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The Feasibility of Wetland Restoration to Reduce Flooding in the Red River Valley: A Case Study of the Maple River Watershed, North Dakota

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Abstract

The economic feasibility of alternative wetland restoration activities to store water and reduce flood damage was evaluated in the Maple River Watershed, North Dakota, a sub-watershed of the Red River of the North Watershed. The evaluation was based on recent hydrologic modeling and wetland restoration studies, the National Wetland Inventory, local land rental values, and site-specific historical flood damage. With benefit-cost ratios ranging from 0.08 to 0.13, neither simple wetland restoration based on plugging existing drains, nor restoration with outlet control devices, nor complete restoration intended to provide a full range of wetland-based environmental services were economically feasible over a 20-year future period. Peak flood stages and flood damage would need to be reduced by between 4 and 12 percent in order for wetland restoration options to break even. The inclusion of additional wetland benefits did not make wetland restoration economically feasible. It is, therefore, not recommended that public funds be used for extensive wetland restoration projects throughout the Maple River Watershed or the Red River Valley in order to reduce flood damage.

Key Words: Economic feasibility, wetland restoration, flooding, Red River Valley

The Feasibility of Wetland Restoration to Reduce Flooding in the Red River Valley: A Case Study of the Maple River Watershed, North Dakota

Steven D. Shultz and Jay A. Leitch[1]

Flooding in the Red River Valley of the North has historically caused large-scale losses of public and private property in North Dakota, Minnesota, and Manitoba (International Joint Commission, 2000). There is an ongoing public debate regarding the relationships between wetlands and flooding in the Red River Valley and whether public funds should be used to restore drained wetlands in order to reduce future flood damage. On one side of the issue are environmental advocacy groups who claim that wetland drainage in the last century has greatly exacerbated recent flood events (Sierra Club, 1998 and 2000). Others, primarily local farmers and watershed authorities, believe that wetland drainage does not have a large impact on flooding in the Red River Valley, especially during major springtime flood events when wetlands are often already at full capacity.

Wetland restoration for flood attenuation is also being actively debated in other parts of the country, especially after the extensive Mississippi River flood of 1993 (Interagency Floodplain Management Review Committee, 1994). Several hydrologic-based studies have been made to quantify the role of wetland storage in reducing peak flood stages, albeit often with inconsistent results (DeLaney, 1995). However, no known studies have yet to evaluate the economic feasibility of restoring wetlands for the purpose of reducing flood damage, probably because such studies require a great deal of integrated biophysical and economic data over time, which are often difficult to collect and interpret.

This present study evaluates the economic feasibility of restoring drained wetlands in North Dakota's Maple River Watershed which is a typical agricultural-based sub-watershed of the Red River Valley, with many acres of both existing and drained wetlands and frequent springtime flooding events both within and downstream of the watershed. Economic feasibility was evaluated through benefit-cost ratios, where avoided flood damage resulting from hypothetical wetland restoration alternatives were compared to associated wetland restoration costs over a future 20-year period. Three specific wetland restoration alternatives were evaluated: 'simple restoration' based on plugging existing surface drains, 'outlet restoration' with regulated storage, and 'complete restoration' intended to provide a range of wetland-based goods and services.

The collection and evaluation of data were the most challenging part of this study. Historical flood damage, in the form of both relief and mitigation payments within and downstream of the Maple River Watershed from 1989 to 1998, was obtained through surveys of numerous private, local, state, and federal government agencies. Estimates of potential reductions on historical flood damage were based on the results of a companion study which used hydrologic modeling of the impact of hypothetical wetland restoration on historic peak

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flood stages (Bengtson and Padmanabahn, 1999). Wetland restoration costs consisted of site-specific land rental values and construction costs based on similar projects in the region and which varied with the size of drained wetlands being restored.

While this study was based on the site-specific conditions of the Red River Valley, its results are considered relevant to the ongoing public policy debates across the nation concerning whether large-scale wetland restoration projects should be implemented in order to reduce flood damage. It is also expected that many of the intermediate results of the study (i.e., cost and benefit data) will be useful for future wetland restoration studies and policymaking.

BACKGROUND AND RELATED LITERATURE

The Red River Valley and the Maple River Watershed

The basin of the Red River of the North, referred to as the Red River Valley, comprises 17,000 square miles of primarily agricultural land occupying parts of eastern North Dakota, northwestern Minnesota, northeast South Dakota, and southern Manitoba (Figure 1). Because the Red River Valley is almost as wide as it is long, is extremely flat, and drains (via the Red River) from south to north, it is subject to recurrent springtime flooding in the months of April and May, especially when preceded by abnormally high fall and winter precipitation (Miller and Frink, 1984 and Krenz and Leitch, 1993).

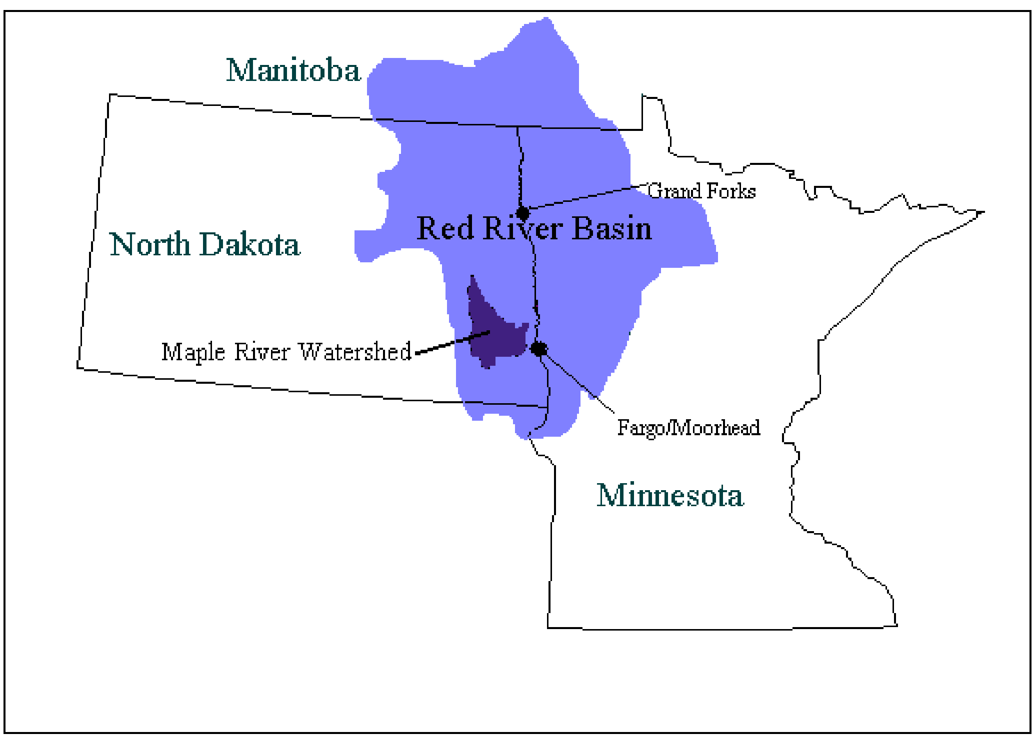

Figure 1. Maple River Watershed and the Red River Valley Basin

The Maple River Watershed, a typical, agricultural-based sub-watershed of the Red River Valley, covers about 1,600 square miles in eastern North Dakota, and is located in the southern part of the Red River Valley, west and northeast of the city of Fargo and south of Grand Forks. Soil productivity and, hence, cropping intensity and land values decrease in a westerly direction away from the Red River. Principal agricultural crops in the more productive eastern part of the watershed are wheat, barley, oats, and sugarbeets while in the western reaches wheat is rotated with potatoes, corn, beans, and forage crops. As much as 55 percent of the original wetlands in the Red River Valley and the Maple River Watershed may have been drained since colonization (Dahl, 1990). The National Wetland Inventory (NWI) by the United States Fish and Wildlife Service includes approximately 45,600 acres of existing wetlands in the watershed, primarily in its middle and upper reaches, and 2,700 acres of recently drained wetlands.

Wetland Restoration and Flooding

The potential of wetland storage for reducing peak flood flows is recognized as one of the most poorly understood functions of wetlands (Interagency Floodplain Management Review Committee, 1994). Nevertheless, several studies and commentary have noted that historical wetland drainage has magnified the impact of recent large (low-frequency) flood events along the Mississippi River System (Hey and Philippi, 1995) and in the Red River Valley (Sierra Club, 1998 and 2000). However, these analyses often make the highly unrealistic assumptions that wetlands are empty at the time of flood events and that all potential wetland storage reduces peak flood flows during these major floods.

Outside of the Red River Valley, a few studies have used hydrologic modeling to evaluate the impact of wetland storage on flooding. A frequently cited study of the semi-urban Charles River Watershed near Boston, Massachusetts, concluded that wetland storage significantly reduced peak flood levels [U.S. Army Corps of Engineers (USACE), 1976]. In Illinois, it was estimated that each percentage increase in wetland area reduced downstream peak flows on medium sized streams and rivers by 3.7 percent and average flood flows by 1.4 percent (Demissie and Khan, 1993). A study of sub-watersheds of the Mississippi River hypothesized that restoring upland wetlands would reduce flood peaks by between 1 and 23 percent with deep wetlands and between 5 and 9 percent with shallow wetlands, and that wetland restoration was most effective in reducing flood damage during high-frequency storm events of 25 years or smaller (Interagency Floodplain Management Review Committee, 1994).

Closer to the Red River Valley, it was estimated through the use of a hydrologic simulation model in the Little Cobb River sub-watershed of the LeSuer River Watershed in Minnesota, that historical drainage of wetlands increased annual peak flood discharge by up to 57 percent during high-frequency flood events but a negligible effect on reducing the magnitude of large (low-frequency) flood events (Miller, 1999). Within the Red River Valley itself, quantitative analyses of historical land use, drainage, and hydrologic relationships and flooding has been noted to be problematic due to spatial and temporal limitations of available data (Moore and Larson, 1980). However, a review and assessment of drainage and flooding issues in the Red River Valley by Miller and Frink (1984) concluded that increased drainage does have an effect on small (high-frequency) flood events and a diminished or negligible effect on large-scale, low-frequency flood events.

In the Maple River Watershed, a recent study based on hydrological modeling quantified the relationships between wetland storage in the upper watershed and flood stage levels (Bengtson and Padmanabahn, 1999). The study used 'HEC-1', a quasi-distributed lumped parameter hydrologic model that accounts for the location and available storage of restored wetlands, surrounding land uses, and hydrologic conditions including rainfall events, and hydrologic transport capacity and timing. After subdividing the watershed into 48 sub-basins, wetland storage was modeled as a diversion that permanently retains some of the outflow from each sub-basin of the watershed. The study concluded that potential storage associated with the restoration of previously drained wetlands (2,700 acres) reduced peak flood stages by 3.8 percent during high-frequency floods, 2.2 percent during medium-frequency floods, 1.7 percent during low-frequency floods, and 1.6 percent during very low-frequency floods with the assumption of 1 foot of storage bounce. The corresponding reductions in peak flood stage with 2 feet of storage bounce were 5.4, 3.2, 2.4, and 2.4 percent.

Storage Potential of Wetlands

A critical factor influencing whether wetlands have an impact in reducing peak flood stages during springtime flood events is their available storage potential which is often referred to as 'bounce' and is a function of wetland volume and depth as well as antecedent soil moisture and precipitation. During major springtime flood events in the Red River Valley and in many other areas of the country, wetlands are already at full capacity due to excessive rainfall in the preceding summer and fall making available wetland storage bounce relevant to the springtime flood event much less than the total storage volume (Miller and Frank, 1984). However, many recent claims of the flood reduction potential of wetlands have incorrectly assumed that all wetland-based storage volume is removed from peak flood stages (Sierra Club, 2000).

Estimates of storage bounce ranging from theoretical maximums, to practical potentials, to ecologically desired levels, range from 0.5 to 1.5 acre-feet per surface acre (afpsa). These estimates are from studies of wetlands in South Dakota (Hubbard, 1982), North Dakota (Ludden, et al. 1983), the Red River Valley (Red River Water Management Board, 1993), and Minnesota (Terry and Adland, 1997). From these studies, it can be concluded that the available storage ('bounce') of restored wetlands in the Red River Valley under a range of flood events, is less than 1 afpsa with uncontrolled drainage, and less than 2 afpsa with outlet control devices.

Wetland Restoration Costs

Hammer et al. (1993) estimated that farmers working on-site with existing equipment should be able to construct an effective wetland, including planting limited vegetative cover for approximately $3,000 per acre. The geographical location associated with this estimate was not provided.

In Minnesota, wetland restoration costs have been found to range from $95 to $30,000 per acre depending on the restoration purpose, with an average value of $3,000 per acre (Minnesota Board of Water and Soil Resources, 1992). The cost of constructing wetlands through excavation or with impoundments ranged from $200 to $20,000 per acre with an average of $1,500 per acre. Also in Minnesota, Eppich, Apfelbaum, and Lewis (1998) estimated that the construction costs of establishing a depressional wetland is approximately $1,500 per acre versus $2,750 per acre with the inclusion of an outlet control device, and $10,000 per acre if dikes or impoundments need to be established.

It is likely that per acre wetland construction costs associated with permitting, design, and engineering tasks can be reduced through economies of scale when large and/or many wetlands are being restored. In fact, evidence of economies of scale associated with large-scale wetland restoration projects have been noted by Heimlich (1994), who estimated through surveys of actual restoration programs, that restoration costs ranged nationally from $48 to $1,193 per acre. A specific North Dakota example of large-scale wetland restoration would be the Alice Lake Project where dikes and outlet flow structures were constructed in order to restore 3,500 wetland acres at a cost of approximately $930,000 or $265 per acre excluding land acquisition costs (Renner, 1999).

In addition to construction costs, wetland restoration requires compensating landowners for forgone production or rental income and/or the costs associated with modifying the production practices on lands adjoining wetlands. Some wetland restoration programs such as the Fish and Wildlife Service Wetland Easement Program, the U.S. Department of Agriculture (USDA) Wetland Reserve Program, and the Reinvest in Minnesota Program make one-time payments to landowners based on the appraised current value of land. Other programs such as the Devils Lake storage program of the North Dakota State Water Commission and the USDA Conservation Reserve Program make annual payments to landowners via a fixed contract (usually ten years) based on local rental market rates. Advantages of paying landowners annual rental rates are that less up-front capital is required to implement a project and that both farmers and program sponsors have the flexibility of being able to withdraw from the program at a later date.

Wetland Values

Wetlands are perceived as providing valuable services to society including water purification, groundwater recharge, fish, wildlife and plant habitat, recreational and amenity services, and flood control (Mitsch and Gosselink, 1993). However, because many of the services that wetlands provide are not actively traded in the market, determining their economic value has been problematic (Whitehead, 1993, and Leitch and Ludwig, 1995).

Hedonic based valuations of the amenities of wetlands in urban areas based on the estimation of statistical relationships between site-specific wetland characteristics and local housing values have been quite successful (Doss and Taff, 1996, and Mahan, Polasky, and Adams, 2000). Both recreational (use) and existence (non-use) values of existing wetlands have been estimated through combinations of the contingent valuation and travel cost methods, but transfer of these site-specific estimates to other areas may be limited (Bergstrom et al., 1990 and Whitehead, 1993).

There are only two known (published) valuations of the flood control benefits associated with wetlands and both were conducted in the urban area of the Charles River, Boston, Massachusetts, over 20 years ago. These studies contained few details on the procedures used to estimate avoided damages, and actually reported very different final results of $80 per acre (Gupta and Foster, 1975), and $2000 per acre (Thibodeau and Ostro, 1981). The economic principle behind such valuations is the straightforward concept of avoided damages, or more specifically, how wetlands contribute to reducing actual or predicted flood damage to public and private property. However, the calculation of such avoided damages requires the time consuming, multi-disciplinary, and potentially complex tasks of quantifying how wetland storage contributes to past and expected peak flood stages as well as the estimation of both historical and expected flood damages.

In and around the Red River Valley, only two site-specific wetland valuation studies have been conducted. The first estimated the societal values of four typical prairie pothole wetlands (including one in the Maple River Watershed), and a single wetland complex, all in North Dakota (Hovde and Leitch, 1994 and Leitch and Hovde, 1996). The average annual value for flood control of $2.5 per acre was estimated by calculating the equivalent storage costs of nearby flood control projects (usually retention basins). The average annual value for reducing sedimentation was estimated to be $0.05 per acre based on calculations of avoided drainage ditch excavation resulting from sediments being trapped by wetlands. Recreation and wildlife related values of $4.12 per acre were made by calculating annual expenditures associated with the use of wetlands to which a 40 percent premium was added to account for consumer surplus. No estimates of the aesthetic or existence (non-use) values of the wetlands were made because of the abundance of wetlands in comparison to people within and nearby the study areas. Similarly, no estimates were made of the groundwater recharge values because groundwater was not utilized as a water source in the areas studied.

The second study by Roberts and Leitch (1997) found that Mud Lake reservoir and wetland complex in the southern end of the Red River Valley contributed to 57 percent of avoided downstream historic flood damage which was equivalent to $440 per acre annually. This same study also used the contingent valuation method to determine that the combined habitat, recreation, and aesthetic values for the wetland complex were $21 per acre per year. Unfortunately, as the authors mention, the characteristics of the Mud Lake wetland complex are more similar to a managed reservoir than the smaller and more ubiquitous prairie pothole wetlands in the region, which limits the transfer these valuation results to other locations.

METHODS

Evaluating the economic feasibility of restoring wetlands for flood control in the Maple River Watershed focused on three wetland restoration options whose construction costs and potential storage capacities (bounce) were extrapolated from previous studies in the region. First, ‘simple restoration’ involves blocking wetland drains with earthen fill to provide 1 foot of storage bounce. Second ‘outlet restoration’ involves the more expensive construction of drainage outlets that increase available storage bounce to 2 feet in advance of springtime flood events. The third and most expensive wetland restoration option evaluated was ‘complete restoration’ again providing 2 feet of bounce while ensuring a full range of environmental goods and services using established restoration criteria.

Wetland restoration was assumed to take place in the middle and upper parts of the watershed because that is where the majority of the recently drained wetlands and the lowest land values are found. Also, hydrologic-based studies in other parts of the Midwest (Bardecki, 1987 and Mitsch, & Gosselink 1993), as well as a study of a nearby watershed in the Red River Valley (Meyer, 1998) concluded that upper wetland storage reduced streamflows more than lower watershed wetland storage.

The first task of this study was to identify the quantity, location, and size of previously drained wetlands in the upper watershed in order to estimate site-specific land rental values and construction costs which varied by wetland size. Second, historical flood damage associated with specific flood events from 1989 to 1998 were estimated though surveys and secondary data. Potential reductions to historical flood damage were calculated based on expected reductions in peak flood stages of alternative flood events due to hypothetical restoration and increased storage capacity of 2,700 wetland acres.

The final task involved calculating benefit-cost ratios of the three alternative wetland restoration options for reducing flood damage over a hypothetical 20-year period. Sensitivity analyses were performed where the life span of the analysis was expanded to 50 years and a lower discount rate of 3 percent was used to calculate present values. Hypothetical reductions in peak flood stages and the required values of other (non-flood related) wetland values required for alternative wetland restoration options to break even were also calculated in order to facilitate revised hydrologic modeling of wetland restoration and flood stages and/or the transfer of the results to other locations.

Wetland Restoration Costs

The number, location, and size of 2,700 acres of previously drained wetlands in the upper watershed were identified through spatial queries of the National Wetland Inventory (NWI) by using a Geographic Information System. The NWI of the United States Fish and Wildlife Service identifies wetlands as ‘previously drained’ based on visible evidence from relatively recent historical collections of air-photographs and remotely sensed images. The exclusion of these ‘long-ago’ drained wetlands from the NWI and this present study is not expected to increase the feasibility of wetland restoration because there is no indication that such wetlands provide any more storage capacity per acre than the more recently drained wetlands and because they are more expensive restore.

Land rental costs in order to compensate farmers for restoring wetlands and forgoing agricultural production were considered to be the same for all three wetland restoration options. Annual per acre rental payments were estimated because they require lower up-front costs, it is not known how long wetland storage is needed, and because of the availability of reasonably accurate county level cropland and pastureland rental values from 1994-1998 as reported by the North Dakota Agricultural Statistics Service (NDASS, 1999).

A weighted average of NDASS county level cropland and pastureland rental rates was estimated based on actual land uses within the watershed. To account for this relatively less productive land in the most western section of the watershed, land rental values were adjusted on the basis of rental values of adjacent counties. Total rental costs were calculated by multiplying per acre rental rates by the acreage of drained wetlands in the watershed. To evaluate a scenario where wetland restoration would occur only on low cost land, the lower range of reported land rental values was used.

Construction costs associated with simple restoration, outlet restoration, and complete restoration were estimated by adjusting the previously reported cost estimates from the literature. Adjustments were made to account for wetland size and potential economies of scale: Simple wetland restoration involving the installation of drain plugs was estimated to cost $300 per acre for small-size wetlands (less than 1 acre), $200 per acre for medium-size wetlands (1 to 5 acres), and $100 per acre for large-size wetlands (greater than 5 acres). Construction costs for wetland restoration with outlet control devices such as flow gates and overflow dams, were estimated to cost twice as much as simple restoration while the construction costs of complete wetland restoration were estimated at $3,000 per acre for small wetlands, $1,000 per acre for medium wetlands, and $500 per acre for large wetlands. Under all restoration options, maintenance costs were considered to be a responsibility of landowners in return for annual land rental payments.

Benefits: Avoided Flood Damage

Historical flood damage within the Maple River Watershed from 1989 to 1998 was quantified by surveying and modifying non-agricultural flood related damage payments made by over 30 public and private agencies and institutions at the local, state, and federal levels and by modifying and by extrapolating previous agricultural flood damage estimates over space and time (Shultz and Kjelland, *forthcoming* 2002).

Surveyed non-agricultural flood damage payments included insurance claims, loans, and public assistance and charity made to both individuals and public agencies that suffered flood related damage to residences, businesses, and public infrastructure. Payments for future flood mitigation projects were excluded from flood damage payments and a consumer price index was used to calculate the 1998 value of all reported flood damage.

Problems associated with incomplete or missing data over time and information that was not reported at the watershed level of analysis were overcome through the following data collection and manipulation strategies: Damage survey reports (DSR's) from the Federal Emergency Management Agency (FEMA) which indicated flood insurance payments, public assistance, grants, and loans disbursed to individuals and public agencies in various towns, cities, and counties were manually reviewed in order to identify the township and, hence, the watershed where the damage occurred (a townships is a county sub-divisions of 36 square miles). When damage data were reported only at the county level, it was assumed that the amount of damage occurring within the watershed was equal to the proportion of a particular county's population living within the watershed.

Agricultural related flood damage payments made by agencies within the USDA were not available due to privacy-disclosure policies and the inability to separate flood damage from other agricultural assistance data. Instead, agriculture-based flood damage was estimated by updating and extrapolating previous agricultural flood damage estimates (number of acres flooded, average value of flood acreage, and incidental damage) made in the watershed by the USACE (1993). Specifically, agricultural flood damage calculated for 1969, 1975, 1978, 1979, and 1996 was extrapolated for the years through 1989 and 1998 based on observed peak flood stage readings and flood duration of spring and summertime floods.

Finally, flood damage downstream of the Maple River on the main-stem of the Red River, was considered only for the City of Grand Forks, North Dakota and East Grand Forks, Minnesota (hereafter referred to simply as Grand Forks), located about 70 river miles downstream of the confluence of the Maple and Red Rivers. Flood damage in communities further downstream was not considered because their peak flood stages are influenced by many other sub-watersheds and complex hydrologic factors of the Red River.

Approximately 7 percent of flow volume in the Red River at Grand Forks is associated with drainage from the Maple River Watershed (USACE, 1978) and the only year between 1989 and 1998 with significant flood damage in Grand Forks was in 1997 when a major flood event occurred. Estimates of flood damage in Grand Forks associated with the 1997 flood range from $98 million (Carlson, 1998), to $2 billion (City of Grand Forks, 1999), to $3.6 billion (U.S. Department of Commerce, 1998). The highest of the three damage estimates ($3.6 billion) included the cost of various flood mitigation projects and, therefore, does not represent actual damage. For this study, the widely quoted damage estimate of $2 billion was used.

Avoided flood damage within and downstream of the Maple River Watershed over a hypothetical 20-year future period was posited to be directly related to reductions in p peak flood stage associated with the hypothetical restoration of 2,700 wetland acres. First, historical flood damage between 1989 and 1998 was matched with peak flow levels (cubic feet per second) and peak flood stage (feet) at the outlet of the watershed during springtime flood events. Avoided flood damage for specific years resulting from wetland restoration was then estimated by multiplying historic damage both within and downstream of the watershed by the probability of a flood event (or events in the case of multiple floods in a given year), and by the expected reduction in peak flood stage associated with 1 and 2 feet of storage bounce (as calculated in a companion study by Bengtson and Padmanabahn, 1999).

Finally, annual avoided flood damage expected over a 20-year future period was then calculated by assuming that average annual damage reductions between 1989 and 1998 would have an equal chance of occurring in any given year over this 20-year future period. The present value of this avoided flood damage was estimated using discount rates of 5 percent.

Feasibility Measures

The principle measure of feasibility of simple, outlet, and compete wetland restoration options was the benefit-cost ratio which, when less than 1 indicates discounted benefits are less than discounted costs resulting in negative returns and economic infeasibility. A benefit-cost ratio equal to 1 is a break-even point (benefits equal to costs) while a ratio greater than 1 indicates positive returns and economic feasibility. Because benefit-cost ratios are unitless, they allow direct comparisons of feasibility among alternative wetland restoration options.

As an alternative to benefit-cost ratio measure, required reductions in peak flood stage for the alternative wetland restoration options to break even were calculated. Also, the annual per acre value of additional (non-flood related) wetland benefits required for the alternative wetland restoration options to break even were estimated and compared to existing estimates of such values in the region. Such wetland values, ranging from the control of sedimentation, the creation of wildlife habitat, and both recreational (use) and existence (non-use) values are most likely associated with the complete wetland restoration option.

Sensitivity Analyses

To evaluate the stability of our estimates of the feasibility of wetland restoration for flood control under changing parameters, benefit-cost ratios were re-estimated with the period of analysis extended from 20 years to 50 and 100 years, a lower discount rate of 3 percent, and, finally, with both of these scenarios combined. A longer time period of analysis increases the likelihood of restoration options being feasible as the relative value of fixed construction costs compared to benefits (avoided flood damage) will be reduced over time. A lower discount rate also increases the likelihood of restoration feasibility as the present value of avoided flood damage is increased relative to fixed construction costs. Other sensitivity analyses included the use of the lower range of possible land values rather than average land values in the estimation of annual rental value payments for restoration land and the extremely optimistic scenario where simple restoration on low-value land was hypothesized to have 2 feet of available storage bounce.

RESULTS

This study produced two types of results useful for future wetland studies and policy making. First, intermediate results of the study, including wetland restoration costs and historical flood damage data required for this study are considered to be potentially useful to future flood mitigation and/or wetland restoration studies and policymaking efforts. Second, benefit-cost ratios and required break-even values used to evaluate the economic feasibility of alternative wetland restoration options are expected to facilitate the ongoing public policy debate regarding whether wetland restoration projects should be undertaken in order to reduce flood damage in the Red River Valley and possibly other areas of the upper Midwest.

Wetland Restoration Costs

An evaluation of the 2,700 acres of previously drained wetlands in the middle and upper reaches of the Maple River Watershed found 700 acres of small (less than 1 acre) wetlands, 1,100 acres of medium (1 to 5 acre) wetlands, and 900 acres of large (greater than 5 acre) wetlands. Accounting for these size distributions, hypothetical construction costs were calculated to be $520,000 for simple restoration, $1,040,000 for restoration with outlet controls, and $3,650,000 for complete restoration.

Average land rental values, based on the location of previously drained wetlands, were estimated to be $35 an acre per year or $26.5 per acre for low cost land. Therefore, the annual land rental cost for restoring 2,700 acres of wetlands in the watershed is $108,000 or $94,500 for low cost land. Farmers are expected to perform annual maintenance to restored wetland structures in return for annual rental payments.

The present value of total wetland restoration costs, discounted over a 20-year period using a 5 percent discount rate, range from $1.67 million to $4.77 million (Table 1). As expected, complete restoration is the most expensive option, followed by outlet restoration and simple restoration. Using only low cost land for restoration reduced total costs by 4 to 10 percent, with the greatest relative cost reduction being associated with simple restoration.

Alternatively, simple restoration with 1 foot of expected storage bounce costs $34 ($31 for low cost land) per AF of water stored per year. Outlet restoration with 2 feet of storage bounce costs $22 ($20 for low cost land), while complete restoration, also with 2 feet of storage bounce, costs $45 ($43 for low cost land).

Potential Benefits Through Avoided Flood Damage

The period of 1989-1998 was considerably wetter than the historical 50-year average. During this 10-year time period there were four high-frequency flood events with a 50 percent probability of occurrence and expected on average every second year, a single medium-frequency flood with a 10 percent probability of occurrence (once every ten years), two low-frequency floods with 4 percent probability of occurrence (once every 25 years), and a single very low-frequency flood with a 2 percent probability of occurrence (once every 50 years).

All of these flood events combined resulted in $29.3 million in damage within the Maple River Watershed of which about half was agricultural damage. As well, the 1997 flood event contributed to the $2 billion in damage downstream in the city of Grand Forks, of which approximately 7 percent ($140 million) can be attributed to flows from the Maple River watershed. Therefore, total flood damage associated with the Maple River Watershed from 1989 to 1998 is $169.3 million measured in 1998 dollars (Table 2).

Accounting for the probability of similar flood events re-occurring in conjunction with expected reductions in peak flood stages and flood damage, the average annual avoided flood damage associated with the hypothetical restoration of 2,700 wetland acres is $9,950 with 1 foot of storage bounce or $14,500 with 2 feet of bounce. The present value of these benefits over a 20-year period using a 5 percent discount rate is $124,000 with 1 foot of bounce and $181,000 with 2 feet of bounce.

The corresponding per acre annual flood control benefits for restored wetlands are $3.7 with 1 foot of storage bounce and $5.3 with 2 feet of storage bounce. Both of these values exceed the previous estimated flood control benefit ($2.5 per acre annually) of among five individual prairie pothole wetlands estimated by Leitch and Hovde (1996) using a preventative expenditures approach.

Table 1. Costs to Restore 2,700 Acres of Previously Drained Wetlands in the Maple River Watershed Over a 20-year Period

	Annual Rent	Construction Costs (Year 1)	Total Discounted Costs (20 Years)	Annual Cost Per Acre-Foot Restored
Simple Restoration 700 acres @ $300/acre (wetlands <1 acre) 1,100 acres @ $200/acre (wetlands 1-5 acres) 900 acres @ $100/.acre (wetlands > 5 acres)	$108,000	$520,000	$1.84 million	$34
Simple Restoration (Low Cost Land)	$94,500	"	$1.67 million	$31
Outlet Restoration 700 acres @ $600/acre (wetlands <1 acre) 1,100 acres @ 400/acre (wetlands 1-5 acres) 900 acres @ $200/acre (wetlands > 5 acres)	$108,000	$1,040,000	$2.34 million	$22
Outlet Restoration (Low Cost Land)	$94,500	"	$2.17 million	$20
Complete Restoration 700 acres @ $3000/acre (wetlands <1 acre) 1,100 acres @ $1000/acre (wetlands 1-5 acres) 900 acres @ $500/.acre (wetlands > 5 acres)	$108,000	$3,650,000	$4.82 million	$45
Complete Restoration (Low Cost Land)	$94,500	"	$4.65 million	$43

NOTES:
1. Based on the restoration of 2,700 acres of previously drained wetlands (from the NWI) and storage bounce of 1 acre feet per acre (afpa) with simple restoration and 2 afpa with outlet and complete restoration.
2. Average annual rent in the upper Maple Watershed is $40 and $35 (low cost land).
3. Total costs represented in present value were calculated using a 5% discount rate.

Table 2. Flood Damage Within and Downstream of the Maple River Watershed (1989-1998)

	1989	1992	1993	1994	1995	1996	1997 [3]	1998
Historical Damage[1] (Millions)	$0.3	$0.1	$12.4	$0.5	$0.9	$1.8	$152.5*	$0.8
Agricultural Damage (Percent of Total)	64%	100%	62%	87%	52%	68%	10%	2%
Peak Flood Flow (CFS)	981	710	3,770	3,040	1,830	3,860	4,060	1,730
Peak Flood Stage (ft)	8.4	7.3	12.7	11.5	10.1	12.3	12.6	9.9
Flood Event	2-year (P = .50)	2-year (P =.50)	25-year (P = .04)	10-year (P = .10)	2-year (P = .50)	25-year (P = .04)	50-year (P = .02)	2-year (P = .50)
Expected Reduction in Damage (1 ft storage)[2]	3.8%	3.8%	1.7%	2.2%	3.8%	1.7%	1.6%	3.8%
Expected Annual Monetary Damage Reduction (1 ft storage)	$5,700	$1,900	$8,432	$1,100	$17,100	$1,224	$48,800	$15,200
Expected Reduction in Damage (2 ft storage)[2]	5.4%	5.4%	2.4%	3.2%	5.4%	2.4%	2.4%	5.4%
Expected Annual Monetary Damage Reduction (2 ft storage)	$8100	$2700	$11,904	$1,600	$24,300	$1,728	$73,200	$21,600

Notes:

1. No major flood damage recorded in 1990 or 1991.
2. Based on expected probability of the occurrence of such a flood in any given year and expected reductions in peak flood stage (from the hydrologic modeling of Bengtson and Padmanabahn, 1999).
3. The 1997 Grand Forks flood resulted in $12.5 million of damage within the Maple River Watershed and $2 billion downstream in Grand Forks (of which 7% or $140 million is associated with drainage from the Maple River Watershed).

The Feasibility of Wetland Restoration

All of the wetland restoration alternatives evaluated have very large negative net present values ranging from - $1.5 million to - $ 4.6 million with corresponding benefit-cost ratios from 0.04 to 0.11 which unequivocally indicates economic infeasibility for each of the wetland restoration options (Table 3). As expected, the more costly outlet and complete restoration options are the least feasible alternatives despite their relatively higher avoided flood damage benefits.

Even the most optimistic (and unlikely) scenario of simple restoration on low cost land with 2 feet of storage bounce is not feasible with costs exceeding benefits nine fold. Alternatively, wetland restoration storage options would have to reduce annual peak flood stages and flood damage by between 4 and 12 percent before breaking even. These break-even values may be useful for future feasibility studies in light of revised and/or improved hydrologic modeling of the relationships between wetland restoration and peak flood stages.

Non-Flood Related Values of Restored Wetlands

The value of non-flood related wetland benefits required for alternative wetland restoration options to break even range from $28 to $86 per acre per year (Table 3). The higher end values of $83 and $86 associated with complete restoration options are of the most interest because these restoration alternatives are specifically designed to provide such wetland values. However, these required break-even values greatly exceed previously reported average annual per acre wetland benefits of $4.2 for sedimentation control and recreation among five nearby wetlands (Leitch and Hovde, 1996), as well as the combined recreation and existence value of $21 for a Red River Valley wetland complex (Roberts and Leitch, 1997), and the $5 to $9 range of recreation-based wetland values in Louisiana (Farber, 1987 and Bergstrom et al., 1990).

Sensitivity Analyses

The evaluation of wetland restoration for flood control with a longer project life span (50 and 100 years) and with a lower discount rate of 3 percent did not change any of our conclusions regarding the infeasibility of wetland restoration for reducing flood damage. Specifically, net present values remained negative and benefit-cost ratios remained considerably less than 1 (Table 4). Even the extremely optimistic scenario of simple restoration on low cost land providing 2 feet of storage bounce evaluated over a 100-year period using a 3 percent discount rate results in a benefit-cost ratio of 0.12.

Table 3. Feasibility Indicators of Wetland Restoration Options to Reduce Flood Damage in the Maple River Watershed

Wetland Restoration Option	Net Present Values	Benefit Cost Ratios	Required Reductions in Peak Flood Stage to 'Break-Even'	Other (non-flood related) Wetland Values Required for Restoration to 'Break- Even' (Acre/Year)
Simple Restoration (1 ft bounce, 2,700 AF storage)	- $1.7 million	0.07	5%	$32
Simple Restoration (Low Cost Land) (1 ft bounce & 2,700 AF storage)	- $1.5 million	0.07	4%	$29
Outlet Restoration (2 ft bounce & 5,400 AF Storage)	- $2.1 million	0.08	6%	$40
Outlet Restoration (Low Cost Land) (2 ft bounce & 5,400 AF Storage)	- $1.9 million	0.08	5%	$37
Complete Restoration (2 ft bounce & 5,400 AF Storage)	- $4.6 million	0.04	12%	$86
Complete Restoration (Low Cost Land) (2 ft bounce & 5,400 AF Storage)	- $4.4 million	0.04	11%	$83
Simple Restoration, Low Cost Land with Maximum Storage Bounce (2 ft of bounce, & 5,400 AF Storage)	- $1.5 million	0.11	4%	$28

Notes:
- Avoided flood damage is a function of historical flood damage reduced by both the expected probability of flood events and expected reductions in peak flood stage.
- Expected annual average avoided flood damage (1989-97) is expected to occur in individual years.
- A discount rate of 5% was used.
- Other (non-flood related) wetland values are associated with the restoration of 2,700 surface acres of wetlands.

Table 4. Sensitivity Analyses: Benefit-Cost Ratios of Alternative Wetland Restoration Options to Reduce Flood Damage in the Maple River Watershed Under Alternative Time Frame and Discount Rate Scenarios

	Simple Restoration	Simple Restoration Low Cost Land	Outlet Restoration	Outlet Restoration Low Cost Land	Complete Restoration	Complete Restoration Low Cost Land	Simple Low Cost Land, 2 Ft Storage Bounce
Baseline 20 Years 5% Discount Rate	0.07	0.07	0.08	0.08	0.04	0.04	0.11
20 years 3% Discount Rate	0.07	0.07	0.08	0.09	0.04	0.04	0.11
50 years 5% Discount Rate	0.07	0.08	0.09	0.10	0.05	0.05	0.12
50 years 3% Discount Rate	0.08	0.08	0.10	0.11	0.06	0.06	0.12
100 Years 3% Discount Rate	0.08	0.09	0.10	0.11	0.07	0.07	0.12

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SUMMARY AND CONCLUSION

This study evaluated the economic feasibility of wetland restoration to reduce flood damage in the Maple River Watershed, a sub-watershed of the Red River Valley. The three wetland restoration options evaluated were simple restoration, outlet restoration with increased storage capacity, and complete restoration intended to provide a full range of wetland-based goods and services.

Information on the location and size of potential wetland restoration sites was used to estimate local land rental and construction costs, which varied by the type of restoration being considered and the size of wetlands to be restored. Benefits in the form of avoided flood damage were estimated by multiplying expected reductions in peak flood stages associated with alternative restoration options by historical flood damage payments associated with actual flood events from 1989 to 1998. Flood damage payments were estimated both within and downstream of the watershed and extrapolated over a hypothetical 20-year time period.

In addition to the use of site-specific wetland restoration cost and flood damage payment data, this study used data from and based on several key assumptions on previous wetland-related studies in the region. Assumptions, ranging from available storage in restored wetlands and their role in reducing peak flood stages and flood damage to the expectation that the historic wet cycle of 1989 to 1998 would continue in the future , were all generous to the cause of using wetland restoration to reduce flood damage. This strengthens the general conclusion that wetland restoration is not an economically feasible way to reduce flood damage across sub-watersheds of the Red River Valley.

In fact, none of the wetland restoration options evaluated were economically feasible, with benefit-cost ratios ranging from 0.12 for the most optimistic scenario (low cost land, 2 feet of storage, a 100-year time frame and a 3 percent discount rate) to 0.04 for more complete restoration intended to provide a full range of wetland-based goods and services over a 20-year period. Alternatively, wetland restoration options would need to reduce peak flood stage and related damage by 4 to 12 percent (under the 20-year time frame scenario) just to break even.

Although the primary motive of this study was to evaluate if wetland restoration was a feasible way to reduce flood damage in the Red River Valley, the potential role that additional (non-flood related) wetland benefits could play in improving the feasibility of wetland restoration options was also evaluated. It was determined that the benefits associated with complete restoration required to obtain feasibility exceeded their actual and/or expected values. However, if simple and low cost restoration provided these non-flood related wetland benefits, it is possible that such restoration could approach a break-even point.

Based on the results of this study, the widespread restoration of wetlands is not considered to be wise use of public funds for the purpose of reducing flood related damage at the watershed or basin-wide level in the Red River Valley. However, this does not completely negate the potential feasibility of wetland restoration for flood control and/or the generation of other wetland-based environmental goods and services on a more limited and site-specific basis. Therefore, more research should be conducted regarding the use and non-use values of restored wetlands and how these values change when large numbers of wetlands are restored under various restoration options. In the meantime, wetland restoration in the Red River Valley should probably only be conducted in cases where simple restoration on low cost land can provide two or more additional feet of available storage bounce, have clear impacts on localized flood damage, and provide the additional (non-flood related) benefits. These scenarios are likely to occur only at a selective number of locations rather than across entire watersheds.

The results and implications of this study are somewhat limited to the North Dakota, Minnesota, and Manitoba portions of the Red River Valley due to local wetland characteristics, land values, and flooding conditions. However, the methods presented here to integrate site-specific restoration costs with hydrologic modeling and historical flood damage payment data over time are potentially replicable in other regions of the country and are considered essential in evaluating the ongoing public policy debate as to what wetlands are worth to society. Until now, such a multi-disciplinary approach to evaluating the feasibility of wetland restoration for the purpose of reducing flood damage has been absent from the literature.

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