Nature's Value in the Skykomish Watershed:

A Rapid Ecosystem Service Valuation

December 2011

EARTH ECONOMICS

December 2011

Suggested Citation:

Schmidt, R., Batker, D., Harrison-Cox, J. 2011. Nature's Value in the Skykomish Watershed: A Rapid Ecosystem Service Valuation. Earth Economics, Tacoma, WA.

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Acknowledgments

This study was conducted with generous support from The Bullitt Foundation. Earth Economics would like to thank all who supported this project. Thank you to Laura Audette and Snohomish County for donating GIS data to the project, and for continued support of this work in the Snohomish Basin. Thank you to Trout Unlimited and The Wilderness Society for providing valuable information on the study site. Thanks also to our Board of Directors, Joshua Reyneveld, Ingrid Rasch, David Cosman and Joshua Farley for your continued leadership and support of Earth Economics.

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Abstract

This document presents an ecological economic characterization of the Skykomish Watershed, located in western Washington State, United States of America. Identifying and valuing nature's contribution to the economy enables better decisions that improve local and regional quality of life. The study introduces the watershed, its geography and other relevant features. Using benefit transfer methodology and Geographic Information Systems (GIS) data, the ecosystem services of the Skykomish Watershed are identified and valued.

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"As long as we are forced to make choices, we are going through the process of valuation."

-Robert Costanza

Executive Summary

This study examines the economic value of the Skykomish Watershed, which spans glaciers, forests, streams, wetlands, grasslands and agricultural lands, which all provide economically valuable goods and services. Nature's goods include fish, timber, drinking water and agricultural products, while services include flood protection, drinking-water filtration, local weather and climate stability, beauty and recreation.

For this study, the Skykomish Watershed was divided into 10 land cover types: Agricultural Lands, Forest, Grasslands, Lakes/Rivers, Pasture, Riparian Buffer, Shrub/Scrub, Urban Green Space, Wetland and Other. Each land cover across the Skykomish Watershed produces a unique suite of ecosystem services. These services were identified, and a subset were valued with dollar estimates based on eight valuation techniques, including market value, cost avoidance and contingent valuation. The ecosystem services examined include climate stability, flood protection, water filtration and supply, wildlife habitat, pollination, soil erosion control, soil formation, biological control, nutrient cycling, aesthetic and recreational value.

The results are compelling. By reducing the frequency and severity of floods, supplying water, buffering climate instability, supporting fisheries and food provisioning, maintaining critical habitat, enhancing recreation and providing waste treatment, among other benefits, the **Skykomish Watershed ecosystems provide between $245 million and $3.3 billion in benefits to the regional economy every year.**

This large range in values represents an appraisal of the Skykomish Watershed's natural capital, similar to a house or business appraisal. This appraisal replaces the former estimate of zero that has been the default value of ecosystems in the Skykomish Watershed. As further studies are added to the Earth Economics database, and as spatial mapping of the watershed's ecosystem services is completed, this range in values will narrow. A limited range of the known ecosystem services on each land cover were valued in this study, thus the low end of the range provided can be considered a baseline value.

Ecosystem services may also be treated like economic assets, as they provide a stream of benefits over time, similar to bridges, roads or other built infrastructure. Valued as such, a discount rate may be applied to these services, allowing for calculation of the present value (or asset value) of these systems. If treated like an asset with a lifespan of 100 years, the asset value of the Skykomish Watershed is between $5.8 billion and $79.5 billion at a 4.125% discount rate. **Using a 0% discount rate, which recognizes the renewable nature of natural capital and that people 100 years from now will enjoy the same level of benefits, the Skykomish Watershed has an asset value of between $24 billion and $334 billion.**

Watersheds house economies, and provide foundational economic goods and services. Healthy watersheds enable cities, communities, households and their residents to thrive. However, society has underinvested in watersheds. When free flood protection provided by natural systems is lost, the flood protection service must be replicated with levees, and flooded houses fixed. When salmon, drinking water, storm water conveyance, local climate regulation and other benefits disappear, the economy suffers from both the direct damage and the expensive tax districts and construction costs that are needed to replace natural capital.

Study Objectives

- Introduce the Skykomish Watershed and show the connections between its ecosystems and the regional economy (Part I).
- Identify and describe the ecosystem goods and services produced in the Skykomish Watershed (Part II).
- Determine the economic value of ecosystem goods and services produced in the Skykomish Watershed (Part III).
- Discuss how the value of ecosystem services can be used to improve natural resource management in the Skykomish Watershed and promote economic advancement, salmon recovery, and flood risk reduction, with specific recommendations for decision-makers (Part IV).

Recommended Next Steps

Natural assets are not indestructible and they are under pressure in the Skykomish Watershed. The following steps will ensure a flow of economic value continues in perpetuity:

- **Protect and Restore Natural Capital.** Consider both the conservation and the restoration of the Skykomish Watershed ecosystems as a key investment in the future economy as supported by green infrastructure. This appraisal of value is defensible and applicable to decision-making at every jurisdictional level.

- **Apply Ecosystem Service Valuation to Support Funding Investment in Natural Assets.** Ecosystem service valuation can provide governments, organizations, and private owners a way to calculate the rate of return on conservation and restoration investment. Beginning in late 2012, values in this report can be regularly updated using the Earth Economics' SERVES (Simple Effect Resource for Valuing Ecosystem Services) web-based tool which can be accessed from www.eartheconomics.org.

- **Adopt an Ecosystem Services Approach to Rural Economic Development.** By including sustainable forestry, forest product development, agriculture, and access to quality outdoor recreation in economic development planning, long-term and sustainable jobs can be identified, quantified and secured. Restoration projects can and should be effectively linked to economic advancement, sustainability and long-term job creation.

- **Review Institutional Options for Planning and Management of Natural Assets.** Ecosystem services can be a guide for improvement by setting a context wherein alternative goals, such as salmon restoration, flood control, storm water conveyance and water quality can be simultaneously improved, thus avoiding infrastructure conflict. Skykomish Watershed leaders should facilitate discussions about institutional improvements that facilitate the coordination of watershed activities including flood risk reduction, salmon habitat restoration, drinking water, water quality, climate adaptation, and forest stewardship by public and private landowners. Earth Economics is working with county, city and other agency reps in the Green/ Duwamish River Watershed, Cedar River Watershed, Snohomish Watershed, Puyallup River Watershed and Nisqually Watershed to develop the concept of a Watershed Investment District as an example of a new institution to manage natural capital. Such an institution would be positioned to take advantage in emerging ecosystem service markets to generate funding for investment in the Skykomish Watershed's natural capital, while also creating a mechanism for incentive funding for stewardship practices on private land through Payments for Ecosystem Services. Adopting an integrated approach saves money and provides greater benefits for Skykomish Watershed residents and other communities in the region.

Part I. The Skykomish Watershed

Nothing explains the explosive growth of the Upper Skykomish Valley beginning about 1890 better than a paraphrase of James Carville's now famous political expression: It's the economy, stupid. For Skykomish Valley, it was economics, plain and simple. The decision to route the Great Northern Railway along the South Fork of the Skykomish River and the discovery of a large deposit of galena (lead ore) above the North Fork triggered an economic frenzy that totally transformed the upper valley within two decades.

- *From "Upper Skykomish Valley," by Warren Carlson and the Skykomish Historical Society.*[1]

Geography

The Skykomish Watershed is located in the Puget Sound region of Washington State, and spans the rocky peaks of the Cascade crest to broad river valleys in the Puget Sound Lowland. The 535,000 acre (836 sq. mi) watershed drains the Skykomish River and its tributaries, including North Fork Skykomish, South Fork Skykomish, Sultan, Tye, Foss and Miller Rivers. The Skykomish Watershed is part of the Snohomish Basin, the second largest watershed in Washington State.[a] The Skykomish Watershed was carved through many glaciations, most recently during the Vashon Glaciation about 15,000 years ago.[2] Today, just a few glaciers remain in the watershed, and these have declined in surface area from 1.5 sq. mi to 0.8 sq. mi since 1958.[3]

History

The name "Skykomish" is derived from the Northern Lushootseed word *sq'íxʷəbš*, meaning "upriver people."[4] At the time of European contact in the 1850s, seven permanent village sites were located in the Skykomish Valley, between present-day Monroe and Index. During the summer months, temporary camps (for hunting and berry-gathering) were also set up further along the river. As signatories to the treaty of Point Elliot in 1855, most of the Skykomish people moved to the Tulalip Reservation. However, some remained in the Skykomish Valley, and a village of approximately 240 people remained near Gold Bar until about 1900.[5]

The Skykomish Watershed was greatly affected by the Great Northern Railway and the development it brought. Following a route across Steven's Pass and along the South Fork of the Skykomish River, the Great Northern Railway was built to exploit the seemingly endless stands of timber and mineral reserves in the Pacific Northwest, and to establish a trade route with Asia. Most of the towns in the Skykomish Watershed were initially formed to support the railway. Today mining and logging no longer dominate the Skykomish Watershed economy, and recreational activities such as rafting, skiing, and fishing, have become more important.[1]

Natural Resources Management

Lands of the Skykomish Watershed are managed by a number of jurisdictions, including private landowners; the municipalities of Monroe, Sultan, Gold Bar, Index and Skykomish; Snohomish and King Counties; the Tulalip Tribes; state and federal government; and the City of Everett (for drinking water supply). Compared to many watersheds in Puget Sound, the Skykomish Watershed contains large tracts of pristine land, including federally designated wilderness lands. In 2008 for example, the Wild Sky Wilderness was approved by the U.S. Congress, creating 106,000 acres of federal wilderness lands north of the Town of Skykomish. This area was the first new wilderness area in Washington State for 24 years, and is now protected from activities such as mining, logging, and the passage of motor vehicles.[6]

Regional Biodiversity

Biodiversity is the variety of life in a given area.[b] Biodiversity is critical to the health and resilience of most ecosystems that humans rely on for survival.[7] In 2005, the Center for Biological Diversity and Friends of the San Juans completed an extensive assessment

a The Snohomish Basin is also identified as Water Resource Inventory Area 7 (WRIA 7).

b Biodiversity is more technically defined as the diversity of multiple levels of biological organization at multiple scales of space and time (Marcot, 2006).

of the Puget Sound Basin's biodiversity that identified the presence of at least 7,013 species, including 4,248 animals, 1,504 plants, 851 fungi and 392 algae. The Puget Sound was thus confirmed as a hotspot for biological diversity in the United States, containing more species than 31 other states combined.[8] The Skykomish Watershed is part of the Puget Sound, and contains key habitats that were identified in the report to house substantial biodiversity. Habitats include old growth forest, rivers and streams, alpine meadows, and freshwater wetlands.

Salmon

Salmon are one species that have played an important role in the social, cultural and spiritual identity of the Skykomish Watershed and the Pacific Northwest for millennia. Fish harvests have always been a central part of the people of the Tulalip Tribe's way of life. Skykomish Chinook are one important population of salmon within the Puget Sound. Most of the Skykomish Chinook spawn in the mainstems of the Skykomish River, and in the Lower Sultan and Upper South Fork Skykomish.[9] An estimated 51,000 Chinook salmon once returned to the Skykomish River. However, between 1999 and 2003, the average number returning to spawn was about 1,700, or 3.3% of the historic level. The Skykomish Watershed also houses several other salmonid species, including four local populations of bull trout and two populations of coho.[10]

Part II. Ecosystem Services in the Skykomish Watershed

Ecosystem services are the benefits that humans receive from nature.[11] Ecosystems perform many functions, but only functions that provide human benefits are considered ecosystem services. Humans need ecosystem services for survival, including breathable air, drinkable water, nourishing food, flood protection, treatment of waste, and stable atmospheric conditions. Ecosystems from forests to wetlands produce a suite of such services.

The benefits of ecosystem services are similar to the economic benefits typically valued in the economy, such as those of skilled workers, buildings and infrastructure. When ecosystem services are lost, economic impacts can be measured in terms of job loss, infrastructure cost, restoration cost and loss of property due to storm events (such as flooding).

Healthy, functioning natural capital is critical to the production of ecosystem services. The natural capital of an ecosystem consists of its structural components, such as trees, forests, soil, and hill slopes. Natural capital produces dynamic processes (water flows, nutrient cycling, animal life cycles, etc.), which in turn create functions (water catchment, soil accumulation, habitat creation, etc.) that generate ecological goods and services (salmon, timber, flood protection, recreation, etc.). This relationship is summarized in Figure 1.

Ecosystem services were recently given higher prominence in the Millennium Ecosystem Assessment (MEA), a project initiated in 2000 by then United Nations Secretary-General Kofi Annan and completed in 2005.[c] The MEA examined the worldwide changes in ecosystems, their impacts on human well-being, and options for enhancing the conservation of ecosystems and their contribution to human well-being. The project, involving over 1,360 experts worldwide and a multi-stakeholder board representing governments, businesses, NGOs, indigenous peoples and international institutions,

Figure 1 - The Link between Natural Infrastructure and Ecosystem Goods and Services

c Information on this project is available at http://www.maweb.org/en/index.aspx.

utilized the concept of ecosystem services to better understand the linkages between ecosystems and human well-being.

Today, a number of federal agencies in the United States, including the Environmental Protection Agency, the United States Geological Service, and the United States Department of Agriculture house dedicated ecosystem services departments to advance understanding of how ecosystem services can be promoted to improve long-term economic prosperity for the nation. Agencies like the Federal Emergency Management Agency (FEMA) are developing tools to include ecosystem services in their benefit-cost calculations that dictate their floodplain policy, including grants and loans. Large private corporations such as PUMA and Dow Chemical have also begun to account for their impact on ecosystem services, for example through disclosure in their profit and loss statements.[d]

Ecosystems provide a wide variety of valuable public goods and services at the least cost over long periods of time, and in most cases they are the best systems for producing such goods and services. It would be impractical, and in some cases impossible and simply undesirable, to replace these economically valuable natural systems with more costly and less efficient capital substitutes. When ecosystems are valued as assets and brought to the center of economic decision-making, their cost-effective services are less likely to be lost.

Ecosystem services can be categorized in different ways. This study follows the approach developed by de Groot and colleagues,[12] dividing 23 ecosystem services into four functional categories: Regulating Services, Habitat Services, Provisioning Services and Information Services. This approach is consistent with the MEA, as well as much of the scientific and economic literature. The four categories of ecosystem services are described below and summarized in Table 1.

- **Provisioning services** provide basic goods including food, water and materials. Forests grow trees that can be used for lumber and paper, wild and cultivated crops provide food, and other plants may be used for medicinal purposes. Rivers provide fresh water for drinking and fish for food. The coastal waters provide fish, shellfish and seaweed.

- **Regulating services** are benefits obtained from the natural control of ecosystem processes. Intact ecosystems provide regulation of climate, water, soil, flood and storms, and keep disease organisms in check.

- **Habitat services** provide refuge and reproduction habitat to wild plants and animals and thereby contribute to the (in situ) conservation of biological and genetic diversity and evolutionary processes.

- **Information services** provide humans with meaningful interaction with nature. These services include spiritually significant species and natural areas, places for recreation, and educational opportunities through science.

d http://safe.puma.com/us/en/2011/05/puma-announces-results-of-unprecedented-environmental-profit-loss/ (accessed October 15, 2011).

Table 1 - Categories of Ecosystem Services

	Good/Service	Economic Benefit to People
Provisioning	Water Supply	Water for human consumption, irrigation, and industrial use.
	Food	Food for human consumption.
	Raw Materials	Biological materials used for clothes, fuel, art, and building. Geological materials used for energy, construction, or other purposes.
	Genetic Resources	Genetic material and evolution in wild plants and animals.
	Medicinal Resources	Biological materials used for medicines.
	Ornamental Resources	Ornamental and companion uses (flowers, plants, pets, and other).
Regulating	Gas Regulation	Generation of atmospheric oxygen, regulation of sulfur dioxide, nitrogen carbon dioxide, and other gaseous atmospheric components.
	Climate Regulation	Regulation of global and local temperature, climate, and weather, including evapotranspiration, cloud formation, and rainfall.
	Disturbance Prevention	Protection from floods, storms, and drought.
	Soil Retention	Erosion protection provided by plant roots and tree cover.
	Water Regulation	Water absorption during rains and release in dry times, temperature and flow regulation for people, plants, and animals.
	Biological Control	Natural control of diseases and pest species.
	Waste Treatment	Absorption of organic waste, natural water filtration, pollution reduction.
	Soil Formation	Formation of sand and soil from decaying vegetation and erosion.
	Pollination	Fertilization of plants and crops through natural systems.
	Nutrient Regulation	Transfer of nutrients from one place to another; transformation of critical nutrients from unusable to usable forms.
Habitat	Habitat Refugium	Providing habitat for plants and animals and their full diversity.
	Nursery	Growth by plants provides basis for all terrestrial and most marine food chains.
Information	Aesthetic Information	The role which natural beauty plays in attracting people to live, work, and recreate in an area.
	Recreation and Tourism	The contribution of ecosystems and environments in attracting people to engage in recreational activities.
	Scientific and Educational Value	The value of natural systems for scientific research and education.
	Spiritual and Religious Experience	The use of nature for religious and spiritual purposes.
	Cultural and Artistic Information	The value of nature for cultural purposes.

The Skykomish Watershed produces all 23 services identified in Table 1. Several specific examples follow.

Raw Materials

The watershed holds abundant natural resource raw materials, such gravel deposits, that result from the encroaching and retreating glaciers that sculpted Western Washington over the past several millennia. Aggregate products like gravel are important in construction; for example, a single mile of freeway typically contains 35,000 tons of aggregate.[13] Quality deposits of gravel are located in a roughly 25-mile-wide band along the rim of the Puget Sound, and some of the coarsest remaining gravel accumulation occurs in the Skykomish Valley, immediately above the Skykomish River's confluence with the Snoqualmie River. This gravel is among the most highly valued remaining aggregate material and is less prone to break down and contribute sediment to adjacent stream channels when used in road surfaces.[14]

Water Supply

Water supply is another important provisioning service in the Skykomish Watershed. Snohomish County residents receive water captured and largely filtered by natural systems. For example, the Sultan River, a tributary of the Skykomish, supplies the City of Everett with drinking water. The river is fed by rain and snowmelt captured by the Sultan Basin, which covers 84 square miles of steep mountain terrain. The City of Everett first purchased the water rights to the Sultan River in 1915. At that time, there were no reservoirs and the water was taken directly from the river and transported to town through large wood-stave and steel pipes. The Sultan River now flows into Spada Lake Reservoir, which holds an average of 50 billion gallons of fresh drinking water.[15] Today the Sultan Basin remains one of the wettest and best-protected watersheds in the Puget Sound.

Flood Protection

The Skykomish Watershed provides crucial disturbance regulation to the local and regional economy. Headwater forests to lowland wetlands and aquifers provide critical water regulation and storage that reduce flooding for downstream urban and rural residents as far as the City of Everett. Forests continue to provide the majority of flood protection in the watershed, although man-made levees are very important, too.

Nutrient Regulation

The regulation of nutrients is another important service and often overlooked. For example, salmon enhance local ecosystems in the Skykomish Watershed by moving nutrients into creeks and rivers such as the Lower Sultan River. Salmon spend most of their lives in the nutrient-rich northern Pacific Ocean, where they accumulate carbon, nitrogen, phosphorous and other micronutrients in their body tissue. When they return to spawn and die, these marine-derived nutrients are released into the freshwater river system, providing an important "energy subsidy" to nutrient-poor rivers and streams.[16; 17] This process is vital to the biological productivity and health of inland streams and riparian vegetation.[18-20]

Part III. Valuation of the Skykomish Watershed

The economy of the Skykomish Watershed cannot be understood without examining the contribution of natural capital as well as its associated flows of ecosystem services to the economy and well-being of people. Our economy and communities reside within the landscape as part of the environment. However, most decisions are made without considering the explicit contribution of functioning ecosystems to economic activity and output. To improve economic decision-making, interest in identifying, describing, and quantifying the value of ecosystem services has grown tremendously over the past 20 years.[21-23]

To estimate the value of ecosystem services produced in the Skykomish Watershed, Earth Economics first identified the ecosystem services present across the watershed using Geographical Information Systems (GIS) data provided by Snohomish County. Existing peer-reviewed ecosystem service valuation studies were then selected from our database and applied to the Skykomish Watershed. Each land cover in the watershed was assigned a total high and low annual per-acre dollar value for its ecosystem services. Values were summed across all land covers, resulting in a total annual flow of value for the Skykomish Watershed.

Land Cover

The spatial distribution of goods and services produced in a region's economy can be mapped across the landscape. Mapping goods and services provided by factories, restaurants, schools and businesses provides a view of the region's economy. For example, retail, residential and industrial areas occur in different parts of the landscape. The economic value of these goods and services, from housing to industry, can be estimated with market or appraisal values. The distribution of ecosystem services provided in the Skykomish Watershed is comparable. Each land cover, from wetland to forest to agricultural land, provides a known suite of ecosystem services. For example, wetlands provide flood risk reduction, biodiversity, climate regulation, salmon habitat, and numerous other services.

To identify ecosystem services present, GIS data was used to determine land cover across the Skykomish Watershed. GIS data is gathered through aerial and/or satellite photography. Snohomish County's 2006 Landsat data was used as the base GIS layer and combined with several other layers: Snohomish County Waterbodies and Watercourse Layers; National Wetlands Inventory (NWI) layer; King and Snohomish County Designated and Non-Designated Agricultural layers; and the Snohomish County Urban Growth Area boundaries. These layers represent the best available GIS data for the Skykomish Watershed.

For the purposes of this study, each section of the watershed was assigned to one of 10 land covers: Agricultural Lands; Forest; Grasslands; Lakes/Rivers; Pasture; Riparian Buffer; Shrub/Scrub; Urban Green Space; Wetland; and Other. A description of each land cover and its total acreage is provided in Table 2, with references to the base GIS layer, Snohomish Landsat data, in Table 3. Figure 2 presents a map of land cover in the Skykomish Watershed.

Figure 2 - Land Cover in the Skykomish Watershed

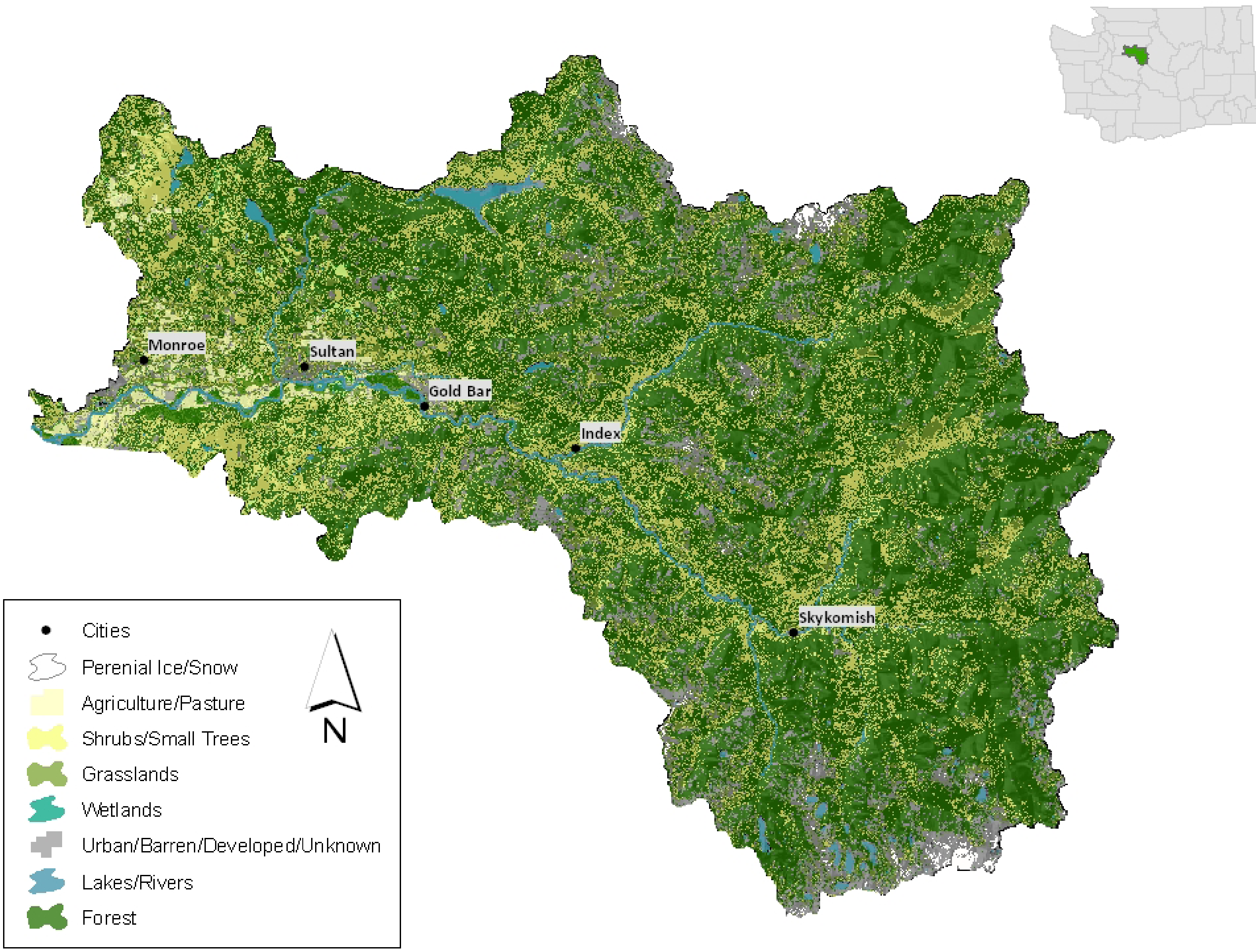

Table 2 - Land Cover Descriptions and Acreage in the Skykomish Watershed

Land Cover	Acreage	Description and Layer(s) Used
Agriculture	449	Designated and Non-Designated Agriculture layers minus Pasture.
Forest	279,803	Landsat 1, 2, 3 minus Riparian Buffer 1, 2, 3 minus Urban Green Space 1, 2, 3.
Grasslands	33,555	Landsat 5 minus Designated and Non-Designated Agricultural Wetland layers minus NWI Wetland layer minus Pasture (Grasslands in Snohomish County 2006 Landsat report include Pasture and Wetland).
Lakes/Rivers	8,981	Snohomish County Waterbodies and Watercourses layer.
Pasture	7,876	Designated and Non-Designated Agriculture layers containing Pasture.
Riparian Buffer	19,642	Landsat 1, 2, 3 within a 50-foot buffer of Lakes/Rivers.
Shrub/Scrub	121,680	Landsat 4 minus Urban Green Space 4.
Urban Green Space	2,126	Landcover 1, 2, 3, 4 within the Urban Growth Area boundary.
Wetland	10,917	NWI Wetland layer and Designated and Non-Designated Agriculture layer containing wetlands .
Other	50,043	Landsat 6, 7, 8, 9, 11.
TOTAL	**535,072**	

Table 3 - Snohomish County 2006 Landsat Data Codes

Landsat Code	Land Cover Class
1	Mature Evergreen Forest
2	Medium Evergreen Forest
3	Deciduous Stands
4	Shrub/ small trees
5	Grass
6	Bare Ground
7	Medium Density Development
8	High Density Development
9	Alpine Rock/ Talus Slope
10	Open Water
11	Unknown

Benefit Transfer Methodology

Benefit Transfer Methodology (BTM) was used to estimate the value of ecosystem services produced across each land cover in the Skykomish Watershed. BTM is used when the cost of conducting original studies on every site for every vegetation type is prohibitive. BTM is a widely accepted economic methodology in which the estimated economic value of an ecological good or service is determined by examining previous valuation studies of similar goods or services in other comparable locations.

The "transfer" refers to the application of derived values and other information from the original study site to a new but sufficiently similar site, like a house or business "comp."[24; 25] As the "bedrock of practical policy analysis",[26] BTM has gained popularity in the last several decades as decision-makers have sought timely and cost-effective ways to value ecosystem services and natural capital.[27]

Earth Economics maintains and is continually expanding a database of published, peer-reviewed ecosystem service valuation studies for use in benefit transfer studies. The valuation techniques used to derive the values in the database studies were primarily developed within the disciplines of environmental and natural resource economics. As Table 4 indicates, these techniques include direct market pricing, replacement cost, avoided cost, factor income method, travel cost, hedonic pricing and contingent valuation.

Table 4 - Valuation Methods Used to Value Ecosystem Services in Primary Studies

Avoided Cost (AC): services allow society to avoid costs that would have been incurred in the absence of those services; for example storm protection provided by barrier islands avoids property damages along the coast.

Replacement Cost (RC): services can be replaced with man-made systems; for example waste treatment provided by wetlands can be replaced with costly built treatment systems.

Factor Income (FI): services provide for the enhancement of incomes; for example water quality improvements increase commercial fisheries catch and therefore fishing incomes.

Travel Cost (TC): service demand may require travel, which have costs that can reflect the implied value of the service; recreation areas can be valued at least by what visitors are willing to pay to travel to it, including the imputed value of their time.

Hedonic Pricing (HP): service demand may be reflected in the prices people will pay for associated goods, for example housing prices along the coastline tend to exceed the prices of in land homes.

Marginal Product Estimation (MP): service demand is generated in a dynamic modeling environment using a production function (Cobb-Douglas) to estimate the change in the value of outputs in response to a change in material inputs.

Contingent Valuation (CV): service demand may be elicited by posing hypothetical scenarios that involve some valuation of alternatives; for instance, people generally state that they are willing to pay to pay for increased preservation of beaches and shoreline.

Group Valuation (GV): this approach is based on principles of deliberative democracy and the assumption that public decision making should result, not from the aggregation of separately measured individual preferences, but from open public debate.

Adapted from Farber et al., 2006

Due to limitations in the range of primary valuation studies conducted on ecosystem services, not all ecosystem services that were identified on each land cover could be assigned a known value from the database. For example, the land cover class "Urban Green Space" has only been valued for four ecosystem services: gas and climate regulation, aesthetic and recreational value, water regulation, and science and education. Yet, areas with urban green space also provide biological control, disturbance prevention, nutrient cycling, and a number of other important benefits. Table 5 provides a matrix that summarizes the suite of ecosystem services identified on each land cover in the Skykomish Watershed, compared with those actually valued in this study.

A total of 23 ecosystem services were identified in the Skykomish Watershed across 10 land covers. Valuation was possible for between 5 and 20 services on a given land cover, depending on the available studies. Table 5 suggests that because a large number of ecosystem services (for most land covers) have yet to be valued in a primary study, this valuation provides a significant underestimate of the true value. As further primary studies are added to the database, the known value of ecosystem services in the Skykomish Watershed will rise.

Table 5 - Ecosystem Services Valued and/or Identified in the Skykomish Watershed

	Agricultural Lands	Forest	Grasslands	Lakes/Rivers	Pasture	Riparian Buffer	Shrub/Scrub	Urban Green Space	Wetland
Provisioning Services									
Food		X	X						X
Raw Materials		X							X
Genetic Resources		X							
Medicinal Resources						X			
Ornamental Resources		X							
Regulating Services									
Gas Regulation	X	X	X			X	X	X	X
Climate Regulation	X	X	X			X	X	X	X
Disturbance Prevention	X	X				X			X
Soil Retention	X	X	X				X		
Water Regulation		X	X			X	X	X	X
Water Supply		X		X		X			X
Biological Control	X	X	X		X		X		
Water Quality, Waste Treatment		X	X						X
Soil Formation	X	X	X		X		X		
Nutrient Regulation	X	X							X
Pollination	X	X	X		X		X		
Habitat Services									
Habitat and Biodiversity		X		X		X	X		X
Nursery		X		X		X	X		X
Information Services									
Aesthetic Information	X	X		X	X	X	X	X	X
Recreation		X		X	X	X	X		X
Cultural and Artistic Information						X			
Science and Education		X					X	X	
Spiritual and Historic Information						X			

Key:

	Ecosystem service produced by land cover but not valued in this report
X	Ecosystem service produced by land cover and valued in this report
	Ecosystem service not produced by land cover

Annual Value of the Skykomish Watershed

Transferred values were converted to 2010 dollars per acre per year, representing the annual flow of value generated by a single ecosystem service on a single land cover each year. Combining the available ecosystem service values (water regulation, habitat, recreation, etc.) for one land cover yields a total value for that land cover in dollars per acre per year. For example, one peer-reviewed scientific paper, used in this valuation, found that Urban Green Space provides between $1,359 and $3,984 in recreational and aesthetic value per acre each year. This value was combined with other available ecosystem service values such as climate regulation, to give a value of $1,430 to $5,173 per acre per year for Urban Green Space. Tables 6 – 10 summarize the combined high and low ecosystem service values for each land cover in the Skykomish Watershed.

Table 6 - High and Low Dollar per-Acre Estimates for Agricultural Lands and Forest

Ecosystem Service	Agricultural lands Low Value ($/acre/year)	Agricultural lands High Value ($/acre/year)	Forest Low Value ($/acre/year)	Forest High Value ($/acre/year)
Aesthetic & Recreational	29.63	29.63	0.18	2158.01
Biological Control	15.29	15.29	2.38	9.98
Disturbance Regulation	2.16	2.16	1.33	5.14
Food Provisioning			33.29	40.23
Gas & Climate Regulation	10.66	124.01	10.57	342.71
Genetic Resources			10.65	10.65
Habitat Refugium & Nursery			1.05	543.42
Medicinal Resources				
Nutrient Cycling	9.07	9.07	74.28	240.37
Pollination	2.59	413.50	59.00	413.50
Raw Materials			1.34	422.76
Science and Education			36.42	62.92
Soil Erosion Control	6.51	6.51	63.92	143.50
Soil Formation	2.34	6.51	5.95	6.66
Waste Treatment			51.80	182.24
Water Regulation			10.35	585.56
Water Supply			9.00	385.00
Total	**78.24**	**606.67**	**371.51**	**5552.67**

Table 7 - High and Low Dollar per-Acre Estimates for Grasslands and Lakes/Rivers

Ecosystem Service	Grasslands		Lakes/Rivers	
	Low Value ($/acre/year)	**High Value ($/acre/year)**	**Low Value ($/acre/year)**	**High Value ($/acre/year)**
Aesthetic & Recreational			1.44	21223.45
Biological Control	13.70	13.70		
Disturbance Regulation				
Food Provisioning	33.02	33.02	22.54	27.30
Gas & Climate Regulation	5.23	163.34		
Genetic Resources				
Habitat Refugium & Nursery			2.33	881.87
Medicinal Resources				
Nutrient Cycling				
Pollination	14.89	413.50		
Raw Materials				
Science and Education				
Soil Erosion Control	17.21	17.21		
Soil Formation	0.59	0.59		
Waste Treatment	51.80	51.80		
Water Regulation	1.78	1.78		
Water Supply			8.15	908.71
Total	**138.21**	**694.94**	**34.45**	**23041.32**

Table 8 - High and Low Dollar per-Acre Estimates for Pasture and Riparian Buffer

Ecosystem Service	Pasture		Riparian Buffer	
	Low Value ($/acre/year)	**High Value ($/acre/year)**	**Low Value ($/acre/year)**	**High Value ($/acre/year)**
Aesthetic & Recreational	0.03	25.77	0.61	11446.31
Biological Control	15.65	15.65		
Disturbance Regulation			8.15	253.97
Food Provisioning				
Gas & Climate Regulation			99.00	990.00
Genetic Resources				
Habitat Refugium & Nursery			1.52	1494.89
Medicinal Resources			11.98	383.59
Nutrient Cycling				
Pollination	2.25	413.50		
Raw Materials				
Science and Education				
Soil Erosion Control				
Soil Formation	0.66	6.70		
Waste Treatment				
Water Regulation			39.92	197.02
Water Supply			5.16	14022.28
Total	**18.59**	**461.63**	**166.33**	**28788.06**

Table 9 - High and Low Dollar per-Acre Estimates for Shrub/Scrub and Urban Green Space

Ecosystem Service	Shrub/Scrub		Urban Green Space	
	Low Value ($/acre/year)	**High Value ($/acre/year)**	**Low Value ($/acre/year)**	**High Value ($/acre/year)**
Aesthetic & Recreational	0.19	1991.64	1358.92	3983.55
Biological Control	15.65	15.65		
Disturbance Regulation				
Food Provisioning				
Gas & Climate Regulation	4.66	73.30	28.88	942.49
Genetic Resources				
Habitat Refugium & Nursery	0.53	538.95		
Medicinal Resources				
Nutrient Cycling				
Pollination	1.13	5.67		
Raw Materials				
Science and Education	36.42	62.92	36.42	62.92
Soil Erosion Control	19.30	19.30		
Soil Formation	0.66	0.66		
Waste Treatment				
Water Regulation	2.00	2.00	6.16	184.11
Water Supply				
Total	**80.54**	**2710.10**	**1430.38**	**5173.08**

Table 10 - High and Low Dollar per-Acre Estimates for Wetland

Ecosystem Service	Wetland	
	Low Value ($/acre/year)	**High Value ($/acre/year)**
Aesthetic & Recreational	1.67	4984.78
Biological Control		
Disturbance Regulation	433.78	7757.92
Food Provisioning	63.40	9372.90
Gas & Climate Regulation	4.85	774.40
Genetic Resources		
Habitat Refugium & Nursery	5.82	2241.85
Medicinal Resources		
Nutrient Cycling	7467.35	7467.35
Pollination		
Raw Materials	2816.43	2816.43
Science and Education		
Soil Erosion Control		
Soil Formation		
Waste Treatment	12.86	1747.07
Water Regulation	148.48	17351.05
Water Supply	0.43	4289.38
Total	**10955.06**	**58803.14**

The combined ecosystem service values for each land cover were then multiplied by the area of that land cover in the Skykomish Watershed. Results were summed across all land covers to arrive at a total annual value for the Skykomish Watershed. Table 9 summarizes the value provided by all ecosystem services across all land cover in the Skykomish Watershed. The table includes the value and area of each land cover, and the estimated total annual value for all lands within the Skykomish Watershed.

Asset Value of the Skykomish Watershed

An ecosystem produces a flow of valuable services across time, like a traditional capital asset. As long as the natural infrastructure of the watershed is not degraded or depleted, this flow of value will likely continue into the future. This analogy can be extended by calculating the net present value of the future flows of ecosystem services, just as the asset value of a capital asset (such as a bridge) can be calculated as the net present value of its future benefits. This calculation is no more than an economic exercise however, because ecosystems are not bought and sold in this manner; its usefulness is to demonstrate their long-term economic worth.

Table 11 - Annual Value of Ecosystem Services Produced in the Skykomish Watershed

Skykomish Land Cover	Total Acreage	Per Acre Low ($/acre/year)	Per Acre High ($/acre/year)	Total Low ($/year)	Total High ($/year)
Agricultural Lands	449	78	607	35117	272298
Forest	279803	372	5553	103950955	1553655473
Grasslands	33555	138	695	4637829	23318880
Lakes/Rivers	8981	34	23041	309399	206926293
Pasture	7876	19	462	146442	3635801
Riparian Buffer	19642	166	28788	3267049	565449239
Shrub/Scrub	121680	81	2710	9800291	329765778
Urban Green Space	2126	1430	5173	3040562	10996408
Wetland	10917	10955	58803	119599173	641968604
Other	50043	0	0	0	0
Total	**535072**			**245,000,000**	**3,300,000,000**

Calculating the net present value of an asset requires the use of a discount rate. The net present value of the Skykomish Watershed was calculated using two discount rates: zero and 4.125%. Using a 0% discount rate recognizes the renewable nature of natural capital and that people 100 years from now will enjoy the same level of benefits we enjoy today. The Army Corps of Engineers use a 4.125% discount rate for large projects, which lowers the value of the benefits by 4.125% every year into the future. Discounting can be adjusted for different types of assets and is designed to control for the following:

1. **Pure time preference of money.** This is the rate at which people value what they can have now, compared with putting off consumption or income until later.

2. **Opportunity cost of investment.** A dollar in one year's time has a present value of less than a dollar today, because a dollar today can be invested for a return in one year.

3. **Depreciation.** Built assets such as cars and levees tend to deteriorate and lose value due to wear and tear.

Discounting has limitations. Using a discount rate assumes that the benefits humans reap in the present are more valuable than the benefits provided to future generations. Also, natural capital assets should be treated with lower discount rates than built capital assets because they tend to appreciate over time, rather than depreciate. Additionally, most of the benefits that a natural asset such as the Skykomish Watershed provides reside in the distant future, whereas most of the benefits of built capital reside in the near-term, with few or no benefits provided into the distant future. Both types of assets are important to maintain a high quality of life, but each operates on a different time scale. It would be unwise to treat human time preference for a forest like it was a building, or that of a building like it was a disposable coffee cup. Thus, a zero discount rate best reflects the asset value of the Skykomish Watershed.

Results

Overall, 23 categories of ecosystem services were valued across the entire Skykomish Watershed. Results show that nature in the Skykomish Watershed generates at least $245 million to $3.3 billion in goods and services to humans every year.

Discount Rate of 4.125%

From this annual flow of value, a net present value, analogous to an asset value, can be calculated. To determine the asset value of the Skykomish Watershed, a discount rate of 4.125% is applied over 100 years from the present day. With this discount rate, the asset value of the Skykomish Watershed is between $5.8 billion and $79.5 billion.

Discount Rate of 0%

The Skykomish Watershed's asset value was also calculated at a zero discount rate, treating the value that these ecosystems will provide to future generations as equal to that of present generations. At a zero discount rate, the watershed's asset value is estimated between $24 billion and $334 billion.

More detailed information on the primary studies used in this benefit transfer is listed in Appendices A and B, and study limitations are outlined in Appendix C.

Part IV. Conclusion

This report provides an appraisal valuation of ecosystem services in the Skykomish Watershed, quantifying the economic value supplied by nature in the watershed every year. By protecting against flooding, assuring water supply, buffering climate instability, supporting fisheries and food provisioning, maintaining critical habitat, providing waste treatment and other benefits, **Skykomish Watershed ecosystems provide between $245 million and $3.3 billion in economic value every year.**

Ecosystem services may also be treated like economic assets, as they provide a stream of benefits over time, similar to bridges, roads or other built infrastructure. Valued as such, a discount rate may be applied to these services, allowing for calculation of the present value (or asset value) of these systems. If treated like an asset with a lifespan of 100 years, the asset value of the Skykomish Watershed is between $5.8 billion and $79.5 billion at a 4.125% discount rate. **Using a 0% discount rate, which recognizes the renewable nature of natural capital and that people 100 years from now will enjoy the same level of benefits, the Skykomish Watershed has an asset value of between $24 billion and $334 billion.** Though a snapshot in time, these appraisal values are defendable and applicable to decision-making at every jurisdictional level.

Discovering and measuring the value of natural capital in the Skykomish Watershed is important, and ecosystem service valuations can aid effective and efficient natural resource management. The creation of macroeconomic measures in the 1930s, such as measures for the Gross Domestic Product, unemployment and inflation, transformed the United States because these measures enabled better economic decision-making. Built capital was scarce, and economic measures of built capital were essential to building a prosperous 20th century economy. Virtually all countries now utilize the same set of macroeconomic measures.

Today, scarcity has shifted from manufactured goods to ecosystem goods and services. To increase their production the value of ecosystems should be correctly measured and included in decision-making. While this report provides a valuation of ecosystem services in the Skykomish Watershed, it is only a first step in the process of developing policies, measures and indicators that support discussions about the tradeoffs in investments of public and private money that ultimately shape the regional economy for generations to come. Recommended next steps include:

- **Protect and Restore Natural Capital.** Consider both the conservation and the restoration of these Skykomish Watershed ecosystems as a key investment in the future economy as supported by green infrastructure. This appraisal of value is defensible and applicable to decision-making at every jurisdictional level.
- **Apply Ecosystem Service Valuation to Support Funding Investment in Natural Assets.** Ecosystem service valuation can provide governments, organizations, and private owners a way to calculate the rate of return on conservation and restoration investment. Beginning in late 2012, values in this report can be regularly updated using Earth Economics' SERVES (Simple Effect Resource for Valuing Ecosystem Services), a web-based tool which can be accessed from www.eartheconomics.org.
- **Adopt an Ecosystem Services Approach to Rural Economic Development.** By including sustainable forestry, forest product development, agriculture, and access to quality outdoor recreation in economic development planning, long-term and sustainable jobs can be identified, quantified and secured. Restoration projects can and should be effectively linked to economic advancement, sustainability and long-term job creation.
- **Review Institutional Options for Planning and Management of Natural Assets.** Ecosystem services can be a guide for improvement by setting a context wherein alternative goals, such as salmon restoration, flood control, storm water conveyance and water quality, can be simultaneously improved, thus avoiding infrastructure conflict. Skykomish Watershed leaders should facilitate discussions about institutional improvements that facilitate the coordination of watershed activities including flood risk reduction, salmon habitat restoration, drinking water, water quality, climate adaptation, and forest stewardship by public and private landowners. Earth Economics is working with county, city and other agency reps in the

Green/Duwamish River Watershed, Cedar River Watershed, Snohomish Watershed, Puyallup River Watershed and Nisqually Watershed to develop the concept of a Watershed Investment District as an example of a new institution to manage natural capital. Such an institution would be positioned to take advantage in emerging ecosystem service markets to generate funding for investment in the Skykomish Watershed's natural capital, while also creating a mechanism for incentive funding for stewardship practices on private land through Payments for Ecosystem Services. Adopting an integrated approach saves money and provides greater benefits for Skykomish Watershed residents and other communities in the region.

Economic sustainability relies on environmental sustainability. The loss of nature's bound has real economic costs. Safeguarding the health of a watershed, like keeping a house in good condition, provides benefits for everyone who uses it. Unlike houses, levees, roads and other man-made infrastructure, watersheds are largely self-maintaining. Watersheds provide goods and services across vast spans of time and well beyond their boundaries. Protecting and restoring the Skykomish Watershed is critical to improving quality of life and to securing sustainability, justice and economic progress in the region.

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Appendix B. Value Transfer Studies Used by Land Cover Class

Skykomish Land Cover	Ecosystem Service General	Author(s)	Minimum	Maximum
Agricultural lands	Aesthetic & Recreational	Bergstrom, J., Dillman, B. L. and Stoll, J. R.	$29.63	$29.63
	Biological Control	Wilson, Sara J.	$15.29	$15.29
	Disturbance Regulation	Wilson, Sara J.	$2.16	$2.16
	Soil Erosion Control	Canadian Urban Institute.	$6.51	$6.51
	Gas & Climate Regulation	Smith, W.N. et al.	$25.72	$25.72
		Wilson, Sara J.	$10.66	$124.01
	Nutrient Cycling	Wilson, Sara J.	$9.07	$9.07
	Pollination	Wilson, Sara J. (high) and Southwick, E. E. and Southwick, L. (low)	$2.59	$413.50
	Soil Formation	Canadian Urban Institute.	$6.51	$6.51
		Wilson, Sara J.	$2.34	$2.34
Forest	Aesthetic & Recreational	Bennett, R., et. al.	$182.22	$182.22
		Bishop, K.	$1,776.78	$1,991.64
		Boxall, P. C., McFarlane, B. L. and Gartrell, M.	$.18	$.18
		Maxwell, S.	$12.69	$12.69
		New Jersey Type A Studies	$.36	$2,158.01
		Prince, R. and Ahmed, E.	$1.49	$1.90
		Willis, K. G. and Garrod, G. D.	$4.04	$4.04
		Willis, K.G.	$.42	$205.41
		Dodds, W.K., et al.	$872.00	$875.43
		Shafer, E. L., et al.	$580.70	$580.70
		Wilson, S. J.	$124.83	$124.83
	Biological Control	Wilson, Sara J.	$9.98	$9.98
		Krieger, D.J.	$9.69	$9.69
		Costanza et al.	$2.65	$2.65
		Pimentel et al.	$2.38	$2.38
	Disturbance Regulation	Dodds, W.K., et al.	$1.40	$5.14
	Soil Erosion Control	Costanza et al.	$63.92	$63.92
	Gas & Climate Regulation	New Jersey Type A Studies	$10.57	$13.33
		Dodds, W.K., et al.	$14.48	$61.93
		Pimentel et al.	$15.39	$15.39
		Mates. W., Reyes, J.	$57.52	$253.97
		Wilson, S. J.	$14.58	$342.71
	Genetic Resources	Costanza et al.	$10.65	$10.65

	Habitat Refugium & Nursery	Kenyon, W. and Nevin, C.	$538.95	$538.95
		New Jersey Type A Studies	$1.05	$543.42
		Dodds, W.K., et al.	$2.79	$2.80
		Garber et al.	$290.73	$487.59
		Wilson, S. J.	$1.12	$1.12
	Nutrient Cycling	Costanza et al.	$240.37	$240.37
		Dodds, W.K., et al.	$74.28	$74.28
	Pollination		$59.00	$413.50
	Raw Materials	Costanza et al.	$16.65	$16.65
		Dodds, W.K., et al.	$1.34	$422.76
		Sharma	$15.54	$15.54
	Soil Erosion Control	Dodds, W.K., et al.	$112.58	$143.50
	Soil Formation	Costanza et al.	$6.66	$6.66
		Pimentel et al.	$5.95	$5.95
	Disturbance Regulation	Costanza et al.	$1.33	$1.33
	Waste Treatment	Wilson, Sara J.	$182.24	$182.24
		Pimentel et al.	$51.80	$51.80
	Water Regulation	Wilson, Sara J.	$585.56	$585.56
		Olewiler, N.	$31.53	$31.53
		Loomis J.B.	$10.35	$10.35
	Water Supply	New Jersey Type A-C studies	$9.00	$385.00
		Dodds, W.K., et al.	$9.81	$47.04
	Food Provisioning	Costanza et al.	$33.29	$33.29
		Lampietti and Dixon	$40.23	$40.23
	Science and Education	Bishop, K.	$36.42	$62.92
Grasslands	Biological Control	Pimentel et al.	$13.70	$13.70
	Gas & Climate Regulation	Wilson, Sara J.	$10.61	$163.34
		Costanza et al.	$5.23	$5.23
	Pollination		$14.89	$413.50
	Soil Erosion Control	Costanza et al.	$17.21	$17.21
	Soil Formation	Costanza et al.	$.59	$.59
	Waste Treatment	Pimentel et al.	$51.80	$51.80
	Water Regulation	Costanza et al.	$1.78	$1.78
	Food Provisioning	US Dept of Comm	$33.02	$33.02
Lakes/Rivers	Aesthetic & Recreational	Bell, F. W.	$2,058.83	$2,058.83
		Burt, O. R. and Brewer, D.	$454.20	$497.56
		Cordell, H. K. and Bergstrom, J. C.	$145.85	$2,040.18
		Kahn, J. R. and Buerger, R. B.	$4.09	$4.09
		Kealy, M. J. and Bishop, R. C.	$12.72	$13.93
		Kreutzwiser, R.	$178.27	$178.27
		New Jersey Type A Studies	$1.44	$1,634.67

		Patrick, R.,et. al.	$1.66	$25.14
		Piper, S.	$236.24	$258.79
		Shafer, E. L. et. al.	$95.64	$1,186.64
		Ward, F. A., Roach, B. A. and Henderson, J. E.	$20.14	$1,886.98
		Young, C. E. and Shortle, J. S.	$80.50	$88.18
		Loomis J.B.	$11,992.39	$21,223.45
		Postel & Carpenter	$126.46	$126.46
		Patrick, R.,et al.	$5.21	$78.84
		Shafer, E. L., et al.	$1,083.25	$1,083.25
		Ward, F. A., et al.	$22.06	$2,067.09
	Habitat Refugium & Nursery	Kahn, J. R. and Buerger, R. B.	$2.33	$18.73
		Streiner and Loomis	$881.87	$881.87
		Loomis J.B.	$17.13	$17.13
	Water Supply	Bouwes, N. W. and Scheider, R.	$607.28	$665.24
		Croke, K., Fabian, R. and Brenniman, G.	$556.58	$556.58
		Henry, R., Ley, R. and Welle, P.	$422.23	$422.23
		Piper, S.	$31.80	$32.34
		Ribaudo, M. and Epp, D. J.	$8.15	$908.71
		Knowler, D.J., MacGregor, B.W., Bradford, M.J., Peterman, R.M.,	$26.95	$123.53
		Croke, K., et al.	$609.70	$609.70
		Henry, R., et al.	$462.52	$462.52
	Food Provisioning	Costanza et al.	$27.30	$27.30
		Postel & Carpenter	$22.54	$22.54
Pasture	Aesthetic & Recreational	Boxall, P. C.	$.03	$.03
		New Jersey Type A Studies	$25.77	$25.77
	Biological Control	Costanza et al.	$15.65	$15.65
	Pollination		$2.25	$413.50
	Soil Formation	Costanza et al.	$.66	$.66
		Pimentel et al.	$6.70	$6.70
Riparian Buffer	Aesthetic & Recreational	Duffield, J. W., Neher, C. J. and Brown, T. C.	$1,124.22	$1,124.22
		Haener, M. K. and Adamowicz, W. L.	$.61	$.61
		Kulshreshtha, S. N. and Gillies, J. A.	$76.90	$76.90
		Mullen, J. K. and Menz, F. C.	$779.06	$779.06
		Rein, F. A.	$39.55	$173.40
		Duffield, J. W., et al.	$366.81	$6,224.64
		Greenley, D., et al.	$20.56	$20.56
		Shafer, E. L., et al.	$112.25	$112.25
		Bowker, J. M., et al.	$4,762.63	$11,446.31
		Sanders, L. D., et al.	$2,475.18	$2,475.18

	Disturbance Regulation	Rein, F. A.	$8.15	$253.97
	Gas & Climate Regulation	local estimate	$99.00	$990.00
	Habitat Refugium & Nursery	Amigues, J. P., et. al.	$37.80	$1,494.89
		Haener, M. K. and Adamowicz, W. L.	$1.52	$10.42
		Shafer, E. L. et. al.	$2.98	$2.98
		Knowler, D. J. et al.	$26.95	$123.53
	Water Regulation	Faux et al.	$39.92	$197.02
	Water Supply	Gramlich, F. W.	$221.01	$221.01
		Oster, S.	$15.16	$15.16
		Ribaudo, M. and Epp, D. J.	$1,395.98	$1,770.14
		Rich, P. R. and Moffitt, L. J.	$5.16	$5.16
		Rein, F. A.	$41.81	$185.36
		Lant? - IL water qual study	$182.23	$182.23
		Berrens, R. P., et al.	$2,268.02	$2,268.02
		Mathews, L. G., et al.	$14,022.28	$14,022.28
	Medicinal Resources	local estimate	$11.98	$383.59
Shrub/Scrub	Aesthetic & Recreational	Bennett, R., et. al.	$182.22	$182.22
		Bishop, K.	$1,776.78	$1,991.64
		Boxall, P. C., McFarlane, B. L. and Gartrell, M.	$.19	$.19
		Haener, M. K. and Adamowicz, W. L.	$.22	$.22
		Maxwell, S.	$12.69	$12.69
		New Jersey Type A Studies	$13.07	$1,091.89
		Prince, R. and Ahmed, E.	$1.61	$2.05
		Willis, K.G.	$.45	$205.41
		Shafer, E. L., et al.	$580.70	$580.70
	Biological Control	Costanza et al.	$15.65	$15.65
	Soil Erosion Control	Costanza et al.	$19.30	$19.30
	Gas & Climate Regulation	local estimate	$6.68	$73.30
		New Jersey Type A Studies	$5.29	$6.67
		Costanza et al.	$4.66	$4.66
	Habitat Refugium & Nursery	Haener, M. K. and Adamowicz, W. L.	$1.33	$9.11
		Kenyon, W. and Nevin, C.	$538.95	$538.95
		New Jersey Type A Studies	$.53	$271.71
		Shafer, E. L. et. al.	$3.21	$3.21
	Pollination		$1.13	$5.67
	Soil Formation	Costanza et al.	$.66	$.66
	Water Regulation	Costanza et al.	$2.00	$2.00
	Science and Education	Bishop, K.	$36.42	$62.92

Urban Green Space	Aesthetic & Recreational	Bishop, K.	$1,776.78	$1,991.64
		Tyrvainen, L.	$1,358.92	$3,983.55
	Gas & Climate Regulation	Birdsey, R.A.	$219.18	$219.18
		McPherson, E. G.	$188.94	$942.49
		McPherson, E. G., Scott, K. I. and Simpson, J. R.	$28.88	$28.88
	Water Regulation	Birdsey, R.A.	$184.11	$184.11
		McPherson, E. G.	$6.16	$6.16
	Science and Education	Bishop, K.	$36.42	$62.92
Wetland	Aesthetic & Recreational	Doss, C. R. and Taff, S. J.	$4,118.83	$4,984.78
		Gund Database	$68.09	$217.79
		Hayes, K. M., Tyrrell, T. J. and Anderson, G.	$1,804.08	$3,448.12
		Kreutzwiser, R.	$195.28	$195.28
		Thibodeau, F. R. and Ostro, B. D.	$18.75	$645.51
		Whitehead, J. C.	$1,027.44	$2,262.93
		Dodds, W.K., et al.	$1,689.67	$1,689.67
		Woodward and Wui, (low value); New Jersey from A-C studies (for high value)	$1.67	$4,641.41
		Hicks et al.	$138.85	$138.85
		Allen, J. et al.	$111.78	$578.92
		Hayes, K. M., et al.	$1,306.70	$2,497.48
		Mahan, B.L.	$49.21	$49.21
		van Vuuren, W. and Roy, P.	$853.81	$853.81
		Wilson, S. J.	$47.36	$128.80
		Cooper J. and Loomis, J.	$327.16	$1,284.80
		Mahan, B. L., et al.	$37.44	$37.44
	Disturbance Regulation	Allen, J. et al.	$433.78	$7,757.92
		Costanza et al.	$176.30	$176.30
		Dodds, W.K., et al.	$123.79	$123.79
		Wilson, S. J.	$4.85	$705.00
	Habitat Refugium & Nursery	Pate, J. and Loomis, J.	$99.76	$317.15
		van Kooten, G. C. and Schmitz, A.	$5.82	$5.82
		Vankooten, G. C. and Schmitz, A.	$5.92	$5.92
		Streiner and Loomis	$677.28	$677.28
		Dodds, W.K., et al.	$179.38	$179.38
		Woodward and Wui, (low value); New Jersey from A-C studies (for high value)	$158.50	$510.52
		Knowler, D. J. et al.	$26.95	$123.53
		Wilson, S. J.	$2,241.85	$2,241.85
	Nutrient Cycling	Dodds, W.K., et al.	$7,467.35	$7,467.35

	Raw Materials	Dodds, W.K., et al.	$2,816.43	$2,816.43
	Waste Treatment	Pate, J. and Loomis, J.	$76.39	$344.14
		Wilson, Sara J.	$285.83	$837.58
		Wilson, S. J.	$12.86	$1,747.07
	Water Regulation	Thibodeau, F. R. and Ostro, B. D.	$3,788.69	$6,876.67
		Woodward and Wui, (low value); New Jersey from A-C studies (for high value)	$148.48	$2,914.64
		Allen, J. et al.	$5,605.72	$17,351.05
		Wilson, S. J.	$1,552.65	$1,552.65
	Water Supply	Creel, M. and Loomis, J.	$533.70	$584.64
		Hayes, K. M., Tyrrell, T. J. and Anderson, G.	$1,915.63	$2,977.72
		Lant, C. L. and Roberts, R. S.	$.43	$.55
		Lant, C. L. and Tobin, G.	$189.14	$2,082.37
		Pate, J. and Loomis, J.	$3,538.95	$3,538.95
		Dodds, W.K., et al.	$1,379.95	$1,379.95
		Lant? - IL water qual study	$182.23	$182.23
		Woodward and Wui, (low value); New Jersey from A-C studies (for high value)	$10.01	$4,289.38
		Hayes, K. M., et al.	$1,387.49	$2,156.77
		Wilson, S. J.	$704.81	$704.81
		Brouwer, R., et al.	$21.77	$64.61
	Food Provisioning	Roel/Ken (for low value); Woodward and Wui, (for high value)	$65.71	$1,518.75
		Woodward and Wui, (low value); New Jersey from A-C studies (for high value)	$180.18	$9,372.90
	Food Provisioning	Allen, J. et al.	$63.40	$1,463.16

Appendix C. Study Limitations

The results of the first attempt to assign monetary value to the ecosystem services rendered by the Skykomish Watershed have important and significant implications on the restoration and management of natural capital. 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:

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

2. 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).

3. Gathering all the information needed to estimate the specific value for every ecosystem within the study area is not feasible. Therefore, the true value of all of the wetlands, forests, pastureland, etc. in a large geographic area cannot be ascertained. In technical terms, we have far too few data points to construct a realistic demand curve or estimate a demand function.

4. 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 & 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 (see below).

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. An area with the size and landscape complexity of the Skykomish Watershed will make this approach to valuation extremely difficult and costly. Responses to the above critiques can be summarized as follows (See Costanza et al., 1998; and Howarth and Farber, 2002 for more detailed discussion):

1. 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. This study's estimate of the aggregate value of the Skykomish Watershed's ecosystem services is a valid and useful (albeit imperfect, as are all aggregated economic measures) basis for assessing and comparing these services with conventional economic goods and services.

2. The results of the spatial modeling analysis that are described in other studies do not support an across-the-board claim that the per-acre value of forest or agricultural land depends on the size of the parcel. While the claim does appear to hold for nutrient cycling and other services, the opposite

position holds up fairly well for what ecologists call "net primary productivity" or NPP, which is a major indicator of ecosystem health. It has the same position, by implication, of services tied to NPP – where each acre makes about the same contribution to the whole, regardless of whether it is part of a large plot of land or a small one. This area of inquiry needs further research, but for the most part, the assumption that average value is a reasonable proxy for marginal value is appropriate for a first approximation. Also, a range of different parcel sizes exist within the study site, and marginal value will average out.

3. As employed here, the prior studies we analyzed 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." Limited sensitivity analyses were also performed. This approach is similar to determining an asking price for a piece of land based on the prices of comparable parcels; 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.

4. The objection to the absence of even an imaginary exchange transaction was made in response to the study by 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).

In this report, 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 extremely 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.

The estimated value of the world's ecosystems presented in Costanza et al. (1997), for example, has been criticized as both (1) a serious underestimate of infinity and (2) impossibly exceeding the entire Gross World Product. These objections seem to be difficult to reconcile, but that may not be so. Just as a human life is priceless so are ecosystems, yet people are paid for the work they do.

Upon some reflection, it should not be surprising that the value ecosystems provide to people exceeds the gross world product. Costanza's estimate of the work that ecosystems do is an underestimate of the "infinity" value of priceless systems, but that is not what he sought to estimate. Consider the value of one ecosystem service, such as photosynthesis, and the ecosystem good it produces: atmospheric oxygen. Neither is valued in Costanza's study. Given the choice between breathable air and possessions, informal surveys have shown the choice of oxygen over material goods is unanimous. This indicates that the value of photosynthesis and atmospheric oxygen to people exceeds the value of the gross world product – and oxygen production is only a single ecosystem service and good.

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 the Skykomish Watershed's ecosystem services are scarcer than assumed here, 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, although the precise impacts are more difficult to predict.

- **Existence Value.** The approach does not fully include the infrastructure or existence value of ecosystems. It is well known that people value the existence of certain ecosystems, even if they never plan to use or benefit from them in any direct way. Estimates of existence value are rare; including this service will obviously increase the total values.

- **Other Non-Economic Values.** Economic and existence values are not the sole decision-making criteria. A technique called multi-criteria decision analysis is available to formally incorporate economic values with other social and policy concerns (see Janssen and Munda, 2002 and de Montis et al., 2005 for reviews). Having economic information on ecosystem services usually helps this process because traditionally, only opportunity costs of forgoing development or exploitation are counted against non-quantified environmental concerns.

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 their contextual 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.

  - *Accuracy*: The source GIS layers are assumed to be accurate but may contain some minor inaccuracies due to land use changes done after the data was sourced, inaccurate satellite readings and other factors.

  - *Categorical Precision*: The absence of certain GIS layers that matched the land cover classes used in the Earth Economics database created the need for multiple datasets to be combined. For example, a "Riparian Buffer layer" was not obtainable for the Skykomish Watershed, so the "Riparian Buffer cover" class was applied to all forest and layers (i.e. forest cover) within 50 feet of the Rivers and Lakes layer (NLCD Code 11 minus Estuary). This process is likely to produce some inaccuracies in final acreage values for each land cover class and thus affect the final dollar valuation of the Skykomish Watershed.

- **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 ripple throughout the economy.

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. Table 5 illustrates which ecosystem services were identified in the Skykomish Watershed for each land cover type, and which of those were valued.

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

- **Consumer Surplus.** Because the benefit transfer method is based on average rather than marginal cost, it cannot provide estimates of consumer surplus. However, this means that valuations based on averages are more likely to underestimate total value.

Primary Study Limitations

- **Willingness-to-pay Limitations.** Most estimates are based on current willingness-to-pay or proxies, which are limited by people's perceptions and knowledge base. Improving people's knowledge base about the contributions of ecosystem services to their welfare would almost certainly increase the values based on willingness-to-pay, as people would realize that ecosystems provided more services than they had previously known.

- **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 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, such as 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.

About Earth Economics

Earth Economics is a non-profit located in Tacoma, Washington. Earth Economics provides robust, science-based, ecologically-sound, economic analysis, policy and tools to governments, agencies, NGOs, and grassroots organizations. This information is intended to positively transform international, national and regional economic systems and business accounting practices. Earth Economics has a small in-house staff of economists that collaborate with experts in economics, ecology, hydrology, policy and systems modeling. Our goal is to help communities shift away from the failed economic policies of the past, towards an approach that is both economically viable and environmentally sustainable.

Mission Statement

Earth Economics applies new economic tools and principles to meet challenges of the 21st century: achieving the need for just and equitable communities, healthy ecosystems, and sustainable economies.

Program Work

Ecosystem Service Valuations: Quantifying the value of the goods and services provided by regional ecosystems.

Economic Environmental Impact Statements: Analyzing specific projects and scenarios based on comprehensive environmental economic analysis.

Jobs Analysis: Calculating the jobs that will be created, maintained, or lost by doing or not doing a project.

Accounting and Management Strategies: Identifying new management approaches that value ecosystem services in addition to built infrastructure and raw materials.

Scenario Mapping and Modeling: Mapping ecosystem services provisioners, beneficiaries and impairments under different planning scenarios.

Funding Mechanisms for Conservation and Restoration: Applying innovative approaches to fund critical natural infrastructure and conservation work.

Educational Outreach: Conducting workshops, lectures and media events to increase awareness about ecological economics.

Conversion to Sustainability: Catalyzing the shift from unsustainable to sustainable technology and industrial processes.

EARTH ECONOMICS

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