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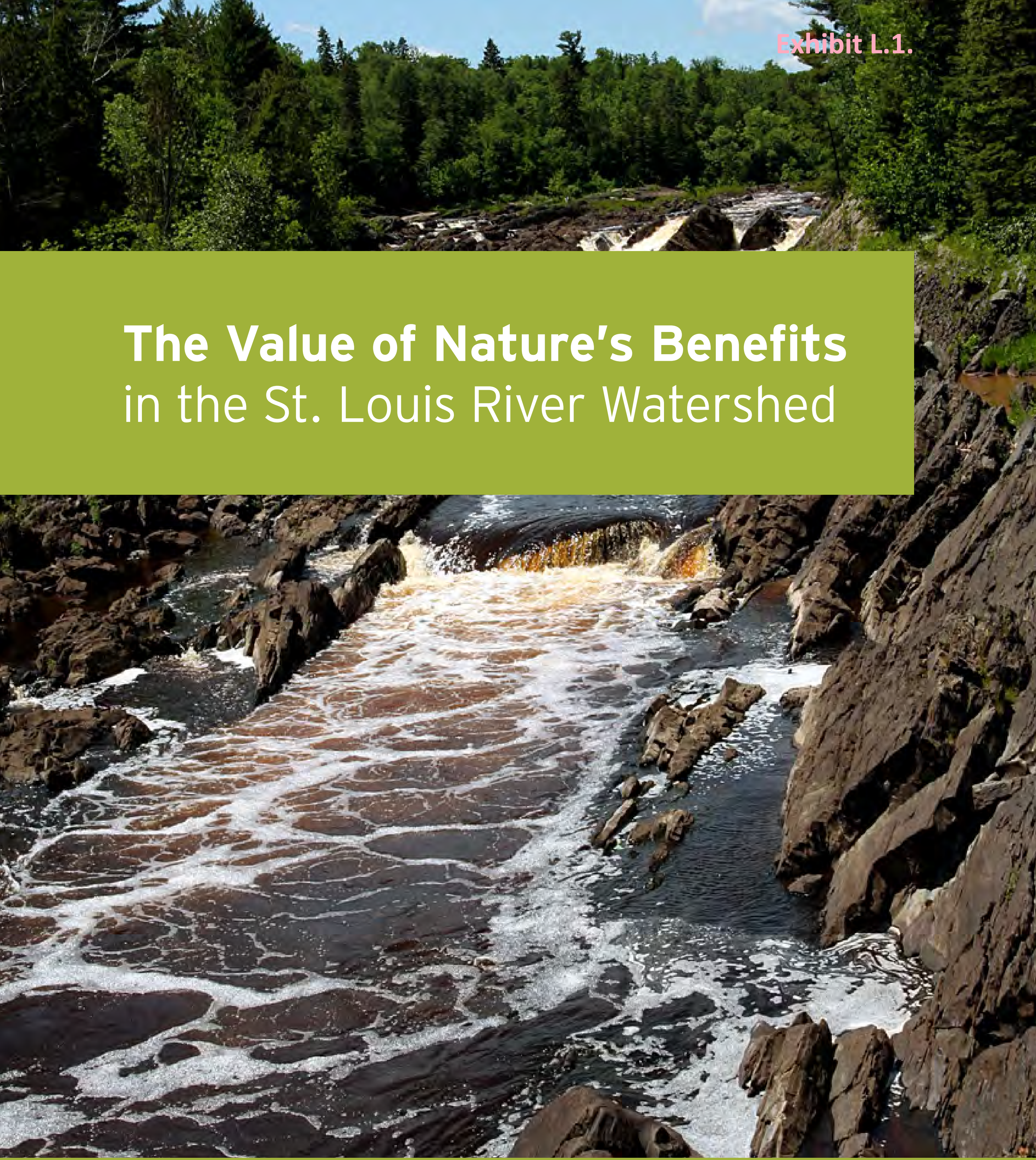

The Value of Nature's Benefits
in the St. Louis River Watershed

EARTH ECONOMICS

The Value of Nature's Benefits in the St. Louis River Watershed

June 2015

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The authors are responsible for the content of this report.

▶ The Cloquet River, a major tributary of the St. Louis River (opposite).
Creative commons share-alike image by Dave Fischer

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Executive Summary

The St. Louis River watershed provides an estimated $5 billion to $14 billion in ecosystem service benefits per year which provides each of the approximately 177 thousand people living in the watershed an annual benefit of $28,248 to $79,096.

Natural capital is an essential asset to both economic development and quality of life (Liu et al., 2010). Trees and freshwater streams are examples of natural capital that are produced by ecosystems, or biological communities interacting with their physical environment. In turn, natural capital produces an abundance of goods and services that everyone uses. Historically, ecosystem services have been either not valued or greatly discounted in economic analyses, leading to a misconception of their fundamental role in our economy (Daly and Farley, 2004). We may receive these ecosystem services for free from the environment, but they are worth far more than that.

Quantifying the value of ecosystem services allows the value of natural capital to be included in economic tools, which enables us to make wiser public and private decisions. The benefits of ecosystem services are similar to the economic benefits typically valued in the economy, such as the services and outputs of skilled workers, buildings, and infrastructure. Some ecosystem goods and services can be valued similarly through marketplaces, such as fish, wild rice, and clean water. However, many ecosystem services are not amenable to marketplaces valuation, even though they provide vast economic value. For example, when the flood protection services of a watershed are lost, economic damages include job losses, infrastructure repairs, reconstruction costs, restoration costs, property damage, and death. Conversely, when investments are made to protect and support these services, local economies are more stable and less prone to the sudden need for burdensome expenditures on disaster mitigation efforts. In addition to the economic value associated with these avoided costs, healthy watersheds provide myriad other services including water supply, carbon sequestration, water filtration, and biodiversity. All of these services provide economic value regionally and beyond.

This report is a valuation of the economic benefits of ecosystem goods and services provided by the St. Louis River watershed. The St. Louis River flows for almost 200 miles and drains an area of about 2.4 million acres in northeastern Minnesota and a small portion of Wisconsin. The watershed encompasses vast spans of forest, wetlands, lakes, rivers, grasslands, and shrubland. One important natural resource produced by the watershed is wild rice. Wild rice is used for food by people and animals. In addition, wild rice provides habitat services to wildlife, and the vegetation removes carbon from the atmosphere.

Spirit Bay, located in the St. Louis River Estuary near Spirit Island. *© Fond du Lac Resource Management Division*

Less tangible, but vitally important to people, are cultural services. Traditions are embedded in ecosystems, from subsistence harvesting of materials to sacred sites that have spiritual and artistic meaning. For example, wild rice has important cultural ties to local heritage and traditions, spiritual fulfillment, and more. Culturally important ecosystem services often cannot be measured in pounds, gallons, acres, or kilowatts. However, the ability to identify cultural value along with the value of other ecosystem services enables a more complete understanding of the intangible benefits and long-term consequences of public policy decisions affecting the watershed's natural assets.

If the lands and waters of the watershed are conserved and protected, the benefits described here will continue to provide important inputs to society and the regional economy.

Using the Benefit Transfer Method,[i] we estimated the dollar value of ecosystem services provided by the thirteen ecosystems in the St. Louis River watershed. Data from previously published studies were used, which valued ecosystem services based on market pricing, cost avoidance, replacement cost, travel cost, hedonic values, and contingent valuation. These methods have been broadly used to monetize things like the relationship between proximity to natural areas and increased property values, people's willingness to pay for outdoor recreation, and the value of water quality improvements provided by wetlands.

i The Benefit Transfer Method is a federally accepted valuation method used to value ecosystem services. Benefit transfer is a timely and cost-effective method of valuation (Liu et al., 2010) that can be applied to decision-making. Benefit Transfers produced by Earth Economics have been used in a variety of situations including Benefit-Cost Analysis by local agencies (Crittenden, J,. Stevens, G., Takahashi, E., Lynch, K., Heiden, D., Lockwood, G., Harrington, L., Li, L. 2010. Business Case 2 for Thornton Confluence Improvement. Seattle Public Utilities, Seattle, WA) and Federal agencies (Federal Emergency Management Agency. 2013. Consideration of Environmental Benefits in the Evaluation of Acquisition Projects under the Hazard Mitigation Assistance (HMA) Programs. FEMA Mitigation Policy FP-108-024-01) and has been supported in legal cases (see Briceno, T., Flores, L., Toledo, D., Aguilar Gonzáles, B., Batker, D., Kocian, M. 2013. Evaluación Económico-Ecológica de los Impactos Ambientales en la Cuenca del Bajo Anchicayá por Vertimiento de Lodos de la Central Hidroeléctrica Anchicayá. Earth Economics, Tacoma, WA, United States. Available at: http://eartheconomics.org/FileLibrary/file/Reports/Anchicaya.pdf).

St. Louis River Annual Benefits: ***$5 billion to $14 billion***

St. Louis River Benefits over 140 Years: ***$273 billion to $687 billion***

The St. Louis River watershed provides an estimated $5 billion to $14 billion in ecosystem service benefits per year. Taking a conservative approach and considering natural capital as a short-lived economic asset, like roads and bridges, the asset value of the watershed is between $273 billion and $687 billion over 140 years.

These values should be considered conservative underestimates. Ecosystem service valuation is an emerging field of economics, and as such, datasets are incomplete. For example, habitat services provided by freshwater estuaries have yet to be valued in peer reviewed literature. However, much effort has been taken to recreate sturgeon habitat in the estuary, which highlights the importance of this service to people. This critical service remains unrepresented in the estimates of this report due to lack of data. The appraised total value of ecosystem services in the St. Louis River watershed will almost certainly increase as more studies are conducted and peer reviewed, and as valuation of specific services is established.

The landscape of natural capital and associated ecosystem services in the St. Louis River watershed is highly valuable and provides the foundation for the regional economy. Understanding the connection between healthy lands, communities, and economies is essential to a thriving economy within the St. Louis River watershed. The results of this valuation study can be used by a wide variety of stakeholders including economists, educators, legislators, researchers, the public, and key decision makers to educate and inform policy.

▶ Big Lake in Cloquet, MN (opposite).
Creative commons image by Cameron Nordholm

Exhibit L.1.

Chapter 1
Introduction

◀ The main stem of the St. Louis River.
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The St. Louis River Watershed: What is it Worth?

The natural environment is the foundation human beings need for survival.

Nature is an economic asset, as economies are housed within natural landscapes (Daily et al., 1997). Every house, building, mine, and business considered in the study area resides in the valleys and hills of the St. Louis River watershed's natural landscape.

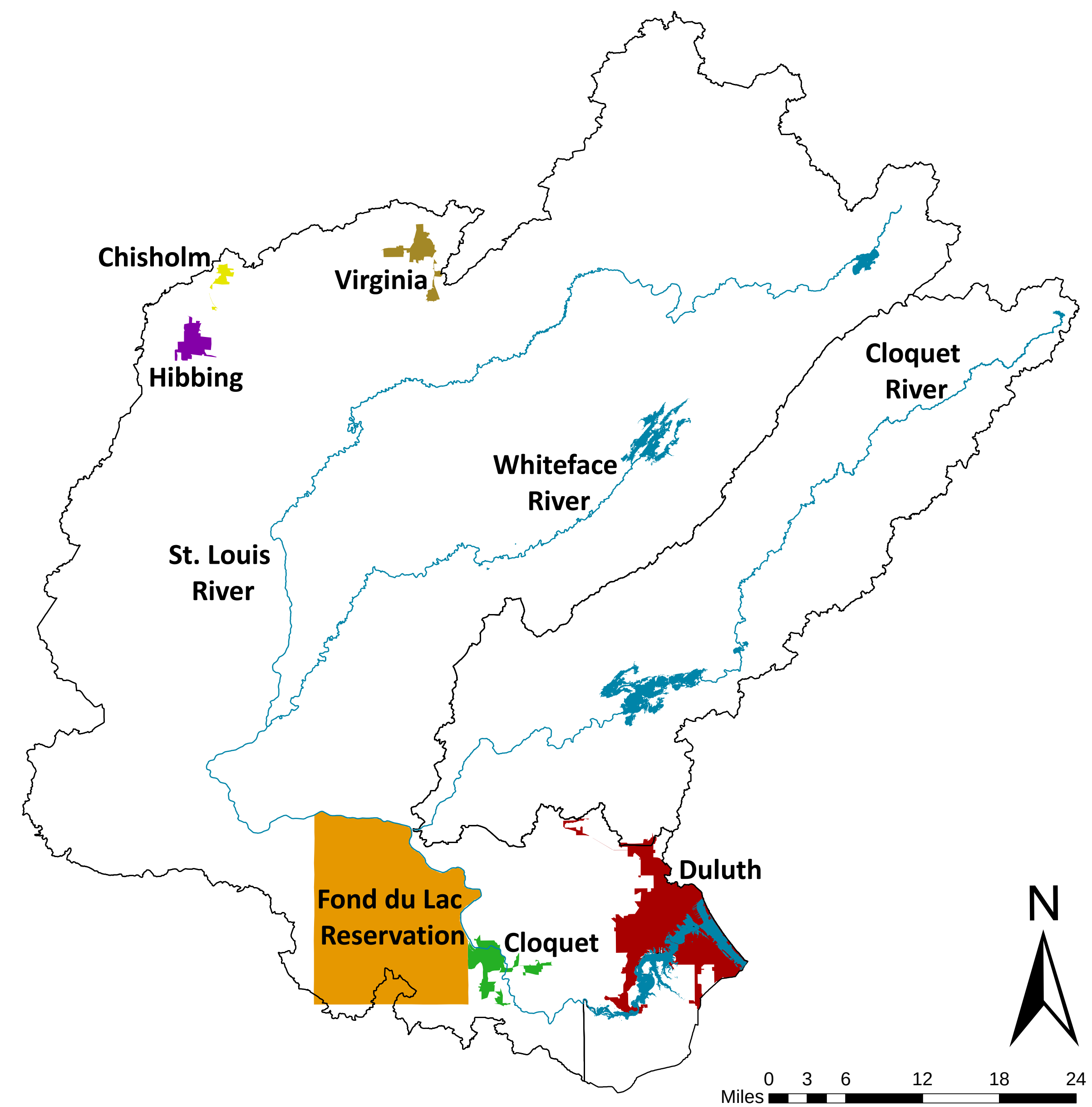
The landscape of the St. Louis River watershed provide goods and services which the economy relies on to thrive. These range from goods such as fish, which are already valued in marketplaces, to the far more intangible value of outdoor recreational opportunities. The natural environment is also the foundation human beings need for survival, as it provides goods and services we need to live, such as clean water and air.

What are these services worth? Many would argue the ecosystems within the watershed are priceless (Augustyniak, 1993). But considering something as priceless generally has one of two possible outcomes: an extremely high value, or, as in traditional economic analyses of nature's benefits, a value of zero. Because the latter outcome has generally prevailed and was often the default value in decision-making, the ecological integrity of the St. Louis River watershed's ability to continue to provide these benefits has deteriorated because of mining, development, and pollution. Pricelessness may not be a practical value when it comes to decisions about development and natural resource extraction. On the other hand, like a human life, the watershed is priceless and this perspective is worthy of further exploration through the use of ecosystem valuation techniques. Ecosystem services can be measured just as the value of peoples' work can be measured in economic measures such as a paycheck. Thus, this report is about the valuable economic work that the natural systems of the St. Louis River watershed provides to people.

Stakeholders of the St. Louis River Watershed

The residents of the watershed have a stake in the health and future of its ecosystems as the services provided by the regional environment are essential for its communities to thrive. The following sections describe the communities residing within the watershed, and provide examples of their interactions with the surrounding ecosystems.

Figure 1. Location of Major Stakeholder Communities within the St. Louis River Watershed
Source: Earth Economics



Fond du Lac Band of Lake Superior Chippewa

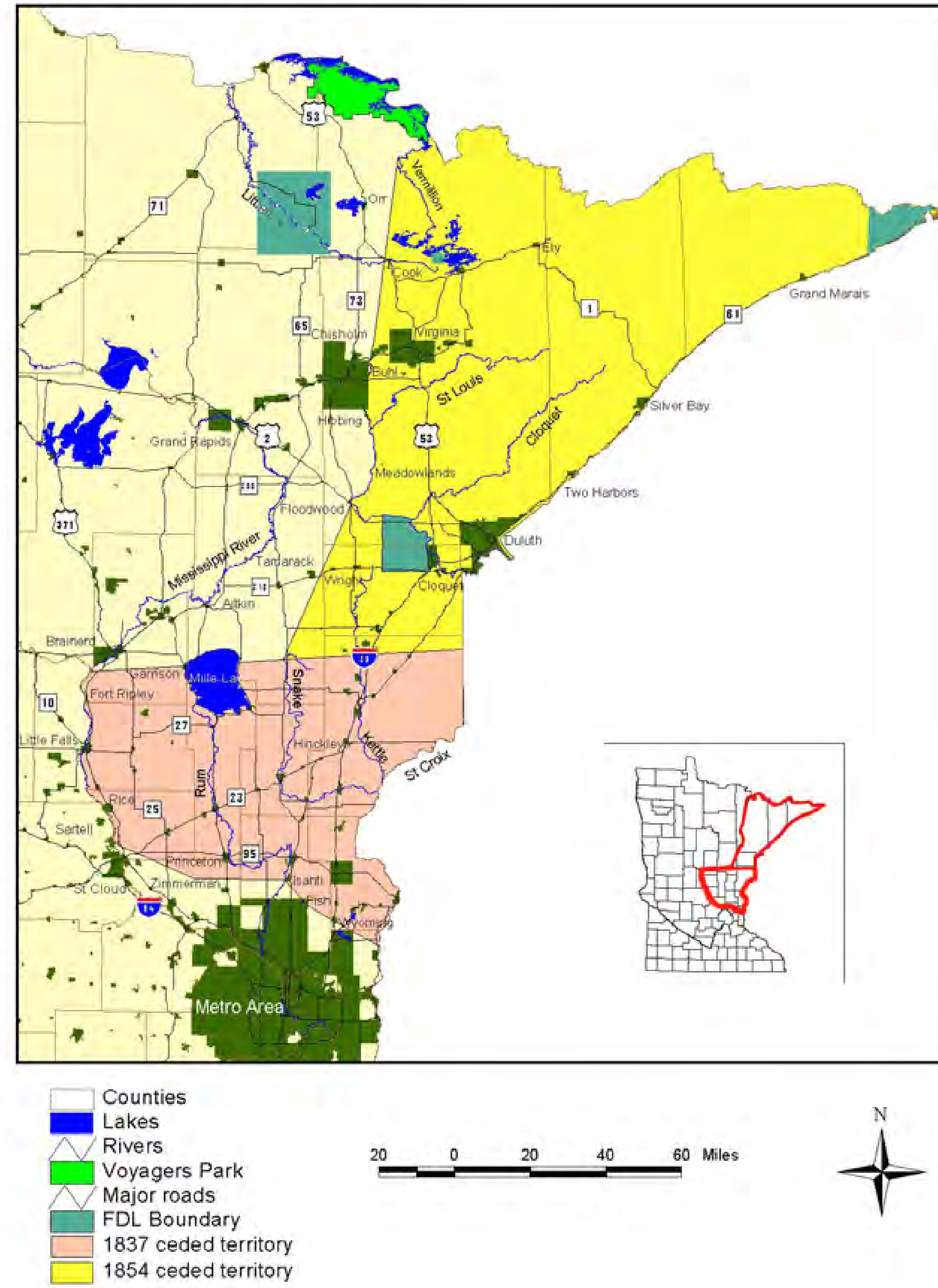
The Fond du Lac Band is part of the Chippewa or Ojibwe Nation, the second largest ethnic group of Indians in the United States (Fond du Lac Band of Lake Superior Chippewa, n.d.). The Ojibwe have resided in the Great Lakes region since 800 A.D. Historically, Ojibwe lands included vast amounts of land around Lake Superior and extending up into Canada. Wild rice played an important role in the Ojibwe's westward migration and the later location of the Fond du Lac reservation. The Fond du Lac Reservation is the only Ojibwe reservation within the St. Louis River watershed, lies approximately 20 miles west of Duluth, Minnesota, and is adjacent to the city of Cloquet, Minnesota. The reservation lies almost entirely within the boundary of the St. Louis River watershed. Many tribal traditions depend on the natural areas of the watershed and the Fond du Lac Band maintains traditional natural resource extraction rights in much of the watershed. Figure 2 indicates the areas where these natural resource extraction rights occur.

Downstream

Duluth is the largest urban area in the St. Louis River watershed, the fifth largest city in Minnesota, and the second largest city on the shores of Lake Superior. It is located at the mouth of the river as it flows into Lake Superior. Duluth is an international port and ranks first in imports and exports on the Great Lakes (Visit Duluth and Explore Minnesota, 2015). Because of the economic importance of the port, navigation is an essential ecosystem service for these downstream communities, and is provided by the waterways of the St. Louis River Estuary and Lake Superior.

Figure 2. Fond du Lac Reservation and Ceded Territories

Source: Great Lakes Indian Fish and Wildlife Commission



Upstream

Several communities are located along the headwaters of the St. Louis River. These sit on the Mesabi Iron Range, the largest mining complex in the nation (Encyclopædia Britannica, 2015). The economies of these communities depend on mining activities, and have done so since they were founded. The city of Hibbing, one of these mining communities, is home to one of the largest open iron mines in the world (Gilman, 1989). The location and activities of these communities has important impacts on the other stakeholders in the watershed. Pollution from mining activities makes its way downstream, heavily affecting natural resources in the lower portions of the watershed (U.S. EPA, 1968).

▼ **Figure 3. Mine Features of the Mesabi Iron Range**
Iron range mine features, cities, and major Minnesota watersheds.
Source: Great Lakes Indian Fish and Wildlife Comission

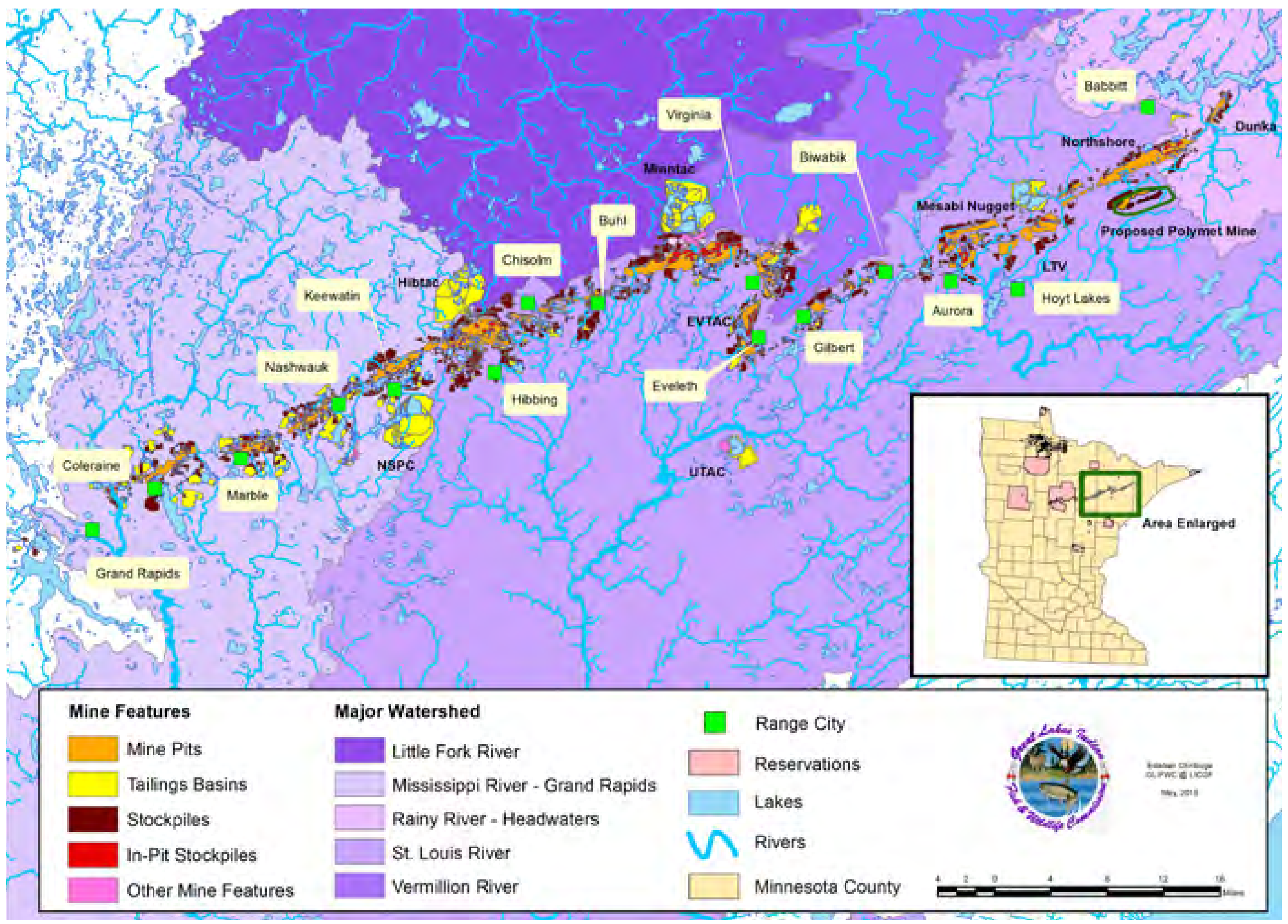


Exhibit L.1.

Study Overview

As environmental, social, and economic challenges become more pressing, policy leaders and planners need to understand the leverage that natural goods and services offer to the region and its economic and social wellbeing. The goal of this report is to provide economic values for the ecosystem services that are sustained by the natural landscape of the St. Louis River watershed.

This report is organized to present an overview of fundamental ecosystem valuation concepts, describe the study methodology, and share detailed valuation data. Finally, it provides observations and recommendations about the findings, and how they can be used to inform more holistic, efficient, and productive environmental policy to shift real dollars to the long-term stewardship and expansion of the region's natural capital.

▶ Norway Point, a well-known location for wild rice lakes and popular with duck hunters.
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Chapter 2
Ecosystem Goods and Services of the St. Louis River Watershed

The St. Louis River.
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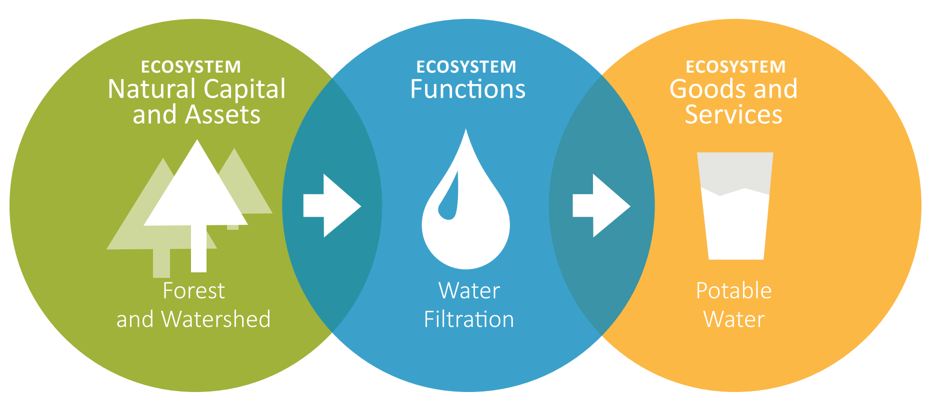
What is Natural Capital?

All economies operate within landscapes. If the landscape is healthy, economies can thrive. If the landscape is degraded, they can falter (Daily, 1997). This chapter introduces the concepts of natural capital, ecosystem services, and how they provide value to human communities and the economic systems that sustain them.

The term “natural capital” can be thought of as an extension of the traditional economic notion of capital. Economies depend upon many types of capital: built, financial, human, social, and natural capital. A robust and resilient economy requires that all forms of capital are healthy and are working productively and synergistically.

Natural capital is defined as “minerals, energy, plants, animals, ecosystems, [climatic processes, nutrient cycles, and other natural structures and systems] found on Earth that provide a flow of natural goods and services” (Daly and Farley, 2004). Natural capital provides the economy with a diverse flow of goods and services much like built and human capital. For example, natural capital assets within a watershed (e.g. forests, wetlands, and rivers) perform critical functions such as capturing, storing, conveying, and filtering rainfall destined for the water supply that humans need to survive (The Millennium Ecosystem Assessment, 2003). The ecosystem goods and services that are produced are defined as the benefits people derive from nature (The Millennium Ecosystem Assessment, 2003). Figure 4 illustrates the relationship between natural capital assets, ecosystem functions, and the production of ecosystem goods and services.

Figure 4. Goods and services flow from natural capital



In summary, natural capital provides the things we need to survive. Without healthy natural capital, many of the services (benefits) that we currently receive from natural capital for free could not exist. These services would need to be replaced with more costly built capital solutions, which often have lower resilience and shorter longevity (Emerton and Bos, 2004). But not every service can be replaced, like a beautiful view or a culturally significant site or resource. Sometimes, if natural capital is lost, the economic goods and services it provides will also be lost.

California’s Water Crisis

The current drought in California began in 2012, affecting the entire state. Unsustainable pumping of groundwater has lowered groundwater tables, increased pumping costs, and caused damage to aqueducts and other infrastructure due to subsidence (PPIC Water Policy Center, 2015). With the current drought, groundwater pumping across California has risen as communities have struggled to make up for less rainfall and snowmelt from the mountains. A third of California’s monitoring wells dropped by more than 10 feet between 2010 and 2014, and another third have seen levels drop between 2.5 and 10 feet (California Department of Water Resources, 2015). While we can produce alternative energy sources, transportation systems, and industrial goods for our economy, there is no substitute for water.

▲ Laguna Lake in San Luis Obispo, California one year before the drought (left) and during the drought (right).
Creative commons images by Joyce Cory

A Framework for Assessing Ecosystem Services

In 2001, an international coalition of over 1,360 scientists and experts from the United Nations Environmental Program, the World Bank, and the World Resources Institute initiated an assessment of the effects of ecosystem change on human well-being. A key goal of the assessment was to develop a better understanding of the interactions between ecological and social systems, and in turn, develop a knowledge base of concepts and methods that would improve our ability to "...assess options that can enhance the contribution of ecosystems to human well-being" (The Millennium Ecosystem Assessment, 2003). This study produced the landmark Millennium Ecosystem Assessment (MEA), which classifies ecosystem services into four broad categories according to how they benefit humans.

Earth Economics has adapted the ecosystem service descriptions in the United Nation's MEA (The Millennium Ecosystem Assessment, 2003) to develop a framework of ecosystem services to better articulate and value the vast array of critical services and benefits that natural capital provides. Table 1 defines the 21 ecosystem services used in this framework and the four broad groups they fall under.

PROVISIONING SERVICES	REGULATING SERVICES	SUPPORTING SERVICES	INFORMATION SERVICES
Provide basic goods including food, water and materials.	Benefits obtained from the natural control of ecosystem processes.	Provide refuge and reproduction habitat to wild plants and animals.	Provide humans meaningful interaction with nature.

Table 1. Framework of ecosystem goods and services
Adapted from de Groot et al., 2002 and TEEB, 2009.

Ecosystem Service	Economic Benefit to People
Provisioning Services	
Food	Producing crops, fish, game, and fruits
Medicinal Resources	Providing traditional medicines, pharmaceuticals, and assay organisms
Ornamental Resources	Providing resources for clothing, jewelry, handicraft, worship, and decoration
Energy & Raw Materials	Providing fuel, fiber, fertilizer, minerals, and energy
Water Supply	Provisioning of surface and groundwater for drinking water, irrigation, and industrial use
Regulating Services	
Biological Control	Providing pest and disease control
Climate Stability	Supporting a stable climate at global and local levels through carbon sequestration and other processes
Air Quality	Providing clean, breathable air
Moderation of Extreme Events	Preventing and mitigating natural hazards such as floods, hurricanes, fires, and droughts
Pollination	Pollination of wild and domestic plant species
Soil Formation	Creating soils for agricultural and ecosystems integrity; maintenance of soil fertility
Soil Retention	Retaining arable land, slope stability, and coastal integrity
Waste Treatment	Improving soil, water, and air quality by decomposing human and animal waste and removing pollutants
Water Regulation	Providing natural irrigation, drainage, ground water recharge, river flows, and navigation
Supporting Services	
Habitat & Nursery	Maintaining genetic and biological diversity, the basis for most other ecosystem functions; promoting growth of commercially harvested species
Genetic Resources	Improving crop and livestock resistance to pathogens and pests
Information Services	
Natural Beauty	Enjoying and appreciating the presence, scenery, sounds, and smells of nature
Cultural and Artistic Information	Using nature as motifs in art, film, folklore, books, cultural symbols, architecture, and media
Recreation and Tourism	Experiencing the natural world and enjoying outdoor activities
Science and Education	Using natural systems for education and scientific research
Spiritual and Historic	Using nature for religious and spiritual purposes

Biophysical and Cultural Ecosystem Services

The MEA was developed to provide decision makers and land managers a way to assess ecosystem service tradeoffs, both in the biophysical and cultural context. Stakeholders who benefit from natural lands are diverse and have varying degrees of need related to access, physical goods, development opportunities, and other uses. A single watershed can face multiple stresses from urban sprawl, agricultural use, transportation infrastructure, and recreational demand. At the same time, existing users are pressured to modify activities to accommodate increasing demands from other sectors (Matiru, 2000). Decision makers are left to satisfy all parties involved while retaining existing rights to increasingly scarce natural goods and services. Under this dichotomy, it becomes increasingly difficult for land managers to appropriately value intangible goods and services, such as cultural value, to those who had first right to the land.

Watersheds can experience stress from urban sprawl.

▶ Duluth's skyline, as seen from Canal Park. *Creative commons image by Randen Pederson*

Ecosystem services such as recreation increase the well–being of people.

▼ A biker rides through Jay Cooke State Park toward Duluth. *Creative ommons share-alike image by M.E. McCarron*

Meanwhile, social scientists, representing a variety of disciplines, have been investigating other dimensions of human health and well-being that are not direct utility functions but are beneficial psychological, social, and physiological health responses (Stiglitz et al., 2010). The integration of ecological and economic approaches has made important advancements under ecosystem service research, and this integration has contributed to policy development. But these approaches have yet to encompass all dimensions of value, thus many important considerations remain marginalized within ecosystem service research and practice. Recent attention to global urbanization trends and associated opportunities to conserve and develop urban ecosystems has been accompanied by more focus on research concerning the health and well-being derived from experiences of nearby nature in high-density built settings (Grinde and Patil, 2009).

Considering human attitudes and preferences that are embedded in cultural and social value becomes essential when assessing possible tradeoffs among ecosystem services. Methods to identify cultural value have become more sophisticated and complete in recent years (Christin et al., 2014). While some of these values can be measured through surveys, other values can be more difficult to quantify, and attaching dollar amounts to them may not be useful, possible, or desirable.

The practice of incorporating ecosystem services into decision-making is a relatively new approach and is often absent of cultural dimensions (Christin et al., 2014). Derivations of human well-being have focused on the utility functions of regulating, supporting, and provisioning services, such as the avoidance of viral disease afforded by clean water supplies and reduction in health care costs from exercising outdoors. Several efforts have been made to show how considerations for cultural services can enter into policy (Statterfield et al., 2013).

One report from 2014 demonstrates a usable framework to assess cultural and social ecosystem services alongside traditional ecosystem service frameworks such as that provided in Table 2 (Christin et al., 2014). The report reviews existing literature on ecosystem services frameworks as well as tools used to measure them and combines each service to create a single framework. Table 2 shows this framework. This cohesive framework enables decision makers to consider a range of cultural, social, and biophysical ecosystem services under a single land use decision (Christin et al., 2014).

Cultural Service	Definition
Aesthetic	Scenery, sights, sounds, smells, etc.
Biological Diversity Value	Variety of fish, wildlife, plant life, etc.
Cultural Heritage, Identity & Place Value	Human condition to pass down wisdom, knowledge, traditions, and way of life to ancestors
Economic Value	Often attributed to foraging and gathering of food and other materials, whether consumed by the gatherer or traded
Future Value	Future generations experiencing the environment
Historic Value	Natural places and things with natural and human history
Intrinsic, Option Value	Value of nature in and of itself, or having the option of deriving value in the future, without actual experience.
Education, Communication & Working Value	Learning about the environment through scientific observation or experimentation
Recreation Value	Providing outdoor recreation activities
Spiritual Value	Sacred, religious, or spiritually special reverence and respect for nature
Therapeutic Value	Opportunities for physical activity and exercise
Social Capital & Community Cohesion Value	Creation of communities and social groups
Crime & Public Safety Value	Deterrent of crime and public awareness of general safety
Active Living & Health Value	Improvements to physical health and recovery from injury or sickness
Reduced Risk Value	Reduction in physical risk of bodily harm via natural infrastructure via bike lanes and natural extremities
Mental Health & Capacity Value	Treatment of mental conditions, disease, and stress
Access to Local Food	Availability of commonly harvested species
Access to Safe Water, Food, & Air	Availability and Boundaries to safe drinking water, food, and clean air
Cultural Events	Participation in natural resource dependent cultural activities
Trust in Government	Trust in government experts in collaboration efforts and response to decisions regarding natural infrastructure
Inspirational Value	Deriving inspiration from landscape experiences

▲ **Table 2. Cultural and Social Ecosystem Services**

Many of the services identified in Table 2 are not measured in this report. They can, however, be qualitatively assessed, ranked in importance, and discussed. In the concluding section that follows, we discuss the importance of measuring cultural, social, and ecosystem services in the St. Louis River watershed.

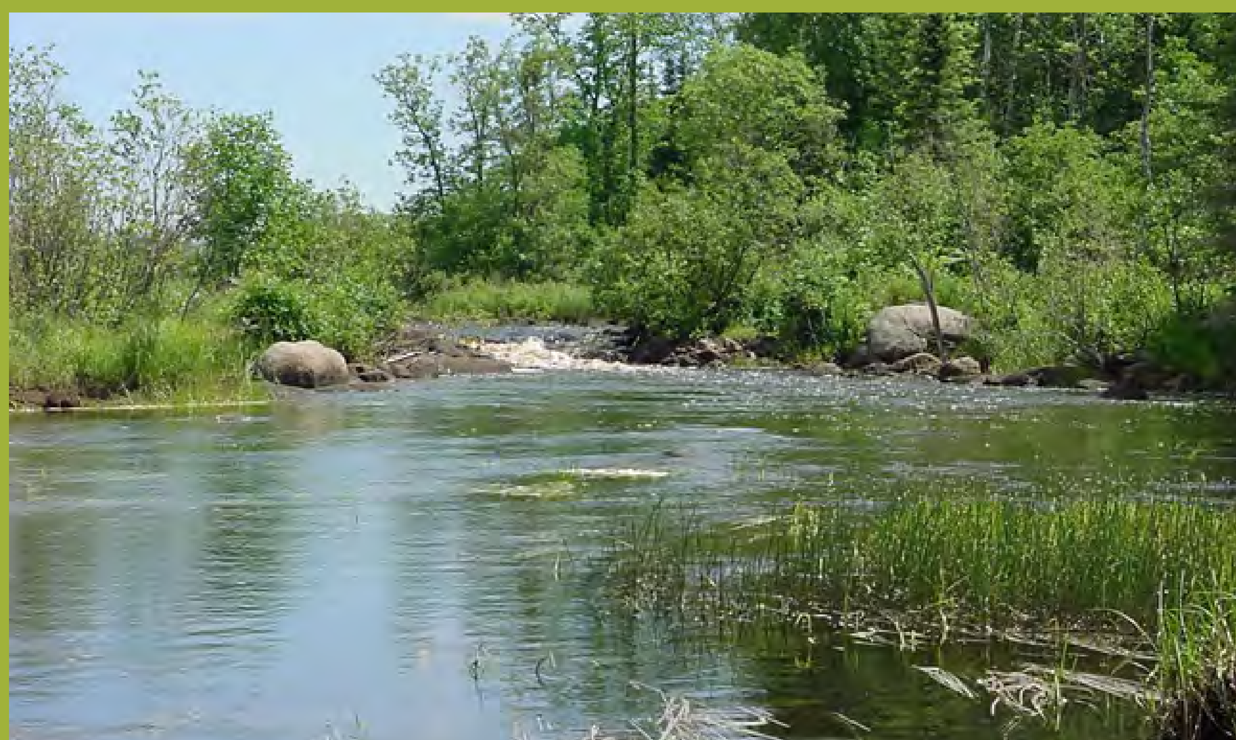
The Importance of Measuring Ecosystem Services

In 1930, the United States lacked measures of Gross Domestic Product (GDP), unemployment, inflation, consumer spending, and money supply (Stiglitz et al., 2010). Benefit-cost analysis and rate of return calculations were initiated after the 1930s to examine and compare investments in built capital assets such as roads, power plants, factories, and dams. Decision-makers were blind without these basic economic measures which are now taken for granted and help guide investment in today's economy. Understanding and accounting for the value of natural capital assets and the ecosystem services they provide gives new economic measures that can reveal the economic benefits of investment in maintaining or restoring these assets.

The benefits provided by ecosystem goods and services are similar to the economic benefits typically valued in the economy, such as the services and outputs of skilled workers, buildings, and infrastructure. Many ecosystem goods, such as fish, wild rice, and clean water, are already valued and sold in markets. However, some ecosystem services, such as flood protection and climate stability have not been traditionally valued in the marketplace even though they provide vast economic value. For example, when the flood protection services of a watershed are lost, direct economic damages include job losses, infrastructure repairs, reconstruction costs, restoration costs, property damage, and death. Conversely, when investments are made to protect and support these services, local economies are more stable and less prone to the sudden need for burdensome expenditures on disaster mitigation efforts (Sukhdev et al., 2010). In addition to the economic value associated with these avoided costs, healthy watersheds provide myriad other services including water supply, carbon sequestration, water filtration, and biodiversity. All of these services provide economic value regionally and beyond.

Relocating Wetland Benefits

Often, wetlands are destroyed in one watershed but mitigated or restored in another. This shifts economic benefits from one region to another and leaves the first watershed degraded. In the St. Louis River watershed, mining operations degrade and destroy the wetlands surrounding mine sites and downstream. PolyMet Mining plans in the headwaters of the St. Louis River include the restoration of wetlands to mitigate this damage, but this mitigation may occur outside of the watershed (Stewart, 2014). This means a net loss of wetlands in the watershed, along with the economic benefits they provide. Additionally, the remaining wetlands not destroyed by mining projects will be degraded, and the benefits they produce reduced. Accounting for natural capital enables insight into the costs incurred to a region by engaging in mitigation elsewhere.



▲ The St. Louis River flowing through its headwaters region.
© Fond du Lac Resource Management Division

Today, economic methods are available to value natural capital and many non-market ecosystem services (Daily, 1997). When valued in dollars, these services can be incorporated into a number of economic tools including benefit-cost analysis, accounting, environmental impact statements, asset management plans, and return on investment calculations. This strengthens decision-making. When natural capital assets and ecosystem services are not considered in economic analysis, they are effectively valued as zero, which can lead to inefficient capital investments, higher incurred costs, and poor decisions. Demonstrating the potential for high returns on conservation investments can lead to more efficient capital investments and reduce incurred costs.

▲ The St. Louis River at Jay Cooke State Park.
Creative commons image by Sharon Mollerus

Chapter 3 Characterization of the St. Louis River Watershed

◀ The St. Louis River.
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Study Area

The St. Louis River is located in Minnesota and is the largest U.S. river to flow into Lake Superior. The headwaters of the St. Louis River are located along the continental divide between waters that flow through the Great Lakes and those that either make their way south through the Mississippi River watershed to the Gulf of Mexico or north through the Rainy River watershed to Hudson's Bay. Much of the upper watershed of the St. Louis River consists of extensive peatlands and pine forests. At its mouth, the St. Louis River becomes a freshwater estuary, mixing with the waters of Lake Superior. Major tributaries include the Cloquet River and the Whiteface River.

Figure 5. Map of the St. Louis River Watershed
Creative commons share-alike image by Karl Musser

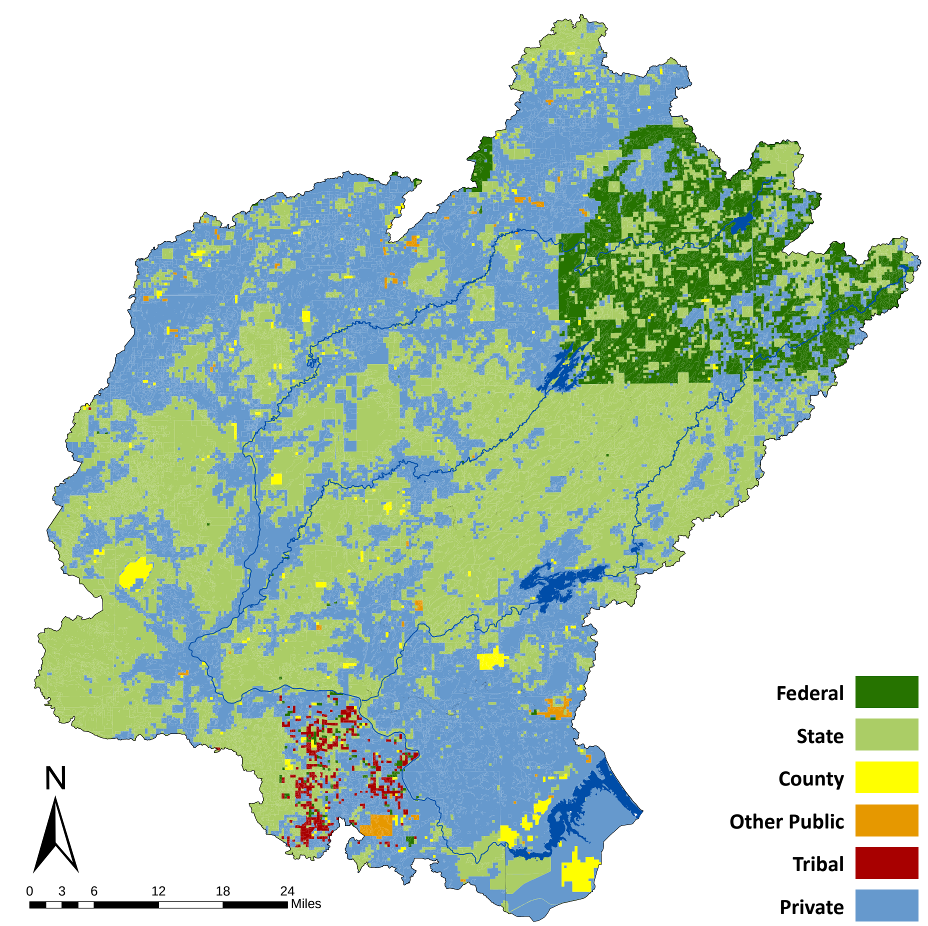
The St. Louis River channel largely was formed by glaciers approximately two million years ago (St. Louis River Citizens Action Committee, 2002a). As glaciers advanced and retreated across the landscape, a complex pattern of sediment was left behind which greatly influences the flow of the river today. Much of the substrate the river flows through is thick red clay deposited by ancestral Lake Superior. The sand bar that formed at the mouth of the river separates the freshwater estuary from the open water of Lake Superior. It shelters the harbor from the high-energy wind and waves on Lake Superior, and allows for the formation of habitat types that require lower energy environments.

The twin ports of Duluth, Minnesota, and Superior, Wisconsin, are located at the mouth of the river. The St. Louis River watershed is relatively undeveloped and contains little cultivated land (NOAA, 2010). The lower watershed is dominated by private land ownership, as is the upper watershed along the Mesabi Range. Tribal land is located primarily in the lower watershed, near Cloquet. The middle watershed is mostly state and county lands. See Table 3 for a breakdown of land ownership within the watershed boundaries.

Figure 6. Land Ownership in the St. Louis River Watershed
Source: Minnesota DNR Division of Fish & Wildlife. 2008. GAP Stewardship 2008. Minnesota DNR, Grand Rapids, Minnesota.

Table 3. Land Ownership in the St. Louis River Watershed
Other Public includes municipalities and universities.
Source: Minnesota DNR Division of Fish & Wildlife. 2008. GAP Stewardship 2008. Minnesota DNR, Grand Rapids, Minnesota.

Land Owner	Percent Land Ownership
Private	54%
State	31%
Federal	15%
County	< 1%
Tribal	< 1%
Other Public	< 1%



Economic and Socioeconomic Characteristics

The St. Louis River watershed is mostly contained in St. Louis County, Minnesota, but also includes portions of five other counties in Minnesota and Wisconsin. The population within the watershed boundary is approximately 177 thousand people (U.S. Census Bureau, 2013). Population within St. Louis County has remained relatively stable since 2010, with a less than 1% increase. Average household size is about two people per household.

Table 4 shows the breakdown of employment in St. Louis County. Median household income in the county is about $46,000 as compared to approximately $60,000 in Minnesota and $53,046 in the United States (U.S. Census Bureau, 2013). Employment has also remained stable in the county, growing at less than 1% in 2013.

Table 4. Employment Industries in St. Louis County, Minnesota
Source: U.S. Census Bureau, 2013

Industry	Number Employed	Percent Employed
Educational services, health care, and social assistance	27,941	30%
Retail trade	11,824	13%
Arts, entertainment, recreation, accommodation, and food services	10,641	11%
Manufacturing	6,485	7%
Professional, scientific, management, administrative, and waste management services	5,971	6%
Construction	5,840	6%
Transportation, warehousing, and utilities	5,215	6%
Finance, insurance, real estate, and rental and leasing	5,213	6%
Other services, except public administration	4,590	5%
Public administration	4,195	4%
Agriculture, forestry, fishing and hunting, and mining	3,354	4%
Wholesale trade	1,776	2%
Information	1,445	2%

Environmental Concerns in the St. Louis River Watershed

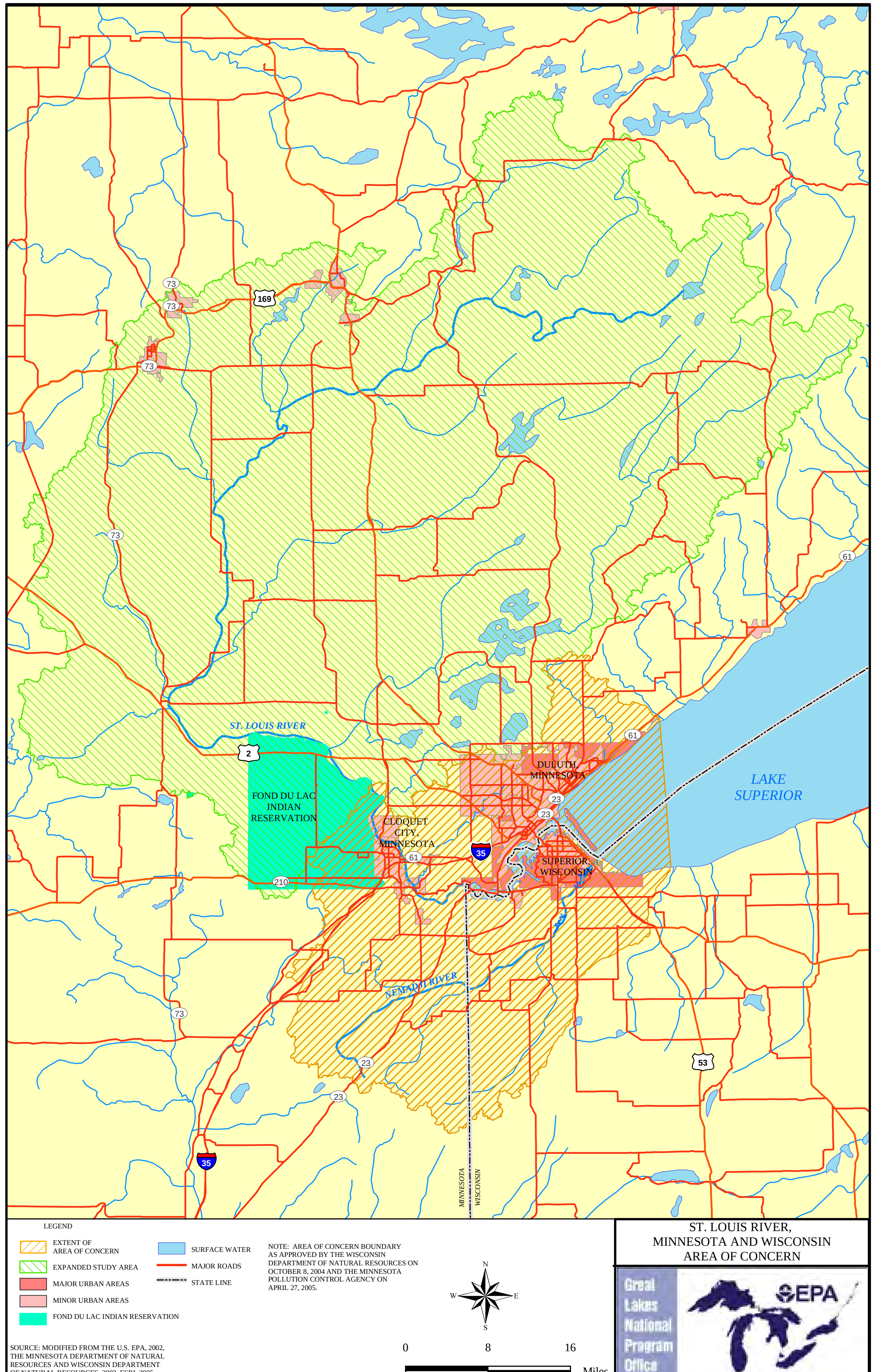
An Area of Concern

The St. Louis River was identified as a "Great Lakes Area of Concern" (AOC) in 1987 (U.S. EPA, 2014). An Area Of Concern is defined by the United States Environmental Protection Agency (U.S. EPA) as "specifically designated geographic areas within the Great Lakes basin that have experienced severe environmental degradation, largely due to the impact of decades of uncontrolled pollution" (U.S. EPA, 2014). The cause of the listing was large amounts of pollutants discharged into the river. After these discharges were treated as required by the Clean Water Act, remaining concerns included legacy contamination, habitat degradation, and excess sediment and nutrient inputs (LimnoTech, 2013). The St. Louis River AOC is one of 38 remaining AOCs in the Great Lakes region, and currently encompasses portions of the watershed in Minnesota and Wisconsin (St. Louis River Alliance, 2013). It is the only AOC in Minnesota (LimnoTech, 2013).

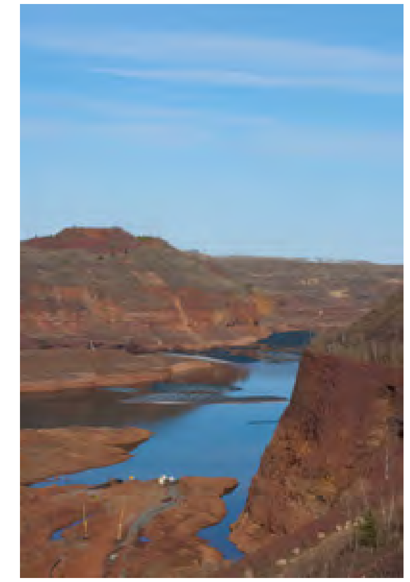
The following sections go into detail about specific environmental concerns in the watershed.

Clough Island, located in the St. Louis River estuary area of concern.
Creative commons image by USFWS Midwest

Figure 7. Map of the St. Louis River Area of Concern
Note: Some definitions of the area of concern include the entire St. Louis River watershed.
Source: U.S. EPA Great Lakes National Program Office



Mining



The Hull Rust Mine in Hibbing, Minnesota is the largest operating open pit iron mine in the U.S.
Creative commons share-alike image by Pete Markham

The headwaters of the St. Louis River have been mined extensively for their abundant iron (Bois Forte Band of Chippewa et al., 2013). However, mining has significant downstream environmental and social costs—costs that are frequently excluded from analyses of the mining industry (Lake Superior Binational Program, 2012). It is well documented that mining effluent has increased levels of contaminants such as heavy metals in downstream water bodies. This creates health hazards for both people and wildlife. Mining is the largest source of mercury emissions in the Lake Superior basin, and is detrimental to the environment and human health. Elemental mercury is converted to methylmercury through bacterial activity, at which point it becomes available to the aquatic food web. Methylmercury then bioaccumulates at high concentrations in fish, wildlife, and humans, resulting in human and ecological health risks. Some tributaries of the St. Louis River have concentrations of sulfate, manganese, and mercury at levels exceeding Minnesota Water Quality Standards (Bois Forte Band of Chippewa et al., 2013). In addition, land conversion from forest and wetland for the creation of open-pit mines creates contaminated landscapes and results in the loss of benefits like water purification, habitat, and flood risk reduction.

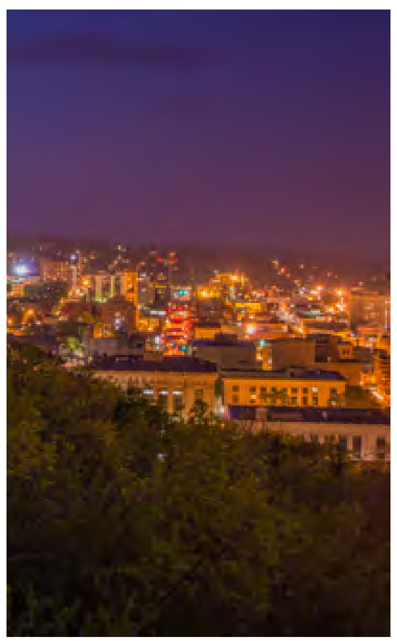
Mercury in Newborns

In 2011, a report was published by the Minnesota Department of Health to determine the level of mercury in the blood of newborns in the Lake Superior Basin (Minnesota Department of Health, 2011). Small amounts of mercury can harm developing nervous systems and the brain. In Minnesota, and the St. Louis River, where fish consumption advisories exist due to mercury, newborns are at a high level of risk, as they are exposed to mercury most often when the mother consumes mercury-contaminated fish. The study found that 10% of tested newborns in Minnesota had concentrations of mercury above safe levels. In addition, the study observed a seasonal effect where mercury concentrations were higher in the summer months. This could suggest that consumption of locally caught fish in the summer months is an important source of mercury exposure in the region. This study highlights the severity of environmental degradation within the St. Louis River watershed.

Wetland Ditching and Filling

Development results in many changes to the landscape and can cause habitat loss.

▼ The Duluth skyline as seen from Observation Hill.
Creative commons image by Jacob Norlund



Extensive filling of wetlands was also a contributing factor in the decision to list the St. Louis River as an AOC (St. Louis River Alliance, 2013). Since 1861, almost 3,000 acres of wetlands in the AOC have been filled. Ditching of wetlands has occurred in more than 14% of wetlands within the watershed (Bois Forte Band of Chippewa et al., 2013). Half of all subwatersheds have been impacted by ditching, with some of these completely ditched. Filling and ditching wetlands has profound impacts on the watershed's hydrology and function of wetlands in the watershed, causing loss in habitat, environmental degradation, and loss of wetlands themselves.

Development

Residential, commercial, and industrial development result in many changes to the landscape. Development has other impacts besides the direct loss of natural areas (St. Louis River Citizens Action Committee, 2002a). Dams prevent fish passage to spawning habitats. Roads and paved surfaces increase the volume of runoff, which also carries contaminants and sediments that decrease water quality. Industries historically discharged waste directly and indirectly into the estuary. Additionally, almost one-third of the estuary was filled or dredged, resulting in extreme habitat loss (St. Louis River Alliance, 2013).

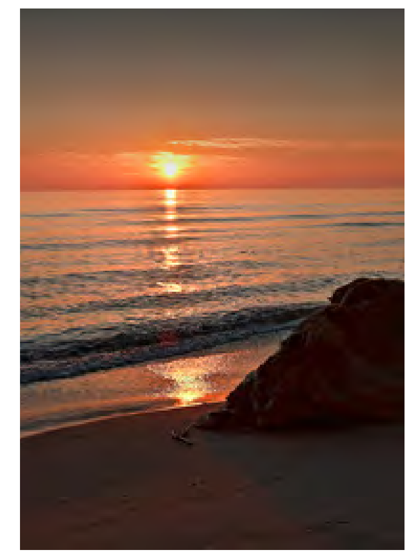
Climate Change

Global climate change is also expected to be a source of environmental stress in the long term (St. Louis River Citizens Action Committee, 2002a). Rising temperatures will affect habitats, making some areas inhospitable to sensitive native species and may even help the spread of invasive species (Bois Forte Band of Chippewa et al., 2013). The water level of Lake Superior is expected to decrease, which affects the formation and distribution of wetlands in the St. Louis River estuary, areas that typically have high ecological productivity (St. Louis River Citizens Action Committee, 2002a). Alterations in rainfall and weather patterns increase the risk of damage from natural disasters such as floods.

Beneficial Use Impairments

Degradation of aesthetics was removed from the area of conern's BUI list in 2014.

▼ Beachfront in Duluth.
Creative commons image by Anita Ritenour



Despite actions taken to clean up the river, the AOC contains several sites known to contain hazardous waste and chemicals from these discharges. These conditions resulted in beneficial use impairments (BUI) of its natural resources. A BUI occurs when changes in environmental integrity result in loss or degradation of environmental uses. For example, the level of mercury is so high in the St. Louis River that strict limitations have been placed on fish consumption by the Minnesota Department of Health. At the time of its listing as an AOC, nine BUIs were identified (St. Louis River Alliance, 2013; U.S. EPA, 2014):

- Restrictions on fish consumption
- Degradation of fish and wildlife populations
- Fish tumors or other deformities
- Degradation of benthos
- Restrictions on dredging activities
- Excessive loading of sediments and nutrients
- Beach closing
- Degradation of aesthetics
- Loss of fish and wildlife habitat

Actions to restore the AOC focus mainly on the freshwater estuary located at the River's mouth (St. Louis River Alliance, 2013). At the time of writing, only one of the nine BUIs have been removed (degradation of aesthetics), with three more expected to be removed in 2016. The Remedial Action Plan anticipates the removal of all BUIs by 2025 (LimnoTech, 2013).

Exhibit L.1.

Key Ecosystem Services in the St. Louis River Watershed

Flood Risk Reduction

Wetlands, grasslands, shrub, and forest all provide protection from flooding. These ecosystems absorb, slow, and store large amounts of rainwater and runoff during storms (Emerton and Bos, 2004). Conversely, impermeable structures increase the flashiness of storm events and increase the potential for flooding. Built structures in the floodplain, such as houses, commercial and industrial facilities, and wastewater treatment plants, all depend on the natural vegetation located upstream to reduce the risk of flooding. This enhanced flood protection provided by natural areas reduces property damage, lost work time, and human casualties caused by floods.

The St. Louis River watershed, along with two other major watersheds, experienced severe flooding in the summer of 2012. June 2012 saw record rainfall in the watershed. In combination with a relatively rainy spring, these conditions resulted in a 500-year flooding event (Czuba et al., 2012). The damage was so extreme that the counties affected by the June flooding were declared federal disaster areas. More than $100 million dollars in damage was incurred (Czuba et al., 2012), and 28% of all buildings in or near Duluth were impacted by the flood (Pelletier and Knight, 2014). Major highways and many local roads were closed, which heavily disrupted transportation in the area. Evacuation procedures took place in several areas. The Lake Superior Zoo was also impacted by structural damage and the death of zoo animals (Czuba et al., 2012).

The retention of natural, permeable land cover and the restoration of natural floodplains contribute to flood risk reduction (Emerton and Bos, 2004). When the natural capital in a watershed is degraded or converted, the land’s capacity to absorb large rainfall events is reduced, leading to floods.

Figure 8. Approximate extent and depth of flood peak inundation at the Fond du Lac Neighborhood in Duluth
Source: Czuba et al., 2012

During the 2012 event, floodwaters took out Highway 210 through Jay Cooke State Park.
© Fond du Lac Resource Management Division

The 2012 event also overtopped a 200 foot culvert.
© Fond du Lac Resource Management Division

Recreation

A man fishing in Cloquet, Minnesota. *Creative commons image by Jacob Norlund*

Attractive landscapes, clean water, and wildlife populations form the basis of the recreational experience. For example, tourism and recreation are often tied to aesthetic values of nature (Daily, 1997). Fishing, swimming, bird watching, and hunting are all activities that can be enhanced by ecosystem services. The St. Louis River watershed and Minnesota provide many opportunities for people to engage in outdoor recreation in natural areas. The results from the studies highlighted in this section show the tremendous importance of recreation in the watershed.

According to a survey administered in 2007 through 2008, almost six million tourists visited the northeast region of Minnesota (Minnesota DNR, 2008a). One quarter of all travelers' expenditures (almost $400 million) were associated with recreational activities. This sum was higher than all other categories of expenditures made by visitors. User spending amounted to $628 million in 2008, and the total size of the regional trail economy was found to be $27.8 billion.

Fishing is a popular activity in the study area. A report on cold water fishing found that the northeastern region of Minnesota accounted for over 37% of all cold water fishing trips made in the state (Fulton et al., 2002). Other popular activities included hiking and walking. A survey on hiking trail use in Minnesota found that people used the trails in the northeast region more than 32 million times in 2008 (Venegas, 2009). Walking and hiking was the activity with the most user participation, followed by bicycle riding and running. In Minnesota, 51% of the population participates in wildlife-related recreation (U.S. Department of the Interior et al., 2011).

Food

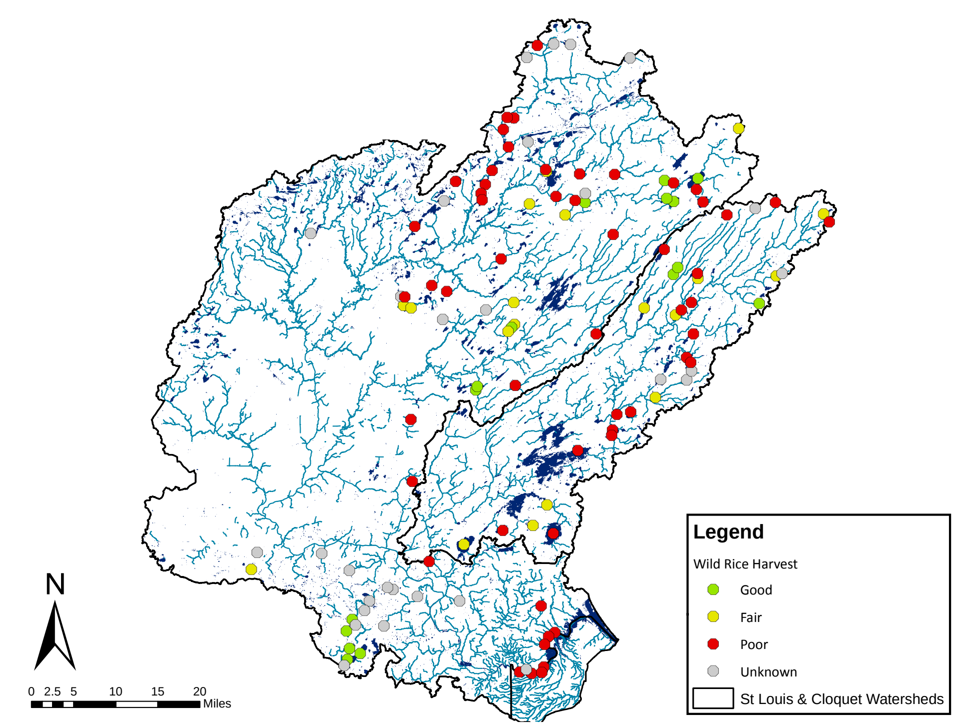
Wild rice beds in the St. Louis River watershed. *© Fond du Lac Resource Management Division*

In the St. Louis River watershed and Great Lakes region, wild rice has tremendous economic and cultural importance as a food source. Natural wild rice has been harvested as a source of staple food in the Great Lakes region for thousands of years by both the native Ojibwe people and non-native people.(Minnesota DNR, 2008b) The Ojibwe have special cultural and spiritual ties to wild rice, and the importance of the wild rice harvest by European settlers has only lessened in recent years due to the availability of other cultivated grains.

An estimated four- to five-thousand people (both tribal and non-tribal) hand harvest wild rice annually with an average annual harvest of 430 pounds per individual (Minnesota DNR, 2008b). Although cultivated wild rice is the majority of total production in Minnesota, hand harvested natural wild rice remains a vital component to tribal and local economies. In 2007, hand harvest of natural wild rice generated more than $400,000 in income for tribal members in Minnesota (Minnesota DNR, 2008b).

St. Louis County has the greatest concentration of wild rice lakes in Minnesota, (Minnesota DNR, 2008b) and there are 118 wild rice locations within the St. Louis River watershed alone (1854 Treaty Authority, 2014). Due to development and other activities, these harvest locations are threatened within the watershed and Minnesota. Any factor that negatively affects water quality can also result in the decline of wild rice (Minnesota DNR, 2008b). Wild rice is a shallow water plant and is sensitive to changing water levels introduced by dams or by channelization. Wild rice requires clean water to grow, and clean water quantities are severely decreased in areas due to pollution from mines. Invasive species compete with wild rice for space, light, and nutrients. Wild rice is often removed near docks or in other high-use areas because it is a nuisance to boat engines and anglers. In 2014, only 30% of these locations had good or fair harvest potential (1854 Treaty Authority, 2014). Figure 9 displays the harvest locations in the St. Louis River watershed spatially.

Figure 9. Locations and Quality of Wild Rice Waters in the St. Louis River Watershed
Source: 1854 Treaty Authority



Carbon Sequestration and Storage

Natural lands including forests, grasslands, and wetlands play essential roles in mitigating the damages of climate change (Lal et al., 2007; Myers, 1997). This process is facilitated by the capture and long-term storage of carbon by the vegetation in forests, grasslands and wetlands. As plants grow they capture carbon where it is stored as biomass and in soils, which reduces atmospheric carbon and the damages associated with this important greenhouse gas.

Peat is an accumulation of decayed vegetation, which is formed over thousands of years in wetland conditions. Although it has a slow rate of accumulation, peatland is a huge carbon sink that stores a tremendous amount of carbon in the soil (Bridgham et al., 2006). In the contiguous United States, peatland stores approximately 600 metric tons of carbon per acre (Bridgham et al., 2006).

Much of the headwaters of the St. Louis River is a large and complex peatland (Anderson and Perry, 2007). Extensive cutting of this peatland for timber occurred in the 1930s and 1940s, and continues today at a smaller scale (Anderson and Perry, 2007). The loss of these peatlands means a loss of an enormous carbon sink in the region. It also means that as these carbon storage areas are destroyed, carbon will be released back into the atmosphere. As peatlands contain about three times more carbon per hectare than other ecosystems, the destruction of peat worldwide could have global implications (Silvius, 2014).

▶ View of forests near Duluth.
Creative commons image by Jacob Norlund

Habitat, Spawning, and Nursery Areas

Ecosystems provide habitat for plants and animals where they find shelter from predators, food, and appropriate living conditions for all their life stages. Nursery areas are a subset of habitats where juvenile wildlife live during a particularly vulnerable part of their life cycle. Species use spawning areas to lay eggs, and often spawning habitat has very different structural features than nursery areas or habitat required by adults of the same species. Without the appropriate habitat throughout their entire life cycles, species populations that are integral to the provision of ecosystem services would die out.

The St. Louis River watershed is home to many native species of plants and animals, such as walleye and black cherry trees. The freshwater estuary provides nursery habitat to wildlife such as freshwater fish species, waterfowl, and bald eagles (St. Louis River Citizens Action Committee, 2002a). Wild rice is a popular food source for animals as well as people, but also provides nursery areas for young fish and amphibians, and habitat for waterfowl and invertebrates (Natural Resources Conservation Service, 2004; Nelson et al., 2003). Since European settlement of the area, filling wetlands, dredging, and pollutants have degraded the land and water providing essential habitat functions (LimnoTech, 2013; St. Louis River Alliance, 2013).

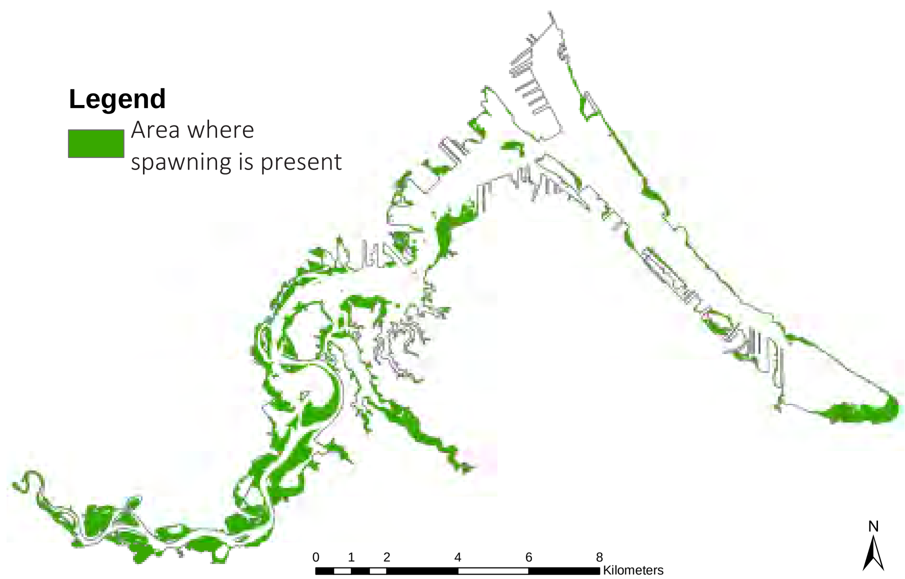
Sturgeon Restoration

Thanks to more than 30 years of restoration efforts, young sturgeon returned to the estuary in 2011. This marked the first evidence of sturgeon reproduction in the estuary in decades (St. Louis River Alliance, 2013). Between 1983 and 2000, Minnesota DNR stocked about 145,000 sturgeon in the St. Louis River (Hemphill, 2010). The DNR spent $150,000 to make the stream bed conducive to sturgeon spawning. When one considers the manpower that has gone into restocking efforts over 30 years, plus the cost of the restoration projects themselves, a considerable sum of money has been put into restoring sturgeon in the St. Louis River. This only highlights that, in fact, conservation saves money. If the St. Louis River had not been degraded in the first place, it would be providing sturgeon habitat for free. Now, money must be spent to keep this important fish in the river.

▲ Sturgeon being radiotagged.
© Fond du Lac Resource Management Division

▲ Juvenile sturgeon being released in the St. Louis River
© Fond du Lac Resource Management Division

Lake sturgeon were once plentiful in the St. Louis River, which held critical spawning habitat for the species. Sturgeon would venture from the depths of Lake Superior to spawn in the shallow rocky areas provided by the river and estuary. Historically, sturgeon were caught for food and leather made from their skin (Kolodge, 2013). This once commercially important species depended on the specific habitat conditions of the St. Louis River to thrive and keep populations abundant. However, due to habitat loss and overfishing, sturgeon were extirpated from the St. Louis River watershed by the mid-20th century (ibid). Currently, sturgeon only spawn in a small portion of the estuary located near the Fond du Lac Dam, while other freshwater fish such as northern pike and muskellunge spawn in numerous sites throughout the estuary (Figure 10) (Angradi et al., 2015). For a full list of fish native to the St. Louis River Estuary, refer to Appendix 5 of the Lower St. Louis River Habitat Plan (St. Louis River Citizens Action Committee, 2002b).



▲ **Figure 10. Spatial extent of spawning locations of northern pike and muskellunge in the St. Louis River Estuary**
Note that spawning areas may also be present outside of the St. Louis River estuary. This map only shows spawning areas for two groups of freshwater fish, and not spawning locations for all species of fish in the region.
Source: Angradi et al., 2015

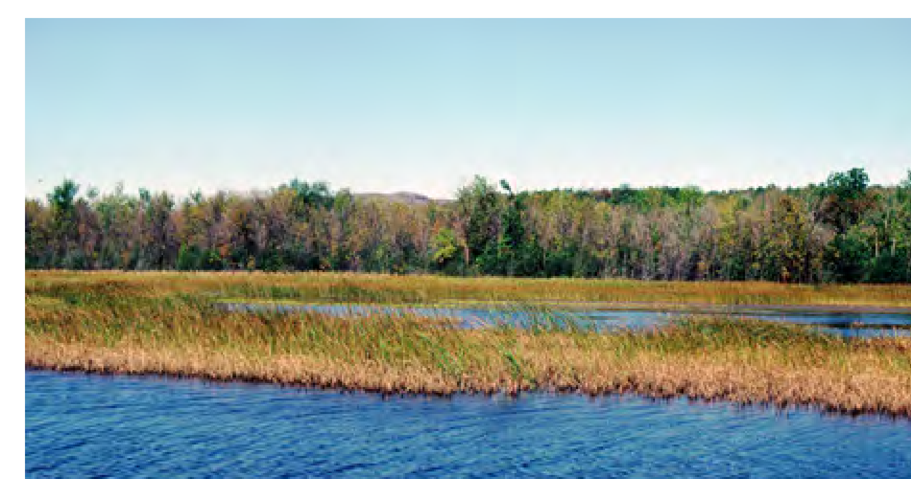
Water Quality

Natural ecosystem processes have the ability to remove elements from the water column that may be toxic to humans. For example, natural vegetated areas provide valuable water filtration services which improve water quality for human and wildlife consumption, as well as for habitat purposes (Ewel, 1997). These services remove a variety of pollutants and can maintain natural water quality conditions, although some constituents might still require mechanical filtration for purification of potable water (ibid).

Natural wetlands are an excellent filtration system that save people money. They are effective at removing a variety of contaminants, including nutrients, metals, organic matter, and sediment, from a variety of sources, including mine, agricultural, and urban runoff and municipal and industrial point sources (Hammer and Bastian, 1988). Complex and dangerous compounds are broken down into simpler, safer substances, and vegetation removes nutrients to use for growth. More than one quarter of the entire St. Louis River watershed is wetland (NOAA, 2010). Conserving existing wetlands and restoring those that have been lost can help improve water quality because of their ability to act as free water purification plants. Wild rice beds also help purify water by stabilizing loose soil, capturing and storing nutrients, and acting as a natural windbreak over shallow water areas (Natural Resources Conservation Service, 2004).

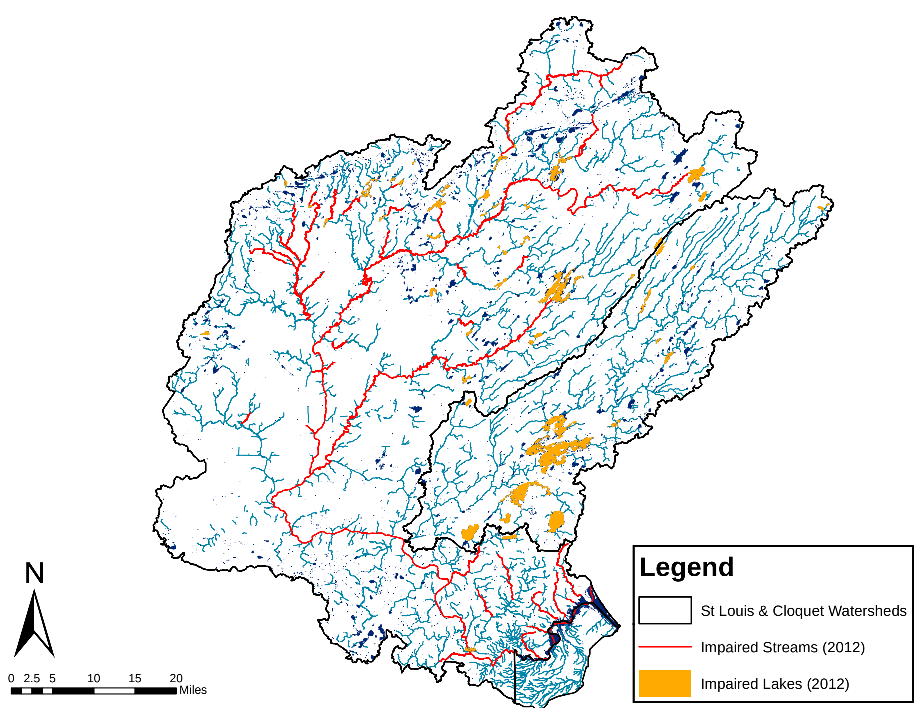
Man-made wetlands have been recognized for their ability to increase water quality. Wetlands constructed to treat water have several benefits over other built capital solutions. They can be used to treat contaminants over long periods of time, they are easy to maintain and required far less frequent maintenance, may remove more than 75% of metal contaminants, and can be used in remote locations (Adams et al., 2014).

▶ Natural wetlands on the St. Louis River.
Creative commons no-derivatives image by Wisconsin DNR



People can be exposed to disease through direct contact with bacterial or viral agents while swimming or by ingesting contaminated fish and water. Beach closures and restrictions on fish consumption are both major problems in the watershed (U.S. EPA, 2014). In St. Louis County, beaches were closed 32 times in 2012 (compared to 9 times for Lake County and 16 times for Cook County, which do not experience as much impact to their watersheds). St. Louis County had 40% more beaches affected by advisories or closings than Cook County in 2012, and 30% more than Lake County (U.S. EPA, 2013). The impaired waters list is developed in accordance with the Clean Water Act, and contains waters that do not meet water quality standards or designated uses. Many streams and lakes have been labeled "impaired" by the state due to high levels of pollution, meaning they do not meet water quality standards. Of all open water monitored in the watershed, 52% of lakes are impaired, and 23% of streams are impaired (MPCA, 2012). Wild rice, a very important natural resource, depends on clean water to grow (Minnesota DNR, 2008b). Several regional groups including non-profit, environmental groups, harvesters, and tribal members requested wild rice waters be added to the impaired waters list as they have been impaired due to pollution (Hemphill, 2012).

Figure 11. Impaired Lakes and Streams in the St. Louis River Watershed
Source: Minnesota Pollution Control Agency



Cultural Services in the St. Louis River Watershed

The natural environment is often connected to the identity of an individual, a community, or a society. Urban dwellers, farmers, and tribal members across the state place value in the societal and spiritual value provided by nearby natural areas (Nelson et al., 2011). This value is apparent in the actions of the residents of the area. For example, Minnesota voters approved a constitutional amendment in 2008 creating a 3/8 cents sales tax to support outdoor heritage, clean waters, sustainable drinking water, parks and trails, arts, history and cultural heritage projects, and activities (ibid).

Nature provides ancestral experiences that are shared across generations, and offers settings for communal interactions important to cultural relationships (Nelson et al., 2011). Cultural heritage is generally defined as the legacy of biophysical features, physical artifacts, and intangible attributes of a group or society that are inherited from past generations, maintained in the present, and bestowed for the benefit of future generations (Daniel et al., 2012). The long-term interactions between nature and humans (e.g., property distribution, cultivation, and nature conservation) are characterizations of cultural heritage and a relationship with the landscape.

Wild rice is a natural resource that has cultural importance.
Creative commons no-derivatives image by Wisconsin DNR

Forests, prairies, deserts, species, and even individual plants and animals are strongly associated with cultural identities and place attachments for many communities and people. Relations between ecosystems and religion include moral and symbolic concepts, such as poetry, song, dance, and language. They can also center on material concerns, such as staking claim to land contested by immigrants, invading states, or development agencies. Non-market economic valuation techniques have, in limited cases, been successfully applied to cultural heritage objects (Daniel et al., 2012). However, valuations of some cultural services such as regional identity or sense of place remain elusive, and even impossible to value monetarily (Christin et al., 2014).

▲ At the mouth of the St. Louis River. *Creative commons image by Randen Pederson*

Prior to 1840, the Ojibwe tribe was located along the mouth of the St. Louis River, which is now Duluth. European settlers seeking control over the St. Louis River estuary, watershed, and port area, slowly pushed the Ojibwe further west onto what is now known as the Fond du Lac and Bois Forte Reservations. By the late 1800s, over 80% of the reservation land was non-Indian land holdings due to implementation of the Nelson Act of 1889 (Norrgard, 2009). This loss of land was also a sacrifice of historic tribal grounds, burial sites, and traditional hunting and foraging locations. The following sections detail known archaeological sites, traditional and sacred locations, and other culturally significant characteristics of the St. Louis watershed, although many culturally significant sites are not identified or known outside of tribal communities.

Archaeological Sites

Archaeological sites are valuable as they provide scientists, archaeologists, and tribal members evidence of the evolution of significant cultural events, such as the introduction of first nations, the emergence of civilizations, or the collapse of communities. These sites also hold important cultural history with intrinsic value to many Native Americans. Generally, these sites provide scientists with better ways to predict how cultures will change, including our own, and how to better plan for the future.

Traditional and Sacred Locations

Unlike archaeological sites, which refer to specific artifacts or discrete areas with evidence of settlement or human use, sacred and traditional sites are broader lands that hold cultural and spiritual value. In the context of this report, sacred sites are often traditional hunting and gathering grounds used by Native Americans for thousands of years, or significant landscapes or places that were used for ceremonies or other cultural practices.

Ancestors of the present day Ojibwe have resided in the Great Lakes area since at least 800 A.D. (Johnson et al., 2009). Wild rice features in the Ojibwe migration story to the Great Lakes: where the prophesized stopping place is where "the food grows on water," or wild rice. The Ojibwe have historically harvested wild rice, blueberries, furs, medicinal plants and maple syrup for the benefit of themselves, and for trade to European settlers. Today, a number of Ojibwe still harvest wild rice and other traditional foods in large parts of the St. Louis watershed (Minnesota Department of Health, 2014). Local band members use the forest as a method to teach children about natural processes (like maple sugar bush, birch bark harvest) and hunting practices.

Social Bonds

▲ Lincoln Park in Duluth. *Creative commons image by Randen Pederson*

People benefit from positive social interactions, and open spaces encourage an even greater sense of community with more opportunities for social interactions (Maas et al., 2009). Lower income communities with a larger population of at-risk youth and families are even more likely to benefit from the social interactions made available by nature. Park programs aid in developing children's social relationships, conflict resolutions skills, resilience, self discipline, and civic-minded ideals (Eccles and Gootman, 2002). Additionally, one study found a positive link between the social integration of the elderly and their exposure to green common spaces (Gies, 2006). People who are exposed to green spaces often are more willing to form connections with their neighbors, have a greater sense of community, civic mindedness, and stronger social ties (Maas et al., 2009).

Chapter 4 Ecosystem Service Valuation Methodology

View of the St. Louis River from Ely's Peak.
Creative commons image by Jacob Norlund

Land Cover Analysis

Land cover data was derived from the National Oceanic and Atmospheric Administration's 2010 Coastal Change Analysis Program (C-CAP) Regional Land Cover Database (NOAA, 2010). This base layer was modified to refine the land cover categories used in the valuation as described in the following sections. Where land cover categories needed no refinement, the acreage for each land cover category within the St. Louis watershed boundary was calculated using the Calculate Geometry tool within the attribute table in ArcGIS.

Table 5. C-CAP Land Cover Types Present in the St. Louis River Watershed
Source: NOAA. Coastal Change Analysis Program (C-CAP) Regional Land Cover Classification Scheme.

C-CAP Land Cover Type	Definition
High Intensity Developed	Highly developed areas where people reside or work in high numbers such as apartment complexes, row houses, and commercial/industrial.
Medium Intensity Developed	Areas with a mixture of constructed materials (50–79% cover) and vegetation. Includes multi- and single-family housing units.
Low Intensity Developed	Areas with a mixture of constructed materials (21–49% cover) and vegetation, such as single-family housing units.
Developed Open Space	Includes areas with a mixture of some constructed materials, but mostly vegetation in the form of lawn grasses.
Cultivated Land	Areas used for the production of annual crops such as vegetables; includes orchards and vineyards.
Pasture/Hay	Areas of grasses, legumes, or grass-legume mixtures planted for livestock grazing or the production of seed or hay crops.
Grassland	Areas dominated by grammanoid or herbaceous vegetation.
Deciduous Forest	Areas dominated by deciduous trees generally greater than 5 meters tall.
Evergreen Forest	Areas dominated by evergreen trees generally greater than 5 meters tall.
Mixed Forest	Areas including both evergreen and deciduous trees generally greater than 5 meters tall.
Scrub/Shrub	Areas dominated by shrubs; less than 5 meters tall. Includes true shrubs, young trees in an early successional stage.
Palustrine Forested Wetland	Tidal and non-tidal wetlands dominated by woody vegetation greater than or equal to 5 meters in height; in areas with less than 0.5% salinity.
Palustrine Scrub/Shrub Wetland	Tidal and non-tidal wetlands dominated by woody vegetation less than 5 meters in height; in areas with less than 0.5% salinity.
Palustrine Emergent Wetland	Tidal and non-tidal wetlands dominated by persistent emergent vascular plants, emergent mosses or lichens in areas with less than 0.5% salinity.
Unconsolidated Shore	Areas dominated by material such as silt, sand, or gravel that is subject to inundation and redistribution due to the action of water. Generally lacks vegetation.
Bare Land	Areas characterized by bare rock, gravel, sand, silt, clay, or other earthen material, with little or no "green" vegetation.
Open Water	Areas of open water, generally with less than 25% cover of vegetation or soil.

Spatial Attributes and Modifications to C–CAP

In this report, a "spatial attribute" is a technique to generate more accurate estimates of ecosystem services. This process allows study values to be applied in a more targeted manner. For example, a primary research value may apply specifically to forested ***urban*** parks, but not forested ***rural*** parks. Applying an urban spatial attribute separates urban forests from other forested areas in the GIS land cover data. In this example, the urban value is then applied only to the acreages of forested urban parks, and not forested rural parks. Without separating these two distinct areas, values may be applied to acreages which do not actually produce the value in question (rural parks not providing the same value as an urban park). Valuations are more accurate when the spatial distribution of values is taken into account (Rosenberger and Johnston, 2013). Spatial attributes and the ability to apply more granular study values are one way to get at this problem and increase the accuracy of this type of analysis. For the St. Louis River watershed, spatial attributes were set for proximity of land cover to urban and riparian areas.

In addition, modifications to the C-CAP dataset were made for the Open Water category. Open Water was divided into three categories: Rivers, Lakes, and Freshwater Estuary. These three ecosystems are fundamentally different from each other and therefore should have independent ecosystem service values associated with them.

Table 6 describes how each spatial attribute or modification was derived.

Table 6. Definition of Spatial Attributes and Datasets Used

Spatial Attribute/ Modification	Definition	Dataset Used
Urban	Areas falling under the Census Bureau's definition of urbanized area (population of 50,000 or more) and urban clusters (population of at least 2,500 and less than 50,000 people).	2010 Census Bureau's MAF/ TIGER Geographic Database
Riparian	Area of land cover within 100 feet of Open Water and the linear stream datasets for Minnesota and Wisconsin.	C-CAP Regional Land Cover Database, DNR 24K Streams
Rivers	Polygon outline of stream or river features, including pools of major rivers formed by dams. Rapids within a river or stream; may be downstream of a dam.	Minnesota DNR 100K Lakes and Rivers
Lakes	Lake or pond; well-defined basins, often named on USGS topo quad map. May include basins in the backwaters of major rivers that are formed from river waters but function as individual basins.	Minnesota DNR 100K Lakes and Rivers
Freshwater Estuary	Open Water downstream of the Fond du Lac Dam.	C-CAP Regional Land Cover Database

The Benefit Transfer Method

Benefit transfer methodology (BTM) is broadly defined as "…the use of existing data or information in settings other than for what it was originally collected" and is used to indirectly estimate the value of ecological goods or services (Rosenberger and Loomis, 2003). BTM is frequently used because it can generate reasonable estimates quickly and at a fraction of the cost of conducting local, primary studies, which may be more than $100,000 per service/land cover combination. BTM is often the most practical option available to produce reasonable estimates, and continues to play a role in the field of ecosystem service valuation (Richardson et al., 2014).

The BTM process identifies previously published ecosystem service values from comparable ecosystems and transfers them to a study site (Rosenberger and Johnston, 2013); in this case, the watershed of the St. Louis River. The BTM process is similar to a home appraisal in which the value and features of comparable, neighboring homes (two bedrooms, garage, one acre, recently remodeled) are used to estimate the value of the home in question. As with home appraisals, the BTM results can be somewhat rough but quickly generate reasonable values appropriate for policy work and analysis.

The process begins by finding primary studies with comparable land cover classifications (wetland, forest, grassland, etc.) within the study area. Any primary studies deemed to have incompatible assumptions or land cover types are excluded. Individual primary study values are adjusted and standardized for units of measure, inflation, and land cover classification to generate an "apples-to-apples" comparison.

Frequently, primary studies offer a range of values that reflect the uncertainty or breadth of features found in the research area. To recognize this variability and uncertainty, high and low dollars per acre values are included for each value provided in this report.

Selecting Primary Studies

Earth Economics maintains a comprehensive repository of published, peer-reviewed primary valuation studies, reports, and gray literature in the world, Ecosystem Service Valuation Toolkit (EVT).[ii] These studies each use techniques developed and vetted within environmental and natural resource economics communities over the last four decades. Table 7 provides descriptions of the most common valuation techniques and examples of how they have been analytically employed.

Table 7. Common Primary Valuation Methods

Method	Description	Example
Market Price	Valuations are directly obtained from what people are willing to pay for the service or good on a private market.	Timber is often sold on a private market.
Replacement Cost	Cost of replacing open space services with man-made systems.	The cost of replacing a watershed's natural filtration services with a filtration facility.
Avoided Cost	Costs avoided or mitigated by open space services that would have been incurred in the absence of those services.	Wetlands buffer hurricane storm surge reducing coastal damage and subsequent recovery costs.
Production Approaches	Value created from an open space service through increased economic outputs.	Improvement in watershed health leads to an increase in commercial and recreational salmon catch.
Travel Cost	Derived from travel costs to consume or enjoy open space services, a reflection of the implied value of the service.	Parks attract tourists who must value the resource at least at the cost of travel incurred for the visit.
Hedonic Pricing	Value implied by what consumers are willing to pay for the service via related markets.	Housing prices along the coastline tend to exceed the prices of inland homes thus indicating open space services value of the coast (beach, saltwater, etc.).
Contingent Valuation	Value elicited by posing hypothetical, valuation scenarios.	People are willing to pay for wilderness preservation to avoid development.

Earth Economics considered several criteria when selecting appropriate primary study values to apply to the St. Louis River watershed. These include geographic location, demographic characteristics, and ecological characteristics of the primary study site. Valuation estimates were also restricted to the United States and Canada in regions with climate similar to the St. Louis River watershed.

All ecosystem service values were then standardized to 2014 United States dollars using Bureau of Labor Statistics Consumer Price Index inflation factors. Appendix C lists the primary studies used for value transfer estimates.

ii Earth Economics Ecosystem Valuation Toolkit (EVT). More information available at www.esvaluation.org.

Exhibit L.1.

Valuation Methodology

For each land cover/ecosystem service/spatial attribute combination (e.g. forest/urban/recreation), the lowest and highest ecosystem service values were chosen to generate a range in value provided by the most appropriate estimates. Values for ecosystem services can vary due to factors such as scarcity, income effects, and uniqueness of habitat, among others. The values provided include an array of marginal and average values for ecosystem services, which incorporate different potential demand scenarios and states of the environment. By extracting values from a large pool of studies and contexts we are able to integrate general wisdom and different situations to illustrate a well-informed value approximation. The range of values gives insight on potential differences in value that can be expected given different contexts.

Table 8 summarizes the land cover/ecosystem service combinations that were valued in this analysis. One to ten ecosystem services were able to be valued for each land cover type.

Table 8. Ecosystem service and land cover combinations valued in the St. Louis River Basin

Key	
■ (blue)	Combination valued in this report
(blank)	Combination not valued in this report

Ecosystem Services Valued		Coniferous Forest	Cropland	Deciduous Forest	Freshwater Estuary	Grassland	Herbaceous Wetland	Lake	Mixed Forest	Pasture	River	Shrub	Shrub Wetland	Woody Wetland
Information	Aesthetic Information	■	■	■	■		■	■	■	■	■		■	■
	Recreation and Tourism	■	■	■	■	■	■	■	■		■	■	■	■
Provisioning	Energy and Raw Materials	■					■						■	■
	Food	■	■				■						■	■
	Water Supply						■						■	■
Regulating	Air Quality	■	■	■			■		■	■			■	■
	Biological Control	■	■	■			■		■	■			■	■
	Climate Stability	■	■	■		■	■		■	■		■	■	■
	Moderation of Extreme Events	■		■	■		■		■				■	■
	Pollination	■	■	■		■			■	■				
	Soil Formation		■							■				
	Soil Retention		■			■				■				
	Waste Treatment	■		■		■	■	■	■				■	■
Supporting	Habitat and Nursery	■		■		■	■		■				■	■

A combination not included in the analysis does not necessarily mean that the ecosystem does not produce that service. It also does not indicate that the service is not valuable. Many ecosystem services that clearly have economic value have not been assigned a value due to the lack of primary, peer-reviewed data. For example, shrub land provides recreation, habitat, carbon sequestration, and more, which are all highly valuable services. However, there are few valuation studies of ecosystem services in shrub land, so they are reflected as having little economic value despite the reality that it is a valuable natural area. This result means that caution should be exercised when comparing total ecosystem services values across land covers, as the difference in values could stem from lack of information and not necessarily true differences in ecosystem service value. This lack of available information underscores the need for investment in conducting local primary valuations. See Appendix A for a detailed discussion on study limitations.

A separate dataset for each spatial attribute was constructed using the transfer data selected. For example, land cover/ecosystem service combination values differed among the riparian zone, urban zone, and rural zone. These values were standardized to units of 2014 U.S. dollars (USD) per acre per year for each land cover/ecosystem service combination under each spatial attribute.

See Equation 1 for the formula used to determine total ecosystem service value. All ecosystem service values were summed to provide a total dollar per acre per year value for each land cover on each spatial attribute (see Table 9 for an example). Thirty seven combinations of land cover and spatial attributes were valued. Due to limitations on space, every detail table for every land cover/spatial attribute combination is not included in this report. Please contact the authors for access to these tables.

Equation 1

$$\text{TESV} = \sum_{i,j} \left(\text{Acres}_{i,j} * \left[\sum_{k} \text{Value}_{i,j,k} \right] \right)$$

Where:

TESV is the total ecosystem service value of the St. Louis River watershed

$\text{Acres}_{i,j}$ is the number of acres of land cover j in spatial attribute i

$\text{Value}_{i,j,k}$ is the dollar/acre/year value of each ecosystem service k on each land cover j in spatial attribute i

Land Cover: Coniferous Forest

Spatial Attribute: Riparian

Table 9. Example of a detailed ecosystem valuation table

Ecosystem Service	Minimum ($/acre/year)	Maximum ($/acre/year)
Air Quality	167	167
Biological Control	12	14
Climate Stability	66	751
Food	0.02	0.02
Habitat and Nursery	1	7
Moderation of Extreme Events	1	687
Pollination	239	421
Recreation and Tourism	.05	21
Waste Treatment	179	1,972
Total	**665**	**4,040**

The per-acre per-year values for each land cover/spatial attribute combination are multiplied by the number of acres fitting the combination. The result is an annual value representing the flow of ecosystem service value provided for each land type in question. These flows are then summed across all land cover types in the St. Louis River watershed to produce a grand total of ecosystem service value for the entire watershed.

This annual dollar value is like an annual flow of income from natural capital. From this annual flow of benefits, the value of the natural capital assets that it can be calculated. This is called the asset value.

Valuing the St. Louis River Estuary

Another significant data gap in ecosystem service valuation occurs for freshwater estuaries. Currently, effort is being made by the United States Environmental Protection Agency to map the distribution of ecosystem services within the estuary (Angradi et al., 2015). However, monetary assessments still pose a challenge. To date, the Ecosystem Valuation Toolkit has no recorded ecosystem service values for freshwater estuaries. Yet, some aspects of the estuary are similar to saltwater estuaries, which have been studied in the ecosystem service literature to a greater extent. We used transferability criteria adapted from Farber et al. (2006) and our benefit transfer criteria noted above to identify three ecosystem services that could be transferred to the freshwater estuary: aesthetic information, recreation and tourism, and flood risk reduction (moderation of extreme events). These transferred values were then applied to the mapped acreages of corresponding ecosystem services in the St. Louis River estuary.

It should be noted that the values derived from this analysis are severe underestimates. Only 3 out of 26 ecosystem services mapped for the estuary were estimated for their value. In addition, per-acre values were derived from other, albeit similar, ecosystems, and may not represent the true level of provision by the estuary.

Valuing Carbon Sequestration and Storage

A wealth of information on biophysical carbon sequestration and storage rates can be found in published scientific literature for most ecosystems. Using biophysical carbon sequestration, storage rates, and the social cost of carbon (Interagency Working Group on Social Cost of Carbon, 2013) (converted to 2014 USD) provides accurate estimates of the economic value of climate stability.

Asset Valuation Methodology

The asset value of built capital can be calculated as the net present value of its expected future benefits. Provided the natural capital of the St. Louis River watershed is not degraded or depleted, the annual flow of ecosystem services will continue into the future. As such, analogous to built capital, we can calculate the asset value of natural capital in the watershed.

Asset values provide a measure of the expected benefits flowing from the study area's natural capital over time. The net present value is used in order to compare benefits that are produced in various points in time. In order for this to be accomplished, a discount rate must be used.

Discounting allows for sums of money occurring in different time periods to be compared by expressing the values in present terms. In other words, discounting shows how much future sums of money are worth today. Discounting is designed to take into account two major factors:

- Time preference. People tend to prefer consumption now over consumption in the future, meaning a dollar today is worth more than a dollar received in the future.
- Opportunity cost of investment. Investment in capital today provides a positive return in the future.

However, due to disagreement among experts, the rate at which natural capital benefits should be discounted is uncertain (Arrow et al., 2004; Sterner and Persson, 2008). According to the popular Ramsey Discounting Framework, the discount rate should reflect the value of additional consumption as income changes and the pure rate of time preference, which "weights utility in one period directly against utility in a later period" (Ramsey, 1928). The formula can be seen in equation 2. We use this formula as a framework to construct an appropriate discount rate.

Equation 2

$$r = \eta g + \rho$$

Where:
r is the calculated discount rate
η is the elasticity of marginal utility
g is the consumption growth rate
ρ is the pure rate of time preference

The pure rate of time preference is a measure of how much people discount the future. Higher values imply that we care less about future sums of money. For example, less weight is placed on damages of a disastrous flood that could happen 100 years from now, and hence less abatement would occur today. This discounts the welfare of future generations living during the aforementioned hypothetical disaster. Because of this reason, many economists posit that zero is the only ethically justifiable value for the rate of time preference (Arrow and More, 2004; Solow, 1974), as this treats all generations as equal instead of assuming current benefits are more valuable. Several experts make the argument that no such justification against a zero rate of time preference exists (Sterner and Persson, 2008). Therefore, we use a value of zero for the pure rate of time preference.

The elasticity of marginal utility measures the change in satisfaction people get from consumption. As people get richer (and η increases), one more dollar of consumption is valued less and less. This idea is anchored in economic theory and empirically founded (Sterner and Persson, 2008). Typically, η accounts for the fact that future generations will have higher incomes and thus lower utility of consumption, but the function of this variable can also be interpreted as a social preference for equality of consumption among generations. Several economists argue that an appropriate value for the elasticity of marginal utility is one (Pearce and Ulph, 1999; Weitzman, 1998).

The consumption growth rate is interpreted as the growth of the economy (Sterner and Persson, 2008). This variable can be estimated through the growth rate of GDP per capita. The growth rate of GDP per capita in Minnesota averages at about 2% since 2010 (Bureau of Economic Analysis, 2012), so we use a value of two for the variable ***g***.

Therefore, following Equation 2 and using the numbers chosen here for the parameters, we assume a 2% discount rate.

The asset value of ecosystem services produced by the St. Louis River is calculated using the net present value of the flow of benefits using a 2% discount rate (see Equation 3).

Equation 3

$$NPV = \sum_{t=1}^{T} \frac{C_t}{(1 + r)^t}$$

Where:
NPV is the calculated net present value
C_t is the net benefits at time t
*r is the disc*ount rate

Net present values can be calculated over different time frames depending on the purpose of the analysis and nature of the project. In the case of natural capital valuations, ecosystems, if unimpaired are self-maintaining, display long-term stability and are continuously productive. An ecological concept called "seven generation sustainability" originated with the Iroquois (Lyons, 1980). The concept encourages people to live sustainably for the benefit of the seventh generation into the future, arguing that we must consider the impact of decisions today on the seventh generation. This study follows this thinking by calculating the net present value on a timespan of 140 years (approximately seven generations). It is worth noting however that, if kept healthy, the natural capital of the St. Louis River watershed will continue to provide benefits well beyond 140 years into the future.

This calculation also includes the carbon stock (storage) for each land cover type calculated with a similar BTM method. As the storage value of carbon in an ecosystem is a static number, not a flow of value, it is added to the present value of the flow of ecosystem services to obtain the total asset value for the St. Louis River watershed.

The current ecosystems in the St. Louis River Watershed have been sequestering and storing carbon for many years. However, the annual flow of values presented previously do not take into account the amount of carbon already stored in natural capital. Instead, this value is calculated separately and added into the asset value of the St. Louis River watershed.

The asset value calculated in this report is based on a snapshot of the current land cover, consumer preferences, population base, and productive capacities. As such, it does not take into account environmental degradation that may occur in the future, or change in value due to scarcity. Rather, it assumes that the ecosystems of the St. Louis River watershed remain the same over the entire duration of the calculation. For more information on the caveats of this report, see Appendix B.

Chapter 5 Valuation Results

The St. Louis River at Jay Cooke State Park.
Creative commons image by Sharon Mollerus

Land Cover

Mapping goods and services provided by built capital such as factories, restaurants, schools, and businesses provides a view of the region's economy across the landscape. Retail, residential, and industrial areas occur in different parts of the landscape. The same is true for the distribution of natural capital in the St. Louis River watershed. Figure 12 shows the distribution of natural capital in the St. Louis River watershed.

Very little of the watershed is developed or cultivated compared to other watersheds outside of the Great Lakes region. Only 2% of the watershed is developed under the C-CAP definition, and less than half a percent is cropland or pasture. However, it is among the most developed watersheds within the Lake Superior Basin. The majority of the watershed is forested (31%) or a wetland (28%). Table 10 shows the acreage of every land cover type in the St. Louis River watershed.

Table 10. Land Cover Acreage in the St. Louis River Watershed
The total area of the estuary covers approximately 12,000 acres. In this report, we consider only the open water area to avoid double counting with other land cover types.
Source: NOAA Office for Coastal Management, 2010. NOAA Coastal Change Analysis Program Regional Land Cover Database.

Land Cover	Acres
Developed, High Intensity	6,214
Developed, Medium Intensity	13,263
Developed, Low Intensity	22,826
Developed, Open Space	12,574
Cultivated Crops	8,142
Pasture/Hay	72,491
Grassland/Herbaceous	38,976
Deciduous Forest	407,741
Evergreen Forest	162,254
Mixed Forest	171,661
Scrub/Shrub	185,512
Palustrine Forested Wetland	655,914
Palustrine Scrub/Shrub Wetland	389,901
Palustrine Emergent Wetland	112,593
Unconsolidated Shore	30
Barren Land	29,406
Lakes	68,733
Rivers	7,681
Freshwater Estuary	10,376
Total	**2,376,286**

Figure 12. Map of C-CAP Land Cover Categories in the St. Louis River Watershed

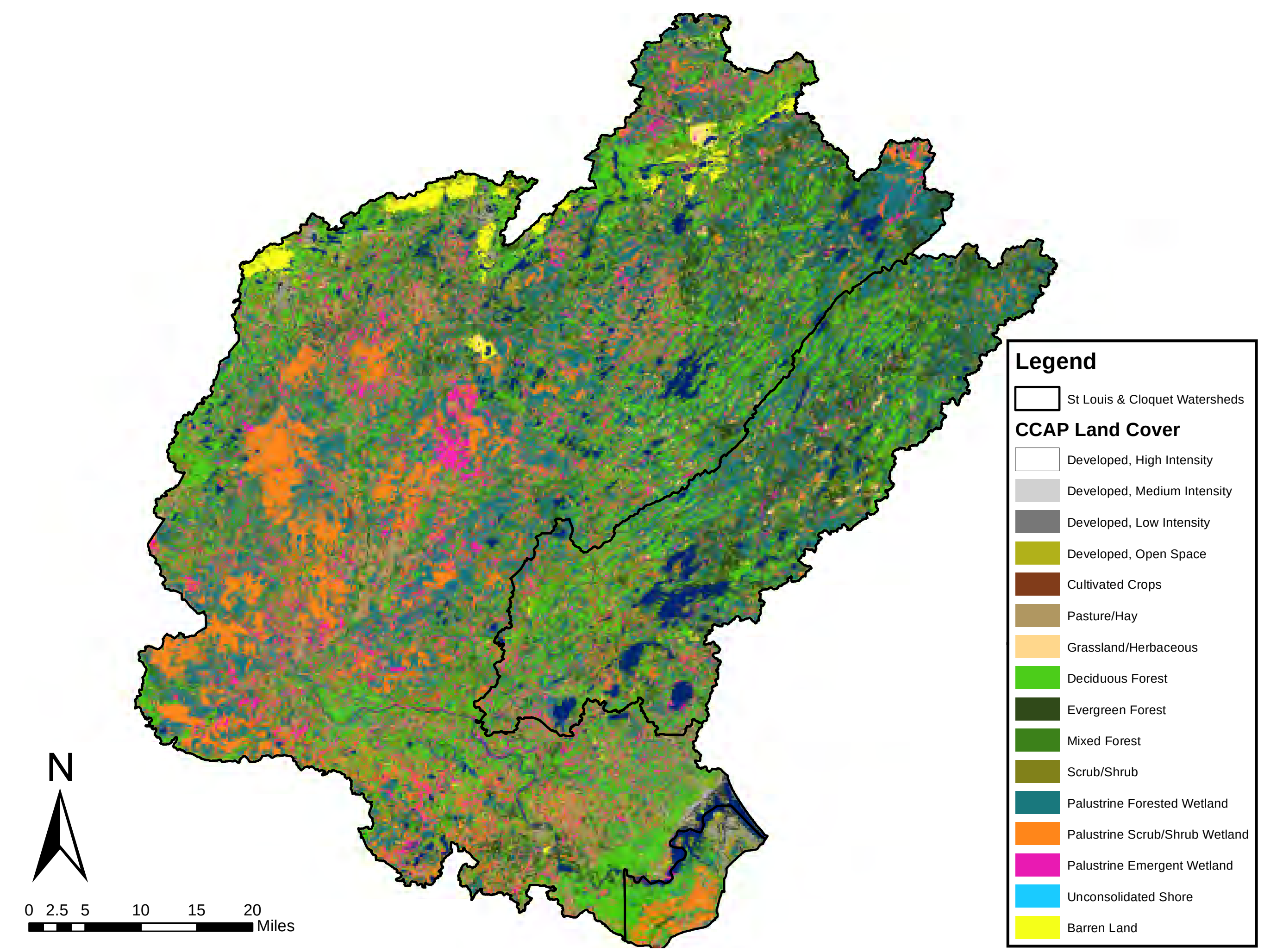


Exhibit L.1.

Annual Value

The St. Louis River watershed provides between $5.0 billion and $13.7 billion in benefits to people each year (see Table 11 and Table 12). These numbers are important and significant annual economic benefits. They indicate that investment in natural capital can provide vast and long-term benefits if these assets are conserved or enhanced. Moreover, investment in natural capital can yield tremendous return on investment due to both the low cost of investment relative to building new assets, and because it supports a suite of ecosystem services and benefits, not just a single benefit.

Table 11. Summary of Ecosystem Service Valuation Results

Land Cover	Acres	Annual Low ($/year)	Annual High ($/year)
Cropland	8,142	5,116,759	6,153,912
Pasture	72,491	40,387,051	42,919,234
Freshwater Estuary	10,376	14,593,676	37,990,209
River	7,681	106,564,256	113,030,502
Lake	68,733	1,899,944,854	4,984,056,378
Deciduous Forest	407,727	720,137,754	1,093,194,294
Coniferous Forest	162,212	278,354,699	465,626,397
Mixed Forest	171,604	227,170,181	462,305,045
Grassland	38,933	25,484,059	27,910,168
Shrub/Scrub	185,477	2,237,422	5,070,892
Herbaceous Wetland	112,587	166,323,735	634,780,104
Shrub Wetland	389,890	579,698,292	2,192,921,144
Woody Wetland	655,855	959,508,012	3,673,227,283
Total	**2,291,707**	**5,025,520,750**	**13,739,185,562**

Table 12. Ecosystem Service Values in the St. Louis River Watershed by Land Cover Type (opposite)
Freshwater estuary was valued on the extent of ecosystems services identified by U.S. EPA. Therefore, no total $/acre/year value was determined.

Land Cover	Spatial Attribute		Acres	Low ($/acre/year)	High ($/acre/year)	Annual Low ($/year)	Annual High ($/year)
	Riparian	Urban					
Cropland			8,142	628	756	5,116,759	6,153,912
Pasture			72,491	557	592	40,387,051	42,919,234
Freshwater Estuary			10,376			14,593,676	37,990,209
River			7,681	13,875	14,717	106,564,256	113,030,502
Lake			68,733	27,642	72,513	1,899,944,854	4,984,056,378
Deciduous Forest			390,499	1,683	2,487	657,239,488	971,335,883
	*		9,578	652	3,766	6,246,192	36,065,694
		*	7,261	7,405	11,215	53,772,246	81,431,248
	*	*	389	7,404	11,213	2,879,827	4,361,469
Coniferous Forest			156,328	1,710	2,776	267,269,110	433,948,657
	*		4,822	665	4,040	3,205,290	19,483,223
		*	1,018	7,425	11,491	7,561,656	11,701,387
	*	*	43	7,424	11,489	318,644	493,129
Mixed Forest			166,489	1,313	2,623	218,619,766	436,640,807
	*		4,349	659	3,901	2,867,516	16,964,018
		*	723	7,415	11,353	5,361,387	8,207,965
	*	*	43	7,414	11,351	321,512	492,255
Grassland			38,021	570	570	21,673,204	21,673,204
	*		526	6,848	11,457	3,604,869	6,030,978
		*	373	535	535	199,680	199,680
	*	*	12	535	535	6,307	6,307
Shrub/Scrub			180,212	12	27	2,162,547	4,865,730
	*		3,046	16	48	48,241	145,236
		*	2,111	12	27	25,329	56,990
	*	*	109	12	27	1,305	2,936
Herbaceous Wetland			97,121	1,471	5,603	142,880,800	544,120,898
	*		14,711	1,506	5,604	22,156,760	82,442,859
		*	599	1,199	11,270	718,152	6,752,418
	*	*	157	3,623	9,337	568,023	1,463,928
Shrub Wetland			363,465	1,493	5,625	542,714,471	2,044,318,603
	*		24,564	1,378	5,229	33,839,875	128,449,619
		*	1,500	1,221	11,185	1,831,586	16,783,157
	*	*	360	3,645	9,359	1,312,360	3,369,765
Woody Wetland			617,549	1,469	5,604	907,282,898	3,460,449,989
	*		35,984	1,354	5,208	48,708,393	187,410,104
		*	2,018	1,197	11,164	2,414,318	22,524,165
	*	*	304	3,621	9,338	1,102,403	2,843,025
Total			**2,291,707**			**5,025,520,750**	**13,739,185,562**

Asset Value

We estimate the asset value of the ecosystems of the St. Louis River watershed to be $273 billion to $687 billion. This calculation does not include market values for property or built infrastructure in the watershed. The asset value calculated in this report includes the net present value of the flow of ecosystems service benefits and carbon storage in land cover types. Table 13 presents the value of carbon storage in the watershed. As outlined in Chapter 4, the net present value is calculated over 140 years at a 2% discount rate. Table 14 shows the total asset value of the watershed. The asset value calculation shown here is useful for revealing the scope and scale of benefits to the regional economy and communities.

Table 13. Carbon Storage in the St. Louis River Watershed by Land Cover Type

Land Cover	Acres	Low ($/acre)	High ($/acre)	Low ($)	High ($)
Cropland	8,142	502	1,731	4,087,199	14,093,508
Pasture	72,491	161	179	11,670,975	12,975,805
Freshwater Estuary	10,376	-	-	-	-
River	7,681	-	-	-	-
Lake	68,733	-	-	-	-
Deciduous Forest	407,727	386	20,228	157,382,484	8,247,494,506
Coniferous Forest	162,212	5,334	25,153	865,238,234	4,080,115,729
Mixed Forest	171,604	2,860	22,691	490,788,766	3,893,876,884
Grassland	38,933	294	455	11,446,206	17,714,366
Shrub	185,477	3,836	9,233	711,491,233	1,712,512,657
Herbaceous Wetland	112,587	1,152	8,064	129,696,235	907,873,643
Shrub Wetland	389,890	38,425	55,561	14,981,515,101	21,662,666,507
Woody Wetland	655,855	60,187	83,048	39,473,928,688	54,467,423,691
Total	**2,291,707**			**56,837,245,120**	**95,016,747,295**

Table 14. Asset value of the St. Louis River Watershed

Value	Low Estimate ($)	High Estimate ($)
Net Present Value	216,591,660,438	592,136,250,607
Carbon Storage	56,837,245,120	95,016,747,295
Total Asset Value	**273,428,905,558**	**687,152,997,902**

Discussion

Values for ecosystem services can vary due to factors such as scarcity, income effects, and uniqueness of habitat (Boumans et al., 2002). The values provided include an array of marginal and average values for ecosystem services, which incorporate different potential demand scenarios and states of the environment. By extracting values from a large pool of studies and contexts we are able to integrate general wisdom and different situations to illustrate a well-informed value approximation. The range of values gives insight on potential differences in value that can be expected given different contexts.

As mentioned in Chapter 4, economic value of ecosystem services often increases in proximity to urban areas. This phenomenon can be seen in Table 12. However, this proximity is not necessarily a good thing for ecosystems. Urban centers introduce pollution and degradation of ecosystems due to human activity. Habitats for commercially important species are degraded, such as fish habitat, and some species of wildlife, such as lynx and wolves, are more productive when human populations are low (Burkhard et al., 2012). The data here shows the economic benefits of ecosystem services, but does not illustrate underlying ecosystem health of the St. Louis River watershed which affects the provision of ecosystem services.

The upper reaches of the St. Louis River. *Creative commons no-derivatives image by David Arpi*

The numbers presented in this chapter are underestimates of the value of the St. Louis River watershed.

Because this study utilizes many valuation studies, the uncertainty associated with these results is not known. However, both the low and high values established are likely underestimates of the actual range of ecosystem services provided within the watershed. Many ecosystem services have not been quantified and were not able to be included in the analysis, as seen in Table 8. Sparse data and omission of existing values are still the greatest hurdles to studies such as this one, and likely the greatest source of uncertainty in this valuation.

Additionally, data availability influences the results of this analysis. The estimates in Table 11 and Table 12 are not necessarily a true representation of the value of a particular land cover because of the gaps in this analysis. Anywhere from 2 to 11 ecosystem services (out of a total of 21) were valued for each land cover type, meaning at best, half of the ecosystem services produced by a land cover were valued. Therefore, a lower annual value on one land cover compared to another does not necessarily mean one land cover is more valuable than another. Some combinations simply have not been studied to the same level of detail as others. For example, only three ecosystem services were valued for freshwater estuaries. Because of this caveat, caution is advised when comparing total ecosystem service values among land cover types.

This also means that, despite being on the order of billions, the estimate of the value of the St. Louis River watershed is an underestimate.

▶ Autumn on the St. Louis River (opposite).
Creative commons image by Randen Pederson

Chapter 6
Historic Changes in Ecosystem Services

Island Lake, located on the Cloquet River.
Creative commons share-alike image by M.E. McCarron

Brief Background on the 1854 Treaty

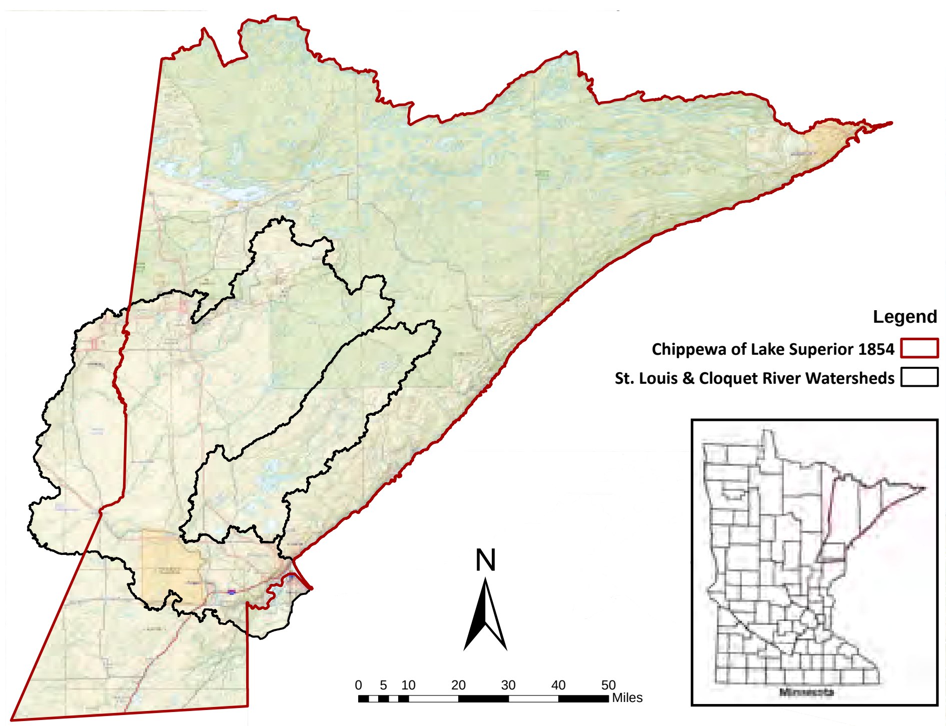
"...and such of them as reside in the territory hereby ceded, shall have the right to hunt and fish therein, until otherwise ordered by the President."

–Article 11 of the 1854 Treaty

In 1854, the Chippewa of Lake Superior in northeastern Minnesota entered into a treaty with the United States in which the Chippewa ceded ownership of their lands to the United States government (see Figure 13). This treaty established the Fond du Lac Reservation at 100,000 acres. Most of the St. Louis River watershed resides within the 1854 treaty area, save the western and Wisconsin portions of the watershed.

The Ojibwe retained extensive usage rights to the ceded land in the treaty. Beginning in 1985, many lawsuits were brought against the United States over harvest rights outlined within the text of the treaty. Article 11 of the 1854 Treaty states the harvest rights in the territory (Kappler, 1904).

Figure 13. The 1854 Treaty Area in Comparison to the St. Louis River Watershed
Source: Earth Economics



Rights to Ecosystem Services

The "Culverts" Decision

In 2013, federal Judge Ricardo Martinez ordered the state of Washington to fix fish-blocking culverts owned by the state because they violated tribal treaty rights, based on the Martinez decision in 2007 (U.S. District Court, 2007). More than 600 culverts must be repaired over the next 17 years to ensure that the state corrects these violations in treaty promises. Because the culverts prevented the free passage of fish and their access to spawning grounds, salmon production decreased in the area, also decreasing the number of fish available for harvest.
It was determined that tribal members had been harmed "economically, socially, educationally, and culturally by the reduced salmon harvests that have resulted from State-created or State-maintained fish passage barriers" (ibid).

Resource extraction has many negative impacts on the landscape. Extensive past and present mining has degraded and will continue to affect large areas of forests, wetlands, and other natural, cultural, and treaty-protected resources (Bois Forte Band of Chippewa et al., 2013). Expansion of existing taconite mines and the development of new copper-nickel mines will undoubtedly add to the existing impacts.

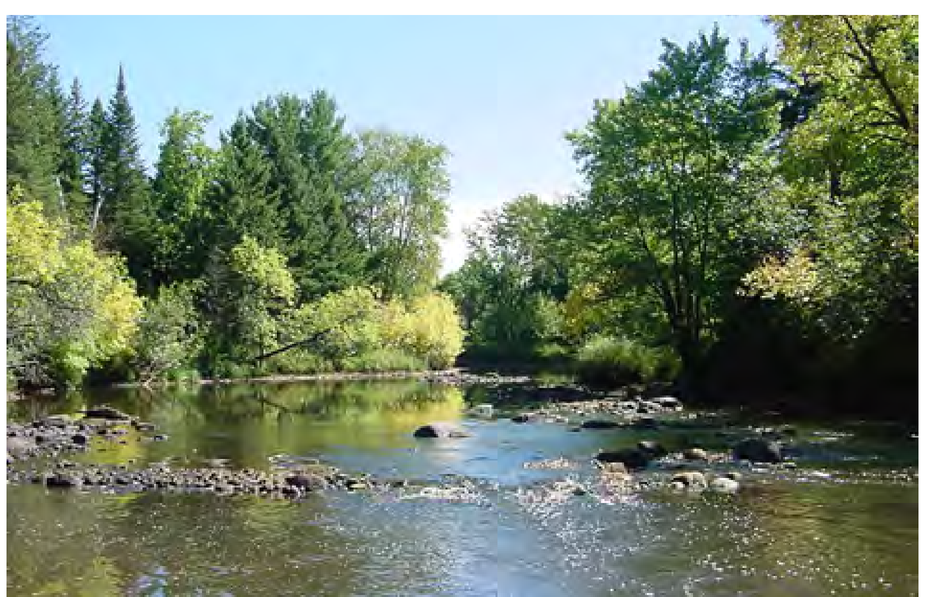
Tribal cultural identities and traditions are inextricably connected to the natural resources present in specific places (Bois Forte Band of Chippewa et al., 2013; Cleland et al., 1995). Impacts to these specific places from mining, logging, and other natural resource extraction have raised concerns on the effect of resource extraction on the harvest rights reserved in the treaties. In the context of changes introduced by mining activities and other stressors to ecosystems such as climate change, debate has begun on people's right to water, food, and other natural resources.

Do land use actions interfere with tribal harvest rights? Do people have a right to prevent other people from altering ecosystems? When does human interference with an ecosystem breach the rights of other humans? Many beneficiaries of ecosystem services lie outside the borders of where they are produced. For example, a ton of carbon sequestered within the watershed provides global benefits by enhancing climate stability (Lal et al., 2007). Water storage in the upper watershed of the St. Louis River helps reduce flood risk in downstream areas like Duluth (Emerton and Bos, 2004). Do the beneficiaries have a right to these benefits? If so, and if that service is inhibited or removed, does this infringe on that right? Harm caused to ecosystem services can be thought of as negative externalities, or a cost imposed on someone other than the party creating the cost. If these externalities violate a legal right, then this violation calls for a remedy (Pardy, 2014). However, the resolution of these issues is complex and contentious.

Changes in Land Cover and Ecosystem Service Provision in the St. Louis River Watershed

The lands in the St. Louis River watershed and the harvest rights within hold immense cultural value to the Ojibwe. Additionally, this report has shown the ecosystem services provided by the watershed hold tremendous economic value. However, human activities have changed, and shifted the locations and levels of ecosystem service provisioning within the watershed. This section aims to describe these changes through review of the literature and datasets.

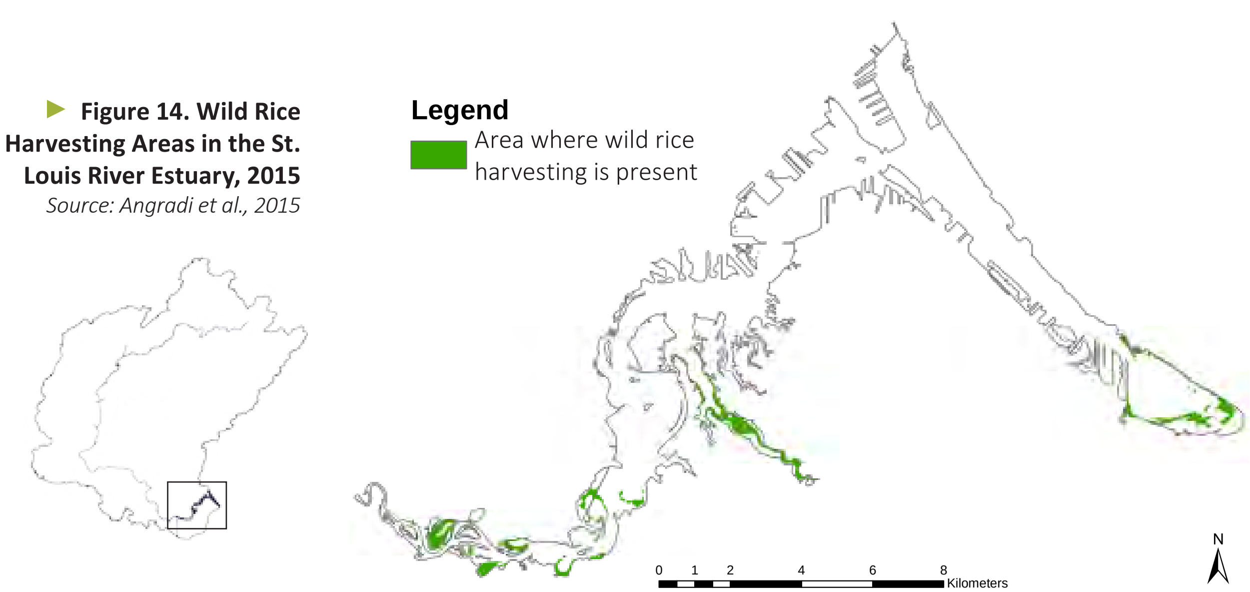
Land cover data can be found dating back to 1895 (Minnesota DNR Division of Forestry, 1994). These data were constructed from public land survey notes and digitized. Comparison of the land cover acreage from this dataset with the 2010 C-CAP acreage presented earlier in the report (see Appendix D for more information on GIS limitations) shows a 22% decrease in forest area, or about 500,000 acres. According to the National Land Cover Database, forest area has continued to decline in recent times (Jin et al., 2013). From 2001 to 2011, more than 18,000 acres of forest cover was lost, a 2% decrease in 10 years. Over this time period, more than 2,000 acres of wetland were lost, with a majority of this change to dry herbaceous cover, such as grassland or shrubland.



▶ The Embarrass River, a tributary of the St. Louis River. *© Fond du Lac Resource Management Division*

Wetland loss is an important issue in Minnesota, which has lost more wetland acreage than any other state except Alaska (Minnesota DNR, 1997). One report estimated that Minnesota has lost approximately 47% of its wetlands since presettlement times (Anderson and Craig, 1984). National Resources Inventory data estimate a loss of 53% of pre-settlement wetlands in Minnesota (Minnesota DNR, 1997). The northeastern region of Minnesota is thought to have at least 80% of its historic wetlands intact (MPCA, 2006). In St. Louis County, of 11,360,000 acres of wetlands estimated in 1981, 94% remained in 1997 (ibid). Although northeastern Minnesota has done well in retention of its wetlands compared to the rest of the state, these figures only consider the loss of wetland quantity, not quality.

Loss of wetlands also affect wild rice abundance, as wild rice grows in shallow water. Several sources note the high abundance of wild rice in the St. Louis River in 1800s. In 1820, the explorer Henry Schoolcraft noted the abundance of wild rice in the St. Louis River estuary. In his journal during an expedition seeking the source of the Mississippi River, Schoolcraft writes "On reaching the mouth of the St. Louis River… we here saw in plenty the folle avoine, or wild rice…" (Schoolcraft, 1821). Reverend T.M. Fullterton notes that "From [the head of the bay], the river is full of islands and fields of wild rice…" at the St. Louis River's mouth (Fullerton, 1872). The cartographer Henry Bayfield also noted in his chart of Lake Superior, which was published in 1825, that "wild rice and rushes line the banks of the River." The river Bayfield refers to is the estuary portion of the St. Louis River. Compared to recent times, wild rice occurs in only a small portion of the estuary (see Figure 14) and are documented as "poor" harvest areas (1854 Treaty Authority, 2014).



▶ **Figure 14. Wild Rice Harvesting Areas in the St. Louis River Estuary, 2015**
Source: Angradi et al., 2015

The loss of natural land cover discussed in this section comes with the loss of ecosystem service provisioning. Additionally, loss of land cover due to development results in a loss in quality, which also negatively affects ecosystem service provisioning. In its wetland assessment strategy, the Minnesota Pollution Control Agency notes the importance of taking account of the quality of the environment, especially wetlands, and not just the change in quantity (MPCA, 2006). Stressors that come from development, like pollutants from mines, agriculture, or developed areas, invasive species, ditching, and other hydrologic changes, can impact the functions and quality of wetlands and other ecosystems, and thus impact their ability to provide ecosystem services. An acre of impacted wetland does not support wildlife or produce high-quality wild rice as well as one acre of pristine wetland. Beach closures due to pollution completely prohibit ecosystem services like recreation. In St. Louis County, 82% of monitored beaches experienced an advisory or closing in 2012 (U.S. EPA, 2013). The beneficial use impairments in the AOC demonstrate that for long spans of time, ecosystem service benefits have been negatively affected, and in some cases, eliminated.

▶ The St. Louis River in the Fond du Lac reservation. *© Fond du Lac Resource Management Division*

It is important to note that the values presented in chapter 5 are baseline levels of ecosystem service values. They do not include the effects of declining ecosystem health on the provision of ecosystem services, and instead assume that ecosystems are healthy (see Appendix B for more details on the limitations of this report). The impacts on environmental quality have grown substantially since presettlement times. Since ecosystem health is currently a major concern in the watershed, this fact should be taken into account in analyzing the cumulative change in ecosystem service provision since presettlement times. However, this comparison goes beyond the scope of the current report.

▶ A turtle on the shore of the St. Louis River. *© Fond du Lac Resource Management Division*

Chapter 7
Conclusion and Recommendations

The Superior Hiking Trail in Duluth.
Creative commons share-alike image by William J. Gage

The natural capital in the St. Louis River watershed is critical to the health and resilience of the regional economy and communities. The initial estimates provided in this report show the economic value of environmental benefits are enormous. Despite the scale of these values, they are still underestimating the full account of goods and services provided by the watershed. Many valuable ecosystem services were not able to be included in the analysis. Future assessments should focus on capturing the full value of natural capital in the St. Louis River watershed.

Recommendation 1

Fill data gaps

Several major data gaps have been identified through the course of this project (see Table 8 for a list of gaps in this valuation). New primary studies and methods are published monthly around the world. These should be reviewed and incorporated to fill in data gaps as appropriate. The lack of available information also underscores the need for investment in conducting local primary valuations. As identified previously in this report, freshwater estuaries are areas that need research on all ecosystem service values. Table 8 can be a good resource when considering which ecosystem service/land cover categories should be prioritized for primary valuation.

Recommendation 2

Conduct a detailed assessment of cultural ecosystem services

Many cultural services identified in the St. Louis River watershed were not measured in this report. Funding limitations for this project resulted in the inability to use tools like SolVES (Social Values for Ecosystem Services), implement the CHIA (Cumulative Health Impacts Analysis) system, or conduct surveys needed to spatially recognize and measure all cultural ecosystem services in the watershed. Future research is needed to identify where cultural value exists with biophysical ecosystem service to further inform enhancement and development of the watershed in order to avoid the loss of cultural value to society.

Recommendation 3

Analyze the cumulative effects of development on the provisioning of ecosystem services

Tribal groups in the study area have pushed for more comprehensive Cumulative Effects Analyses (CEA) for mining projects that affect natural resources (Bois Forte Band of Chippewa et al., 2013). Ecosystem services would provide an interesting and insightful input into this type of analysis. The values in this report provide a baseline level of provision, but assume that the ecosystems of the St. Louis River watershed are healthy. However, mining activities have profoundly degraded natural resources of importance to tribes(Bois Forte Band of Chippewa et al., 2013). To include ecosystem values into CEA, ecosystem health and its effects on ecosystem services should be considered. A detailed assessment of changes in ecosystem health should be conducted in the study area and be used to describe cumulative effects of ecosystem service change due to development.

While this report provides a valuation of ecosystem services in the St. Louis River watershed, it is only the first step in the process of developing sustainable policies, measures, and indicators that support discussions about the tradeoffs in investment of public and private money that ultimately shape the regional economy.

Recommendation 4

Invest in natural capital

The conservation and restoration of natural systems in the St. Louis River watershed should be considered as a key asset and investment opportunity for promoting economic prosperity and sustainability. The watershed's natural capital has a large asset value and high rate of return. Investments in natural capital deliver economic benefits to rural and urban communities including water supply, flood risk reduction, recreation, and healthier ecosystems (Sukhdev et al., 2010). This appraisal of value is legally defensible and applicable to decision-making at every jurisdictional level.[iii]

iii Earth Economics work has been used in legal cases to showcase the value of natural assets (see Briceno, T., Flores, L., Toledo, D., Aguilar Gonzáles, B., Batker, D., Kocian, M. 2013. Evaluación Económico-Ecológica de los Impactos Ambientales en la Cuenca del Bajo Anchicayá por Vertimiento de Lodos de la Central Hidroeléctrica Anchicayá. Earth Economics, Tacoma, WA, United States. Available at: http://eartheconomics.org/FileLibrary/file/Reports/Anchicaya.pdf.

Recommendation 5

Bring ecosystem service valuation into standard accounting and decision-making tools

Accounting rules currently recognize timber and fossil fuel natural capital values, but need to be improved to include water provisioning. Ecosystem service valuation can provide governments, businesses, and private landowners with a way to calculate the rate of return on conservation and restoration investments. Benefit/cost analysis is a widely used economic decision support tool. Strengthening benefit/cost analyses with ecosystem services will shift investment of public and private funds toward more productive and sustainable projects.[iv]

Ecosystem service valuations provide opportunities for decision-makers and community leaders to understand economic trade-offs in planning, growing, and building cities and rural communities, as well as investing in the areas natural capital. Land use planning and management efforts provide opportunities for establishing economic measures that ensure quality and overall health of ecosystems. We have an opportunity to make better decisions concerning how to meet required standards for the region's ecologically and economically important ecosystems.

Recommendation 6

Land use policy and management

Consideration of both the conservation and the restoration of the area's ecosystems as a key investment for the future economy is one of the first steps toward investing in natural capital. The valuation provided is applicable to decision-making at every jurisdictional level. Restoration projects can and should be effectively linked to economic advancement, sustainability, and long-term job creation.

iv Benefit Transfers produced by Earth Economics have been used in Benefit-Cost Analyses, including Seattle Public Utilities' analysis on improving a creek in Seattle (see Crittenden, J,. Stevens, G., Takahashi, E., Lynch, K., Heiden, D., Lockwood, G., Harrington, L., Li, L. 2010. Business Case 2 for Thornton Confluence Improvement. Seattle Public Utilities, Seattle, WA)

Investment in natural capital is essential to the long-term health of the economy and natural environment within the St. Louis River watershed. Consider the conservation of the St. Louis River watershed as a key investment opportunity to generate economic and social prosperity. Investing in the restoration of the St. Louis River to non-impaired status will maintain and expand the vast value of this natural asset. The maintenance and expansion of healthy natural systems underlies the production of many economic benefits. Without this investment and with increasing impacts from pollutants and development, current economic assets will be degraded. This study enables better actions, incentives, and outcomes for long-term economic prosperity at local and watershed scales. Integrated into decision-making, this analysis can provide long-term benefits to everyone who benefits from the natural capital of the St. Louis River watershed.

The St. Louis River in Wisconsin.
Creative commons image by Randen Pederson

References and Appendices

◀ Grass overlooking Lake Superior at Park Point in Duluth.
Creative commons image by Sharon Mollerus

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Appendix A. Glossary

Benefit-Cost Analysis (BCA): Benefit-Cost Analysis (BCA) is a technique for evaluating a project or investment by comparing the economic benefits with the economic costs of the activity. It has several objectives. First, BCA can be used to evaluate the economic merit of a project. Second, the results from a series of benefit-cost analyses can be used to compare competing projects. BCA can be used to assess business decisions, to examine the worth of public investments, or to assess the wisdom of using natural resources or altering environmental conditions. Ultimately, BCA aims to examine potential actions with the objective of increasing social welfare.

Benefit Transfer: Economic valuation approach in which estimates obtained in one context are used to estimate values in a different context. This approach is widely used because of its ease and low cost, but is risky because values are context-specific and must be used carefully.

Biodiversity: The variability among living organisms from all sources including terrestrial, marine, and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within and among species and diversity within and among ecosystems. Biodiversity itself is not an ecosystem service, but provides the major foundation for all ecosystem services.

Built Capital: Refers to the productive infrastructure of technologies, machines, tools, and transport that humans design, build, and use for productive purposes. Coupled with our learned skills and capabilities, our built techno-infrastructure is what directly allows raw materials to be turned into intermediate products and eventually finished products.

Capital Value/Asset Value (of an ecosystem): The present value of the stream of future benefits that an ecosystem will generate under a particular management regime. Present values are typically obtained by discounting future benefits and costs; the appropriate rates of discount are often set arbitrarily.

Cultural Services: Ecosystem services that provide humans with meaningful interaction with nature. These services include the role of natural beauty in attracting humans to live, work and recreate, and the value of nature for science and education.

Discount Rate: The rate at which people value consumption or income now, compared with consumption or income later. This may be due to uncertainty, productivity, or pure time preference for the present. "Intertemporal discounting" is the process of systematically weighing future costs and benefits as less valuable than present ones.

Elasticity of marginal utility: The change in utility, or consumer satisfaction, gained or lost by people from consumption.

Growth rate of consumption: The change in consumption (the flow of materials and energy through society) by a population.

Natural Capital: Refers to the earth's stock of organic and inorganic materials and energies, both renewable and nonrenewable, as well as the planetary inventory of living biological systems (ecosystems) that when taken as one whole system provides the total biophysical context for the human economy. Nature provides the inputs of natural resources, energy, and ecosystem function to human economic processes of production. Nature by itself produces many things that are useful and necessary to human well-being.

Net Present Value: Net Present value is the amount that, at some discount rate, will produce the future benefits less costs after a defined length of time.

Pure Rate of Time Preference: a measure of how much people discount sums of money in the future. It is the relative value a person places on an amount of money at an earlier date compared with the same person's valuation of the same amount of money at a later date.

Stakeholder: An actor having a stake or interest in a physical resource, ecosystem service, institution, or social system, or someone who is or may be affected by a public policy.

Sustainability: A characteristic or state whereby the needs of the present and local population can be met without compromising the ability of future generations or populations in other locations to meet their needs.

Threshold: A point or level at which new properties emerge in an ecological, economic, or other system, invalidating predictions based on mathematical relationships that apply at lower levels. For example, species diversity of a landscape may decline steadily with increasing habitat degradation to a certain point, then fall sharply after a critical threshold of degradation is reached. Human behavior, especially at group levels, sometimes exhibits threshold effects. Thresholds at which irreversible changes occur are especially of concern to decision-makers.

Value: The contribution of an action or object to user-specified goals, objectives, or conditions. Value can be measured in a number of ways (see Valuation).

Valuation: The process of expressing a value for a particular good or service in a certain context (e.g., of decision-making), usually in terms of something that can be counted, often money, but also through methods and measures from other disciplines (sociology, ecology, and so on).

Watershed: The area of land where all of the water that is under it or drains off of it goes into the same place. A good example of a watershed is a river valley that drains into the ocean.

Appendix B. Study Limitations

Valuation exercises have limitations that must be noted, although these limitations should not detract from the core finding that ecosystems produce a significant economic value to society. A benefit transfer analysis estimates the economic value of a given ecosystem (e.g., wetlands) from prior studies of that ecosystem type. Like any economic analysis, this methodology has strengths and weaknesses. Some arguments against benefit transfer include:

- Every ecosystem is unique; per-acre values derived from another location may be irrelevant to the ecosystems being studied.

- Even within a single ecosystem, the value per acre depends on the size of the ecosystem. In most cases, as the size decreases, the per-acre value is expected to increase and vice versa. (In technical terms, the marginal cost per acre is generally expected to increase as the quantity supplied decreases; a single average value is not the same as a range of marginal values).

- To value all, or a large proportion, of the ecosystems in a large geographic area is questionable in terms of the standard definition of exchange value. We cannot conceive of a transaction in which all or most of a large area's ecosystems would be bought and sold. This emphasizes the point that the value estimates for large areas (as opposed to the unit values per acre) are more comparable to national income account aggregates and not exchange values (Howarth and Farber, 2002). These aggregates (i.e. GDP) routinely impute values to public goods for which no conceivable market transaction is possible. The value of ecosystem services of large geographic areas is comparable to these kinds of aggregates.

Proponents of the above arguments recommend an alternative valuation methodology that amounts to limiting valuation to a single ecosystem in a single location. This method only uses data developed expressly for the unique ecosystem being studied, with no attempt to extrapolate from other ecosystems in other locations. The size and landscape complexity of most ecosystems makes this approach to valuation extremely difficult and costly. Responses to the above critiques can be summarized as follows (See (Costanza et al., 1997) and (Howarth and Farber, 2002) for a more detailed discussion):

- While every wetland, forest or other ecosystem is unique in some way, ecosystems of a given type, by their definition, have many things in common. The use of average values in ecosystem valuation is no more or less justified than their use in other macroeconomic contexts; for instance, the development of economic statistics such as Gross Domestic or Gross State Product.

- As employed here, the prior studies upon which we based our calculations encompass a wide variety of time periods, geographic areas, investigators and analytic methods. Many of them provide a range of estimated values rather than single-point estimates. The present study preserves this variance; no studies were removed from the database because their estimated values were deemed to be "too high" or "too low." Also, only limited sensitivity analyses were performed. This approach is similar to determining an asking price for a piece of land based on the prices of comparable parcels ("comps"): Even though the property being sold is unique, realtors and lenders feel justified in following this procedure to the extent of publicizing a single asking price rather than a price range.

- The objection to the absence of even an imaginary exchange transaction was made in response to the study by Costanza (Costanza et al., 1997) of the value of all of the world's ecosystems. Leaving that debate aside, one can conceive of an exchange transaction in which, for example, all of, or a large portion of a watershed was sold for development, so that the basic technical requirement of an economic value reflecting the exchange value could be satisfied. Even this is not necessary if one recognizes the different purpose of valuation at this scale, a purpose that is more analogous to national income accounting than to estimating exchange values (Howarth and Farber, 2002).

We have displayed our study results in a way that allows one to appreciate the range of values and their distribution. It is clear from inspection of the tables that the final estimates are not precise. However, they are much better estimates than the alternative of assuming that ecosystem services have zero value, or, alternatively, of assuming they have infinite value. Pragmatically, in estimating the value of ecosystem services, it seems better to be approximately right than precisely wrong.

General Limitations

- Static Analysis. This analysis is a static, partial equilibrium framework that ignores interdependencies and dynamics, though new dynamic models are being developed. The effect of this omission on valuations is difficult to assess.

- Increases in Scarcity. The valuations probably underestimate shifts in the relevant demand curves as the sources of ecosystem services become more limited. The values of many ecological services rapidly increase as they become increasingly scarce (Boumans et al., 2002). If ecosystem services are scarcer than assumed, their value has been underestimated in this study. Such reductions in supply appear likely as land conversion and development proceed. Climate change may also adversely affect the ecosystems, leading to a scarcity of ecosystem services, and thus higher values.

Benefit Transfer/Database Limitations

- Incomplete coverage. That not all ecosystems have been valued or studied well is perhaps the most serious issue, because it results in a significant underestimate of the value of ecosystem services. More complete coverage would almost certainly increase the values shown in this report, since no known valuation studies have reported estimated values of zero or less for an ecosystem service.

- Selection Bias. Bias can be introduced in choosing the valuation studies, as in any appraisal methodology. The use of ranges partially mitigates this problem.

Primary Study Limitations

- Price Distortions. Distortions in the current prices used to estimate ecosystem service values are carried through the analysis. These prices do not reflect environmental externalities and are therefore again likely to be underestimates of true values.

- Non-linear/Threshold Effects. The valuations assume smooth and/or linear responses to changes in ecosystem quantity with no thresholds or discontinuities. Assuming (as seems likely) that such gaps or jumps in the demand curve would move demand to higher levels than a smooth curve, the presence of thresholds or discontinuities would likely produce higher values for affected services.(Limburg et al., 2002) Further, if a critical threshold is passed, valuation may leave the normal sphere of marginal change and larger-scale social and ethical considerations dominate, as with an endangered species listing.

- Sustainable Use Levels. The value estimates are not necessarily based on sustainable use levels. Limiting use to sustainable levels would imply higher values for ecosystem services as the effective supply of such services is reduced. If the above problems and limitations were addressed, the result would most likely be a narrower range of values and significantly higher values overall. At this point, however, it is impossible to determine more precisely how much the low and high values would change.

Appendix C. Value Transfer Studies Used

Ecosystem Service Studies and Values Used

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▼ **Table 15. Ecosystem service literature and values used**

Land Cover	Ecosystem Service	Author(s)	Valuation Methodology	Minimum (2014 USD/ acre/year)	Maximum (2014 USD/ acre/year)
Coniferous Forest	Aesthetic Information	Nowak et al.	Replacement Cost	6,104	9,125
	Air Quality	Wilson	Avoided Cost	167	167
	Biological Control	Pimentel et al.	Benefit Transfer	2	2
		Wilson	Replacement Cost	12	14
	Energy and Raw Materials	Haener and Adamowicz	Market Price	4	9
	Food	Haener and Adamowicz	Market Price	0	0
	Habitat and Nursery	Haener and Adamowicz	Contingent Valuation	1	7
		Tanguay et al.	Contingent Valuation	2	6
	Moderation of Extreme Events	Olewiler	Benefit Transfer	1	3
		Wilson	Replacement Cost	687	687
	Pollination	Wilson	Market Price	421	421
			Replacement Cost	239	239
	Recreation and Tourism	Boxall et al.	Travel Cost	0	0
		Haener and Adamowicz	Contingent Valuation	0	0
		Olewiler	Benefit Transfer	0	20
		Shafer et al.	Contingent Valuation	504	504
		Wilson	Contingent Valuation	127	127
	Waste Treatment	Lant et al.	Contingent Valuation	179	1,972
		Wilson	Avoided Cost	34	211
		Zhongwei	Avoided Cost	266	266
Cropland	Aesthetic Information	Bergstrom and Ready	Contingent Valuation	0	2
			Contingent Valuation	0	0
			Travel Cost	0	0
	Air Quality	Wilson	Benefit Transfer	100	100
	Biological Control	Wilson	Benefit Transfer	18	18
	Food	Zhou et al.	Market Price	22	110
	Pollination	Wilson	Benefit Transfer	421	421
	Recreation and Tourism	Knoche and Lupi	Travel Cost	23	27
	Soil Formation	Wilson	Benefit Transfer	3	10
	Soil Retention	Wilson	Benefit Transfer	2	2
Deciduous Forest	Aesthetic Information	Nowak et al.	Replacement Cost	6,104	9,125
	Air Quality	Wilson	Avoided Cost	167	167
	Biological Control	Pimentel et al.	Benefit Transfer	2	2
		Wilson	Replacement Cost	12	14
	Habitat and Nursery	Tanguay et al.	Contingent Valuation	2	6
	Moderation of Extreme Events	Olewiler	Benefit Transfer	1	3
		Wilson	Replacement Cost	687	687
	Pollination	Wilson	Market Price	421	421
			Replacement Cost	239	239

▼ **Table 15. Ecosystem service literature and values used**

Land Cover	Ecosystem Service	Author(s)	Valuation Methodology	Minimum (2014 USD/ acre/year)	Maximum (2014 USD/ acre/year)
Deciduous Forest	Recreation and Tourism	Olewiler	Benefit Transfer	0	20
		Shafer et al.	Contingent Valuation	3	504
		Wilson	Contingent Valuation	127	127
	Waste Treatment	Lant et al.	Contingent Valuation	179	1,972
		Wilson	Avoided Cost	34	211
		Zhongwei	Avoided Cost	266	266
Freshwater Estuary	Aesthetic Information	Berman and Armagost	Hedonic Pricing	252	252
		Young and Shortle	Hedonic Pricing	2	2
	Moderation of Extreme Events	Costanza et al.	Benefit Transfer	348	348
	Recreation and Tourism	Bockstael et al.	Travel Cost	0	5
		Jaworski and Raphael	Market Price	96	96
		Johnston et al.	Travel Cost	259	340
		Kealy and Bishop	Travel Cost	21	21
		Lipton	Contingent Valuation	3	3
		Mullen and Menz	Travel Cost	245	245
		Opaluch. et al.	Contingent Valuation	164	215
		Sohngen et al.	Travel Cost	226,138	536,311
Grassland	Habitat and Nursery	Gascoigne et al.	Contingent Valuation	35	35
	Pollination	Wilson	Market Price	421	421
	Recreation and Tourism	Boxall	Travel Cost	0	0
	Soil Retention	Gascoigne et al.	Avoided Cost	7	7
	Waste Treatment	Zhongwei	Avoided Cost	6,278	10,887
Herbaceous Wetland	Aesthetic Information	Thibodeau and Ostro	Hedonic Pricing	37	118
	Air Quality	Wilson	Avoided Cost	167	167
	Biological Control	Pimentel et al.	Benefit Transfer	2	2
	Energy and Raw Materials	Jaworski and Raphael	Market Price	94	94
	Food	Jaworski and Raphael	Market Price	12	12
	Habitat and Nursery	Poor	Contingent Valuation	87	437
		van Kooten and Schmitz	Contingent Valuation	2	36
		Wilson	Avoided Cost	2,592	2,592
	Moderation of Extreme Events	Roberts and Leitch	Avoided Cost	632	632
		Thibodeau and Ostro	Avoided Cost	6,159	6,159
		Wilson	Benefit Transfer	1,795	1,795
	Recreation and Tourism	Gupta and Foster	Travel Cost	152	303
		Jaworski. and Raphael	Market Price	96	1,321
		Kreutzwiser	Contingent Valuation	170	170
		Roberts and Leitch	Contingent Valuation	7	13
		Shafer et al.	Contingent Valuation	91	91
		Whitehead et al.	Contingent Valuation	35	38

Table 15. Ecosystem service literature and values used

Land Cover	Ecosystem Service	Author(s)	Valuation Methodology	Minimum (2014 USD/ acre/year)	Maximum (2014 USD/ acre/year)
Herbaceous Wetland	Recreation and Tourism	Whitehead et al.	Travel Cost	120	120
		Whitehead et al.	Travel Cost	98	98
		Wilson	Contingent Valuation	127	127
	Waste Treatment	Thibodeau and Ostro	Replacement Cost	4,560	4,560
		Wilson	Avoided Cost	211	211
			Replacement Cost	1,341	1,341
	Water Supply	Roberts and Leitch	Replacement Cost	135	135
Lake	Aesthetic Information	Berman and Armagost	Hedonic Pricing	252	252
		Corrigan et al.	Contingent Valuation	56	56
	Recreation and Tourism	Corrigan et al.	Contingent Valuation	27,295	71,970
	Waste Treatment	Bouwes and Schneider	Travel Cost	292	292
Mixed Forest	Aesthetic Information	Nowak et al.	Replacement Cost	6,104	9,125
	Air Quality	Wilson	Avoided Cost	167	167
	Biological Control	Pimentel et al.	Benefit Transfer	2	2
		Wilson	Replacement Cost	12	14
	Habitat and Nursery	Tanguay et al.	Contingent Valuation	2	6
	Moderation of Extreme Events	Olewiler	Benefit Transfer	1	3
		Wilson	Replacement Cost	687	687
	Pollination	Wilson	Market Price	421	421
			Replacement Cost	239	239
	Recreation and Tourism	Olewiler	Benefit Transfer	0	20
		Shafer et al.	Contingent Valuation	504	504
		Wilson	Contingent Valuation	127	127
	Waste Treatment	Lant et al.	Contingent Valuation	179	1,972
		Wilson	Avoided Cost	34	211
Pasture	Aesthetic Information	Bergstrom and Ready	Contingent Valuation	0	2
			Contingent Valuation	0	0
			Travel Cost	0	0
	Air Quality	Wilson	Benefit Transfer	100	100
	Biological Control	Wilson	Benefit Transfer	18	18
	Pollination	Wilson	Benefit Transfer	421	421
	Soil Formation	Wilson	Benefit Transfer	10	10
	Soil Retention	Wilson	Benefit Transfer	2	6
River	Aesthetic Information	Kulshreshtha and Gillies	Hedonic Pricing	32	874
	Recreation and Tourism	Mathews et al.	Contingent Valuation & Travel Cost	13,843	13,843
Shrub	Recreation and Tourism	Olewiler	Benefit Transfer	0	20
Shrub Wetland	Aesthetic Information	Thibodeau and Ostro	Hedonic Pricing	37	118
	Air Quality	Wilson	Avoided Cost	167	167

Table 15. Ecosystem service literature and values used

Land Cover	Ecosystem Service	Author(s)	Valuation Methodology	Minimum (2014 USD/ acre/year)	Maximum (2014 USD/ acre/year)
Shrub Wetland	Biological Control	Pimentel et al.	Benefit Transfer	2	2
	Energy and Raw Materials	Jaworski and Raphael	Market Price	94	94
	Food	Jaworski and Raphael	Market Price	12	12
	Habitat and Nursery	Poor	Contingent Valuation	87	437
		van Kooten and Schmitz	Contingent Valuation	2	15
		Wilson	Avoided Cost	2,592	2,592
	Moderation of Extreme Events	Roberts and Leitch	Damage Cost Avoided	632	632
		Thibodeau and Ostro	Avoided Cost	6,159	6,159
		Wilson	Benefit Transfer	1,795	1,795
	Recreation and Tourism	Gupta and Foster	Travel Cost	152	303
		Jaworski and Raphael	Market Price	96	1,321
		Kreutzwiser	Contingent Valuation	170	170
		Olewiler	Benefit Transfer	0	20
		Roberts and Leitch	Contingent Valuation	7	13
		Shafer et al.	Contingent Valuation	91	91
		Wilson	Contingent Valuation	127	127
	Waste Treatment	Lant et al.	Contingent Valuation	179	1,972
		Thibodeau and Ostro	Replacement Cost	4,560	4,560
		Wilson	Avoided Cost	211	211
			Replacement Cost	1,341	1,341
	Water Supply	Roberts and Leitch	Replacement Cost	135	135
Woody Wetland	Aesthetic Information	Thibodeau and Ostro	Hedonic Pricing	37	118
	Air Quality	Wilson	Avoided Cost	167	167
	Biological Control	Pimentel et al.	Benefit Transfer	2	2
	Energy and Raw Materials	Jaworski and Raphael	Market Price	94	94
	Food	Jaworski and Raphael	Market Price	12	12
	Habitat and Nursery	Poor	Contingent Valuation	87	437
		van Kooten and Schmitz	Contingent Valuation	2	15
		Wilson	Avoided Cost	2,592	2,592
	Moderation of Extreme Events	Roberts and Leitch	Avoided Cost	632	632
		Thibodeau and Ostro	Avoided Cost	6,159	6,159
		Wilson	Benefit Transfer	1,795	1,795
	Recreation and Tourism	Gupta and Foster	Travel Cost	152	303
		Jaworski and Raphael	Market Price	96	1,321
		Kreutzwiser	Contingent Valuation	170	170
		Olewiler	Benefit Transfer	0	20
		Roberts and Leitch	Contingent Valuation	7	13
		Shafer et al.	Contingent Valuation	91	91
		Wilson	Contingent Valuation	127	127

Table 15. Ecosystem service literature and values used

Land Cover	Ecosystem Service	Author(s)	Valuation Methodology	Minimum (2014 USD/ acre/year)	Maximum (2014 USD/ acre/year)
Woody Wetland	Waste Treatment	Lant et al.	Contingent Valuation	179	1,972
		Thibodeau and Ostro	Replacement Cost	4,560	4,560
		Wilson	Avoided Cost	211	211
			Replacement Cost	1,341	1,341
		Zhongwei	Avoided Cost	266	267
	Water Supply	Roberts and Leitch	Replacement Cost	135	135

Carbon Sequestration Studies and Values Used

Black, T.A., Chen, W.J., Barr, A.G., Arain, M.A., Chen, Z., Nesic, Z., Hogg, E.H., Neumann, H.H., Yang, P.C., 2000. Increased carbon sequestration by a boreal deciduous forest in years with a warm spring. Geophys. Res. Lett. 27, 1271–1274.

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Chen, W.J., Black, T.A., Yang, P.C., Barr, A.G., Neumann, H.H., Nesic, Z., Blanken, P.D., Novak, M.D., Eley, J., Ketler, R.J., Cuenca, R., 1999. Effects of climatic variability on the annual carbon sequestration by a boreal aspen forest. Glob. Chang. Biol. 5, 41–53.

Malmer, N., Johansson, T., Olsrud, M., Christensen, T.R., 2005. Vegetation, climatic changes and net carbon sequestration in a North-Scandinavian subarctic mire over 30 years. Glob. Chang. Biol. 11, 1895–1909. doi:10.1111/j.1365-2486.2005.01042.x

Schuman, G.E., Janzen, H.H., Herrick, J.E., 2002. Soil carbon dynamics and potential carbon sequestration by rangelands. Environ. Pollut. 116, 391–6.

Smith, J.E., Heath, L.S., Skog, K.E., Birdsey, R.A., 2006. Methods for Calculating Forest Ecosystem and Harvested Carbon with Standard Estimates for Forest Types of the United States.

Smith, W.N., Desjardins, R.L., Grant, B., 2001. Estimated changes in soil carbon associated with agricultural practices in Canada. Can. J. Soil Sci. 81, 221–227.

Table 16. Carbon sequestration literature and values used

Land Cover	Author(s)	Minimum ($/acre/ year)	Maximum ($/acre/ year)
Cropland	Smith, W.N. et al.	2	36
Deciduous forest	Black, T.A. et al.	46	167
	Chen, W.J. et al.	75	115
	Smith, J.E. et al.	66	475
Evergreen Forest	Smith, J.E. et al.	66	751
Grassland	Malmer, N. et al.	107	107
Herbaceous wetland	Bridgeham, S.D. et al.	10	10
Pasture	Schuman, G.E. et al.	6	35
Shrub	Malmer, N. et al.	12	27
Shrub wetland	Malmer, N. et al.	32	32
Woody wetland	Bridgeham, S.D. et al.	8	11

Carbon Storage Studies and Values Used

Bridgham, S.D., Megonigal, J.P., Keller, J.K., Bliss, N.B., Trettin, C., 2006. The Carbon Balance of North American Wetlands. Wetlands 26, 889–916.

Davies, Z.G., Edmondson, J.L., Heinemeyer, A., Leake, J.R., Gaston, K.J., 2011. Mapping an urban ecosystem service: Quantifying above-ground carbon storage at a city-wide scale. J. Appl. Ecol. 48, 1125–1134. doi:10.1111/j.1365-2664.2011.02021.x

Heath, L.S., Smith, J.E., Birdsey, R.A., 2003. Chapter 3: the potential of US forest soils to sequester carbon, in: Carbon Trends in US Forestlands: A Context for the Role of Soils in Forest Carbon Sequestration. pp. 35–45.

Manley, J., van Kooten, G.C., Moeltner, K., Johnson, D.W., 2005. Creating carbon offsets in agriculture through no-till cultivation: a meta-analysis of costs and carbon benefits. Clim. Change 68, 41–65.

Ryals, R., Silver, W.L., 2013. Effects of organic matter amendments on net primary productivity and greenhouse gas emissions in annual grasslands. Ecol. Appl. 23, 46–59.

Smith, J.E., Heath, L.S., Skog, K.E., Birdsey, R.A., 2006. Methods for Calculating Forest Ecosystem and Harvested Carbon with Standard Estimates for Forest Types of the United States.

Tufekcioglu, A., Raich, J.W., Isenhart, T.M., Schultz, R.C., 2003. Biomass, carbon and nitrogen dynamics of multi-species riparian buffers within an agricultural watershed in Iowa , USA. Agrofor. Syst. 57, 187–198.

Wilson, K., Smith, E., 2015. Marsh Carbon Storage in the National Estuarine Research Reserves, USA. Montreal, Canada.

Table 17. Carbon storage literature and values used

Land Cover	Author(s)	Minimum ($/acre)	Maximum ($/acre)
Cropland	Manley, J. et al.	502	1,731
Deciduous Forest	Smith, J.E. et al.	4,314	20,228
	Tufekcioglu, A. et al.	386	386
Evergreen Forest	Heath, L.S. et al.	15,155	15,155
	Smith, J.E. et al.	5,334	25,153
Grassland	Tufekcioglu, A. et al.	294	455
Herbaceous Wetland	Wilson, K. and Smith, E.	1,152	8,064
Pasture	Ryals, R. and Silver, W.L.	161	179
Shrub	Davies, Z.G. et al.	3,836	9,233
	Heath, L.S. et al.	6,082	6,082
Woody wetland	Bridgeham, S.D. et al.	60,187	83,048

Appendix D. GIS Sources Used and Limitations

Watershed boundaries for the St. Louis and Cloquet River
Coordinated effort between the United States Department of Agriculture-Natural Resources Conservation Service (USDA-NRCS), the United States Geological Survey (USGS), and the Environmental Protection Agency (EPA). Watershed Boundary Dataset for the St. Louis River and Cloquet River watersheds. http://datagateway.nrcs.usda.gov.

Land cover acreage
NOAA Coastal Change Analysis Program Regional Land Cover Database. National Oceanic and Atmospheric Administration Office for Coastal Management, Charleston.

Urban Boundaries
2010 Census Urban Area. United States Census Bureau. https://www.census.gov/geo/reference/ua/uafaq.html.

Riparian Buffers
NOAA Coastal Change Analysis Program Regional Land Cover Database. National Oceanic and Atmospheric Administration Office for Coastal Management, Charleston.

Lakes and Streams
Minnesota DNR Division of Fisheries. "MN DNR 100K Lakes and Rivers." 2002.

Estuary
NOAA Coastal Change Analysis Program Regional Land Cover Database. National Oceanic and Atmospheric Administration Office for Coastal Management, Charleston.

GIS Limitations

- GIS Data. Since this valuation approach involves using benefit transfer methods to assign values to land cover types based, in some cases, on the context of their surroundings, one of the most important issues with GIS quality assurance is reliability of the land cover maps used in the benefits transfer, both in terms of categorical precision and accuracy.

- Presettlement vegetation. This data layer was captured from the recompiled version of the Marschner Map and contains omission of many small polygons. The data also exhibits significant positional off-sets, of up to one thousand feet in places. The authors of this dataset advise caution when using this data.

- Ecosystem Health. There is the potential that ecosystems identified in the GIS analysis are fully functioning to the point where they are delivering higher values than those assumed in the original primary studies, which would result in an underestimate of current value. On the other hand, if ecosystems are less healthy than those in primary studies, this valuation will overestimate current value.

- Spatial Effects. This ecosystem service valuation assumes spatial homogeneity of services within ecosystems, i.e. that every acre of forest produces the same ecosystem services. This is clearly not the case. Whether this would increase or decrease valuations depends on the spatial patterns and services involved. Solving this difficulty requires spatial dynamic analysis. More elaborate system dynamic studies of ecosystem services have shown that including interdependencies and dynamics leads to significantly higher values,(Boumans et al., 2002) as changes in ecosystem service levels cascade throughout the economy.

- Land Cover Change. Because of the land cover class definition changes between the pre-settlement data and the current C-CAP classification, the classes still aggregate differently and do not provide an accurate change categorization, particularly in small-scale cases. Though not advised, this comparison was still made in this report.

Exhibit L.1.

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