetics and education/research is assumed to be a small positive value due to the presence of many substitutes. One dollar was added to the aggregate user value to account for the user value for aesthetics and education/research.

The aggregate annual user value for the Nome wetland is $11.61 per acre (Table 2). This aggregate value is based on flood control cost savings (an average value), wildlife habitat value, agricultural hay value (each value representing a maximum upper bound), aesthetics, and education/research. The capitalized user value of the Nome wetland is $200 per acre, when capitalized at 4 percent for 30 years.

Table 2. User Values of the Nome Wetland, 1993

	Annual Per Acre	Capitalized Per Acre
	---- dollars ----	
Flood control cost savings	2.68	46
Wildlife habitat value	2.22	38
Aquatic habitat value	0.00	0
Agricultural hay value	6.38	110
Aesthetics & education/research	0.33	6
Totals	11.61	200

Capitalized at 4 percent for 30 years.

Owner value. The present owner of the Nome wetland allows his neighbor to harvest wetland hay rent free. The pure profit of the harvester would be the maximum amount he/she would pay to use the wetland. In theory, the agricultural industry closely represents a perfectly competitive market where pure profit does not exist. Although the industry has no pure profit, individual producers within the agricultural industry may receive pure profits. In this case, since the owner did not charge rent to use the wetland, pure profit is assumed to be 15 percent of total payments for the sale of the wetland hay. The rent that may have been collected by the owner equals the pure profit of the harvester, which is 15 percent of the average total payments for the Nome wetland's hay ($76.50) or $11.50 annually.

The owner reported capturing no other returns from this wetland. Therefore, the annual owner value of the Nome wetland is $11.50 ($3.83 per acre), which comes entirely from the maximum upper-bound estimate of rent for agricultural uses. The capitalized owner value is $199 ($66 per acre).

Regional value. Expenditures of $94 ($77 from agricultural crops and $17 from recreational activities) accounted for $340 in gross business volume. Personal income accounted for $86 of gross business volume. This wetland does not generate enough economic activity to support any employment. The business volume of 230 wetlands comparable to the Nome wetland would be required to support the equivalent of one full-time job.

Social value. The value of sediment entrapment of the Nome wetland is the cost savings of not having to remove sediments from drainage ditches. The Nome wetland can be expected to trap 7 cubic yards of sediments. If all of the sediments ended up where they had to be excavated, the annual cost would be $50 (a maximum upper bound). If none of the sediments ended up where they had to be excavated, the costs would equal $0 (a minimum lower bound). In the absence of the Nome wetland, the eroded sediments would be caught in the next lower elevation wetland, where the probability that the sediments would cause drainage problems is low. A 1 percent probability of excavation was assumed, leading to $0.50 as the average annual social value of sediment entrapment.

The value of nutrient assimilation of the Nome wetland at the present time is zero because excessive nutrients do not impair the groundwater or the stream in the surrounding area. This represents a minimum lower bound because an option value may exist.

The annual social value of the Nome wetland is $46.85 ($15.62 per acre), the sum of sediment entrapment and nutrient assimilation ($0.50), user values ($34.85), and owner values ($11.50). The capitalized value of the annual social benefits is $810 ($270 per acre). Social decision making about the Nome wetland should compare its $47 of annual social value with the social value of the alternative use. Annual regional business activity of $340 may be used as supplementary input if social values are inconclusive.

Buchanan Wetland

The Buchanan wetland provides users with wildlife habitat benefits, baitfish production, agricultural uses, aesthetics, and education/research benefits. Annual wetland habitat-related expenditures for the Buchanan wetland are $212.03. The annual value of the consumers' surplus for the Buchanan wetland's wildlife habitat is 40 percent of $212.03 or $84.81 ($4.99 per acre). Average annual expenditures on leeches and baitfish from this wetland are $0.17 ($0.01 per acre). The wetland's average annual user value is $0.17 ($0.01 per acre), assuming that 100 percent is consumers' surplus and that 100 percent of consumers' surplus is attributable to the wetlands. The average annual expenditure on the Buchanan wetland's 2.4 tons of bulrush hay is $57.10.

Assigning all of consumers' surplus to the user value of wetland hay will make $14.28 ($0.84 per acre) a maximum upper bound to the actual value. One dollar was added to the aggregate user value to account for the value of aesthetics and education/research. The aggregated annual user value for the Buchanan wetland is $100.26 ($5.89 per acre) (Table 3). This aggregate value is the result of totaling flood control cost savings (an average value), wildlife habitat value and agricultural hay value (each value representing a maximum upper bound), and the value of aesthetics and education/research. The capitalized user value is $2268 ($133 per acre), assuming a discount rate of 4 percent for 60 years.

Table 3. User Values of the Buchanan Wetland, 1993

	Annual Per Acre	Capitalized Per Acre
	---- dollars ----	
Flood control cost savings	0.00	0
Wildlife habitat value	4.99	113
Aquatic habitat value	0.01	0
Agricultural hay value	0.83	19
Aesthetics & education/research	0.06	1
Totals	5.89	133

Capitalized at 4 percent for 60 years.

The owner reports no agricultural uses of the wetland for as long as the wetland has been in the family (approximately 60 years). The owner does use the wetland almost every year for waterfowl hunting. Average expenditures of North Dakota waterfowl hunters were used to estimate the owner value of the wetland for waterfowl hunting. Average waterfowl hunting expenditures were used to represent the owner's willingness to pay. The average annual expenditures of a resident waterfowl hunter ($1,232) multiplied by the estimated 40 percent consumers surplus for this activity yields $308 as the annual value of the waterfowl hunting experience for the owner.

The owner also hunts nearby wetlands. Approximately one-fourth the time is spent hunting on the study wetland; therefore, only one-fourth of $308 or $77 can be attributed to the Buchanan wetland. Seventy-seven dollars represents the value of the hunting experience, of which the wetland is a part. Although a hedonic analysis could be used to allocate the value each aspect of the hunting experience contributes, time and money constraints are prohibitive. Therefore, the entire $77 from the hunting experience will be assigned to the wetland as owner value. The annual waterfowl hunting value of $77 is a maximum upper bound of the actual value. The owner's waterfowl hunting value comprises the entire $77 ($4.52 per acre) of annual owner value. The capitalized value is $1742 ($102 per acre).

Expenditures of $293 for wetland-related products and activities accounted for $1001 in gross business volume in the region of the Buchanan wetland. Personal income accounted for $221 of gross business volume. This wetland does not generate enough economic activity to totally support any jobs. Seventy-eight wetlands comparable to the Buchanan wetland are needed to support one full-time job.

The value of the Buchanan wetland entrapping 228 cubic yards of sediments ranges from $1,119 to $0 depending on the probability that the sediments would have to be moved. The average annual social value of sediment entrapment is $11.19, assuming a 1 percent probability. The value of nutrient assimilation of the Buchanan wetland is zero. The annual social value of the Buchanan wetland is $188 ($11 per acre), the sum of sediment entrapment and nutrient assimilation ($11), user values ($100), and owner values ($77). The capitalized value of the annual social benefits is $4,253 ($250 per acre). For social decision making, regional business volume of $1,001 may also be considered with the $188 of annual social value.

Alice Wetland

The Alice wetland provides its users with flood control, wildlife habitat benefits, agricultural uses, and education/research benefits. This wetland is situated in the landscape similar to the Nome wetland and is in the same subbasin (Maple River). Therefore, the estimated value of water detained from entering the Maple River because of the Nome wetland ($2.67 per acre-foot) can be applied to the Alice wetland. Assuming 1 acre-foot of water is detained per wetland surface acre, the Alice wetland would detain 8 acre-feet of runoff water. The value of flood control for the Alice wetland is $21 ($2.67 per acre).

A farmed-through wetland provides much less wildlife habitat than the average wetland. Twenty-five percent of average was assumed. Average annual wildlife-related expenditures of $29 amounts to a consumers' surplus of $11 ($1.43 per acre).

The wetland can be expected to produce 245 bushels of wheat [8 acres X 30.6 bushels per acre yield, based on 1986 to 1990 Barnes county average (Wiyatt and Hamlin 1992)]. The five year non-indexed average price of wheat is $3.20 per bushel (Wiyatt and Hamlin 1992). The purchaser of this wheat gains $196 of consumers' surplus (25 percent consumers' surplus) from the $784 purchase ($3.20 per bushel X 245 bushels). The $196 ($24.50 per acre) is the user value of the agricultural commodities of the Alice wetland. One dollar was added to the aggregate user value to account for the user value of aesthetics and education/research. The aggregate annual user value for the Alice wetland is $230 ($29 per acre) (Table 4), which is the total of flood damage savings, wildlife habitat value, agricultural value, and the value of aesthetics and education/research. The capitalized user value, when discounted at 4 percent for 30 years, is $3974 ($497 per acre).

Table 4. User Values of the Alice Wetland, 1993

	Annual Per acre	Capitalized Per Acre
	---- dollars ----	
Flood control cost savings	2.67	46
Wildlife habitat value	1.43	25
Aquatic habitat value	0.00	0
Agricultural value	24.50	424
Education/research	0.13	2
Totals	28.73	497

Capitalized at 4 percent for 30 years.

The Alice wetland is located in cropland and is farmed by a tenant. The owner value of the wetland is equal to any rents received for the use of the wetland. The owner of the Alice wetland receives $35 per acre annually from a renter who farms the land ($605 per acre when capitalized at 4 percent for 30 years).

Expenditures of $813 for farming inputs and wildlife-related recreation accounted for $2,986 in gross business volume. Personal income accounted for $776 of gross business volume. This wetland does not generate enough economic activity to totally support any jobs. Twenty-six wetlands comparable to the Alice wetland are required to support one full-time job.

The Alice wetland is located near the center of an undrained section of land. In the absence of this wetland, all sediments originally trapped would enter one of the nearest six surrounding local depressions. The social value for sediment entrapment is zero under current conditions. The social value for nutrient assimilation is also zero. The social value of the Alice wetland is $529 ($66 per acre); the user value ($249) plus the owner value ($280) plus the value of sediment entrapment and nutrient assimilation ($0). The present value of the annual social benefits is $9,147 ($1,143 per acre). For social decision making, regional business volume of $2,986 may also be considered with the $9,147 of annual social value.

Tower City Wetland

The Tower City wetland provides its users with flood control, wildlife habitat benefits, agricultural uses, aesthetics, and education/research benefits. This wetland captures runoff from approximately 20 acres and keeps a portion of this water from entering an intermittent stream. This stream does not have measurable flood damages associated with it because of its small watershed area. Therefore, the value of the water-retaining function of this wetland is assumed to be zero.

Average annual wildlife-related expenditures are $35. The user value for wildlife habitat equals $14 ($3.54 per acre), assuming 40 percent consumers' surplus. Agricultural uses would add $60 or $15 per acre to the average annual user value, assuming 25 percent consumers' surplus of the $240 of average annual expenditures for wetland hay (12 tons of hay times $25 per acre times 80 percent chance of harvest). One dollar added to the aggregate user value accounts for the user value for aesthetics and education/research. The aggregated annual user value for the Tower City wetland is $75 ($18.75 per acre) (Table 5). This aggregate value is the sum of flood damage savings, wildlife habitat value, agricultural value, and the value of aesthetics and education/research. The capitalized user value is $1,297 ($324 per acre), when discounted at 4 percent for 30 years.

Table 5. User Values of the Tower City Wetland, 1993

	Annual Per Acre	Capitalized Per Acre
	------ dollars	-----
Flood control cost savings	0.00	0
Wildlife habitat value	3.50	61
Aquatic habitat value	0.00	0
Agricultural value	15.00	259
Aesthetics & education/research	0.25	4
Totals	18.75	324

Capitalized at 4 percent for 30 years.

The Tower City wetland may provide returns to the owner because of the potential for hay production. Estimates of producers' surplus from wetland hay represent the owner value of the wetland. The annual owner value of wetland hay, as with the expenditures of $240 or $36 ($9 per acre). The capitalized owner value is $623 ($156 per acre).

Expenditures of $275 for wetland-related products and activities accounted for $1,000 in gross business volume. Personal income accounted for $255 of gross business volume. This wetland does not generate enough economic activity to totally support any jobs. It would take the business volume from 78 wetlands comparable to the Tower City wetland to support one full-time job.

The sediment entrapment and nutrient assimilation values of the Tower City wetland are zero for similar reasons as the Alice wetland. The annual social value of $111 ($28 per acre) for the Tower City wetland is based on the user value ($75) and the owner value ($36). The capitalized social value is $1,919 ($480 per acre), capitalized at 4 percent for 30 years. For social decision making, regional business activity of $1,000 may also be considered with the $111 of annual social value.

Rush Lake Wetland Complex

The Rush Lake wetland complex provides users with flood control benefits, wildlife habitat benefits, agricultural uses, aesthetics, and education/research benefits. The Rush Lake wetland complex stores runoff water from surrounding land. These wetlands have small storage capacities because of the extremely flat topography.

Assuming the downstream area protected is equal to twice the acreage of wetlands, 4,400 acres are protected annually. Under somewhat similar conditions in the Devils Lake watershed, flood damages from spring and summer floods were $17 (1977 dollars inflated to 1992) per acre for cropland (Leitch and Scott 1977). Since the Rush Lake upland acreage primarily consists of native and tame hay and has some marginal cropland, the value of the damaged acreage was assumed to be 20 percent of the value of the Devils Lake estimate. Thus, the estimated annual flood damage prevented by the Rush Lake wetland complex is $14,960 ($7 per acre).

The Rush Lake wetland complex has been cited as being an exceptional habitat for waterfowl. Expenditures for waterfowl-related experiences and nongame-related experiences in this area are assumed to be twice the state average, and other wildlife-related expenditures are assumed to be at the average. The average annual expenditure for wildlife in the Rush Lake area equals $46,310. The average annual value of the wildlife-related consumers' surplus for this area equals $18,524 ($8.42 per acre). Rush Lake proper contains adequate water to support leeches and baitfish. The value of leeches and bait fish per wetland acre is $0.01 or $7 for the 700-acre Rush Lake.

The value of agricultural uses for a large wetland complex is based on a number of assumptions, including the wetlands are (on average) 67 percent vegetated, 50 percent of the wetlands could be harvested in any one year (Hubbard 1988), the average acre of wetland produces 3 tons of hay, and the hay could sell for $25 per ton. Under these assumptions, expenditures on the wetland hay would equal $37,700. Average annual user value for agriculture is $9,425 ($4.28 per acre). The aggregated annual user value for the Rush Lake wetland complex is $42,900 ($19.71 per acre). This aggregate value is the sum of flood damage savings, wildlife habitat value, aquatic value, and agricultural use value (Table 6). The capitalized user value is $970,527 ($446 per acre), when discounted at 4 percent for 60 years.

Table 6. User Values of the Rush Lake Wetland Complex, 1993

	Annual Per Acre	Capitalized Per Acre
	---- dollars ----	
Flood control cost savings	7.00	158
Wildlife habitat value	8.42	191
Aquatic habitat value	0.01	0
Agricultural value	4.28	97
Aesthetics & education/research	---not estimated---	
Totals	19.71	446

Capitalized at 4 percent for 60 years.

The expected annual expenditures on wetland hay were $37,700. Pure profit is $5,655 ($2.57 per acre), which represents the amount of rent that could be collected for the agricultural use of the wetlands. Some of the owners of these wetlands are expected to use them for hunting and trapping. Assuming 30 owners gain $308 consumers' surplus each from hunting their wetlands leads to $9,240 ($4.20 per acre) of recreational-based owner value annually. The average annual owner value of the Rush Lake wetland complex is $6.77 per acre ($153 when capitalized at 4 percent for 60 years).

Expenditures of $83,700 for wetland-related products and activities accounted for $321,400 in gross business volume in 1993 in North Dakota. Personal income accounted for $70,300 of gross business volume. This group of wetlands generates business volume to support four full-time jobs.

The values of sediment entrapment and nutrient assimilation were not estimated. Data were not available to make an educated generalization. Without estimates of value for sediment entrapment and nutrient assimilation, the social value would be the sum of owner value and user value. Average annual social value of $26.48 per acre would represent the minimum lower bound to the actual value. Social value for the Rush Lake wetland complex is $599 per acre, when capitalized at 4 percent for 60 years.

Results Summary

The annual per acre values of the five wetlands vary from a $4 owner value for the Nome wetland to a $373 regional value for the Alice wetland (Table 7). These estimated values result

Table 7. Summary of Annual and Capitalized Per Acre Values of Five Prairie Potholes, 1993

	ANNUAL Per Acre	CAPITALIZED[a] Per Acre
	--------- dollars	---------
USER VALUES		
Nome	12	200
Buchanan	6	133
Alice	31	540
Tower City	19	324
Rush Lake	20	446
OWNER VALUES		
Nome	4	66
Buchanan	5	102
Alice	35	605
Tower City	9	156
Rush Lake	7	153
REGIONAL ACTIVITY (GBV[b])		
Nome	113	n/a
Buchanan	59	n/a
Alice	373	n/a
Tower City	250	n/a
Rush Lake	146	n/a
SOCIAL VALUES		
Nome	16	270
Buchanan	11	250
Alice	66	1,141
Tower City	28	480
Rush Lake	26	599
NEGATIVE VALUES[c]	------ 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 a minimum lower bound to the actual value because all social values were not estimated.

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 grain produced in the wetland. Thus, prairie potholes are not homogeneous in the mixes of valued outputs they provide society.

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 $18 annually, then society should encourage that alternative use. Wetland preservation would be inefficient because the social value as a wetland is only $16. However, policymakers must be aware of the impacts to users, the owner, and the region and may need 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 $11 per acre annual value, then society should choose to protect it as wetland. As with any social decision, policymakers cannot ignore the possible adverse impacts on the other three value perspectives.

The process used to estimate the value of the wetland outputs can be improved. The greatest analytical obstacles to more refined estimates are the physical and biological data needed to technically quantify wetland functions. Specifically, interdisciplinary cooperative research is needed in

- 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.

CONCLUSIONS

This study represents the first attempt to assign a comprehensive dollar value to specific wetlands in the Prairie Pothole Region. Methods of estimating value were comprehensive, identifying all outputs. Some outputs, such as aesthetics and education/research, were not evaluated because of the high costs of surveying a sample large enough to be statistically reliable of this study were used to specifically evaluate the five case study wetlands, but the methods are broadly applicable.

With the help of studies such as this one, reasonable and credible ranges of the value of prairie potholes can begin to emerge. These estimates are better suited at this time for relative rather than absolute comparisons (Figure 3). For example, on a per acre basis, the Tower City wetland is worth more to society than the Buchanan wetland.

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 the 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.

POLICY IMPLICATIONS

The social values estimated in this study do not represent the value of each and every wetland to society, but rather the values of the five specific North Dakota wetlands in 1993. These social values are appropriate only for social decisions (trade-offs) about the use or condition of these specific wetlands. Decision makers must be careful when making choices based on this study's estimated values or similarly estimated values. Many outputs were not quantified because under current conditions their value is negligible. Changing conditions (i.e., further loss of wetlands) may substantially increase the remaining wetlands' values. Decision makers must be aware of current conditions (at the time of the decision) to ensure decisions are not irreversible in the future.

The range of wetland values should not be generalized into the value of the other millions of acres of wetlands in the Prairie Pothole Region. Wetlands that look just like any of the study wetlands may have different values due to differences in their locations relative to flood plains, aquifers, waterfowl flyways, other wetlands, and other topographical features of the landscape or because of different intensity of use by wildlife or people. The values estimated in this study will change if the total number of wetlands changes or if certain other changes occur in their watersheds or downstream.

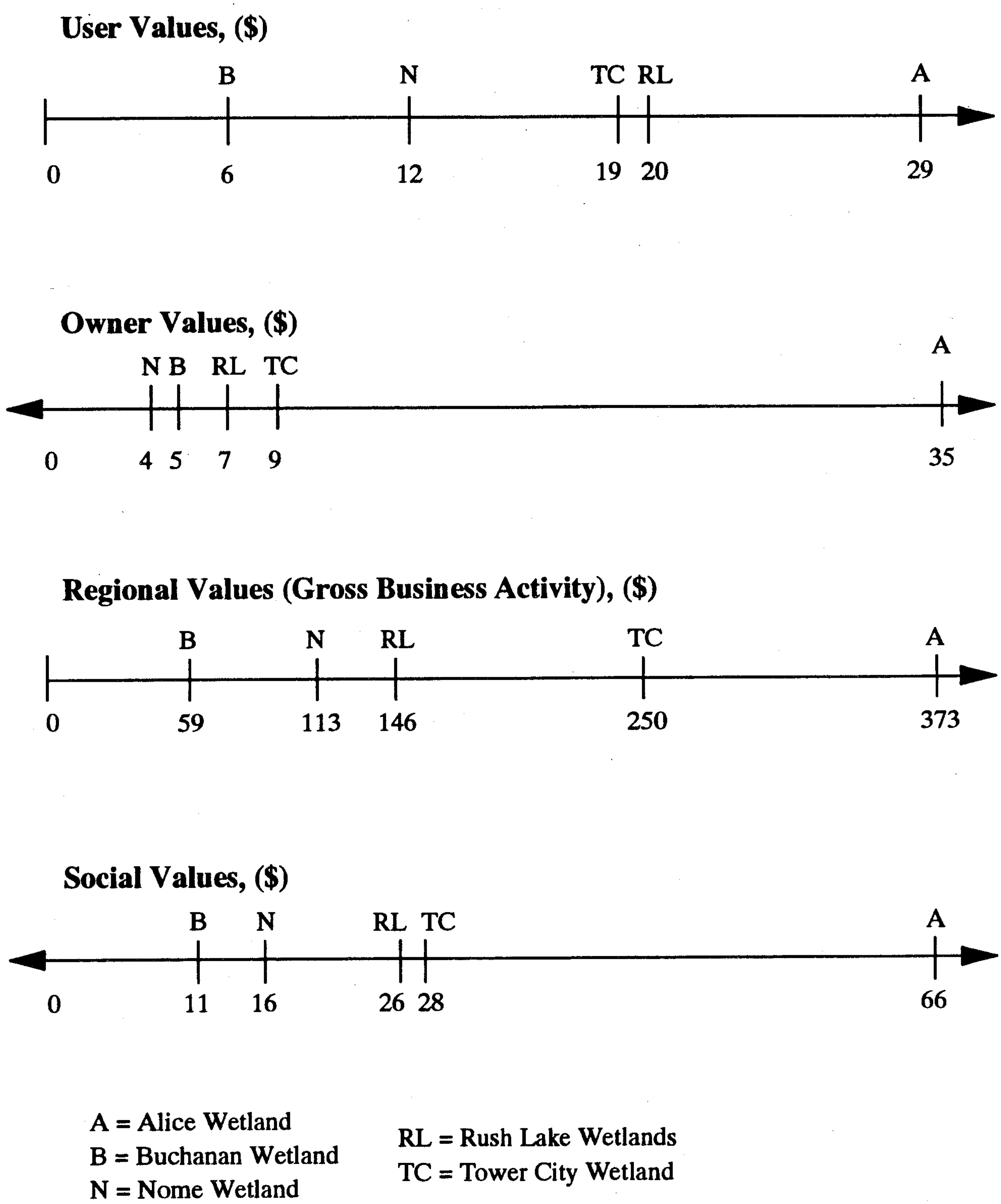

Figure 3. Annual values per acre of five North Dakota wetlands, 1993.

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