An Exploratory Study of the Economic Perspectives of River Systems

Final Draft

June 2016

Report to the National Great Rivers Research and Education Center

Steve Sonka

Grace Kenney

Yu-Tien (Casey) Cheng

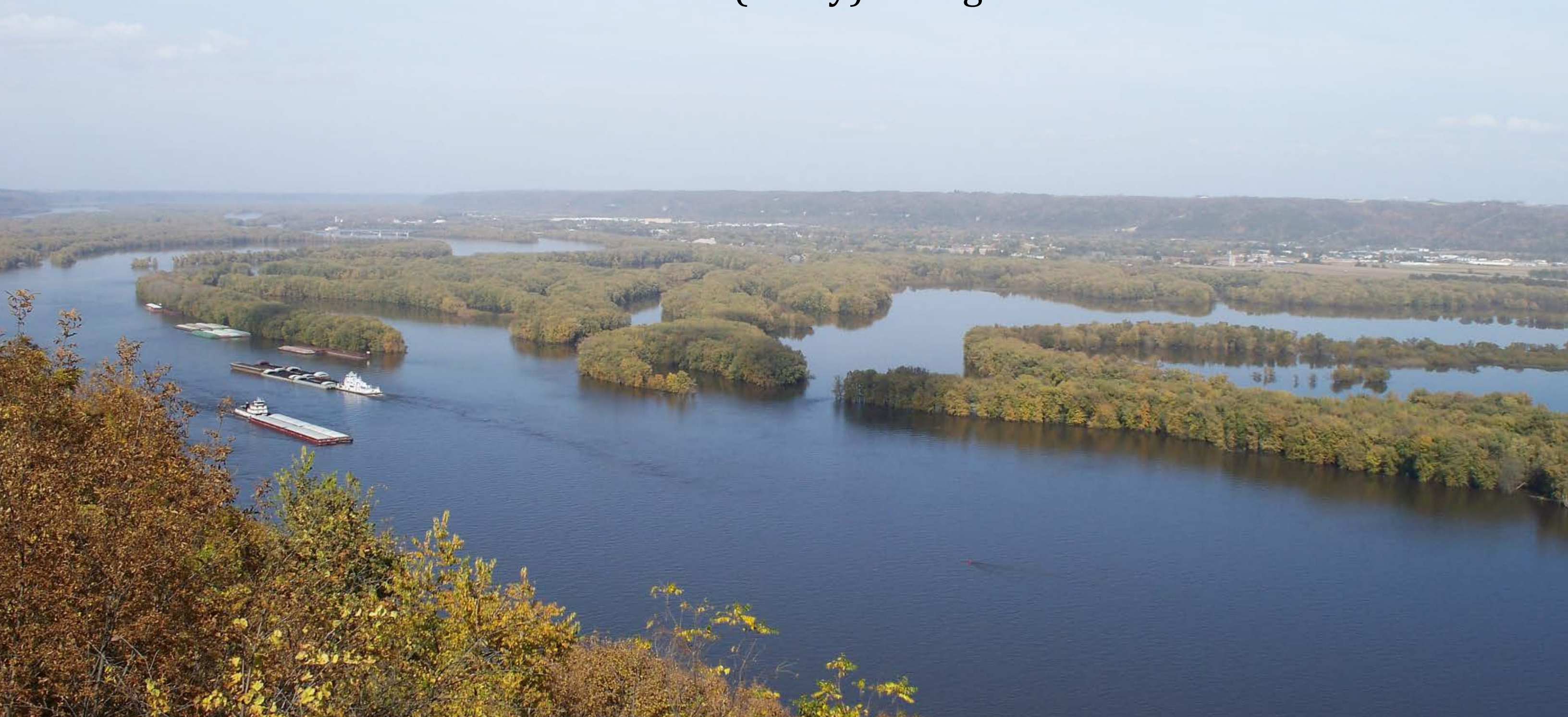

Table of Contents

(Cover photo credit: annaica at Pixabay)

Executive Summary

This report presents the results of an exploratory effort to identify and document key economic perspectives relating to river systems and their societal contributions. Understanding those perspectives is important if appropriate resources are to be devoted to such systems and to ensure that societal gains from their implementation are maximized. The project's two explicit goals are to identify and categorize:

- research findings that provide economic perspectives relating to river systems and associated information systems and
- methods employed to document the economic value of information related to river systems.

As an exploratory study, its conduct relied heavily upon review and interpretation of published literature, primarily involving identification and analysis of written reports and studies. However, interviews with scientists and economists were conducted to guide the analysts as to human and information resources available.

The report's second section explores estimation methods employed to assess economic issues relating to rivers, with eight methods identified. It should be noted that economic methods are in themselves not correct or incorrect. Rather the purpose of the study for which they are used is an important determinant of the appropriateness of a method for a specific task. Further, empirical application of economic methods likely never is "perfect" as data availability typically requires comprises from the rigor required in theory. Therefore, shortcomings and strengths are characteristics of economic analysis. In the Estimation Methods section, specific example studies are provided for each approach.

> The National Great Rivers Research and Education Center (NGRREC) is making significant progress in the development and implementation of important information resource capabilities, specifically the Great Lakes to Gulf (GLTG) Virtual Observatory and the Great Rivers Ecological Observation Network (GREON). These tools have the potential to provide important information and enhance the economic effectiveness of actions to improve our river's capability to provide ecosystem services.
>
> While not a specific task within the study which this report describes, the authors observe that careful analysis of the GLTG/GREON capabilities would be best conducted through application of hydroeconomic modeling. Effective efforts could estimate net economic benefits or use a minimizing cost approach. However, such efforts likely require application of economic models, possibly best done through collaboration with entities that have existing capabilities.
>
> A second observation is that while considerable information exists relative to economic issues associated with rivers, relatively little understanding is readily available from that information. NGRREC could be an organization which uniquely contributes to the growth of such understanding, especially as it relates to the Upper Mississippi River Basin.

A common approach to assessing economic issues is to focus on specific commercial sectors in the context of particular river geographies. The report's third section provides examples of such applications, devoted in particular to commercial fishing, recreation, and transportation. Because of their commercial nature, this type of analysis "fits" within typical economic analysis frameworks. Table 3.1 in the section highlights the diversity of types of economic information (in terms of geography, approach, and values reported) that characterize economic analysis related to rivers. Of the three sectors considered, transportation has received the most extensive analysis with a body of knowledge that is the most actionable in nature.

The study's fourth section addresses various dimensions associated with economic analysis of issues related to rivers and ecosystem services provided by rivers and river systems. In 2003, the UN Millennium Ecosystem Assessment provided the following framework for attempting to understand ecosystems:

> *A well-defined ecosystem has strong interactions among its components and weak interactions across its boundaries. A practical approach to the spatial delimitation of an ecosystem is to build up a series of overlays of significant factors, mapping the location of discontinuities, such as in the distribution of organisms, the biophysical environment (soil types, drainage basins, depth in a water body), and spatial interactions (home ranges, migration patterns, fluxes of matter). A useful ecosystem boundary is the place where a number of these relative discontinuities coincide.*

While conceptually powerful, application of that framework to issues related to rivers has provided individually useful, but fragmented, results.

As a specific targeted activity, a search of articles in nine Midwestern newspapers was conducted for reports addressing the economic implications of ecosystem services provided by Midwestern rivers. The time period examined was from the turn of the century to now. Somewhat surprisingly few such articles were found in that search. A number of articles were identified that discussed proposed activities to address river issues. However, the focus was on the funding provided (or proposed) with little attention devoted to analysis of economic benefits.

The report's fourth section also addresses river issues including those affecting water quality and quantity, policy directed to improve the services provided by rivers, and the process of evaluating the economics of information targeted to river issues. Again, while numerous studies have been conducted, aggregating those findings into an integrated understanding of the "economics of rivers" is difficult.

As another observation, it appears that a comprehensive analysis of the economics of a specific river (or river segment) could contribute significantly to understanding the relationship between economics and the ecosystem services of rivers.

1. Introduction

The world's rivers, and the resources/services they provide, are critically important to society. In both their quantity and quality dimensions, rivers have importance at local, regional, national, and global levels. Decision makers in the public sector (both as policy makers and in executing regulations) and managers in the private sector increasingly need access to ever more accurate, timely, and extensive information to make informed choices that best serve society.

The purpose of this report is to present the results of an exploratory effort to identify and document key economic perspectives relating to river systems and their societal contributions. Understanding those perspectives is important in determining if appropriate resources are to be devoted to similar systems and to ensure that societal gains from their implementation are maximized.

Economic assessment of the value of information systems cannot be conducted in isolation of the phenomena and the decisions that will be influenced/determined by the information provided. This means that economic evaluation of entities as complex as river systems are themselves complex. As an exploratory step, the efforts conducted in this project had the explicit purpose of discovering and categorizing relevant findings relating to the economics of river systems. The project's two explicit goals are to identify and categorize:

- research findings that provide economic perspectives relating to river systems and associated information systems and
- methods employed to document the economic value of information related to river systems.

The activities conducted were relatively straightforward, with an emphasis on review and interpretation of published literature. However, the broad scope of the topic presented some challenges. The approach primarily focused on identification and analysis of written reports and studies. However, interviews with scientists and economists were conducted to guide the analysts as to human and information resources available. This approach sometimes is referred to as a "waterfall approach"; where initial activities focus on both citing directly useful information and identifying potentially valuable sources of further "leads" as to economists who've conducted such work and information sources likely to contain pertinent information.

The remainder of this report is organized as follows: Section 2 discusses the estimation methods employed in the identified studies; Section 3 presents the economic values of river-related sectors; and Section 4 discusses the issues relating to river systems and the economic assessment of such issues. (In each of the following sections, part of the text is taken directly from the original resource and is shown in italics.)

2. Estimation Methods Employed

A variety of methods have been employed to provide estimates of economic activity and/or the economic impact of changing policies and conditions of rivers. More commonly employed examples are listed below. For each type of analysis, an example application is provided.

Even if a conceptually rigorous method is employed, effective and thorough application is required and typically requires expertise and resources. Indeed, there probably is no applied economic analysis that is "perfect". Generally, the data available have been collected for multiple purposes and often sufficient quantities of ideal data are not available. Further, economic analysis relates to human decisions and behavior. Seldom is accurate information available as to the motivations for those behaviors and decisions and has to be inferred. Recognizing those inherent limitations, however, some analyses employ methods and approaches that seriously compromise the value of the estimates reported. Examples of both more and less credible approaches are noted below.

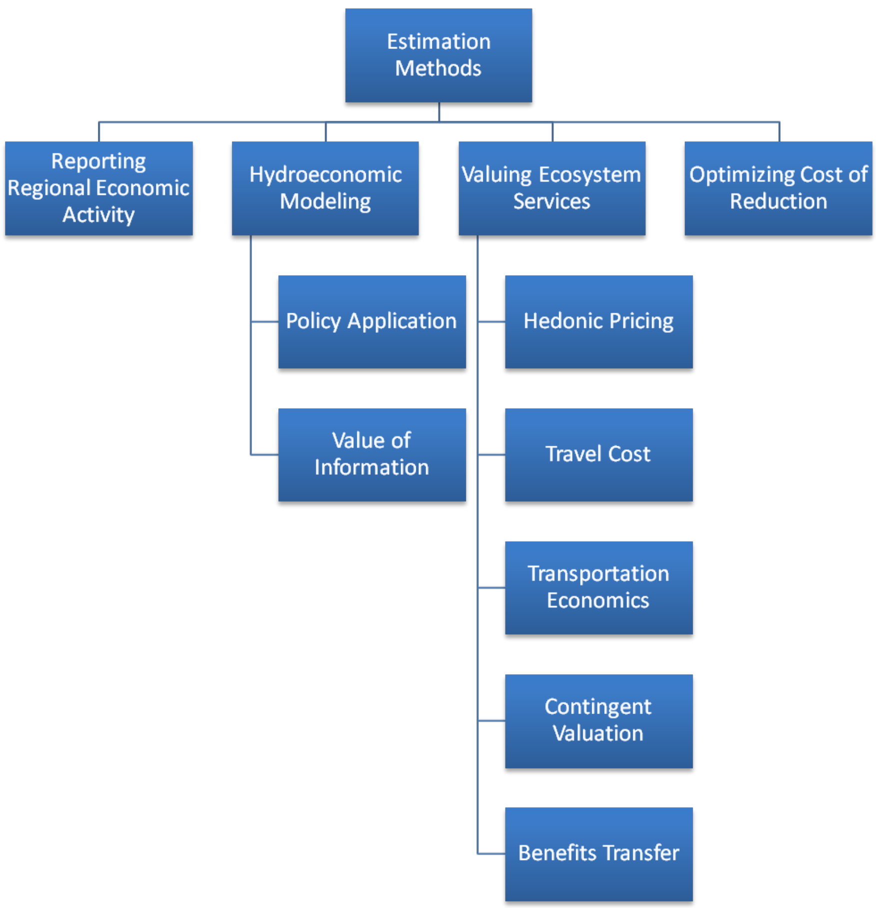

Figure 2.1. Estimation Methods

2.1. Reporting Regional Economic Activity

(US Fish and Wildlife Service, 2015, "Upper Mississippi River economic assessment Part 1: 60 county assessment") One of several similar efforts, this work attempts to link parts or all of a region's economic activity to a major river in the region. Clearly, the Mississippi River historically exerted and continues to exert considerable influence on economic development and growth in the areas adjacent to it. However, it is not the only factor contributing to the region's economy. A primary purpose of such efforts appears to be to generate large dollar values with the goal of raising awareness regarding the economic importance of the river and associated river issues. The values reported, however, tend to be disconnected from meaningful decisions relating to key river issues.

> *This study develops an economic profile of the Upper Mississippi River Corridor (UMRC) across five states and 60 counties stretching from St. Louis Missouri to the Minneapolis-St. Paul area in Minnesota. The report focuses on nine industrial sectors: (1) commercial harvest of natural resources; (2) outdoor recreation; (3) tourism and travel; (4) water supply; (5) agriculture; (6) mineral resources; (7) energy generation and production; (8) commercial navigation and (9) manufacturing.* ***Total revenue generated in the corridor annually is $239.5 billion*** *with associated employment of over 744,000. Manufacturing, Tourism and Agriculture account for over 95 percent of total revenue (same as in the 1999 UMR report) and 94 percent of total employment (96 percent in the 1999 UMR report) in the UMRC.*

As noted in the preceding excerpt from the study's Executive Summary, the study considered nine sectors. The linkage between the river and each of those sectors varies to a considerable extent with, for example, commercial harvest of natural resources, outdoor recreation, and commercial navigation having strong linkages.

Conversely the total revenues earned in the manufacturing, tourism, and agriculture sectors are much more weakly linked to the river. While river shipping is an advantage for farming closer to the river, the effect of the river would best be demonstrated by calculating differential transportation rates rather than simply reporting total farm revenues. Or as another example, it's likely that fans attending Cardinal baseball games are not primarily motivated to do so because the stadium is near the river. However as noted above, these three sectors (manufacturing, tourism, and agriculture) accounted for over 95 percent of total revenue reported in this study.

2.2. Hydroeconomic Modeling

Hydroeconomic modeling is useful when evaluating change to a condition or policy, which has the potential to change productivity of a commercial activity/sector. It is also useful in assessing the value of information related to river conditions and policy. In some instances, both potential behavioral change and hydrology factors are integrated within a single model. In other instances, a change in the river condition is specified and the economic impact of that change is assessed through a separate model.

Two example applications are discussed below. Subject to the specified environmental constraints, the objective of the first is cost minimization. The objective of the second is maximization of net economic benefits. The first illustrates evaluation of policy alternatives, while the second application is focused on assessing the value of new information capabilities.

2.2.1. Policy Application

(Rabotyagov et al., 2014, "Cost-effective targeting of conservation investments to reduce the northern Gulf of Mexico hypoxic zone") The study is an example of a very extensive and presumably resource intensive analysis that links actions in the field to nutrient runoff and river transport and subsequently to hypoxia levels in the Gulf. The integrated assessment model employed is quite comprehensive. The approach taken is to find the set of constraints and actions needed to achieve national policy goals at minimum cost.

> *A seasonally occurring summer hypoxic (low oxygen) zone in the northern Gulf of Mexico is the second largest in the world. Reductions in nutrients from agricultural cropland in its watershed are needed to reduce the hypoxic zone size to the national policy goal of 5,000 km^2 (as a 5-y running average) set by the national Gulf of Mexico Task Force's Action Plan. We develop an integrated assessment model linking the water quality effects of cropland conservation investment decisions on the more than 550 agricultural subwatersheds that deliver nutrients into the Gulf with a hypoxic zone model. We use this integrated assessment model to identify the most cost-effective subwatersheds to target for cropland conservation investments. We consider targeting of the location (which subwatersheds to treat) and the extent of conservation investment to undertake (how much cropland within a subwatershed to treat). We use process models to simulate the dynamics of the effects of cropland conservation investments on nutrient delivery to the Gulf and use an evolutionary algorithm to solve the optimization problem.* ***Model results suggest that by targeting cropland conservation investments to the most cost-effective location and extent of coverage, the Action Plan goal of 5,000 km^2 can be achieved at a cost of $2.7 billion annually****. A large set of cost-hypoxia tradeoffs is developed, ranging from the baseline to the nontargeted adoption of the most aggressive cropland conservation investments in all subwatersheds (estimated to reduce the hypoxic zone to less than 3,000 km^2 at a cost of $5.6 billion annually).*

2.2.2. Value of Information

(Forney, Raunikar, Bernknopf, and Mishra, 2012, "An economic value of remote-sensing information—Application to agricultural production and maintaining groundwater quality") The study is an example of use of an integrated assessment modeling capability. Although focused on groundwater, the study is included in this review because:

- it illustrates (although with limitations to be discussed later) an appropriate approach to valuation of information (such as that which might be forthcoming from NGRREC's capabilities);
- it explores the effects of potential environmental constraints on agricultural production and profitability; and
- the focus on satellite-provided information could be of interest.

> *Does remote-sensing information provide economic benefits to society, and can a value be assigned to those benefits? Can resource management and policy decisions be better informed by coupling past and present Earth observations with groundwater nitrate measurements? Using an integrated assessment approach, the U.S. Geological Survey (USGS) applied an established conceptual framework to answer these questions, as well as to estimate the value of information (VOI) for remote-sensing imagery. The approach uses*

moderate-resolution land-imagery (MRLI) data from the Landsat and Advanced Wide Field Sensor satellites that has been classified by the National Agricultural Statistics Service into the Cropland Data Layer (CDL). Within the constraint of the U.S. Environmental Protection Agency's public health threshold for potable groundwater resources, the USGS modeled the relation between a population of the CDL's land uses and dynamic nitrate (NO_3^-) contamination of aquifers in a case study region in northeastern Iowa Employing various multiscaled, multitemporal geospatial datasets with MRLI to maximize the value of agricultural production, the approach develops and uses multiple environmental science models to address dynamic nitrogen loading and transport at specified distances from specific sites (wells) and at landscape scales (for example, across 35 counties and two aquifers). In addition to the ecosystem service of potable groundwater, this effort focuses on the use of MRLI for the management of the major land uses in the study region—the production of corn and soybeans, which can impact groundwater quality. Derived methods and results include (1) economic and dynamic nitrate-pollution models, (2) probabilities of the survival of groundwater, and (3) a VOI for remote sensing. ***For the northeastern Iowa study region, the marginal benefit of the MRLI VOI (in 2010 dollars) is $858 million ± $197 million annualized, which corresponds to a net present value of $38.1 billion ± $8.8 billion for that flow of benefits in perpetuity.*** *Given that these economic estimates are derived from one case study in a part of only one State, the estimates provide a lower estimate related to the potential value of the Landsat Data Continuity Mission.*

Examination of the information provided in the cited report reveals that the physical and hydrologic aspects of the integrated assessment were modeled in great detail and with appropriate diligence (from the perspective of an economist reviewer). However, the agricultural economic aspects of the analysis appear to be rather naïve. Even after several readings, it appears that the only management decision modeled was whether to grow corn or to grow soybeans. This, of course, appears to ignore the potentially beneficial impacts of application of alternative practices or adoption of conservation practices in reducing excess nutrient uses.

For purposes of this economic review, the more troubling aspect of this approach is that the gain in economic benefits reported appears to be solely the result of:

- increasing overall corn production;
- accomplished by shifting acres from corn/soybean rotations to continuous corn or to continuous soybeans.

The report notes, *"By moving corn production to lands identified to be less prone to leach nitrate and additionally to lands with fate and transport properties that render aquifers less vulnerable to leached nitrate, the value of the crop can be increased substantially, while holding level the risk of groundwater contamination."*

During the time period modeled (2001 to 2010), corn production became increasing more profitable relative to soybeans because of the increased demand for ethanol. In fact, actual corn production increased relative to soybeans over this period. Unfortunately, the report doesn't provide information on the amount of estimated corn or soybeans production in its "with information" results. That production amount would directly link to the estimated economic benefits that were claimed in the analysis.

Actual farmers, of course, realized that there were potential economic benefits from increasing corn acreage during the 2001-2010 period. However, their interest in shifting to continuous corn (or continuous soybeans) was constrained by the well-known production and environmental disadvantages of such a shift. Based upon the information provided in the cited report, it appears that the integrated assessment model wasn't aware of those disadvantages.

2.3. Valuing Ecosystem Services

Rivers provide value which extends beyond their direct impact in commercial activities. One setting is where there is a "Use Value" associated with the river services. In those instances, the willingness to pay of citizens and users (hunters, tourists) can be assessed even if there is not a direct commercial transaction for the river services. The alternative setting is characterized by the term "Non-Use Value", where individuals can derive benefits from the existence of natural resources, even though they are not directly "consuming" those services. For example, individuals who someday may travel down the Mississippi River may value the option of being able to do so, even though they currently don't do so. Further, we may assign value to the opportunity for future generations to do so. Alternative methods employed in both the use value and non-use value settings are presented below. The first three methods provide examples relative to use value situations. The fourth method, contingent valuation, is the primary method employed in non-use value situations. However, contingent valuation can be employed in use value settings as well.

2.3.1. Hedonic Pricing

(Braden et al., 2008, "Economic benefits of remediating the Sheboygan River, Wisconsin Area of Concern") In certain circumstances, econometric analysis of commercial transactions can be used to discern the price associated with a specific factor of interest (proximity to a river and/or quality of river water). Assessing house values by their nearness to polluted versus attractive river segments is an example of this approach.

> *This study estimates the economic benefits of remediation in the Sheboygan River, WI Area of Concern (AOC) using two distinct empirical methods. The methodology parallels that described by Braden et al. (2008). The results are mixed. Using hedonic analysis of property sales, for owner-occupied homes within a 5-mile radius of the Sheboygan River AOC***, the overall estimated loss of value is $158 million (8% of market value). Of this total, only $49 million in losses for homes closest to the upper river segment has strong statistical support***. The impacts are greatest proportionally for properties closest to the AOC.* ***A survey-based method yields a mean estimate of $218 million (10% of property value) in willingness to pay for full cleanup of the AOC.*** *If remediation were to induce recovery of property values, then the local communities could benefit through increased property tax revenues.*

Braden conducted a number of studies relating to the economic benefits of remediating rivers that had been designated Areas of Concern. The extent to which the hedonic pricing approach produces credible assessments of the value of the river depends upon the specific circumstances of the study setting. If there are many diverse factors affecting home values, the economic link to the river will be weak. In the Area of Concern setting, where contaminated areas had been designated by the Canadian and US governments for remedial action, it's likely that the linkage would be relatively strong. The study performs a willingness-to-pay survey which yields relatively similar results: that housing values would be improved by remediation but the extent of that improvement would be in the higher single digits in percentage terms.

2.3.2. Travel Cost

(NorthStar Economics, 2008, "The economic impact of recreational trout angling in the Driftless Area")
Especially for recreational services, individuals indicate the minimum amount of their willingness to pay for benefits of a resource in terms of the actual expenditures they incur to travel to and utilize the resource. Capturing information on actual expenses typically requires conducting a survey of users of the natural resource. The study referenced here conducted such a survey regarding fishing in the Driftless area within the Upper Mississippi River Basin. While the survey information appears to provide useful information regarding individual expenditures, the effort to create an aggregate value at the macro level is somewhat lacking in credibility.

> *Recreational trout angling is a significant economic driver in the Driftless Area, a geographic region covering parts of southwest Wisconsin, southeast Minnesota, northeast Iowa, and northwest Illinois. Stream restoration efforts have played a significant role in restoring the region to a popular fishing destination for trout anglers, who contribute more than $1 billion per year to the regional economy. NorthStar Economics was retained by Trout Unlimited (TU) to calculate the economic impact resulting from the restoration of trout streams in the Driftless Area. …*
>
> - *In this study, we set out to calculate the economic contribution made by those anglers. …*
> - *A survey instrument was designed to gather data from anglers who fish in the region. …*
> - *A significant number of respondents don't fish the Driftless Area at all. Others fish the region quite frequently, and a majority fall somewhere between the two extremes. …*
> - *The average angler therefore spends $4171.15 each year on trout fishing in the Driftless Area (a weighted average representing 39% of the Driftless Area average and 61% of the Non-Driftless Area average). …*
> - *As there are more than 155,000 trout stamp holders in the Driftless Area states, we conclude that direct spending in the region totals nearly $647 million.*
> - *155,070 trout stamp holders x $4171.15 spent per angler = $646,819,673*

- *Spending produces not only a direct economic effect, but indirect and induced effects as well as those dollars continue to flow through the economy. Economic multipliers were applied to the spending data to determine the indirect and induced (or "ripple effect") of the direct spending. …*
- *Adding the direct spending total to the indirect and induced spending total reveals that trout anglers produce an economic benefit to the Driftless Area in excess of $1.1 billion every year.*

There are two relatively apparent concerns with the macroeconomic values reported:

- While the estimate for the individual expenditure appears to have been achieved in a relatively appropriate fashion, the process of multiplying that value times the number of all stamp holders is suspect. No effort was reported to determine if the percentage of survey respondents who don't fish in the Driftless region was consistent with that of fishing stamp holders in the states that encompass the Driftless region.
- Estimation of indirect effects of spending is appropriate. However, the approach employed in this study implicitly assumes that the angler who resides in the Driftless Area would not spend any money in the area if they decided not to go fishing. That likely is not a reasonable assumption.

2.3.3. Transportation Economics

(Kruse et al., 2011, "America's locks & dams: "A ticking time bomb for agriculture?") Commercial transportation is an important economic activity for a number of US and Midwest rivers, including the Mississippi. For that reason, analysis of transportation issues is a topic that has received considerable attention. Because of its commercial nature, analysis of economic effects on transportation is relatively more straightforward than is analysis of other issues. The study described here focuses on the issues of maintaining the lock and dam infrastructure in the Midwest.

The rapidly deteriorating condition of the nation's lock and dam infrastructure imperils the ability of the waterborne transportation system to provide a service that will enable U.S. agricultural producers to continue to compete. Should a catastrophic failure of lock and dam infrastructure occur, agricultural producers—and consequently the American consumer—will suffer severe economic distress. This research analyzed and evaluated data and information that will illustrate this vulnerability at a micro level rather than the traditional macro level.

This research examined the condition of locks on key segments of the nation's waterways, analyzed their usage, determined which are most likely to suffer catastrophic failure, and estimated the impact at the local level based on projected freight flows. …

Based on analytical work reported in Chapter 3, six locks were chosen for detailed analysis. They were chosen based on their economic importance and physical condition. The six locks are:

- *Illinois River LaGrange Lock and Dam.*
- *Ohio River Emsworth Lock and Dam.*
- *Ohio River Markland Lock and Dam.*
- *Ohio River Olmsted Lock and Dam (replacement for L&D 52 and 53).*
- *Upper Mississippi River Lock and Dam 20.*
- *Upper Mississippi River Lock and Dam 25*

…

Chapter 4: Economic Impact at Congressional District/Regional Level

Chapter 4 provides the following information:

- *Impacts by Crop Reporting District (CRD) and Congressional District (CD) including:*
    - *Effect on agricultural commodity prices.*
    - *Effect on agricultural inputs.*
    - *Effect on energy prices.*
- *Profiles of mode use and costs for farmers, grain elevators, and soybean processors.*

Four closure durations were modeled at five of the six focus locks (those with agricultural movements): two weeks, one month, one quarter, and one year. ***A failure at any one of the focus locks would cost agricultural producers anywhere between $900,000 and $45 million, and result in lost revenues to barge companies between $2.2 million and $162.9 million****, depending on duration. …*

A closer examination of just one of the focus locks—LaGrange Lock on the Illinois River—reveals the wide-ranging nature of the economic impacts. The most vulnerable CRD to a failure of the LaGrange Lock on the Illinois River is Illinois CRD 20. Illinois CRD 20 is principally composed of Illinois CD 11; however, CDs 1, 2, 3, 6, 8, 9, 10, 13, 14, and 16 contain small parts of CRD 20. This CRD would ***lose $4.3 million and the price of corn would be reduced $0.70 per ton and the price for soybeans by $2.45 per ton****. The second most vulnerable CRD would be Illinois CRD 10 with* ***$3.1 million lost from a failure of the LaGrange Lock****. Illinois CRD 10 is principally composed of CD 16 but CDs 11, 14, 17, and 18 also have parts of their area in this CRD. …*

The model also allowed insights into incidence of the costs and effects on welfare distribution, costs, flows etc. that can be summarized as:

- *International consumers have the most to lose.*
- *Barge companies lose significant revenue.*
- *Barge use is reduced and replaced by rail and small ship.*
- *The U.S. loses a small amount of export share.*
- *Cost of closure is about $1.50 per ton that traverses a lock.*

This report provides a number of interesting thoughts regarding economic analysis of issues relating to rivers. One is the importance of utilizing existing modeling infrastructure. The ability to take advantage of existing modeling capabilities at Texas A&M undoubtedly reduced costs. Further, knowledge and experience relative to agricultural systems of the key researchers likely contributed to the professional nature of the findings. An additional feature of the economic component of this study is its focus on economic impacts of micro areas – Crop Reporting Districts and Congressional Districts.

2.3.4. Contingent Valuation

(Loomis, Strange, Kent, Covich, and Fausch, 2000, "Measuring the total economic value of restoring ecosystem services in an impaired river basin: results from a contingent valuation survey") Citizens can derive benefits from the existence of natural resources, even though they are not directly "consuming" those services. For example, individuals who someday may travel down the Mississippi River may value having the option to do so, even though they currently don't do so. Further, we may assign value to the opportunity for future generations to do so.

Contingent valuation is the common approach employed to develop estimates of willingness to pay when economic information on actual expenditures (revealed preferences) are lacking. Contingent valuation relies upon <u>stated preferences</u> to indicate willingness to pay. Because actual behavior is not involved, critics have been skeptical as to the validity of estimates obtained through such approaches. Conversely, contingent valuation often is used when actual behavior cannot be observed, even though there is likely to be economic value associated with the service/resource in question.

> *Five ecosystem services that could be restored along a 45-mile section of the Platte River were described to respondents using a building block approach developed by an interdisciplinary team. These ecosystem services were dilution of wastewater, natural purification of water, erosion control, habitat for fish and wildlife, and recreation. Households were asked a dichotomous choice willingness to pay question regarding purchasing the increase in ecosystem services through a higher water bill.* ***Results from nearly 100 in-person interviews indicate that households would pay an average of $21 per month or $252 annually for the additional ecosystem services. Generalizing this to the households living along the river yields a value of $19 million to $70 million*** *depending on whether those refusing to be interviewed have a zero value or not. Even the lower bound benefit estimates exceed the high estimate of water leasing costs ($1.13 million) and conservation reserve program farmland easements costs ($12.3 million) necessary to produce the increase in ecosystem services.*

The Loomis et al. study is cited here as it reflects several actions to enhance the credibility and usefulness of its findings for decision makers. Important among them were:

- conduct of in-person interviews, which is particularly relevant because the ecosystem services being considered are somewhat complex,
- relating the willingness to pay to an economic action easily understood by the survey respondents (the amount of the monthly water bill),

- recognition that non-respondents may not be willing to pay anything for enhanced ecosystem services, and
- comparison of willingness to pay estimates to alternative means to enhance the river ecosystem.

2.3.5. Benefits Transfer

(Ingraham and Foster, 2008, "The value of ecosystem services provided by the U.S. National Wildlife Refuge System in the contiguous U.S.") Often estimation of value is a costly, time-consuming process, even when using relatively low-cost survey instruments. In some instances, the relationship between an ecosystem service and economic value is known for a circumstance (situation A) similar to the one of interest (Situation B). The benefits transfer method is used to apply the relationship of Situation A to the setting of Situation B. If the circumstances between Situations A and B are sufficiently similar, the results of this approach would have validity. However, the term, sufficiently similar, is not well defined.

> *Studies that demonstrate the economic value of the ecosystem services provided by public conservation lands can contribute to a more accurate appraisal of the benefit of these lands. The objective of this study was to estimate the economic value, in real (2004) dollars, of the ecosystem services provided by the U.S. National Wildlife Refuge System (Refuge System) in the contiguous U.S. In order to estimate this value, we determined the ecosystems present on the Refuge System in the contiguous 48 states, the proportion in which they are represented, and the dollar value of services provided by each. We used land cover classes as an approximation of ecosystems present in the Refuge System. In a geographic information system (GIS), we combined land cover geospatial data with a map of the Refuge System boundaries to calculate the number of acres for each refuge and land cover class within the Refuge System. We transferred values for the following ecosystem services: climate and atmospheric gas regulation; disturbance prevention; freshwater regulation and supply; waste assimilation and nutrient regulation; and habitat provision. We conducted a central tendency value transfer by transferring averaged values taken from primarily original site studies to the Refuge System based on the ecoregion in which each study site and refuge was located and the ecoregion's relative net primary productivity (NPP). NPP is a parameter used to quantify the net carbon absorption rate by living plants, and has been shown to be correlated with spatially fungible ecosystem services. The methodologies used in the site studies included direct market valuation, indirect market valuation and contingent valuation. We estimated* ***the total value of ecosystem services provided by the Refuge System in the contiguous U.S. to be approximately $26.9 billion/year****. This estimate is a first cut attempt to demonstrate that the value of the Refuge System likely exceeds the value derived purely from recreational activities. Due to limitations of current understanding, methods and data, there is a potentially large margin of error associated with the estimate.*

The Refuge System studied in this report is rather large, encompassing more than 11 million acres across the contiguous 48 states. Considerable effort was required therefore to locate and map the various sites included in the Refuge System. The report describes in some detail the methods employed to accomplish this task.

The study employed a benefit transfer approach to link the ecosystem services provided by sites within the Refuge System to economic value. While listing the characteristics used to determine which studies were used to provide those economic values, much less information is provided regarding those studies and their results. The magnitude of the economic values estimated in the study deserves scrutiny:

- On a per acre basis, the total value estimated ($26.9 billion/year) converts to approximately $2,400/year. Except for a limited number of specialty crops, this amount significantly exceeds the gross revenue earned from crop farming for any crop produced in the United States.
- Further, the services of wetlands provide a substantial portion ($22.9 billion/year) of the total estimated economic benefit. The per acre estimated value of ecosystem services provided by wetlands is $8,800/year.

2.4. Optimizing Cost of Reduction

(Hyberg, Iovanna, Crumpton, & Richmond, 2015, "The cost effectiveness of wetlands designed and sited for nitrate removal: The effect of increased efficiency, rising easement costs, and lower interest rates"). While economic estimation often is linked to benefit/cost analysis and estimation of net benefits, in some settings the benefits may be difficult or impossible to quantify. Or if society has dictated that a specific standard has to be met, the more relevant approach would be to focus on evaluating alternative means to achieve the standard by determining the least cost option or set of options. For example, a socially mandated reduction in the hypoxia zone could be linked to reduction of nitrate in Midwest rivers and streams. Achieving the minimal cost means to accomplish that question is a natural question.

> *Maintaining efficient agricultural production while addressing NO_3 loads in agricultural drainage water continues to be a challenge. Achieving water quality goals for United States waters, especially reducing the hypoxic zone in the Gulf of Mexico, will require a set of effective and cost-efficient conservation practices to reduce NO_3 and phosphorus (P) loadings. This analysis reexamines the cost effectiveness of wetlands designed and sited to intercept and reduce N runoff in the face of rapidly rising cropland cost. Our analysis demonstrates that these wetlands remain a cost-effective way to reduce NO_3 loadings and should remain a tool for enhancing water quality.*

Nitrate removal in the Iowa study area was estimated at $1.26 per lb. of N removed. Although not detailed in this report, the study authors cite this value as being significantly more cost effective than alternatives.

3. Economic Assessment of River-Related Sectors

The search for economic assessments on river-related resources yielded diverse information. Research scope could be as broad as a region (e.g. Upper Mississippi River Basin) or as small as a park within a state. As shown in Table 3.1, some studies focus on the economic value of a specific sector in a region, while some analyzed issues relating to rivers and assessed the cost of mitigating those issues. Not only do the broad scope and various topics of economic assessment of rivers make the values hard to compare, but the methods and assumptions used to assess economic value also contribute to the difficulty of comparing these values.

Table 3.1. Partial economic values reported in this study

Category	Type of Assessment	Value	Location	Year of Dollar	Source
Sectors	Total revenues generated in the Upper Mississippi River Corridor	$239.5 billion/year	Upper Mississippi River Corridor	2014	USFWS, 2015
	Economic value of ecosystem	$19 million-$70 million/year	Platte river		Loomis et al., 2000
	Total revenues generated in the Lower Mississippi River Corridor	$151.7 billion/year	Lower Mississippi River Corridor	2011	IEc, 2014
	Economic value of commercial fisheries of the Great Lakes	$22.5 million/year	The Great Lakes	2010	GLMRIS, 2012
	Economic value of recreational fishing	$1.228 billion/year	The Great Lakes		Ready et al., 2012
	Transportation value of corn and soybeans	$4.7 billion/year	Illinois River, Dresden Island Lock	average of 2008-2010	Kruse et al., 2011
	Transportation value of corn	$7.6 billion/year	Upper Mississippi River, Melvin Price Lock	average of 2008-2010	Kruse et al., 2011
	Transportation value of petroleum	$11.2 billion/year	Ohio River, Greenup Lock	average of 2008-2010	Kruse et al., 2011
	Economic value of remote-sensing information (applied to agricultural production and maintaining groundwater quality)	$858 million ± $197 million/year	35 counties in northeastern Iowa	2010	Forney et al., 2012
Issues	Achieving the Action Plan goal of reducing hypoxic zone to 5,000 km2	Cost $.27 billion/year	Gulf of Mexico		Rabotyagov et al., 2014
	Failure of lock for two weeks	Cost $2.8 million	Lock 20 in Upper Mississippi River		Kruse et al., 2011
	Economic losses in recreational water usage	$1 billion/year	United States		Dodds et al., 2009
	Ecosystem services provided by the Refuge System	$26.9 billion/year	The contiguous U.S.	2004	Ingraham and Foster, 2008
	Ecosystem services from wetland restoration	$1,435-$1,486/ha/year	Mississippi Alluvial Valley	2008	Jenkins, Murray, Kramer, & Faulkner, 2010
	Ecosystem services provided by oyster reefs (excluding oyster harvesting)	$5,500-$99,000/ha/year	United States	2011	Grabowski et al., 2012
	Societal value of geologic maps	$1.28 million-$3.5 million	Loudoun County, Virginia		Bernknopf et al., 1993

In this section, seven studies reporting the economic values of specific sector(s) are presented. Few studies assessed large areas of the Mississippi River (e.g. Upper Mississippi River Basin). The firm, Industrial Economics, Incorporated (IEc), conducted an updated economic assessment of the Lower Mississippi River Basin in 2014 and the U.S. Fish and Wildlife Services (USFWS) conducted a similar assessment of the Upper Mississippi River Basin in 2015. Findings from both reports are shown in Table 3.2.

Table 3.2. Revenues in the Upper and Lower Mississippi River Corridor (IEc, 2014; USFWS, 2015)

Sector	Revenue	
	Upper Mississippi River $ million (in 2014 dollars)	Lower Mississippi River $ million (in 2011 dollars)
Harvest of Natural Resources	2.8	559
Outdoor Recreation	2,000.0	1,335
Tourism	15,000.0	15,501
Water Supply	288.0	385
Agriculture and Aquaculture	9,400.0	8,737
Mineral resources	2,300.0	7,816
Energy	4,900.0	6,758
Navigation	663.0	4,219
Manufacturing	204,900.0	106,394
Ecosystem Services (non-market)	Unquantified	Unquantified
Total	**239,453.8**	**151, 703**

In addition to the general overview of sector values provided in the above two reports, the following studies examined the economic value of commercial harvesting, outdoor recreation, and navigation sectors that have strong linkages to river.

3.1. Commercial Harvesting

The Great Lakes and Mississippi River Interbasin Study (GLMRIS) evaluated the economic value of commercial fisheries of the Great Lakes, Upper Mississippi River, and Ohio River Basins.

> *<u>Great Lakes Basin</u>: The average harvest level from the most recent 5 years (2005 through 2009) for the U.S. waters of the Great Lakes Basin was determined to be approximately 19.3 million pounds with an associated ex-vessel value of about $22.5 million in 2010 dollars. This forms the baseline harvest and value against which future conditions will be compared.*
>
> *<u>Upper Mississippi River Basin</u>: The average harvest level from the most recent 5 years (2001 through 2005) for the Upper Mississippi River Basin was determined to be approximately 10.0 million pounds with an associated ex-vessel value of about $4.0 million in 2010 dollars. This forms the baseline harvest and value against which future conditions will be compared.*
>
> *<u>Ohio River Basin</u>: The average harvest level from the most recent 5 years (2001 through 2005) for the Ohio River Basin was determined to be approximately 1.4 million pounds with*

> *an associated ex-vessel value of about $2.0 million in 2010 dollars. This forms the baseline harvest and value against which future conditions will be compared.*

3.2. Outdoor Recreation

Ready et al. (2012) used the travel cost method to evaluate the value of recreational fishing in 12 states located in the Great Lakes, Upper Mississippi River, and Ohio River Basins.

> *Cornell University (CU) developed an economic model to estimate net baseline recreational fishing values using the travel cost valuation method. The development of these net benefit estimates took place in three stages: (a) a series of focus groups with recreational anglers; (b) surveys of recreational anglers; and (c) the development and estimation of an economic model of angler behavior. The surveys were also used to develop estimates of trip expenditures. …*
>
> *The average net value per angler day, estimated from CU's recreational fishing model, was $19.52. The aggregate net value of recreational fishing in those portions of the Great Lakes basin below barriers impassable to fish is estimated to be $1.228 billion for calendar year 2011. The corresponding aggregate net value of recreational fishing in those portions of the Upper Mississippi and Ohio River basins below barriers impassable to fish is estimated to be $1.124 billion.*

Treiman, Sheriff, Renken, and Loomis (2014) used exit interviews to estimate public use along 811 miles of the Missouri River over a 13-month period, and discerned the type and amount of use, as well as its economic value. To determine the value, they used both the Travel Cost Method (TCM) and the Contingent Valuation Model (CVM). Under the TCM method, the estimated consumer surplus value was $20.11 million for the estimated 1.57 million visitors at $12.79/visitor. For the CVM method, the total Willingness to Pay (WTP) was $38.74 million or $46.47/party, and the WTP per individual visit was $23.65.

3.3. Navigation

Kruse, Fellin, Fuller, Meyer, and Womack (2007) applied spatial equilibrium models to evaluate the value of grain transportation of the Upper Mississippi and Illinois Rivers. They also assessed alternative routes to transport grains to the Lower Mississippi River Basin.

> *Grain is the primary commodity transported on the upper Mississippi and Illinois Rivers, comprising about half of the tonnage on the upper Mississippi and 40 percent of the Illinois River traffic. It is estimated these rivers annually originate about 36 million metric tons of corn and soybeans that are primarily destined for export at lower Mississippi River ports. Spatial models representing the international grain economy are developed to estimate the annual contribution of the upper Mississippi and Illinois Rivers to Midwest grain producer revenues and evaluate alternate grain routing necessitated by a catastrophic event at Lock and Dam 27 near St. Louis, a facility grain must pass on its route to lower Mississippi River ports. The analysis suggests the annual value of the upper Mississippi and Illinois Rivers for*

grain transport ranges from $233 to $799 million but based on the most likely scenario to range from $312 to $549 million.

Another study conducted by the Texas Transportation Institute and the Texas A&M University focused on the locks and dams in the Upper Mississippi, Ohio, and Illinois Rivers (Kruse et al., 2011). The authors first examined volumes and values of the locks, their operation, and current condition. They further examined six locks for the impact of lock failures. This will be discussed in a later section of this report.

…commodity flows and their values by commodity group passing through the locks on the Illinois River for the three-year period 2008 to 2010. …the petroleum products group shows the highest value on the upper river and grain shows the highest value on the lower reaches. The highest value of petroleum products was recorded at more than $1 billion at Dresden Island Lock and the combined value of corn and soybeans was estimated at $4.7 billion. …

… grain transportation on the Upper Mississippi River is the dominant freight movement in terms of both volume and value throughout all reaches of the river. … For the three-year period 2008 to 2010, the volume of corn and soybeans passing through Melvin Price Lock amounted to 52.8 and 17.2 million tons, respectively, with corresponding values of $7.6 billion and $6.1 billion, respectively. …

… Coal constitutes the dominant freight flow on the Ohio River. During 2008–2010, the volume of coal movements was a high percentage of tonnage at all locks on the river…. Its three-year volume of 131.6 million tons reached its highest point at Cannelton Lock…. the petroleum products category dominates over all other categories, with coal being the second largest value group … For example, $11.2 billion worth of petroleum products passed through Greenup Lock during this period.

4. Economic Assessment of River-Related Issues

4.1. Economic Assessments on Ecosystem Services

Ecosystem services were recognized in the economic profile reports of the Upper and Lower Mississippi River but the reports did not quantify their value. Ecosystems are dynamic and valuation of services provided by an ecosystem requires a comprehensive understanding of the ecosystem.

The United Nations initiated the Millennium Ecosystem Assessment (MA) in 2001 to assess the interactions between ecosystems and human beings. The valuation approaches described by MA are applied in many of the studies included in this report. The following paragraphs are excerpted from the "Ecosystems and Human Well-being: A Framework for Assessment" by the MA (2003), describing the MA's approach to defining an ecosystem, categorizing ecosystem services, and valuing ecosystem services, as well as the motivations for economic valuation.

> *A well-defined ecosystem has strong interactions among its components and weak interactions across its boundaries. A practical approach to the spatial delimitation of an ecosystem is to build up a series of overlays of significant factors, mapping the location of discontinuities, such as in the distribution of organisms, the biophysical environment (soil types, drainage basins, depth in a water body), and spatial interactions (home ranges, migration patterns, fluxes of matter). A useful ecosystem boundary is the place where a number of these relative discontinuities coincide. …*

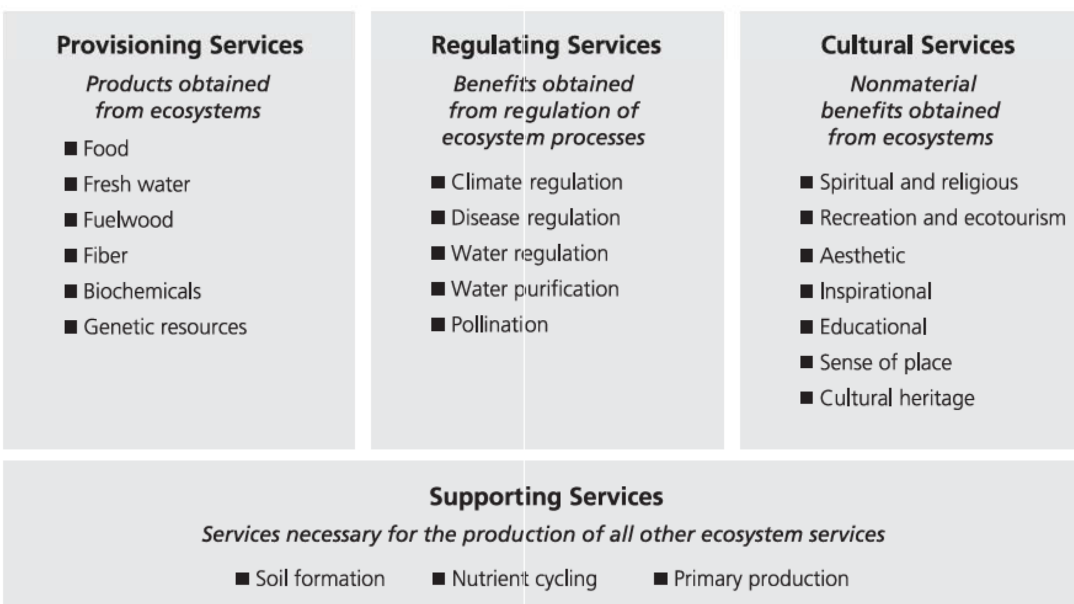

Figure 4.1. Categories of ecosystem services by the MA (MA, 2003)

The most common reasons for undertaking a valuation of ecosystems are:

- *to assess the overall contribution of ecosystems to social and economic well-being,*
- *to understand how and why economic actors use ecosystems as they do, and*

- *to assess the relative impact of alternative actions so as to help guide decision-making. …*

The MA plans to use valuation primarily for the third rationale for undertaking it: assessing the impacts—the gains and losses—of alternative ecosystem management regimes. This provides a tool that enhances the ability of decision-makers to evaluate trade-offs between alternative ecosystem management regimes and courses of social actions that alter the use of ecosystems and the multiple services they provide.

However, van Beukering, Brouwer, and Koetse (2015) noted in their article, "Economic values of ecosystem services" that the values reflect the services and goods provided by ecosystems but not the ecosystem itself.

It is important to note that what is being valued is not the ecosystem per se (i.e. its intrinsic value), but rather the goods and services provided by ecosystems that are beneficial to human beings. Valuation therefore intrinsically reflects an anthropocentric approach, that is, humans attach value to the environment and the services provided.

To evaluate ecosystems, the first step is to define the studied ecosystem(s). The scope of an assessed ecosystem can be as big as the whole world or as small as a specific species in an area. For example, Ingraham and Foster (2008) analyzed the value of ecosystem services provided by the U.S. National Wildlife Refuge System.

We transferred values for the following ecosystem services: climate and atmospheric gas regulation; disturbance prevention; freshwater regulation and supply; waste assimilation and nutrient regulation; and habitat provision. …We estimated the total value of ecosystem services provided by the Refuge System in the contiguous U.S. to be approximately $26.9 billion/year.

Jenkins, Murray, Kramer, and Faulkner (2010) examined the value of ecosystem services from wetland restoration in the Mississippi Alluvial Valley. Although the authors did not assess all of the ecosystem services provided by wetlands, the study serves as an example of how to assess the economic value of ecosystem services using the benefit-cost analysis.

This study assesses the value of restoring forested wetlands via the U.S. government's Wetlands Reserve Program (WRP) in the Mississippi Alluvial Valley by quantifying and monetizing ecosystem services. The three focal services are greenhouse gas (GHG) mitigation, nitrogen mitigation, and waterfowl recreation. Site- and region-level measurements of these ecosystem services are combined with process models to quantify their production on agricultural land, which serves as the baseline, and on restored wetlands. We adjust and transform these measures into per-hectare, valuation-ready units and monetize them with prices from emerging ecosystem markets and the environmental economics literature. By valuing three of the many ecosystem services produced, we generate lower bound estimates for the total ecosystem value of the wetlands restoration.

> *Social welfare value is found to be between $1435 and $1486/ha/year, with GHG mitigation valued in the range of $171 to $222, nitrogen mitigation at $1248, and waterfowl recreation at $16. Limited to existing markets, the estimate for annual market value is merely $70/ha, but when fully accounting for potential markets, this estimate rises to $1035/ha. The estimated social value surpasses the public expenditure or social cost of wetlands restoration in only 1 year, indicating that the return on public investment is very attractive for the WRP. Moreover, the potential market value is substantially greater than landowner opportunity costs, showing that payments to private landowners to restore wetlands could also be profitable for individual landowners.*

Not only is the scope of ecosystem assessments diverse but the uncertainties within the assessment also make valuing ecosystem services difficult. Grabowski et al. (2012) evaluated the economic valuation of ecosystem services provided by oyster reefs. They estimated that the per hectare value of the ecosystem services provided by an oyster reef is $5,500-99,000/year, excluding oyster harvesting. They indicated the uncertainty within their study because of the lack of understanding of every aspect of the oyster reef ecosystem.

> *The incomplete state of scientific understanding of ecosystem function in many systems limits our ability to quantify all of their associated ecosystem services, which consequently impedes decisions about how best to manage for the long-term return and sustainability of these services (Nelson et al., 2009 cited in Grabowski et al., 2012). …We have not included nitrogen incorporated into oyster shells and tissue because of the uncertainty of its fate. There is the potential for long-term storage in shells or tissue, but there is also a significant likelihood of relatively short-term release of nitrogen by senescence of oysters …We have also not included the fate of remineralized nitrogen provided to the rest of the food web through oyster excretion and biodeposition, because these processes have not been quantified adequately, and it is not completely clear that they would be characterized as an ecosystem service.*

Bingham et al. (1995) also noted the issue of uncertainty and other limitations and issues in ecosystem valuation.

> *Although environmental and business interests disagree about when and how information about the economic costs of achieving environmental objectives should be weighed, all sides are concerned about improving the availability and use of information about ecosystem values in making policy decisions.*
>
> *However, information often is lacking about: (1) the physical changes to ecosystems and the socio-economic consequences that might result from alternative course of action; and (2) the "value" of those changes. …*
>
> *One of the limits to providing sufficient ecosystem valuation information to decision makers is that it is extremely difficult to measure fully the functions and processes of an ecological system or predict the ecological impacts of disturbances to those complex systems.*

Furthermore, even where relatively simple ecosystems are fairly well defined, it is difficult to determine the causal relationship between human actions and ecosystem functions and processes.

The issues noted in Bingham et al. (1995), include:

- the need of linking information produced by different disciplines;
- different terminology use among disciplines, e.g. the meaning of the word, benefit, to an economist and to a biologist could be very different;
- the need for improved methods and assessments of the limitation of methods; and
- the irreversible nature of ecosystems.

4.1.1. News on Ecosystem Services in the Midwestern Media

To examine the information on ecosystem services in the Midwest, nine newspapers were searched to collect related news articles in the Midwestern media, including:

- Des Moines Register (Des Moines, IA)
- St. Louis Post-Dispatch (St. Louis, MO)
- Omaha World-Herald (Omaha, NE)
- The Telegraph, formerly the Alton Evening Telegraph (Alton, IL)
- The State Journal-Register (Springfield, IL)
- Quad City Times (Peoria, IL)
- Peoria Journal Star (Peoria, IL)
- Telegraph Herald (Dubuque, IA)
- Enquirer (Cincinnati, OH)

The search timeframe for each newspaper starts from 2000 to current, except for Alton Telegraph. The Alton Telegraph articles written before 2007 are not digitalized and thus are not searchable in the database.

The search did not yield results on economic values of ecosystem services. Only one article mentioned that the value of ecosystem worldwide is $33 trillion a year from a 1997 report (St. Louis Post-Dispatch, 2003). Another article noted that efforts of the Conservation Research Program on reducing water pollution and soil erosion valued $5 billion a year (Wiles, 2008). One other article reported the fishing industry in the Great Lakes valued $7 billion (Flesher, 2013).

Nearly one-fifth of the related articles discussed plans and/or budgets approved or waiting to be approved to restore ecosystem. Articles about budgets would mention the amount of funding approved but only a few articles mentioned the costs of restoration. For example, a State Journal-Register article from 2006 talking about the approval of expansion of river locks reported, "*The bill calls for lengthening five locks on the Mississippi River and two on the Illinois River at Peoria and LaGrange at an estimated cost of $1.8 billion. Another $235 million is included for small-scale navigation improvements, and $1.6 billion is for ecosystem restoration along the two rivers*" (Copley, 2006). These numbers tended to be general in nature and were rarely broken down into details.

More than 10% of the identified articles reported concerns and impacts of invasive species, i.e. Asian Carp, on the natural species in Mississippi River Basin and the Great Lakes. About one-third of the identified articles reported the restoration of wetland, habitats of specific species, or ecosystem in general.

4.2. Economic Impacts of Water Quality and Quantity Change

The issues that contribute to the change of water quality and quantity in the Mississippi River Basin are numerous. Some are naturally caused, such as flooding and drought, and others are man-made, such as agricultural runoff and point source pollution. In this section, we focus on the major contributors to water quality and quantity change and their economic effects.

Evaluating benefit and costs of change in water quality

Koteen, Alexander, and Loomis (2002) present their analysis on the valuation of water quality. They stress that value is tied to use. Use is tied to attributes; the importance of which varies by user. In estimating economic values, willingness-to-pay is the most fundamental measure, whether for market, nonmarket use, or nonmarket "nonuse" value (value for its existence).

The table below summarizes non-market values, and is the result of a meta-analysis of 17 studies.

Table 4.1. Linear and double log meta-analysis regression results for marginal benefits from an increase in streamflow (Koteen et al., 2002)

Form	Dependent variable	Constant	Valmethod	Fish	Boat	Linear: CFS[b] Log-log: LNCFS[c]	F-stat	R^2
Linear	VAF[d]	40.88	50.42	-26.53	-35.84	0 .004	4.37	.59
		(2.82)[e]	(3.69)	(-1.56)	(-1.99)	(.48)		
Log-Log	LNVAF[f]	3.13	1.76	-0.84	-1.04	.02	3.30	.52
		(2.90)	(3.28)	(-1.26)	(-1.48)	(.09)		

[a] Number of observations = 17 with 12 degrees of freedom. Studies are outlined in table 7.
[b] CFS = water flow in cubic feet per second.
[c] LNCFS = log of CFS.
[d] VAF = value per acre-foot increase.
[e] Numbers in parentheses are t statistics.
[f] LNVAF = log of VAF.

> *The estimation resulted in the following equation: VAF = ß0 + ß1valmethod - ß2fish - ß3boat + ß4CFS where VAF is the value per acre-foot increase in 1998 dollars, valmethod is a dummy variable for the valuation method used where 0 = contingent valuation and 1 = travel cost, fish is a dummy variable for fishing where fishing = 1 and not fishing = 0, boat is a dummy variable for boating where boating = 1 and not boating = 0, and CFS is waterflow in cubic feet per second. In the log-log equation, LNVAF is the log of the value per acre-foot increase in flow, and LNCFS is the log of waterflow in cubic feet per second. The overall*

linear regression does a good job explaining nearly 60 percent of the variation in values for instream flow. The coefficient on valmethod indicates that if the travel cost method was used, then the marginal value per acre-foot increases by $50.42, as compared to a contingent valuation method study. The t-statistic is significant at the 1-percent level. If the activity performed is boating, the marginal value per acre-foot decreases by $35.84. The t-statistic for this variable is significant at the 5-percent level. The variable CFS has a low t-statistic, indicating waterflow is not significant in the model. This suggests that the recreational value of instream flow appears not to be related to the absolute flow level. It may be that relative flow concepts, such as percentage bankfull elevation2, used in the Walsh and others (1980) analysis is a more meaningful concept when comparing waterflows across rivers and studies. As additional instream flow studies become available, this analysis could be updated to improve the meta-analysis. An improved meta-analysis equation could be used to provide a simple benefit-transfer for providing rough estimates of the value of instream flow on rivers without existing studies.

The table below is a summary of market values only. It is a good example of results of detailed analysis, based on a literature review.

Table 4.2. Summary of mean water values by use and parameter in adjusted 1998 dollars (Koteen et al., 2002)

	Water parameter				
Water use	**Clarity**	**Quantity**	**Salinity and total suspended solids**	**Temperature**	**Dissolved oxygen levels**
Municipal	16.06 [a] (n=4) [d]	249.97 [b] (n=6)	0.0656 [c] (n=10)	Not applicable (NA)	NA
Agriculture	NA	131.96 [e] (n=11)	52.04 (n=21)	Negative effect	NA
Recreation	Positive effect	33.8 [f] (n=17)	52.72 [g] (per household; n=9) 67,100.00 (total value; n=4)	Negative or positive effect depending on activity	1.54 [h] (boat and fish, n=21) 1.74 [h] (boat and swim, n=21)
Industrial	NA	313.0 [i] (n=7)	1.43 billion annual damages (n=2)	Negative effect	NA
Hydropower	NA	58.84 [j] (n=15)	Negative effect	NA	NA

[a] Value per foot of lake frontage for 1-foot improvement in water clarity; data from table 1.
[b] Value per acre-foot for municipal use; data from table 2.
[c] Value of water quality for municipal use; data from table 3.
[d] n = number of studies assessed.
[e] Value per acre-foot for agriculture; data from table 4.
[f] Value per acre-foot for recreation; data from table 7.
[g] Value of water quality for recreation use; data from table 5.
[h] Value per recreational trip for an improvement in dissolved oxygen; data from table 6.
[i] Value per acre-foot for industrial use; data from table 9.
[j] Value per acre-foot for hydropower; data from table 10.

Table 13 [Table 4.2] *is a summary of water values by use and parameter for the studies cited in this paper. Although this is a useful summary of the information we have presented, the variation in value by use outlined in previous tables must be kept in mind. Nonmarket values* *are not summarized in table 13, as the type of meta-analysis outlined in table 8 is a better way to assess the similarity of nonmarket valuation studies.*

4.2.1. Nonpoint Source Pollution

Nonpoint source pollution (NSP) refers to the movement of rainfall or snowmelt across the ground, and in particular the pollution it picks up and carries with it and deposits into bodies of water. Perhaps the most obvious source of NSP is agricultural runoff, which is often full of nitrogen and phosphorus, which are major contributors to hypoxia and dead zones.

Eutrophication of U.S. freshwaters: Analysis of potential economic damages

Dodds et al. (2009) looked at the status of all US freshwaters and found that eutrophication (excess nutrients leading to algal growth) has high costs, particularly for lakefront real estate value and recreational use. Recreational angling and boating were particularly high losers from eutrophication at $1.16 billion lost annually. Additionally, an estimated $44 million/year is spent on prevention of eutrophication-linked loss of aquatic biodiversity.

We provide broad annual estimates of economic losses in recreational water usage ($1 billion), waterfront property ($0.3-$2.8 billion), recovery of threatened and endangered species ($44 million), and drinking water ($813 million), resulting from human-induced eutrophication. These potential losses total over $2.2 billion annually and our estimates are probably conservative.

We calculated potential annual value losses in recreational water usage, waterfront real estate, spending on recovery of threatened and endangered species, and drinking water. The combined costs were approximately $2.2 billion annually as a result of eutrophication in U.S. freshwaters. The greatest economic losses were attributed to lakefront property values ($0.3-2.8 billion per year, although this number was poorly constrained) and recreational use ($0.37-1.16 billion per year). Our evaluation likely underestimates economic losses incurred from freshwater eutrophication.

Economics of water quality protection from nonpoint sources: Theory and practice

Although slightly dated, Ribaudo, Horan, and Smith (1999) discuss the damage from nonpoint source pollution on water quality, presenting a list of studies with economic values of damage from the 1980's through 1990's.

Table 4.3. National estimates of the damages from water pollution or benefits of water pollution control (Ribaudo et al., 1999)

Estimate of—	Study/year	Description
	Selected estimates of annual damages	
Water quality damages from soil erosion	Clark and others (1985)	Damages to all uses: $3.2-$13 billion, "best guess" of $6.1 billion (1980 dollars). Cropland's share of damages: $2.2 billion.
Water quality damages from soil erosion	Ribaudo (1989)	Damages to all uses: $5.1-$17.6 billion, "best guess" of $8.8 billion. Agriculture's share of damages: $2-$8 billion.
Adjustments to net farm income considering effects of soil erosion	Hrubovcak, LeBlanc, and Eakin (1995)	Reduction in net farm income account of about $4 billion due to soil erosion effects.
Environmental costs of pesticides	Pimentel and others (1991)	Direct costs from fish kills: less than $1 million.
Infrastructure needs to protect drinking water from poor source-water quality	EPA (1997a)	$20 billion in current and future (20-year) need under Safe Drinking Water Act requirements for microbial treatment; $0.2 billion for nitrates; and $0.5 billion for other synthetic chemicals, including pesticides.
Health costs from waterborne disease outbreaks	EPA (1997b)	Damages from *Giardia* outbreaks: $1.2-$1.5 billion in health costs.
Recreational damages of water pollution	Freeman (1982)	Total recreational damages from all forms of water pollution: $1.8-$8.7 billion; "best guess" of $4.6 billion (1978 dollars/year).
	Selected estimates of annual benefits from water pollution control	
Water quality benefits of reduced soil erosion from conservation practices	Ribaudo (1986)	Erosion reduction from practices adopted under the 1983 soil conservation programs were estimated to produce $340 million in offsite benefits over the lives of the practices.
Water quality benefits of reduced soil erosion from Conservation Reserve Prog.	Ribaudo (1989)	Reducing erosion via retirement of 40-45 million acres of highly erodible cropland would generate $3.5-$4.5 billion in surface-water quality benefits over the life of the program.
Recreational fishing benefits from controlling water pollution	Russell and Vaughan (1982)	Total benefits of $300-$966 million, depending on the quality of fishery achieved.
Recreational benefits of surface-water pollution control	Carson and Mitchell (1993)	Annual household willingness to pay for improved recreational uses of $205-$279 per household per year, or about $29 billion.
Recreational benefits of soil erosion reductions	Feather and Hellerstein (1997)	Total of $611 million in benefits from erosion reductions on agricultural lands since 1982, based on recreation survey data.

They also note how difficult it is to measure, valuate, and address the costs of NSP:

> *Nonpoint emissions (runoff) cannot be measured at reasonable cost with current technologies because they are diffuse (i.e., they move off the fields in a great number of places) and are affected by random events such as weather, as is the process by which runoff is transported to a water body. This randomness narrows the way that policy goals*

with good economic properties are defined, and limits the types of policy tools that can be used to attain a cost-effective outcome. Finally, runoff depends on many site-specific factors. The more policies and goals are able to address these site-specific factors, the more efficient nonpoint policies will be.

Although Ribaudo et al. (1999) provide a list of policy goals, tools, and instruments to effectively reduce NSP, it is lacking in economic analysis of policy impact to reduce NSP. This is a common theme among the literature on water quality and policies.

4.2.2. Point Source Pollution

Point source pollution is a single identifiable source of pollution from which pollutants are discharged. Examples include pipes, ditches, ships, or factory smokestacks. The Mississippi River is no stranger to point source pollution. Recently outside of Memphis, Tennessee, a sewer line was found broken, dumping about 1 million gallons of wastewater a day into a Mississippi River tributary (Sainz, 2016). Earlier this year, a pipe collapsed in a nearby location, sending 50 million gallons of sewage/day into Cypress Creek, which adjoins McKellar Lake, and flows into the Mississippi River. This spill killed a major amount of fish and led to high levels of E. coli in the water. At the same time that crews were fixing the March leak, a second and smaller leak was found and fixed. Costs are unknown for the extent of the damage.

In 2012, the Department of Justice, the Environmental Protection Agency, TDEC and the state attorney general reached a settlement with Memphis over a complaint filed together with the Tennessee Clean Water Network against the city for alleged violations of the federal Clean Water Act and the Tennessee Water Quality Control Act.

The city agreed to make improvements to its sewer systems to eliminate unauthorized overflows of untreated raw sewage, work estimated to cost approximately $250 million. Knecht said the city could face fines due to the spills and the environmental damage they have caused.

Despite earlier commitments, pipes around Memphis continue to break due to lack of proper maintenance. Work costs were noted to be about $250 million, but that doesn’t take into account the extent of damage to ecosystems and the services they provided, and other downstream or long-lasting impacts.

A search through news media shows similar situations outside of St. Louis and other cities along the Mississippi River. Few are able to provide estimates of the costs of damage or the methods by which those numbers were sourced.

The Hypoxia Task Force (2016) recently released their report on point source progress in hypoxia task force states. Although they did not make their goal of 45% reduction by 2015, they did provide some information on incentives and programs that are used to encourage more reduction of point source loading into the Mississippi River. Ohio provided a good example of trading programs for nutrient credits, which were funded by several grants:

> *Another trading program is the Electric Power Research Institute's (EPRI) pilot project, focused on developing a framework for interstate trading of nutrient credits. In October 2009, EPRI announced $1.3 million in federal grants from US EPA and the USDA NRCS, as well as $700,000 dollars in matching funding from project collaborators. Assisting EPRI in this venture is the American Farmland Trust. Stakeholders in the pilot project include ORSANCO, Ohio DNR-DSWR, Ohio DA, Ohio EPA, our sister agencies in Indiana and Kentucky and county Soil and Water Conservation Districts. In 2012, Ohio entered into an agreement with EPRI along with Indiana and Kentucky to conduct the pilot project. Nonpoint source BMPs have been put in place in Ohio. Three power companies subsequently agreed to buy the nutrient credits generated through these best management practices and immediately retire them as "stewardship credits." These credits were purchased by AEP, Duke Energy, and Hoosier Energy on March 11, 2014. Since then, several more projects have been implemented across the tristate and have generated approximately 90,000 credits.*

In Wisconsin, three multi-discharger phosphorus variance watershed plans were designed for point source dischargers to choose from. These plans were made to make economically feasible reductions to phosphorus entering state surface waters.

> *Similar to "pollution minimization plans" for other variances, the multi-discharger phosphorus variance watershed plan is designed to make economically feasible reductions to phosphorus entering surface waters of the state. There are three types of watershed projects for the multi-discharger variance. The point source discharger has discretion to select the option that works best for them:*
>
> - *Make payments to county land and water conservation departments located in the same HUC8 basin in the amount of $50 per pound times the difference between what they discharge and a target value. Payments are capped for any one point source at $640,000 per year.*
> - *Enter into an agreement with DNR to implement a plan or project designed to result in an annual reduction of phosphorus from other sources in the HUC8 basin in an amount equal to the difference between what they discharge and a target value.*
> - *Enter into an agreement with a third party and approved by DNR to implement a plan or project designed to result in an annual reduction of phosphorus from other sources in the HUC8 basin in an amount equal to the difference between what they discharge and a target value.*

Making options that are economically feasible for point source dischargers is just one of several methods the Hypoxia Task Force is recommending to achieve 20% reduction in nutrient loading by 2025.

4.2.3. Benefits of Remediation

Lakeshore property values and water quality: Evidence from property sales in the Mississippi Headwaters Region

The Mississippi Headwaters Board and Bemidji State University (2003) discuss how a change in water quality from the Mississippi River affects lakeshore property prices: if a one-meter change in water clarity occurred in the site, expected property price changes for the lakes were in the magnitude of tens of thousands to millions of dollars. Thus, management of quality of lake water is important to maintaining the natural and economic assets of the region.

Economic benefits of remediating the Sheboygan River, Wisconsin Area of Concern

Braden et al. (2008) uses empirical methods to analyze the economic benefits of remediation for the Sheboygan River in Wisconsin, finding that remediation could increase property values from 8-10%.

> *Using hedonic analysis of property sales, for owner-occupied homes within a 5-mile radius of the Sheboygan River AOC, the overall estimated loss of value is $158 million (8% of market value). Of this total, only $49 million in losses for homes closest to the upper river segment has strong statistical support. The impacts are greatest proportionally for properties closest to the AOC. A survey-based method yields a mean estimate of $218 million (10% of property value) in willingness to pay for full cleanup of the AOC. If remediation were to induce recovery of property values, then the local communities could benefit through increased property tax revenues.*

4.2.4. Hypoxia and Nitrogen Loading

Hypoxia refers to the state of oxygen deficiency in a biotic environment. As the Mississippi River drains into the Gulf of Mexico, it carries with it nutrients, in particular nitrogen and phosphorus, in large quantities, which come from agricultural runoff and other nonpoint source pollution. These in turn promote algal growth. When those growths decompose, the water is depleted of oxygen, which can create a 'dead zone'. A dead zone does exist at the mouth of the Gulf and a bevy of task forces, research studies, and initiatives have been created to find ways to combat this issue. The following papers analyze the possibility for cost-effectively reducing nitrogen loading into the Mississippi River.

Evaluation of the economic costs and benefits of methods for reducing nutrient loads to the Gulf of Mexico: Topic 6 report for the integrated assessment on hypoxia in the Gulf of Mexico.

Doering et al. (1999) lay out an assessment that combines a reduction in fertilizer application with wetland restoration as a means to achieve a 20% nitrogen loss-reduction goal. Higher reductions in fertilizer do meet the goal for a slightly higher cost, and thus the most cost-effective scenario revolves around the use of wetlands combined with fertilizer restrictions (as opposed to bans).

> *Fertilizer restrictions are a more cost-effective means of reducing nitrogen losses than strategies based only on wetland restoration or buffers. They are more cost-effective than a fertilizer tax, because of the tax's impacts on producer net returns. Wetland-based*

strategies are more expensive than fertilizer reduction strategies to achieve the same goal of reducing nitrogen loss. Land- retirement costs and wetland-restoration costs outweigh the higher environmental benefits generated by wetlands. Based on uniform assumptions about denitrification efficiency, focusing on restoring wetlands proportional to nitrogen losses is less cost-effective than enrolling wetlands at lowest cost. Vegetative buffers are least cost effective, due to low nitrogen filtering relative to wetlands, lower wildlife-associated benefits, and high land retirement costs.

A 5-million-acre wetland restoration combined with a 20% reduction in fertilizer is the most cost-effective, practicable strategy we examined for meeting a 20% nitrogen loss-reduction goal. This strategy reduces nitrogen loss by about 20% with few, if any, secondary effects that are beyond our historical experience of sectoral adjustment in agriculture. Reducing fertilizer by 45% meets the goal for a slightly higher cost. A policy that includes wetlands has additional advantages because it meets other policy objectives and generates wildlife and recreation benefits.

The bottom line is that reducing nitrogen losses in the 20% range is feasible, and there are relatively cost-effective ways to achieve this goal.

• Wetland-based strategies are more expensive than fertilizer-reduction strategies to achieve the same nitrogen-loss reduction goal. Land-retirement costs and wetland-restoration costs outweigh the higher environmental benefits generated by wetlands.

• Vegetative buffers are not very cost-effective for the specific task of reducing the nitrogen losses we are concerned with here, due to low nitrogen filtering relative to wetlands, lower wildlife-associated benefits, and high land-retirement costs.

• Fertilizer restrictions are more cost-effective than a fertilizer tax, due to the tax's impacts on producers' net returns.

• A strategy that combined a 5-million-acre wetland restoration goal with a 20% fertilizer-reduction goal was the most cost-effective, practicable approach for meeting a 20% nitrogen loss-reduction goal. Reducing fertilizer application by 45% met the 20% goal at a slightly higher cost. A policy that includes wetlands has additional advantages because it meets other policy objectives and probably generates wildlife and recreation benefits greater than those estimated here. Figure 8.1 [Figure 4.2] *summarizes this strategy, comparing its costs and benefits. The results of this report are based on estimates of wetland- and buffer-filtering capacities, and estimates of environmental benefits that are crude at best. The research in these areas is sparse and incomplete. Finally, cost-effectiveness depends upon the actual delivery of nitrogen at the point of concern. When the objective is reducing nutrients delivered to the Gulf, the critical issue is going to be the relationship between an action upstream and what actually comes out of the mouth of the river. Because such nonpoint sources as agriculture and the interacting soil systems represent a large volume of the absolute nitrogen in the system, a given percentage*

reduction of nitrogen loss from agriculture within the basin may result in a different proportional decrease in the amount of nitrogen flowing into the Gulf.

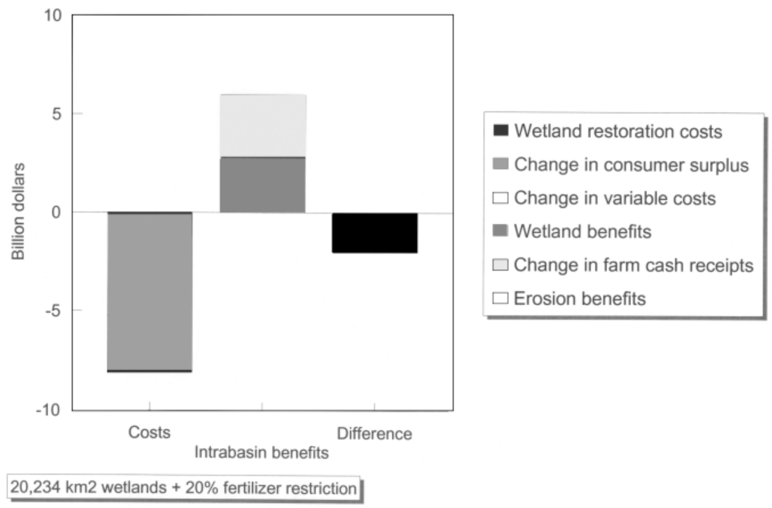

Figure 4.2. Illustrative costs and benefits of nonpoint nitrogen control in the U.S. (Doering et al., 1999)

<u>Reducing nitrogen export from the Corn Belt to the Gulf of Mexico: Agricultural strategies for remediating hypoxia</u>

McLellan et al. (2015) take this assessment a step further by providing specific strategies to reduce nitrogen export, and in particular, targeting watersheds with the greatest cropland-use effectiveness, to only use 1% of the cropland in the Basin for conversion purposes.

> *Our results indicate that a conservation scenario that combines nitrogen-management practices with a diverse suite of nitrogen-removal practices on 2.5% of the land in the Basin can achieve a 45% reduction in nitrogen while requiring the conversion of just over 750,000 ha of cropland. Targeting efforts to those watersheds with the greatest cropland-use effectiveness can achieve the same goal with the conversion of just under 270,000 ha of cropland, or 1% of the cropland in the Basin.*
>
> *Results of our analysis suggest that solving regional water-quality problems, such as hypoxia, requires a different approach to conservation than that which has been so successful in addressing producer-identified resource concerns, such as soil erosion. In particular, it indicates that addressing regional water quality goals will require expanding the toolbox of conservation practices to include a variety of innovative nitrogen-removal practices, such as tile-drainage treatment wetlands, stream-channel restoration, and floodplain reconnection. To maximize environmental outcomes and minimize impacts on crop production, these practices should be selected and sited in a watershed context. This suggests a need to adapt conservation planning to include new approaches to community engagement, new incentives for cooperative conservation, and improved technical tools that enable stakeholders to develop and evaluate alternative conservation scenarios.*

Cost-effective targeting of conservation investments to reduce the northern Gulf of Mexico hypoxic zone

Rabotyagov et al. (2014) focus on modeling for cost-effective improvement of hypoxia in the northern Gulf of Mexico. It analyzed which watershed to treat and the trade-offs on cost and hypoxia. In the 2008 Action Plan for Reducing, Mitigating, and Controlling Hypoxia in the northern Gulf of Mexico, it aims to reduce the size of hypoxia to 5,000 km^2 within 5 years. The authors first determined if the goal is workable–it is, in the scenario of treating a larger cropland of moderate or high conservation needs and with better fertilizer management, but with an annual cost of $5.7 billion. The authors then examined how to reduce the annual cost to achieve the goal, i.e. which watersheds to target. The model indicated the need for a larger investment in the Upper Mississippi River and the Ohio-Tennessee River Basins; with additional investments in the Missouri River, the Lower Mississippi River, and the Arkansas-White-Red River Basins. The annual cost of such a scenario is $2.7 billion. It is noted that the scenarios do not require a change in the cropping system, i.e. taking land from farming and devoting it to a more natural condition.

Financial comparison of seven nitrate reduction strategies for Midwestern agricultural drainage

Christianson, Tyndall, and Helmers (2013) found that the cost effectiveness of a practice to reduce nitrogen loading changed depending on whether government payments were included in the scenario.

> *Without government payments, the practices in order of average cost effectiveness were (based on mean value): Spring N application, N application rate reduction, controlled drainage, bioreactors, wetlands, crop rotation and cover crops. When government payments were included, wetlands and bioreactors became the third and fourth most cost effective practices, respectively, and diversified crop rotations became the least cost effective (from the farmer's perspective) (Fig. 2).*

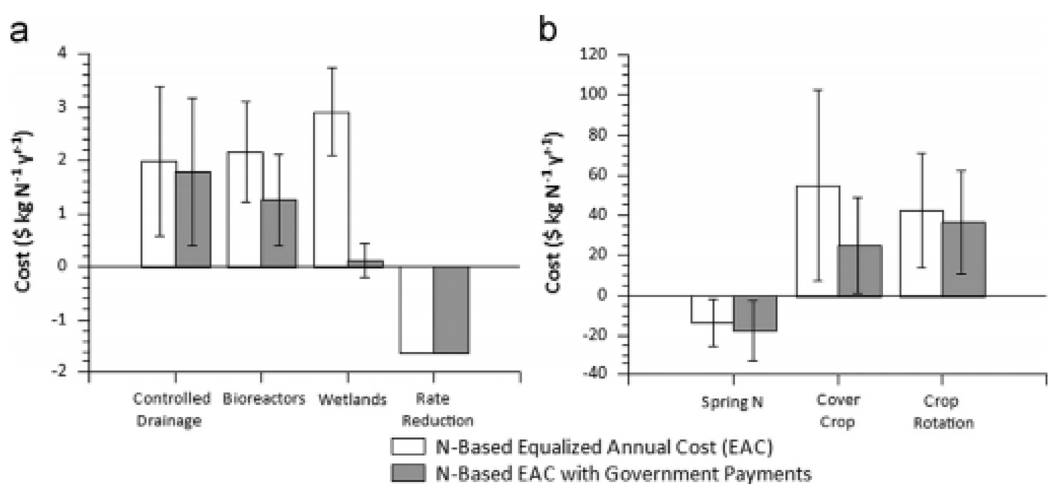

Fig. 2. Equal Annual Costs ($ kg N^{-1} yr^{-1}) on a nitrogen removal basis for seven agricultural practices in the U.S. Midwest with and without government payments at real discount rate of 4% and analysis horizons of practicable lifespans by practice; note y-axis scales differ for figure parts (a) and (b).

Figure 4.3. Fig. 2 in Christianson et al. (2013)

Targeting wetland restoration to cost-effectively reduce nitrogen loadings in the Gulf of Mexico

Hansen and Ribaudo (2016) present a poster on their work with cost-effectiveness estimation of nitrogen loading reduction in the Gulf of Mexico. Their theory focuses on wetland restoration as the platform by which nitrogen may be reduced, and find that nitrogen removal is much less costly than was previously reported by other researchers.

> *Cost-effectiveness estimates are generated at grid points by laying costs on N removal rate estimates. But wetlands cannot be restored everywhere. So we apply some reasonable assumptions. 1. Not knowing where wetlands once existed, we assumed that hydric soils are an indicator of prior-existing wetlands. SSURGO data indicate that ~13% of the study-area has hydric soils. Thus we assume that the probability that a parcel of land was once a wetland equals 0.13. 2. We assumed that it is not practical to restore 25% of the converted wetlands because the land is in high-valued uses (roads, urban development, etc.). 3. We assumed that 50% of eligible landowners would not participate. Based on these assumptions, the probable restorable acreage at grid points is 5.4 (=0.13*0.75*0.5*247). This is mathematically equivalent to assuming 5.4 acres are restored at each grid point. The N-removal cost function (total quantity removed based on cost-effectiveness) is derived by 1) sorting GIS estimates by cost-effectiveness and 2) summing the quantity of N-removed across grid point based on cost.*
>
> ***Results***
>
> *Among other things, the table indicates that 842,000 wetland acres will remove 424,000 tons of N at less than $0.15/lb.*

Removal cost/price ($/lb)	Total N removed (1,000 tons)	Wetland acres restored (1,000)	Total cost (million $)	Average total cost ($/lb)
0.15	424	842	82.9	0.098
0.50	722	2,330	225	0.16
1.00	774	3,390	297	0.19
3.00	793	3,990	347	0.22

> *The estimates of cost-effectiveness and quantities of N removed suggest that restoring wetlands is an effective N-conservation policy tool. Cost is competitive: Petrolia and Gowda*

(2006) estimated on-field N conservation costs to be $0.78/lb for a 20% reduction in N losses—which is higher than average-cost estimate of $0.22/lb reported here. Also note that, at a removal cost/price of $0.78/lb, about 3 million wetland acres would be restored reducing N loadings by 759,000 tons/yr.

4.2.5. Floodplain and Stormwater

Downstream economic benefits from storm-water management

Braden and Johnston (2004) describe the benefits of storm water management:

- *reduced frequency, area, and impact of flooding;*
- *less costly public drainage infrastructure;*
- *reduced pollution treatment;*
- *reduced erosion and sedimentation;*
- *improved water quality;*
- *improved in-stream biological integrity and aesthetics; and*
- *increased groundwater recharge.*

They also note a case study in the Upper Mississippi River/Illinois area – the Blackberry Creek Watershed, west of Chicago, Illinois – which provides an application of a methodology for assessing economic benefits. It uses widely available data, and standard practices to examine the direction and magnitude of off-site benefits. However it fails to provide information on why benefit ranges start at $0.

We use widely accepted simulation models to compare alternative development scenarios. For the case study, reduced downstream flooding with the employment of conservation design practices generates from $3,949 to $47,033 per hectare ($1,795 to $21,379 per acre) in downstream property value benefits over all affected areas. For comparison purposes, flood-damage estimation methods generate an average of $10,638 to $28,778 per hectare ($4,337 to $11,732 per acre) present value reduction in damages for the 0.01 probability flood event alone. The two methods yield conservative, but mutually reinforcing estimates. For infrastructure benefits, considering only downstream road culverts, the use of conservation design practices upstream avoids $3.3 million to $4.5 million in costs of culvert replacement or upgrades The results indicate that implementation of upstream conservation design practices should have substantial off-site benefits in addition to any on-site economic benefits. Using very conservative benefit estimation methods, our case study reveals downstream flood mitigation benefits and infrastructure savings ranging from $744 to $1,684 per upstream developed hectare ($301 and $681/ developed acre). Clearly, downstream economic impacts should be included in any evaluation of on-site practices.

Naturalization of developed floodplains: An integrated analysis

Sparks and Braden (2007) provide economic value estimates from careful analysis of floodplain conversion. Their study linked hydrologic models and economic analysis. They focus on the Upper

Mississippi River/Illinois location, La Grange Reach of the river, a section spanning 125 km south of Peoria, Illinois.

The table below reports results—the regional impact is small; but local impacts can have differing effects.

Table 4.4. Potential naturalization impacts (Sparks and Braden, 2007)

	Farming Eliminated	Refuge Management	Refuge with Recreation	Potential Net Change
Land	- 2,550 ha	2,550 ha	2,550 ha	2,550 ha
Labor	- 17 jobs	10 jobs	66 jobs	+ 49 jobs
Output Value	$ - 1,251,031	$ 500,000	$ 3,280,000	$+ 2,028,969

4.2.6. Infrastructure

America's locks and dams: "A ticking time bomb for agriculture?"

Kruse et al. from the Texas Transportation Institute and Texas A&M University (2011) provide a detailed assessment of the costs of lock failures along the Mississippi River. Findings for Lock 20 include:

- *A two-week failure costs the industry $2.8 million.*
- *A one-month failure costs $4.9 million.*
- *A three-month failure costs $15.4 million.*
- *A one-year failure costs $44.0 million.*

In addition to these costs, barge companies would lose revenues of between $5.1 million and $150.1 million, depending on the duration of the lock failure.

In addition to industrial and barge company costs, agricultural producers also are hit hard by lock closures:

Table 4.5. Tables 4.1 and 4.2 in Kruse et al. (2011) on cost of and lost from lock closures

Table 4.1. Cost to Agricultural Producers of Lock Closures (Thousand USD).

	Two Weeks	One Month	Three Month	One Year
LaGrange Lock - Illinois River	2,712	4,789	21,197	30,369
Lock 20 - Upper Mississippi	2,821	4,884	15,444	44,030
Lock 25 - Upper Mississippi	2,821	4,884	15,445	44,706
Markland Lock - Ohio River	895	1,024	3,764	4,864
Lock 52 - Ohio River	2,911	3,118	11,857	13,881

Table 4.2. Lost Revenue to Barge Companies from Lock Closures (Thousand USD).

	Two Weeks	One Month	Three Month	One Year
LaGrange Lock - Illinois River	3,555	5,617	4,277	104,753
Lock 20 - Upper Mississippi	5,103	15,001	33,324	150,154
Lock 25 - Upper Mississippi	5,056	14,223	32,351	162,936
Markland Lock - Ohio River	2,232	4,674	7,389	11,037
Lock 52 - Ohio River	17,239	26,120	68,003	71,522

Inland navigation in the United States: An evaluation of economic impacts and the potential effects of infrastructure investment

The Universities of Kentucky and Tennessee (2014) examined the issue of inland waterway transportation—could it be replaced by railroads? Would the benefits of modernizing waterway transportation justify public investments? The authors first examined the impact of abandoning the inland waterway navigation and found immediate economic impacts of 550,000 job losses and loss of incomes of $29 billion. The job loss could be restored by the economy, but only for 40%. The authors then examined the impact of modernizing navigation. The model showed an increase of nearly 350,000 job-years of full-time employment with associated incomes at over $14 billion ($41,000 per job) for the first 30 years. It is mentioned in the report that

> *"the Mississippi River System accounted for 80% of the total internal domestic freight traffic in 2011. It is dominated by coal (29.04%), petroleum (23%), and grains (20.4%). Crude materials and chemicals products are also significant."*

The authors predict that that the future growth in inland river traffic will be related to the increase of petroleum and natural gas—mostly liquid products. The model showed a 75 million tons increase of liquid traffic, roughly an increase of 80% from current level of liquid traffic and an increase of more than 13% of the total river traffic.

The study analyzed over 11,000 barge movements, detailing observed charges and transport-related charges in 2012 dollars. They used the Regional Economic Models, Inc. (REMI) software to simulate scenarios.

Table 4.6. Average annual project benefits and 10-year annualized cost-to-complete values for modernization program (2012 dollars) (The Universities of Kentucky and Tennessee, 2014)

Region	Average Annual 10-Year Construction Cost (Millions)	Average Annual Direct Project Benefits (Over Project Life) (Millions)
Ohio River	$258.0	$474.6
Upper Mississippi	$182.3	$235.9
Lower Mississippi	$3.9	$22.7
Gulf Intracoastal	$134.4	$165.7
Pacific Northwest	$2.9	$3.3
Total	**$581.5**	**$902.2**

4.2.7. Drought

An article by Time.com (Sanburn, 2012) noted the impact of drought on the nation's economy. They referenced the 1988 drought which cost the country about $1 billion, and the 2012 drought was expected to be worse.

Some estimate that closing the river to traffic could lead to losses of about $300 million a day, which would then grow exponentially after a few days. The cost of running an idle tugboat is about $10,000 daily, largely due to fuel costs, says Muench. One tow company says it's been losing about $500,000 a month since May.

The $180 billion barge, tugboat and towboat industry transports just about anything you can think of that comes in bulk: petroleum, grain, fertilizer, sand, gravel, mulch, steel. "The building blocks of the nation are on our barges," says Muench. About 60% of the country's grain exports and one-fifth of its coal is transported along the nation's inland waterway system, according to the AWO.

The economic costs that come from shipping delays and lighter loads could eventually trickle down to consumers. The AWO estimates that transporting goods via waterways costs $11 a ton less than by rail or truck. If those products are moved to other modes of transportation, the costs for consumers will likely rise.

4.3. Policy Adoption

There appear to be many articles espousing the merits of certain policies and acts to improve water quality in the United States. Many provide information on the costs of remediation or adoption of policies. Most of those studies omit an important piece of data: the economic impact of those policies. Fortunately for our study, a few exist and are documented below.

Valuation of surface water quality improvements

Griffiths et al. (2012) discuss the effects of specific laws, ordinances, and others on water quality. Their article also gives information on how the EPA measures and values water quality, and the subsequent issues with their approach.

For more than thirty years, surface water pollution has been regulated under the CWA. Over time, EPA regulation has attempted to control increasingly focused sets of water quality stressors and to monetize increasingly less tangible categories of benefits. Since 1982, the main assessment tool has been benefit-cost analysis. Solid progress has been made in estimating benefits, with EPA now relying less heavily on case studies and using more sophisticated water quality models. However, the valuation of the benefits from surface water quality improvements has lagged somewhat behind. This article has discussed three areas that have been particularly challenging for EPA as it has sought to improve its benefits estimates.

First, the benefit transfer of values for surface water quality improvements has been difficult because of differing definitions of water quality. It would be helpful to have a more consistent measure that could be applied for all states and all rules. Both EPA and the academic literature have moved toward the use of compound indicators of water quality, but there is still no single standard indicator.

Second, both EPA and the academic literature have moved toward estimation of ecological values that are based on the outputs of ecological production functions rather than on direct valuation of water quality changes. While the use of EPFs can reduce bias relative to more simplistic approaches to ecological valuation and facilitate benefit transfers, EPFs remain difficult to execute. EPAs Science Advisory Board and others within the agency have made improvements in this area a priority.

Finally, economic studies suggest that nonuse benefits can contribute substantially to the total economic value of water quality improvements. EPAs recent move toward functional benefit transfer and its reliance on the more recent literature recognize the heterogeneity in benefits from a national rule and take advantage of the relatively recent improvements in stated preference methodology.

Clearly there has been improvement in water quality modeling since 1982. Similar improvements in benefits estimation may follow in the next few years as EPA moves to regulate additional water quality stressors and the need to examine less tangible benefits continues to grow.

Lastly, Appendix 1 (Table 4.7 below) includes an excellent table on EPA policies for surface water regulation that include benefits analyses (freshwater only).

Table 4.7. Appendix 1 in Griffiths et al. (2012)

Appendix 1. EPA surface water regulations that include benefits analyses (freshwater only)

Year (Proposal/Final)	Rule	Pollutants Regulated	Water Quality Modeling	Benefit Category: Specific economic end point (if relevant) and methodology or transfer study
1982	Iron and Steel Manufacturing	TSS, pH, oil and grease, and five toxic pollutants	None	Recreation, Nonuse, Health, Market, Avoided Costs: Estimated as proportionate share of Freeman's (1979) estimate of the total benefits of water pollution control.
1987	Organic Chemicals, Plastics, and Synthetic Fibers	BOD, TSS, and 128 toxic pollutants	None	Recreation, Nonuse: Estimated as proportionate share of Mitchell and Carson (1984). Market, Avoided Costs: Estimated as proportionate share of Freeman's (1979) estimate.
1995	Great Lakes Water Quality Guidance (WQS)	Twenty-nine toxic pollutants	None	Recreation:[a] Fishing estimated as proportionate increase in value for achieving a contaminant-free fishery from Lyke (1993), applied to baseline consumer surplus values from Milliman, Bishop, and Johnson (1987) and Walsh, Johnson, and McKean (1988, 1990).Wildlife viewing estimated as percentage of baseline consumer surplus from Walsh, Johnson, and McKean (1988, 1990). Nonuse: Valued as 50 percent of use benefits from Fisher and Raucher (1984). Market: Commercial fishing estimated as percentage of baseline producer and consumer surplus from Crutchfield, Cooper, and Hellerstein (1997) and Huppert (1990). Health: Reduced cancer risk from fish consumption valued using VSL.
1998	Pulp, Paper, and Paperboard	Fifteen toxic pollutants	Dilution and DRE model	Recreation: Lifting fish consumption advisories transferred from Lyke (1993) (for percentage increase in value) and Walsh, Johnson, and McKean (1990) (for baseline consumer surplus). Health: Reduced cancer risk from fish consumption valued using VSL. Avoided Costs: Sludge disposal.
1998	Pharmaceuticals	Thirty-two toxic pollutants	Dilution model	Recreation: Elimination of AWQC exceedances transferred from Lyke (for percentage increase in value) and Walsh, Johnson, and McKean (1990) (for baseline consumer surplus). Nonuse: Valued as 50 percent of use benefits. Health: Reduced cancer risk from fish consumption valued using VSL.

Table 4.7. Appendix 1 in Griffiths et al. (2012) (cont'd)

Year (Proposal/Final)	Rule	Pollutants Regulated	Water Quality Modeling	Benefit Category: Specific economic end point (if relevant) and methodology or transfer study
2000	Centralized Waste Treatment (CWT)	BOD, TSS, oil and grease, and thirty-six toxic pollutants	Dilution model	Recreation: Elimination of AWQC exceedances. Nonuse: Valued as 50 percent of use benefits (except for CWT) Health: Reduced cancer risk from fish consumption valued using VSL. Increased IQ valued using lifetime earnings (CWT only)
2000	Waste Combustors	TSS, pH, and nine toxic pollutants	Dilution model	Avoided Costs: Sludge disposal.
2000	Landfills	BOD, TSS, and fourteen toxic pollutants	Dilution and DRE model	
2000	Transportation Equipment Cleaning	BOD , TSS, oil and grease, pH, and nine toxic pollutants	Dilution model	
2000	California Toxics Rule (WQS)	Ambient aquatic life criteria for twenty-three priority toxics and ambient human health criteria for fifty-seven priority toxics	None	Recreation: Proportionate reduction in benefits transferred from Lyke (1993) (for percentage increase in value) and range of values based on three saltwater fishing studies and two saltwater fishing studies (benchmarked to Walsh, Johnson, and McKean 1988). Nonuse: Valued as 50 percent of use benefits. Health: Reduced cancer risk from fish consumption valued using VSL.
2003	Metal Products and Machinery	TSS, oil and grease	Dilution and exponential decay for drinking water analyses	Recreation: Lifting fish consumption advisories, improved wildlife viewing, and improved boating transferred from original meta-analyses (for percentage increase in value) and Bergstrom and Cordell (1991) and Walsh, Johnson, and McKean (1990) (for baseline consumer surplus). Nonuse: Valued as 50 percent of use benefits. Health: Reduced cancer risk from fish consumption valued using VSL. Reduced cancer risk from drinking water valued using VSL. Increased IQ valued using lifetime earnings. Avoided Costs: Sludge disposal.
2003	CAFO	TSS, BOD, fecal coliform, COD, nitrogen, phosphorus, pathogens, hormones/antibiotics	NWPCAM	Recreation, Nonuse: Transferred from Carson and Mitchell (1993). Market: Reduced fish kills valued using replacement costs and average recreational value. Reduced cattle mortality valued using replacement costs. Increased commercial shellfish harvests valued using consumer surplus. Health: Reduced contamination in private wells valued using Crutchfield, Cooper, and Hellerstein (1997), de Zoysa (1995), and Poe and Bishop (1999). Avoided Costs: Drinking water treatment.
2004	Meat and Poultry Products	TSS, oil and grease, ammonia, nitrogen, phosphorus, fecal coliform, total residual chlorine	NWPCAM	Recreation, Nonuse: Transferred from Carson and Mitchell (1993). Avoided Costs: Drinking water treatment.
2004	Concentrated Aquatic Animal Production	TSS, phosphorus, nitrogen, drugs/pesticides	QUAL2E	Recreation, Nonuse: Transferred from Carson and Mitchell (1993).
2006	Cooling Water Intake Structures (316b)	Not applicable; based on harmful impacts to aquatic life caused by cooling water intake structures	Thompson Bell model of fisheries yield	Recreation: Increased fish catch valued using a meta-analysis of random utility models. Nonuse: Qualitative discussion. Market: Increased commercial fish harvest valued using market prices.
2009	Construction and Development	TSS, turbidity	SPARROW	Recreation, Nonuse: Transferred from an original meta-analysis (regression) of 45 studies. Avoided Costs: Dredging. Drinking water treatment.

Notes: Table indicates EPA surface water quality regulations related to freshwater only and therefore excludes some EPA actions. Air benefits were estimated in several of these rules, but those benefits are not reflected here. All rules are effluent guidelines unless otherwise noted as Water Quality Standard (WQS).

Sources: Based on data from EPA Office of Water historical sources and planning documents, supplemented by Morgenstern (1997). For data on EPA-issued water-quality standards, see http://water.epa.gov/scitech/swguidance/waterquality/standards/Laws-and-Regulations.cfm. For EPA's effluent guidelines, see http://water.epa.gov/scitech/wastetech/guide/industry.cfm. RIAs not found on these pages may be obtained through the NCEE Regulatory Economic Analysis database (http://yosemite.epa.gov/ee/epa/eed.nsf/webpages/RegulatoryImpactAnalyses.html) or EPA's National Service Center for Environmental Publications (http://www.epa.gov/nscep/). Data on the Office of Water's biennial plan for effluent guidelines (going back to 1990) are at http://water.epa.gov/lawsregs/lawsguidance/cwa/304m/.

[a]Estimated benefits for three case studies in the Great Lakes for this rule, but benefits were not estimated for the entire rule and slightly different approaches were used in each case.

Economic evaluation of Governor Branstad's water quality initiative

Hayes, Kling, and Lawrence (2016) evaluate the governor of Iowa's $4.7 billion proposal to improve Iowa's water quality over three decades, finding that the proposal would create 2,800 jobs annually and generate $691 million in economic activity.

The Governor's proposal would provide approximately half of the funds required to implement the Iowa Nutrient Reduction Strategy. The rest of the funds would need to come from cost shares from landowners, the federal government, or other third party organizations (such as NGO's). Landowners might be willing to contribute because of reduced soil erosion and improved soil quality or because they prefer this program to possible future regulation. One argument for federal cost is that many of the environmental benefits would be felt downstream of Iowa to the Gulf of Mexico. The benefits of the strategy exceed the costs when these downstream benefits are included. The spending level that the Governor has proposed is approximately equal to the currently identifiable and quantifiable benefits that residents of Iowa would receive from achieving the goals of the strategy. The adoption of this voluntary strategy might also deter potential regulatory approaches.

On an annualized basis, projected spending under this proposal would generate approximately $690 million in economic activity, 1,150 full-time direct employment positions and 2,800 total full-time positions. However, it should be understood that alternative projects and proposals are likely to result in similar economic activity and employment.

The IMPLAN results are provided only for NCS1 because benefits of this alternative clearly exceed the costs. These results are presented in Table 4 [Table 4.8] *below and show that the $444 million in total spending under this program would create $691 million in total economic activity, $173 million in direct labor income and $250 million in total labor income. A total of 1,149 full-time positions would be required for the preparation of wetlands, construction of bioreactors and the planting of cover crops. The total number of jobs direct and indirect is 2,801.*

Table 4.8. Economic impact of NCS1 (Hayes et al., 2016)

	Direct	Total
Economic Impact of Wetlands Under NCS1		
Output ($)	80,000,000	107,323,225
Value Added ($)	33,830,640	49,149,962
Labor Income ($)	30,729,410	38,749,227
Employment	554	826
Economic Impact of Bioreactors Under NCS1		
Output ($)	50,000,000	67,077,016
Value Added ($)	21,144,150	30,718,726
Labor Income ($)	19,205,881	24,218,267
Employment	346	516
Economic Impact of Cover Crops Under NCS1		
Output ($)	315,000,000	516,600,000
Value Added ($)	100,227,273	216,490,909
Labor Income ($)	123,494,318	187,711,364
Employment	248	1459
Total Economic Impact of Cover Crops Under NCS1		
Output ($)	445,000,000	691,000,241
Value Added ($)	155,202,063	296,359,597
Labor Income ($)	173,429,609	250,678,858
Employment	1149	2801

What is interesting about this policy is the connection it makes to down-the-stream needs, which it says would make the benefits of this policy exceed the implementation costs. It does note that this policy may not be the only way to achieve the economic outcomes it projects.

Critiques of this policy note that the policy fails to include producer or agricultural accountability, has no metrics, and doesn't have specific enforceable time lines (Telegraph Herald, 2016).

<u>Mississippi River/Gulf of Mexico Watershed Nutrient Task Force: 2015 Report to Congress</u>

The Mississippi River/Gulf of Mexico Watershed Nutrient Task Force's First Biennial Report (2015) estimates the costs of reducing nitrate levels in Hypoxia Task Force states – about $4.8 billion/year. Nutrient loading from NSP pollution triggered toxic algal blooms, which lead to the death of fish, birds, and dogs, and illnesses in at least seven people. Recreation revenues were hit in return, with losses of more than $250,000 a year at Grand Lake St. Mary's State Park. Local businesses related to water sports closed or had a substantial reduction in revenue – estimated to be at $35-40 million in 2010. Federal, local, and state resources have been pooled to restore the lake, with great cost, but with results of improved dissolved oxygen and water circulation.

> *The city of Celina, which draws its drinking water from Grand Lake St. Marys, has spent $7.2 million in capital costs for a new granular activated carbon (GAC) facility and spends $340,000 per year on GAC filter media to address trihalomethanes (THMs) and algae concerns (Michael Eggert, Ohio EPA, personal communication, November 9, 2012).*
>
> *Anderson et al. (2000) estimated the potential annual impacts of HABs nationally on public health, fisheries, recreation and tourism, and monitoring and management. The authors note that their results are underestimates due to additional unquantified categories of impacts, but estimated that:*
>
> - *Shellfish and ciguatera fish poisoning resulted in $33.9–81.6 million in public health expenditures.*
> - *Wild harvest and aquaculture losses associated with shellfish poisoning, ciguatera, and brown tides resulted in $18.5–24.9 million in commercial fishing losses.*
> - *Tourism industries in North Carolina, Oregon, and Washington lost up to $29.3 million.*
> - *Monitoring and management programs (such as routine shellfish toxin monitoring) in just 12 states cost $2.0–2.1 million. Dodds et al. (2009) also developed national-level estimates of the impacts of nutrient pollution. They compared nutrient concentrations for EPA ecoregions to reference conditions to identify areas potentially impacted by nutrient pollution, then estimated annual impacts to recreation, real estate, spending on threatened and endangered species recovery, and drinking water.*

The results for each sector were:

- *$189–589 million in fishing expenditure losses and $182–567 million in boating expenditure losses (based on lake area closures and expenditures).*
- *$0.3–2.8 billion in property value losses (depending on the assumed land availability).*
- *$44 million in spending to develop conservation plans for 60 species impacted by eutrophication.*
- *$813 million in expenditures on bottled water due to taste and odor issues in public water supplies attributable to eutrophication.*

Estimates of the costs of controlling hypoxia vary. One recent study published by the National Academy of Sciences indicates that if agricultural conservation investments could be targeted to the most cost-effective locations, a combined federal, state, local and private investment of $2.7 billion per year could effectively reduce the size of the hypoxic zone (Rabotyagov et al. 2014). A number of qualifications apply to this estimate. Notably, it only considers conservation practices installed on agricultural lands in production, specifically overland flow practices, edge-of-field practices, and improvements in irrigation efficiency. It does not consider innovative approaches to preventing nutrient runoff that have the potential to further reduce costs, such as agricultural drainage water management and bioreactors, saturated buffers, cover crops, use of easements for wetlands restoration/creation, streambank conservation, and/or advances in technologies such a urease inhibitors or slow release fertilizers.

Measuring the total economic value of restoring ecosystem services in an impaired river basin: Results from a contingent valuation survey

Loomis et al. (2000) perform a contingent valuation survey with ties to the water bill. The study provides a comparison with likely costs.

Results from nearly 100 in-person interviews indicate that households would pay an average of $21 per month or $252 annually for the additional ecosystem services. Generalizing this to the households living along the river yields a value of $19 million to $70 million depending on whether those refusing to be interviewed have a zero value or not. Even the lower bound benefit estimates exceed the high estimate of water leasing costs ($1.13 million) and conservation reserve program farmland easements costs ($12.3 million) necessary to produce the increase in ecosystem services.

4.4. Value of Information

The studies included in this section are related to groundwater. Although groundwater is not the focus of this study, these articles are selected because they present an appropriate approach to valuation of information. The following studies focus on the value of geospatial information or geological maps. Studies on economic value of information in the river system context are difficult to find.

Bernknopf and Shapiro's study presents the concept of value of information (2015):

> *Most value of information (VOI) analyses consider the costs of geospatial data collection and the potential cost savings to society accruing from the presence (rather than absence) of geospatial data. This type of analysis can be referred to as cost-savings applications. There also are societal benefits that can result from making more informed decisions. Analyses measuring this type of benefits can be referred to as innovation applications. Both types of applications can be pursued with the systematic availability of archival and current geospatial data that result from open access to replicable, and continuous data frameworks that do not exclude anyone from the benefits of its use. …Both cost-savings and innovation applications are used to document the expected use value of information.*

Their study focused on the innovation applications, and they used a two-step approach to estimate the value of geospatial information:

> *The VOI contained in geospatial data is the difference between the net benefits (in present value terms) of a decision with and without the information. A range of technologies is used to collect and distribute geospatial data. These technical activities are linked to examples that show how the data can be applied in decision making, which is a cultural activity. …*
>
> *Monetary values are established in specific applications in an empirical economics approach as the basis for the use value of the information. The method has two stages. The first is the development of an interdisciplinary model of economic behavior in which the application of the geospatial information is demonstrated as a consequence of spatiotemporal observations. The second stage is to compare the net benefits with and without the geospatial information to estimate the VOI. In this paper, we only address estimation of the economic value of geospatial data used for decision-making.*

Bernknopf and Shapiro (2015) used the study by Forney et al. (2012) as an example to examine if farmers and regulators were better informed to make land use decisions with the use of the moderate resolution land imagery (MRLI).

> *The VOI is estimated as (1) the economic benefit stream of a net increase in agricultural production across a region without sacrificing groundwater resources and (2) how agricultural production and its environmental impacts may change with or without the availability of MRLI. For the 35 counties in northeastern Iowa the estimated VOI for MRLI is an annualized $858M ± $197M/yr (in $2010) and has a current value of $38.1B ± $8.8B for that flow of benefits into the foreseeable future.*

Bernknopf et al. (1993) examined the societal value of geologic maps using the cost-savings application. The study showed clear steps of how the evaluations were conducted.

> *This report describes a method for estimating the economic value of applying geologic map information to land use decision making. …*

> *The costs of producing geologic maps can be grouped into five categories: (1) data collection in the field, (2) data compilation and interpretation, (3) data presentation such as drafting, digitizing, and data-base construction, (4) printing and publication, and (5) distribution. …*
>
> *The specific societal benefits considered in this study are the savings (defined in terms of economic losses avoided) realized when geologic map information is considered in a public-domain land use decision. Benefits accrue when regulatory decisions are made from geologic maps that contain improved information. These benefits are realized as a reduction in the level of uncertainty of information (geologic map information in this case) that serves as the basis for implementing land use regulations. …*
>
> *The expected net benefit of using the improved geologic map information (the modern USGS 1:100,000-scale geologic map), derived from just two of the many situations that require geologic data in Loudoun County, is the gross benefit derived from the use of the improved geologic map information ($2.44 to $4.66 million for the two case studies described above) minus the cost of producing that geologic map ($1.16 million). Therefore, the expected net benefit (societal value) for the two applications of the 1:100,000-scale Loudoun County geologic map ranges from about $1.28 million to $3.50 million.*

Both studies evaluated the value of better informed decisions on land use but took different approaches. As specified in the steps, the process of determining the value of information is generally the same. However, details of characteristics for valuation are issue specific. In the Bernknopf et al. study (1993), the value was determined by the costs of producing geological maps and the savings (benefits) of including that information for decision making. Applying the same process to a different scenario, e.g. the value of a water quality information system in reducing hypoxia, the value would be estimated by the cost of producing the information system and the savings of including that information for decision making.

5. References

Bernknopf, R. L., Brookshire, D. S., Soller, D. R., McKee, M. J., Suttef, J. F., Matti, J. C., & Campbell, R. H. (1993). Societal value of geologic maps. U.S. Department of the Interior. Retrieved from https://pubs.er.usgs.gov/publication/cir1111

Bernknopf, R., & Shapiro, C. (2015). Economic assessment of the use value of geospatial information. *ISPRS International Journal of Geo-Information, 2015*(4), 1142-1165. doi:10.3390/ijgi4031142

Bingham, G., Bishop, R., Brody, M., Bromley, D., Clark, E., Cooper, W., … Suter, G. (1995). Issues in ecosystem valuation: Improving information for decision making. *Ecological Economics, 14*, 73-90.

Braden, J. B., & Johnston, D. M. (2004). Downstream economic benefits from storm-water management. *Journal of Water Resources Planning and Management, 130*(6), 498-505. doi: 10.1061/(ASCE)0733-9496(2004)130:6(498)

Braden, J. B., Won, D., Taylor, L. O., Mays, N., Cangelosi, A., & Patunru, A. (2008). Economic benefits of remediating the Sheboygan River, Wisconsin Area of concern. *Journal of Great Lakes research, 34*(4), 649-660.

Christianson, L., Tyndall, J., & Helmers, M. (2013). Financial comparison of seven nitrate reduction strategies for Midwestern agricultural drainage. *Water Resources and Economics*, *2-3*, 30-56.

Copley, D. M. (2006, July 20). Senate OKs expansion of river locks. *State Journal-Register*, p. 12.

Dodds, W. K., Bouska, W., Eitzmann, J. L., Pilger, T. J., Pitts, K. L., Riley, A. J., ... Thornbrugh, D. J. (2009). Eutrophication of U.S. freshwaters: Analysis of potential economic damages. *Environmental Science & Technology, 43*(1), 12-19.

Doering, O., Diaz-Hermelo, F., Howard, C., Heimlich, R., Hitzhusen, F., Kazmierczak, R. … Ribaudo, M. (1999). *Evaluation of the economic costs and benefits of methods for reducing nutrient loads to the Gulf of Mexico: Topic 6 report for the integrated assessment on hypoxia in the Gulf of Mexico*. Retrieved from http://oceanservice.noaa.gov/products/hypox_t6final.pdf

Flesher, J. (2013, April 4). Asian carp may have reached Great Lakes. *Peoria Journal Star*. Retrieved from http://www.pjstar.com/x1037532435/Asian-carp-may-have-reached-Great-Lakes

Forney, W. M., Raunikar, R. P. Bernknopf, R. L., & Mishra, S. K. (2012). *An economic value of remote-sensing information—Application to agricultural production and maintaining groundwater quality*. U.S. Geological Survey, Professional paper 1796. Retrieved from http://permanent.access.gpo.gov/gpo35209/826201759.pdf

GLMRIS [The Great Lakes and Mississippi River Interbasin Study]. (2012). *Commercial fisheries baseline economic assessment – U.S. waters of the Great Lakes, Upper Mississippi River, and Ohio River*

Basins. U.S. Army Corps of Engineers. Retrieved from http://glmris.anl.gov/documents/docs/Commercial_Fisheries_Report.pdf

Grabowski, J. H., Brumbaugh, R. D., Conrad, R. F., Keeler, A. G., Opaluch, J. J., Peterson, C. H., … Smyth, A. R. (2012). Economic valuation of ecosystem services provided by oyster reefs. *BioScience*, *62*(10), 900-909.

Griffiths, C., Klemick, H., Massey, M., Moore, C., Newbold, S., Simpson, D., ... Wheeler, W. (2012). U.S. Environmental Protection Agency valuation of surface water quality improvements. *Review of Environmental Economics and Policy, 6*(1), 130-146. doi: 10.1093/reep/rer025

Hansen, L., & Ribaudo, M. (2016). Targeting wetland restoration to cost-effectively reduce nitrogen loadings in the Gulf of Mexico. Agricultural and Applied Economics Association 2016 Annual Meeting, July 31-August 2, Boston, Massachusetts. Poster 9791. Retrieved from: http://ageconsearch.umn.edu//handle/235665

Hayes, D., Kling, C., & Lawrence, J. (2016). *Economic evaluation of Governor Branstad's water quality initiative*. Issue brief no. 16-PB 19. Iowa State University Center for Agricultural and Rural Development. Retrieved from https://governor.iowa.gov/sites/default/files/documents/ISU%20CARD%20Economic%20Evaluation.pdf

Hyberg, S., Iovanna, R., Crumpton, W., & Richmond, S. (2015). The cost effectiveness of wetlands designed and sited for nitrate removal: The effect of increased efficiency, rising easement costs, and lower interest rates. *Journal of Soil & Water Conservation*, *70*(2), 30A-32A. doi:10.2489/jswc.70.2.30A

Hypoxia Task Force (2016). *Report on point source progress in Hypoxia Task Force states*. U.S. Environmental Protection Agency. Retrieved from https://www.epa.gov/sites/production/files/2016-03/documents/htf_pointsource_progressreport_02-25-16_508.pdf

IEc [Industrial Economics, Incorporated]. (2014). *The economic profile of the Lower Mississippi River: An update*. Retrieved from http://www.lmrcc.org/wp-content/uploads/2014/02/LMR_Economic_Profile_February2014.pdf

Ingraham, M. W., & Foster, S. G. (2008). The value of ecosystem services provided by the U.S. National Wildlife Refuge System in the contiguous U.S. *Ecological Economics, 67*, 608-618. doi: 10.1016/j.ecolecon.2008.01.012

Jenkins, W. A., Murray, B. C., Kramer, R. A., & Faulkner, S. P. (2010). Valuing ecosystem services from wetlands restoration in the Mississippi Alluvial Valley. *Ecological Economics, 69*, 1051-1061. doi: 10.1016/j.ecolecon.2009.11.022

Koteen, J., Alexander, S. J., & Loomis, J. B. (2002). *Evaluating benefit and costs of change in water quality*. Gen. Tech. Rep. PNW-GTR-548. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. Retrieved from http://www.fs.fed.us/pnw/pubs/gtr548.pdf

Kruse, J. C., Protopapas, A., Ahmedov, Z., McCarl, B., Wu, X., & Mjelde, J. (2011). *America's locks and dams: "A ticking time bomb for agriculture?"*. Texas Transportation Institute, Center for Ports and Waterways and Texas A&M University, Department of Agricultural Economics. Retrieved from http://unitedsoybean.org/wp-content/uploads/Americas_Locks_And_Dams.pdf

Kruse, J., Fellin, L., Fuller, S., Meyer, S., & Womack, A. (2007). Analyses of the Upper Mississippi and Illinois Rivers as grain transport arteries: A spatial equilibrium analyses. Paper presented at the 48th Annual Transportation Research Forum, Boston, Massachusetts, March 15-17, 2007. Retrieved from http://ageconsearch.umn.edu/bitstream/207923/2/2007_6B_Mississippi_paper.pdf

Loomis, J., Strange, L., Kent, P., Covich, A., & Fausch, K. (2000). Measuring the total economic value of restoring ecosystem services in an impaired river basin: Results from a contingent valuation survey. *Ecological Economics*, *33*(1), 103.

MA [The Millennium Ecosystem Assessment]. (2003). *Ecosystems and human well-being: A framework for assessment*. Washington, DC: Island Press. Retrieved from http://www.millenniumassessment.org/en/Framework.html

McLellan, E., Robertson, D., Schilling, K., Tomer, M., Kostel, J., Smith, D., & King, K. (2015). Reducing nitrogen export from the Corn Belt to the Gulf of Mexico: Agricultural strategies for remediating hypoxia. *Journal of the American Water Resources Association*, *51*(1), 263-289. doi:10.1111/jawr.12246

Mississippi Headwaters Board & Bemidji State University. (2003). *Lakeshore property values and water quality: Evidence from property sales in the Mississippi Headwaters Region*. Retrieved from: http://www.nrcs.usda.gov//Internet/FSE_DOCUMENTS/nrcs143_009613.pdf

Mississippi River/Gulf of Mexico Watershed Nutrient Task Force. (2015). *2015 report to Congress. First Biennial Report*. U.S. Environmental Protection Agency. Retrieved from https://www.epa.gov/sites/production/files/2015-10/documents/htf_report_to_congress_final_-_10.1.15.pdf

NorthStar Economics. (2008). *The economic impact of recreational trout angling in the Driftless Area*. Retrieved from http://fishhabitat.org/sites/default/files/partnership_uploads/TUImpact-Final.pdf

Rabotyagov, S. S., Campbell, T. D., White, M., Arnold, J. G., Atwood, J., Lee Norfleet, M., … Rabalais, N. N. (2014). Cost-effective targeting of conservation investments to reduce the northern Gulf of Mexico hypoxic zone. *Proceedings of the National Academy of Sciences of the United States of America, 111*(52), 18530-18535.

Ready, R. C., Poe, G. L., Lauber, T. B., Creamer, S., Connelly, N. A., & Stedman, R. C. (2012). *Net benefits of recreational fishing in the Great Lakes, Upper Mississippi River, and Ohio River Basins*. Retrieved from https://ecommons.cornell.edu/bitstream/handle/1813/40534/2012_NetBenefitsOfRecreationalFishingReport.pdf?sequence=2

Ribaudo, M. O., Horan, R. D., & Smith, M. E. (1999). *Economics of water quality protection from nonpoint sources: Theory and practice*. Resource Economics Division, Economic Research Service, U.S. Department of Agriculture. Agricultural Economic Report No. 782. Retrieved from http://www.ers.usda.gov/media/1385896/aer782.pdf

Sainz, A. (2016, April 20). 3rd sewage line breaks in Memphis, spills waste into river. *The Big Story*. Retrieved from http://bigstory.ap.org/article/f6b6d930519342fbadcfbbae37213b00/3rd-sewage-line-breaks-

Sanburn, J. (2012, July 30). The not-so-mighty Mississippi: How the river's low water levels are impacting the economy. *Time.com*. Retrieved from http://business.time.com/2012/07/30/the-not-so-mighty-mississippi-how-the-rivers-low-water-levels-are-impacting-the-economy/

Sparks, R. E., & Braden, J. B. (2007). Naturalization of developed floodplains: An integrated analysis. *Journal of Contemporary Water Research and Education, 136*, 7-16.

St. Louis Post-Dispatch. (2003, July 31). Cities, States try new ways to live with flood plains - Here's a look at some alternative approaches to flood plain management and flood control being used around the country. *St. Louis Post-Dispatch,* p. A10.

Telegraph Herald. (2016, March 10). Report says cleaning Iowa water would add 2,800 jobs annually. *Telegraph Herald*. Retrieved from http://www.thonline.com/news/iowa-illinois-wisconsin/article_294be6e2-7df2-5596-8d60-88805b416645.html

Treiman, T. B., Sheriff, S. L., Renken, R. B., & Loomis, J. (2014). The economic value of Missouri River recreation: Estimates from the Missouri River public use assessment. *River Research and Applications, 30*(5), 639-649.

University of Kentucky, & University of Tennessee. (2014). *Inland navigation in the United States: An evaluation of economic impacts and the potential effects of infrastructure investment*. Retrieved from http://www.nationalwaterwaysfoundation.org/documents/INLANDNAVIGATIONINTHEUSDECEMBER2014.pdf

USFWS [U.S. Fish and Wildlife Service]. (2015). *Upper Mississippi River economic assessment Part 1: 60 county assessment*. Retrieved from http://www.umrcc.org/Reports/2015%20Upper%20Miss%20River%20econ%20assessment%20(4)reduced.pdf van Beukering, P. J. H., Brouwer, R., & Koetse, M. J. (2015). Economic values of ecosystem services. In J. A. Bouma & P. J. H. van Beukering (Eds.), *Ecosystem services: From concept to practice* (pp. 89-107). Cambridge, UK: Cambridge University Press.

Wiles, R. (2008, July 3). We need to protect more land, not less - Conservation Reserve Program reduces water pollution, soil erosion and greenhouse gases. *St. Louis Post-Dispatch*, p. B9.

6. Appendices

6.1. Related Organizations

- American Rivers http://www.nemw.org/reports/
- American Soybean Association http://soygrowers.com/
- American Water Works Association http://www.awwa.org/
- America's Watershed Initiative http://americaswatershed.org/
- EPA Mississippi River/Gulf of Mexico Hypoxia Task Force https://www.epa.gov/ms-htf
- Gulf Coast Ecosystem Restoration Council https://www.restorethegulf.gov/
- Louisiana's Total Maximum Daily http://www.deq.louisiana.gov/portal/tabid/130/Default.aspx
- Lower Mississippi River Conservation Committee http://www.lmrcc.org/reports/
- Mississippi River Cities & Towns Initiative http://www.mrcti.org/home.html
- Mississippi River Collaborative http://www.msrivercollab.org/
- Mississippi River Delta Restoration http://www.mississippiriverdelta.org/mediaroom/reports-and-additional-resources/
- Mississippi River Network http://1mississippi.org/mrn/
- Mississippi River Parkway Commission http://mrpcmembers.com/national-meetings/
- Northeast-Midwest Institute http://www.nemw.org/reports/
- SERA-46 http://northcentralwater.org/sera-46/
- Soy Transportation Coalition http://www.soytransportation.org/
- Tennessee's Total Maximum Daily Load (TMDL) http://www.tn.gov/environment/article/wr-ws-tennessees-total-maximum-daily-load-tmdl-program
- Texas A&M Transportation Institute/Center for Ports and Waterways http://tti.tamu.edu/group/multimodal/groups/center-for-ports-waterways/
- The Big River Coalition http://www.bigrivercoalition.org/
- The Great River Partnership http://www.greatriverspartnership.org/en-us/Pages/default.aspx
- The Nature Conservancy http://www.nature.org/
- United Soybean Board http://unitedsoybean.org/farmer-resources/tools/other-resources/americas-locks-dams-a-ticking-time-bomb-for-agriculture/
- Upper Mississippi River Basin Association (UMRBA) http://www.umrba.org/publications.htm#wq
- US Army Corps of Engineers (USACE) http://cdm16021.contentdm.oclc.org/cdm/search
- US Department of Agriculture (USDA) http://www.usda.gov/wps/portal/usda/usdahome
- US Environmental Protection Agency (USEPA) https://www3.epa.gov/
- US Fish and Wildlife Services (USFWS) https://www.fws.gov/
- USFWS, Coastal Wetlands Conservation and Restoration Task Force https://www.fws.gov/lafayette/CR_Program.html
- US Geological Survey (USGS) http://www.usgs.gov/
- USGS, Toxic Substances Hydrology Program http://toxics.usgs.gov/
- Waterways Council, Inc. http://waterwayscouncil.org/
- World Resources Institute http://www.wri.org/

6.2. Related Projects

- Integrated Valuation of Ecosystem Services Tool (InVEST)
  http://www.naturalcapitalproject.org/invest/
- The Federal Recreation Council of the Department of Interior collaborates with Bureau of Economic Analysis of the Department of Commerce to establish statistics on outdoor recreation economy. A one-year feasibility study will be completed in 2017.
  https://www.doi.gov/sites/doi.gov/files/uploads/Fact%20Sheet%20-%20Outdoor%20Recreation%20Economic%20Study%20final.pdf

6.3. Interviewed Experts

- **John Braden,** Professor Emeritus/Interim Head, Department of Agricultural and Consumer Economics, University of Illinois at Urbana-Champaign
- **Nick Brozović**, Director of Policy, Water for Food Institute at the University of Nebrask
- **Ximing Cai**, Professor, Department of Civil and Environmental Engineering, University of Illinois at Urbana-Champaign
- **Laura Christianson**, Research Assistant Professor, Department of Crop Sciences, University of Illinois at Urbana-Champaign
- **Katie Flahive**, Environmental Scientists, Coordinating Committee Co-Chair of the Mississippi River/Gulf of Mexico Hypoxia Task Force, US Environmental Protection Agency
- **Skip Hyberg**, Economic and Policy Analyst and Senior Agricultural Economist, Farm Service Agency, US Department of Agriculture
- **Bill Kruidenier**, Associate Director, National Great Rivers Research and Education Center
- **Patrick McGinnis**, Senior Advisor, Water Resources Policy, Development & Sustainable Communities Group, The Horinko Group
- **Paul Rohde**, Vice President, Midwest Area, Waterways Coucil
- **Gary Rolfe**, Executive Director, National Great Rivers Research and Education Center
- **Dick Warner**, Senior Scientist, National Great Rivers Research and Education Center