The Whole Economy of the Snohomish Basin:

The Essential Economics of Ecosystem Services

EARTH ECONOMICS

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For the Native American tribes pre-treaty the ownership of the land was unquestioned, and after the treaties the tribes retained rights. Among the rights is the ownership of salmon and the habitats that support them; the same would be said for the culture and the habitats that support it. If you look at current surveys in the Native American Indian cultures, the average use of plants alone is about 350 species, if you add animals, fish, and shellfish about an additional 1,500 species. In assessing the quality of life through the use of these species to a culture, how do we describe the appropriate values? As tribes, we had similar cultures including trade and travel. Tulalip's trade was from the ocean inland as far as Montana (as documented by US negotiators). Natural resources are what made the culture possible- from cedar canoes to fishing gear, or from building (for at least 500 years) long houses to totem poles to paintings.

Terry Williams,
Fisheries and Natural Resources Commissioner,
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The authors are responsible for the content of this report.

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CBD	Center for Biological Diversity
EE	Earth Economics
ESA	Endangered Species Act
ESV	Ecosystem Service Valuation
The Forum	Snohomish Basin Salmon Recovery Forum
GDP	Gross Domestic Product
GIEE	Gund Institute for Ecological Economics
GIS	Geographic Information System
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
OFM	Washington State Office of Financial Management
The Partnership	Puget Sound Partnership
PES	Payments for Ecosystem Services
PSRC	Puget Sound Regional Council
PV	Present Value
USFWS	United States Fish and Wildlife Service
WRIA	Water Resource Inventory Area
NPP	Net Primary Productivity

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Executive Summary

The Snohomish Basin economy is comprised of a unique combination of natural, built, human, social and financial capital, and is the outcome of previous centuries of investment- from the first Coast Salish peoples to our current generations. Our investments in the Snohomish Basin economy today will determine its physical appearance tomorrow. Smart investments are crucial to ensuring our well-being and economic health and freedom into the future. In the 21st Century, the Snohomish Basin economy faces unique challenges. Wise investments require an economic model that is equipped for these challenges.

In the 20th Century, our economy was limited by its production of built capital: to catch more fish for example required more boats and nets. Conversely, in the 21st Century our economy is limited by the natural capital we can produce: boats and nets are plentiful while fish are scarce. Some of the most pressing challenges facing the Snohomish Basin economy will stem from a loss or degradation in natural capital: food and water security, rises in peak flood flow and loss of salmon populations are just several examples.

Decision makers in the Snohomish Basin can choose now to advance the economy for a sustainable, desirable future through sound investment decisions that strike the optimal balance between the production of built and natural capital. Improvements in social, financial and human capital will also flow from these investments. Using this new, "Whole Economy" model will lower costs, promote justice, improve efficiency, and advance the Snohomish Basin economy, while maintaining a suite of positive externalities through ecosystem services.

The economy of the Snohomish Basin - and the quality of life for its citizens - depends upon functioning ecosystems. When natural systems are healthy, they provide considerable economic value for free or at relatively little cost; once degraded, natural systems require investments such as the installation of "built infrastructure", which depreciates over time. Degraded ecosystems require restoration investments to reestablish viability and improve ecosystem service production, but once healthy, ecosystems are largely self-organizing and provide critical ecological goods and services on an ongoing basis, at minimal cost to humans.

Purpose of Report

This report presents an economic analysis of the Snohomish Basin economy to illuminate the critical links between natural capital and our economy's health and resilience. Natural capital, such as a forest or a wetland, ensures a flow of local food and freshwater supply, flood protection and a host of other services without which the economy would be crippled. For example, most of the flood protection benefits within the Snohomish Basin are provided by natural systems such as upland forests and floodplains. Floodplains also provide a suite of ecosystem services including salmon nursery, water quality improvements, agricultural food production and recreation.

Methods

This study provides a structured understanding of nature's benefits in the Snohomish Basin by introducing an ecosystem services framework. The ecosystem services framework was developed within ecological economics as a tool for mainstreaming nature's value into economic decision making. Ecosystem services were recently given higher prominence in the Millennium Ecosystem Assessment, a project involving over 1,360 experts worldwide and a multi-stakeholder board representing governments, businesses, NGOs, indigenous peoples and international institutions.

Although most often used in economic models (as opposed to other cultural or social value systems), the concept of ecosystem services has proven effective for understanding the linkages between ecosystems and human well-being. Today, a number of federal agencies in the United States, including the Environmental Protection Agency, United States Forest Service, 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.

Major Findings and their Implications

This report includes a valuation of ecosystem services in the Snohomish Basin, quantifying the economic value supplied by nature in the Basin every year. The results are compelling: by protecting against flooding, assuring water supply, buffering climate instability, supporting fisheries and food production, maintaining critical habitat, providing waste treatment, and additional benefits **Snohomish Basin ecosystems are providing between *$383.1 million to $5.2 billion* in benefits every year.**

Ecosystem services may also be treated like an economic asset, providing a stream of benefits over time, similar to a bridge or other capital infrastructure. Valued as such, a discount rate may be applied to these services, allowing for calculation of the present value of these systems. If treated like an asset with a life span of 100 years, **the present value of the Snohomish Basin would be between $13.2 billion and $180.1 billion**, using a 2.7% discount rate. These results raise the following considerations:

- Nature in the Snohomish Basin provides immense economic value through ecosystem services, and recognizing this value presents an opportunity for advancement of the whole Snohomish Basin economy;
- Allowing natural systems to be further degraded will create real and potentially significant negative economic tradeoffs for the Snohomish Basin economy, constraining future economic decisions;
- To ensure a healthy, resilient Snohomish Basin economy and a sustainable future, nature's immense value should be incorporated into economic decision making in the Basin to the extent possible.

Conclusions and Recommendations

As functioning natural systems become increasingly scarce, quantification of tradeoffs among ecosystem services and their interactions with the economy and human well-being are now among the most pressing areas of concern in the Snohomish Basin. Basin leaders can use the concepts and values presented in this report to begin incorporating ecosystem services concepts into agency goals, metrics, indicators, assessment and general operations.

Ecosystem service values could be considered when developing budgets, program planning, and grant applications, examining policies and accounting practices, reporting and aligning to Puget Sound health indicators, and developing review and permitting processes in rural areas. Snohomish Basin decision-makers have the opportunity to shift from addressing challenges at a single-issue scale, to taking an integrated approach that develops a sustainable – and whole – economy in which natural capital is an asset of significant worth.

Understanding the linkage between natural systems and economic vitality is growing among individuals, government and non-governmental organizations. Policies drive investment decisions. Good economic policy decisions in turn require good information. Large-scale policy decisions to shift to green infrastructure require better information through improvements in economic analysis and indicators. If analysis is flawed, then investments will be inefficient or ineffective. However, if analysis can account for each of the five capitals- human, social, natural, built, and financial- then investments will be more likely to contribute to a balanced and resilient economy. Three core questions are essential in making well-informed economic decisions for the Snohomish Basin:

1. **"What are our scarce resources?"**
2. **"What are our desired ends?"**
3. **"How do we allocate our scarce resources to our desired ends?"**

To answer the third and most difficult question of how to allocate our scarce resources for the ultimate goal of human well-being, four guiding principles should be considered:

1. **Sustainability**
2. **Justice**
3. **Efficiency**
4. **Good Governance**

This report provides a valuation of ecosystem services in the Snohomish River Basin and a whole view of the economy. It is a first step in the process of developing measures and indicators that support policy discussions about the tradeoffs in investments of public and private money that ultimately affect human well-being.

Introduction

Ecological economics provides a framework with which to understand our local, regional and global community in the face of ever more scarce natural assets. This report applies ecological economics to the Snohomish Basin and illuminates how the planning decisions we make every day can have demonstrable positive or negative long-term economic impact on our economy.

How should we evaluate projects? What kind of investments should be made? How do we maximize the effectiveness and efficiency of our tax dollars and ensure the best possible long-term outcomes? Ecological economics helps us answer these types of questions and provides a critical and necessary context for policy discussions at all levels of government.

Study Objectives

- **Illuminate the connections between natural systems and the economy** of the Snohomish Basin.
- **Introduce the discipline of ecological economics** and describe applications that integrate five types of capital (human, social, built, natural and financial) that comprise the economy of the Snohomish Basin.
- **Provide a conceptual model** for aligning multiple investment goals in the Snohomish Basin to form a comprehensive watershed approach that includes economic advancement, agriculture and community food security, salmon recovery, flood protection and recreation.
- **Identify and describe the many ecosystem services** generated by nature which are economic assets.
- **Calculate the dollar-value for the natural goods and services** that ecosystems in the Snohomish Basin provide to people.
- **Discuss the economic value of nature in the Snohomish Basin** and why this value should be included in Basin accounting systems.

About this Report

Because the terms and concepts used are introduced progressively, readers are encouraged to read the sections of this report in the order presented. However, recognizing that not all readers will have the opportunity to read this full report, in some places a concept or definition has been repeated to ensure that its meaning will be understood in the correct context. Each Part begins with a *Section Summary* of the concepts and arguments presented in that section.

This report is defined by primary subject headings as follows:

- **Part I: The Snohomish Basin** introduces the geography, population, economy and ecology of the Snohomish Basin.
- **Part II: Key Ecological Economics Concepts** defines fundamental elements and definitions necessary for an ecological economics approach to understanding the Snohomish Basin.
- **Part III: Ecosystem Services in the Snohomish Basin** describes a selection of the ecosystem services valued in this report, with specific examples from within the Snohomish Basin.
- **Part IV: Valuation of the Snohomish Basin** determines a range of dollar values for goods and services provided by the natural systems of the Snohomish Basin.
- **Part V: Applications of Study Findings** synthesizes the previous chapters into a coherent argument for investing in green infrastructure and building green economy with specific recommendations for decision-makers at all levels.

Part I: The Snohomish Basin

Section Summary: *The Snohomish River Basin houses both an advanced industrial economy and a diverse set of ecosystems. Due to population pressures, the Basin's delicate natural systems and biological diversity are steadily diminishing. Recognizing that human well-being is ultimately dependent on healthy natural systems, Basin partners are working to restore a number of cornerstone habitats and processes within the Snohomish Basin.*

Geography

At 1,856 square miles, the Snohomish River Basin is the second largest basin in Puget Sound and includes the Skykomish, Snoqualmie and Snohomish Rivers, which join outside of the city of Monroe, Washington. The Snohomish Basin is also identified as Water Resource Inventory Area 7 (WRIA 7) as established by Washington State law in order to develop natural resource and salmon recovery planning at the watershed scale.[1] The Snohomish Basin's is amongst the most rapidly growing populations in the Puget Sound region and houses a number of jurisdictions including the Tulalip and Snoqualmie Tribes, King and Snohomish Counties and the municipalities of Carnation, Duvall, Everett, Gold Bar, Granite Falls, Index, Lake Stevens, Marysville, Monroe, Mukilteo, North Bend, Skykomish, Snohomish, and Snoqualmie. The Basin's incorporated areas, major rivers and roads are shown in Figure 1.

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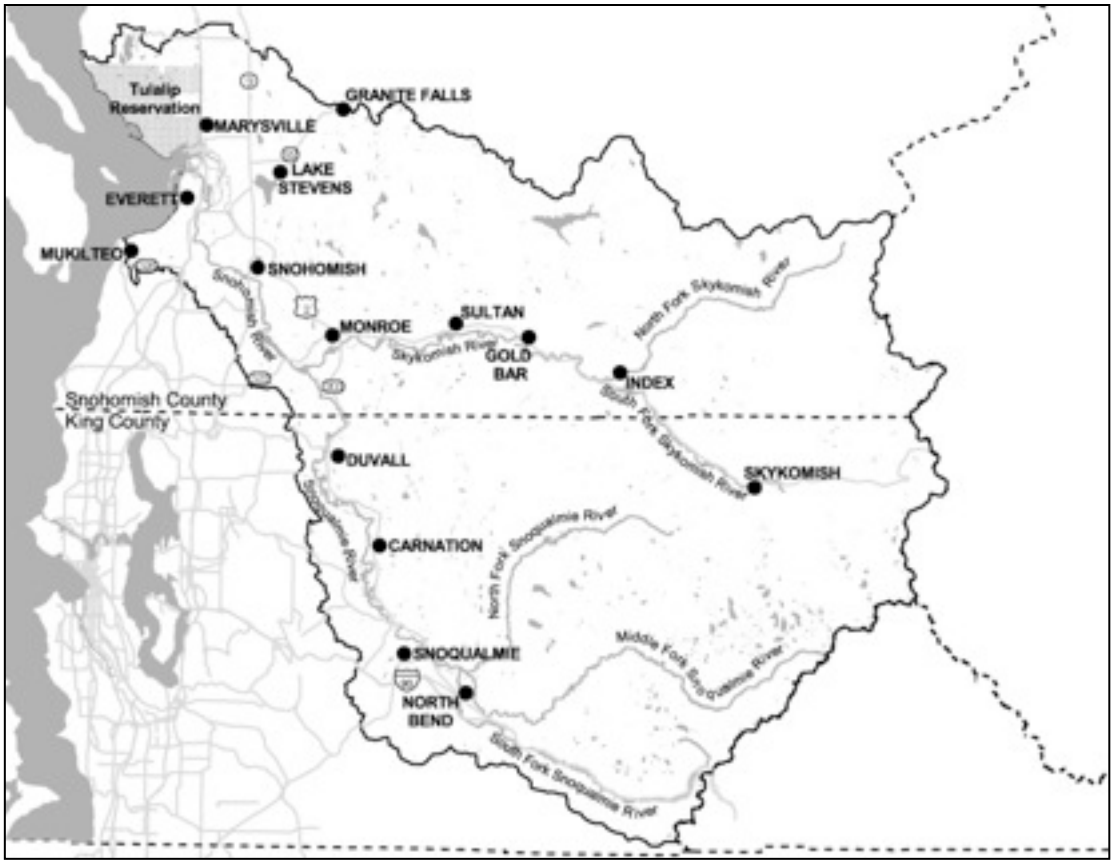
[1] Water Resource Inventory Areas (WRIAs) were formalized under Washington Administrative Code (WAC) 173-500-040 and authorized under the Water Resources Act of 1971, Revised Code of Washington (RCW) 90.54.

Figure 1: The Snohomish Basin.

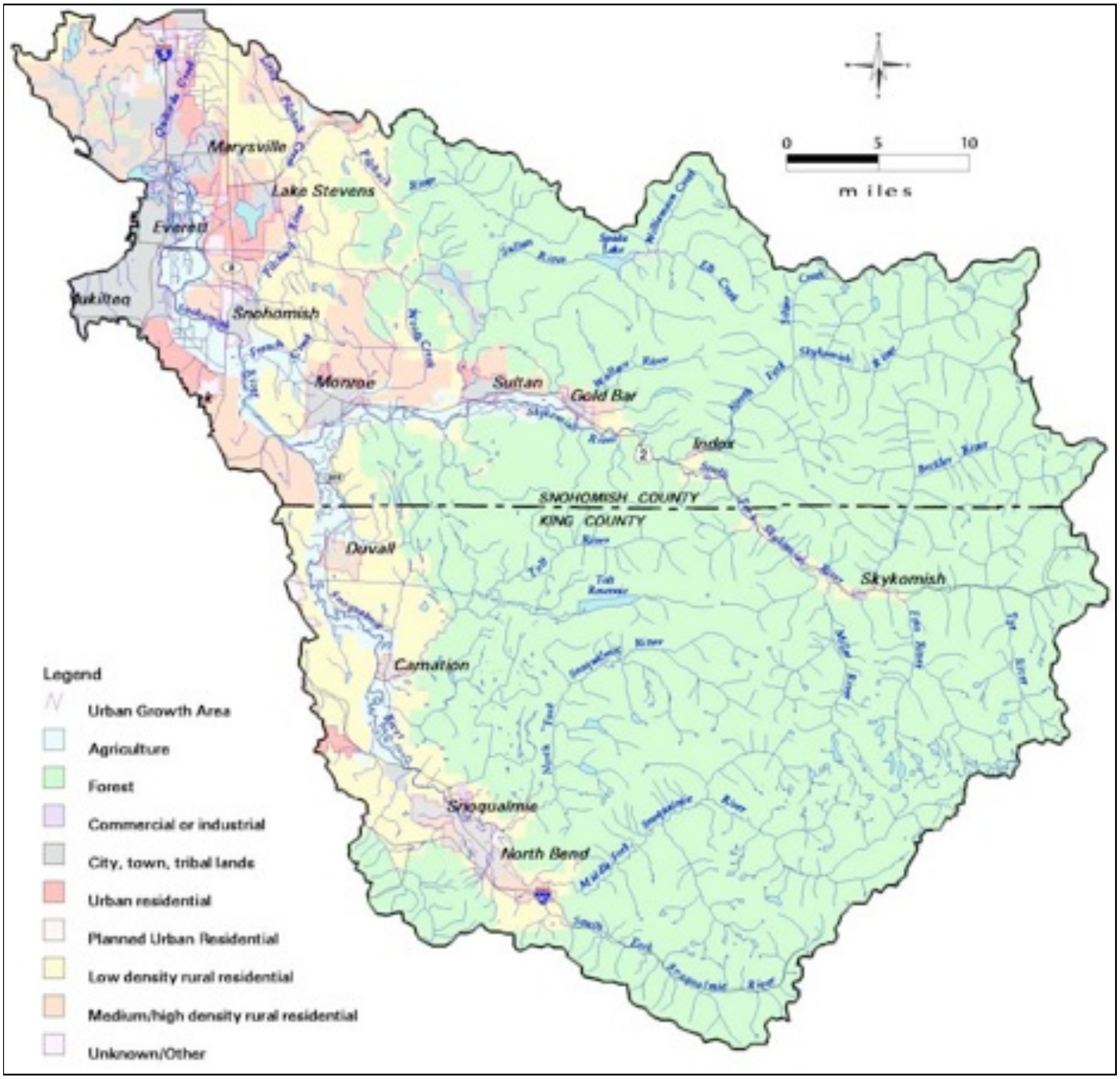


Source: Snohomish County.

Population and Economy

The Snohomish Basin is part of the vibrant Puget Sound economy, housing a range of economic sectors, including manufacturing, forestry, recreation and tourism, agriculture and retail. All of these industries rely on goods and services provided by natural systems. The economies of Snohomish, King and Pierce Counties – which together represent the three most populous counties in Washington State – are closely linked. The spread of land use and land ownership in the Basin is shown in Figures 2 and 3 respectively.

Figure 2: Snohomish Basin Land Use

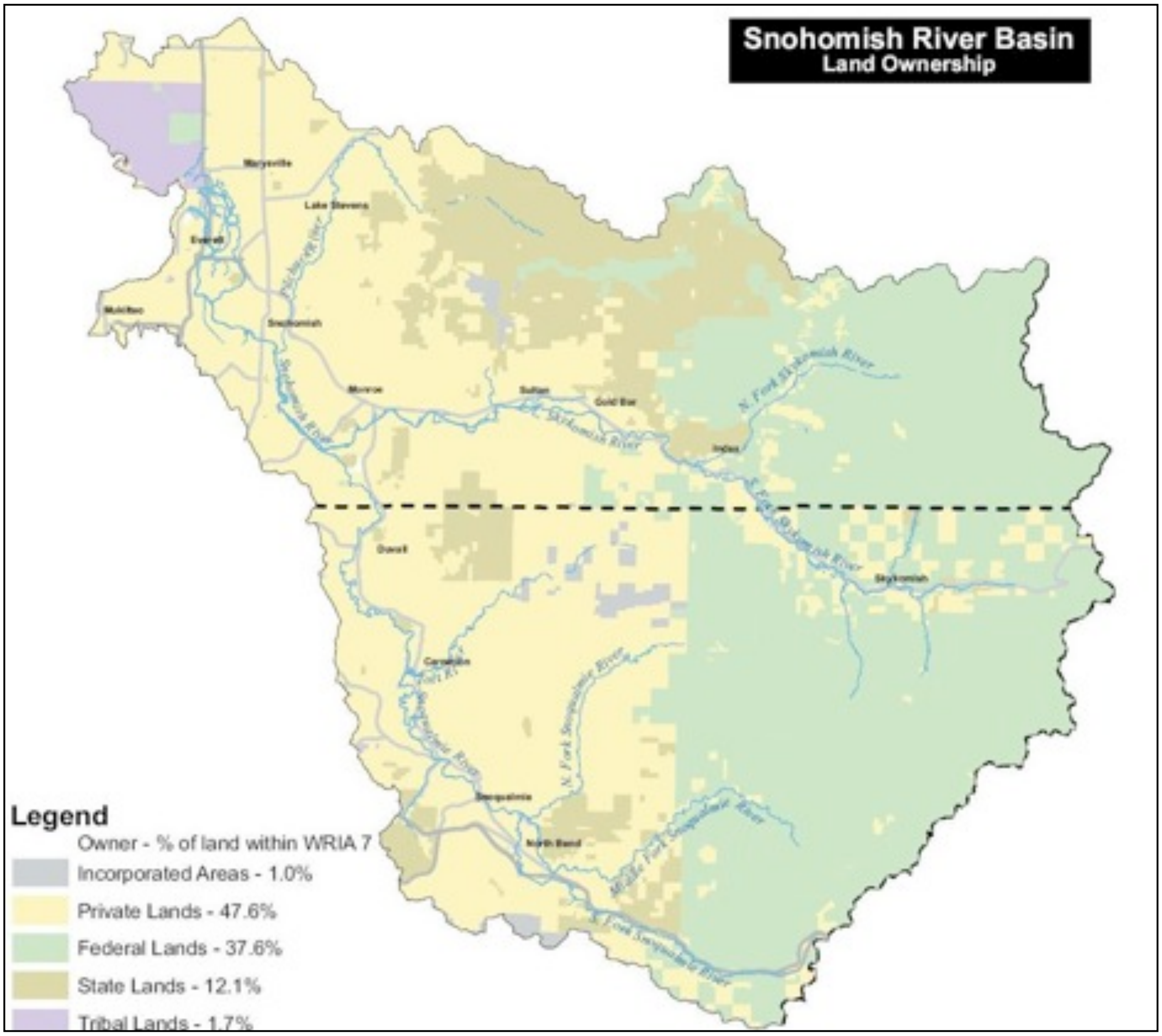


Source: Snohomish River Basin Salmon Recovery Forum, 2005.

From 2000-2010, Snohomish County was, by percent growth, the fastest growing county in the Puget Sound region, and the Puget Sound Regional Council estimates that Snohomish County's population will rise from around 600,000 in 2010 to over 960,000 in 2030[2]; King County's population may also grow by over 300,000 over the same period, to over 2.2 million (Puget Sound Regional Council, 2006).

[2] The Puget Sound Regional Council is targeting a substantially lower growth rate for several cities in the Basin (Puget Sound Regional Council, 2005). For example, Monroe experienced a high annual growth rate of 8.9% during the 1990's, well beyond Snohomish County's forecast (Schwarzen, 2003), and is now targeted to grow at 1.5% through 2025 (Puget Sound Regional Council, 2005).

Figure 3: Snohomish Basin Land Ownership.



Source: Snohomish River Basin Salmon Recovery Forum, 2005.

Rapidly increasing demand for housing has raised land prices and increased pressure on farm and forest land for conversion to development. In order to accommodate continued population growth without detriment to local agriculture, environment, or quality of life, partners in the watershed are considering planning strategies for the future. Snohomish Basin partners are working towards sustainability planning in many areas, including growth management, water supply, salmon recovery, climate (including plans to implement a carbon emissions inventory), and policies to support key land uses such as natural areas/open space, agriculture, residential communities, and forestry.

Basin Agriculture

Agricultural lands are an important part of the cultural and economic landscape in both Snohomish and King Counties. Small farms in Snohomish County are still prevalent, where median farm size is 18 acres. In 2002, 81% of the County's farms were below 50 acres, a proportion significantly above the Washington State average of 58%. Of the land in Snohomish County that is in active agricultural production 36% is non-designated farmland. This land nonetheless plays an important role in the viability of Snohomish County's agricultural sector by providing a supply and market for forage, supporting agricultural services such as processing and farm equipment, and diversifying the range of crops and specialized services that Snohomish County agriculture provides. Non-designated farmland tends to occur adjacent to low density rural residential development or urban growth areas, and experiences the pressure of urban growth more acutely than designated farmland (SAEDAT, 2009).

Overall, Snohomish County farms collectively sold agricultural products worth over $126 million in 2002, and King County sales were comparable (USDA, 2009). Some farms are exploring new strategies to increase the viability of farming including organic certification and direct sales to local consumers. In 2007, total organic product sales in Snohomish County totaled $849,000, the 18th highest figure of Washington's 39 Counties. King County's organic sales totaled over $8 million, making it 7th in the state for organic sales (USDA, 2009). This success may be linked to the Counties' close proximity to regional urban centers, and presents an opportunity for further growth. A national desire to reduce carbon emissions, as well as higher oil prices, will also help to drive the consumption of locally grown food.

Snohomish and King Counties conduct planning to ensure that farms of all sizes will continue to contribute to the watershed economy, while promoting sustainability and Best Management Practices. To protect quality farmland, King County currently has 42,000 acres in Agricultural Production Districts (areas designated for agriculture) and Snohomish County has designated Agriculture Resource Lands, a zoning category of their comprehensive plan. Agriculture provides some important environmental services for the Basin, including carbon sequestration, aesthetic value, and wildlife refuge. Washington State University (WSU) Snohomish Extension, Snohomish Conservation District (SCD) and King Conservation District (KCD) are working in concert to successfully promote management techniques with rural landowners that increase the level of these services, thereby improving economic viability.

Basin Forestry

Forestry is also an important land use within the Snohomish Basin. Approximately 75% of the land is forested (Snohomish Basin Salmon Recovery Forum, 2005). The majority of these lands, approximately 662,000 acres, are in federal ownership, and about 244,000 acres are in private or state ownership (Snohomish County webpage, 2010). The existing regulatory framework for state and private forestlands includes the Washington Forest Practice Rules and the Washington Department of Natural Resources Habitat Conservation Plan, both of which aim to limit the environmental impacts of forest practices on state and private forestland. The lands under federal ownership are managed under the Northwest Forest Plan guidelines, and often have longer harvest rotations, or less harvesting overall, than state or private forestlands (Edwards, 2003).

Much of the Basin's original forestland has been converted, or is under pressure to convert, to non-forest purposes. Between 1988 and 2004, over 100,000 acres (> 6% of each County's total area) of forestland in King and Snohomish Counties was converted to either a developed land use or agricultural land use. Of the 19 counties in western Washington, only Pierce County converted more of its forestland during this period (Washington Department of Natural Resources, 2007). Into the future, the forestlands of King and Snohomish Counties (and other counties along the Interstate-5 corridor) are at the greatest risk for conversion compared with other Washington counties (Washington Department of Natural Resources, 2007); to illustrate, a recent study by the University of Washington's School of Forest Resources found that over 150,000 acres of private forestland in the Snohomish Basin were at "high risk" of conversion, a figure second only to the Kitsap Watershed (University of Washington School of Forest Resources, 2009).

Regional Biodiversity

Biodiversity is generally defined as the diversity of multiple levels of biological organization at multiple scales of space and time (Marcot, 2006), and is critical to the health and resilience of most natural systems that humans rely on for survival (see Worm et al., 2006 for a marine example). In 2005, the Center for Biological Diversity (CBD) and Friends of the San Juans (FSJ) completed an extensive assessment 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 individual states combined (CBD and FSJ, 2005).

While not addressed directly in the CBD report, it is likely that Snohomish Basin, as part of the Puget Sound, is also home to a large number of these species. Some of the animals and plants that contribute to biodiversity and recreational value in the Snohomish Basin include salmonids, Roosevelt elk, cougars, Pacific tree frogs, Pacific giant salamanders, great blue herons, woodpeckers, beavers, otters, freshwater mussels, crayfish, and many insects. The Northwest is also known for its spectacular trees; the Snohomish Basin contains tree species such as western red-cedar, Douglas-fir, Sitka spruce, Pacific yew, western hemlock, red alder and cottonwood. Native plants are numerous and include salmonberry, willow, Indian plum, false lily-of-the-valley, foam flower, lady fern, maidenhair fern, trillium, bleeding heart, and salal.

Despite their size, Puget Sound and the Snohomish Basin are ecologically fragile, and their significant biodiversity is today threatened by a number of factors. To illustrate, as of 2010, more than 21 species in the Puget Sound have been listed as threatened or endangered under the Endangered Species Act (ESA) of 1973 (Puget Sound Partnership, 2009). The 2005 report by CBD and FSJ, offering a wider perspective on species threats, suggests that over 957 species are imperiled, of which 285 are critically imperiled (CBD and FSJ, 2005).

It is generally agreed that the most significant threat to biodiversity is the loss or degradation of habitat due to urban and suburban development, logging, and shoreline armoring (CBD and FSJ, 2005; Puget Sound Partnership, 2009). Habitat is the biophysical space formed by (typically natural) processes in which wild species meet their needs, and a healthy ecosystem provides physical structure, adequate food availability, appropriate chemical and temperature regimes, protection from predators and nursery functions.

Groups such as the Puget Sound Partnership (the Partnership) and Snohomish Basin Salmon Recovery Forum (the Forum) have thus focused primarily on habitat restoration and protection as a means to improve watershed health, and by extension human well-being. The majority of indicators used by the Partnership, for example, are focused on habitat, human well-being or species health, and the Forum has developed a “habitat hypothesis” that underscores the need for quality and quantity of salmon habitat within the Snohomish Basin (Puget Sound Partnership, 2009; Snohomish Basin Salmon Recovery Forum, 2005).

Other threats to biodiversity in the Puget Sound Basin include the introduction of exotic species, pollution, global climate change, and intensive use or exploitation that reduces species populations. For example, in many areas of the Snohomish Basin, invasive species, such as bullfrogs, Himalayan blackberry, Japanese knotweed, reed canary grass and English ivy, are vying for resources with native species, altering ecosystem dynamics, and reducing ecosystem productivity and value. Pollution threatens insects in water, as well as salmonids. Global climate change may have the largest impact on hydrology in the watershed, affecting the timing and magnitude of flood flows, as well as summer low flows.

Case Study: Threats to Salmonid Diversity

The Snohomish Basin has traditionally been home to important fish populations within the Puget Sound; however, overfishing, loss of estuarine habitat, pollution and development contributed to dramatic population declines in the last century. Historical abundance of Chinook salmon in the Skykomish and Snoqualmie Rivers, for example, was 51,000 and 31,000 fish respectively, but between 1999 and 2003, the average number of Chinook returning to spawn was 1,700 (Skykomish) and 1,200 (Snoqualmie). Respectively, their populations are therefore at 3.3% and 3.8% of historic equilibrium abundance (Snohomish Basin Salmon Recovery Forum, 2005).

Several species of salmon are now listed under the Endangered Species Act (ESA). The United States Fish and Wildlife Service (USFWS) and the National Marine Fisheries Service (NMFS), a division of the National Oceanic and Atmospheric Administration (NOAA), are the two federal agencies responsible for determining an ESA listing, and may list species that are endangered or threatened throughout all, or a significant portion of, their range.[3] Puget Sound Chinook salmon and bull trout were listed as threatened in 1999, and Puget Sound Steelhead was designated as threatened in 2007. With the listing of Chinook, in the face of threats of "take" of these listed species, local jurisdictions across Puget Sound worked with the NMFS to maintain local flexibility and control of land use and other decisions. Take is defined as harming or harassing a listed species, or significantly modifying its habitat (Albrecht and Christman, Findlaw webpage).

The Snohomish Basin Salmon Recovery Forum was formed in 1999 in response to the listings of Chinook salmon and bull trout char. Together with regional stakeholders, the Forum developed the *Snohomish River Basin Salmon Conservation Plan* (2005) as a chapter in the regional *Puget Sound Salmon Recovery Plan.* The Salmon Conservation Plan was also required as a local species

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[3] Depending on how they were listed under the ESA, species is defined as species, subspecies, distinct population segment (DPS), or Evolutionarily Significant Unit (ESU). See http://www.nmfs.noaa.gov/pr/glossary.htm#species (last accessed October 2010).

recovery plan under the ESA. Snohomish County provides the lead staff to the Forum and helps to guide salmon recovery efforts in the basin.

As members of the Forum, citizens, businesses, tribal representatives, farmers, environmentalists, and elected officials work together to understand one another's diverse viewpoints and find mutually agreeable solutions to restore traditional salmon runs. The Forum has become a knowledgeable and committed team dedicated to creating a future for people and fish in the Snohomish River basin. The Forum focuses primarily on habitat issues, because this is where local governments and organizations have the most influence, though members also stay informed about harvest and hatchery changes and issues. The Forum's work emphasizes the federally listed species of Chinook and bull trout, but at the same time includes all salmon species with the goal of avoiding future listings, especially of coho.

The Snohomish Basin Salmonid Recovery Technical Committee assists the Forum and includes scientific staff from agencies and organizations represented on the Forum, as well as federal agencies such as NOAA Fisheries. The Forum's Policy Development Committee, which includes several Forum members and alternates, as well as staff to Forum member agencies and organizations, previews policy issues for the Forum and makes recommendations for the group's consideration.

The Forum's staff lead outreach activities that are focused on plan development, identifying parties interested in salmon recovery efforts, providing information, and soliciting community input for consideration. Reaching recovery goals will allow for economic growth in fishing and tourism industries and local catch for the Tribes and anglers, and will provide a number of concomitant benefits. Past salmon habitat restoration projects have demonstrated flood reduction effects, recreational benefits, increase carbon sequestration, and many other economic rewards (Batker, 2005).

Part II: Key Ecological Economics Concepts

Section Summary: *Human well-being and advancement has always been tied to a healthy supply of nature's goods and services, but early economic models were created in a time of abundant natural resources. In that context, only built, financial and human capital (labor) were identified as constraining factors in the production process. Today's context is very different: our planet has become "full" of built capital, and natural capital is now the scarce, limiting factor in production. Ecological economics extends basic economic concepts and reflects today's economy more accurately. The "ecosystem services" framework is an operational way of including natural capital in economic analysis and is important to understanding and embracing an integrated approach to managing a watershed economy.*

What's an Economy for, Anyway?

Economies have existed since humans began to make and distribute goods and services; they have been instrumental in raising our standard of living and comfort. In the late 18th century, Adam Smith, David Ricardo and others articulated many of the basic market concepts that guide economic policy today. When Smith and Ricardo lived, the population of the Earth was less than one billion people, the Industrial Revolution was just beginning, the science of ecology did not exist, and natural goods and services were plentiful relative to manufactured and built capital (Norgaard et al., 2007). Thus, the economy focused on improving quality of life through built capital, allocating plentiful natural resources to build and distribute these built goods.

Early Economics and the Three Economic Questions

Economics is the study of the allocation of limited, or scarce, resources, among alternative, competing ends. This definition can be stated as three questions, in the following priority order:

1. What ends do we desire?
2. What scarce resources do we need to attain these ends?
3. What ends receive priority, and to what extent do we allocate resources to them?

Traditionally, economists have answered "utility" or "human welfare" to the first question. Human welfare was thought to depend on what people wanted, revealed through market transactions i.e. goods and services they bought and sold on a market. Early economics assumed that markets revealed most desired ends, and that most scarce resources were market goods, so gave most attention to one mechanism for allocating alternative resources to alternative ends: the market. Early economics focused secondarily on how the final goods and services were divided up (i.e. distribution), and not at all on the problem of an economy's size relative to the natural systems in which it existed (i.e. scale).

Today, economic activity is tracked using measures such as the Gross Domestic Product (GDP). GDP adds together both final goods and services (salmon, theatre visits, etc.) and 'bads' (oil spill cleanup costs, policing costs etc.) to arrive at an indication of the economy's total throughput. Today, GDP is used to measure market health on the assumption that the market is thought to supply most of our desired ends (or more specifically, preferences that we reveal for *market* goods and services). GDP is often falsely used as a human welfare measure, a purpose for which it was never intended.[4]

Today's economic models and norms were developed when natural capital (such as forests and fish) was abundant and built capital (such as roads and factories) was scarce. Because economic logic tells us that we should maximize the productivity of the scarcest, most constraining factors, as well as to try to increase their supply, our economy, facilitated by the instrument of finance, has focused on the production of built capital. This focus on built capital has yielded a highly productive market system for manufactured goods. Capital (such as machinery), land and labor have traditionally been considered the primary "factors of production," and the most constraining to economic development. Natural, social (such as culture), and human capital (such as education), on the other hand, have infrequently been included in economic analysis[5].

Figure 4 provides a sketch of the "Partial Economy" model, which includes the traditional "factors of production" and the GDP measure.

Figure 4: The Partial Economy Model.

A Shift in Scarcity

Over the past 50 years, humans have changed ecosystems more rapidly and extensively than in any comparable period in human history (Millennium Ecosystem Assessment, 2005), and there is ample evidence that scarcity has shifted from built capital to natural capital. This is true for many resources within the Puget Sound: our ability to produce boats and nets, for instance,

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[4] The architects of the GDP, John Maynard Keynes and Simon Kuznets, cautioned against using the GDP as a measure of the welfare of a nation. In 1962, Kuznets lamented that, "…the welfare of a nation can scarcely be inferred from a measurement of national income as defined by the GDP…goals for 'more' growth should specify of what and for what." (Anielski, 2009)

[5] An important caveat is that many of the environmental and social issues we face today are due to *insufficient* attention to standard economics in everyday decision-making. Subsidized prices for natural resources, neglect of external costs and benefits, and political unwillingness to respect the basic notions of scarcity and opportunity cost are among the uneconomic policies that are often promoted in today's economy (Daly and Farley, 2004).

now far outweighs the Sound's ability to produce salmon, and salmon harvest must be limited by laws and agreements.

Equally, in contrast to several generations prior, timber harvest is now limited by land availability and tree growth, rather than available logging equipment. Consider that in 1900, the well-known timberman Frederick Weyerhaeuser purchased 900,000 acres of prime Washington forest land for just $137 million (in 2009 dollars), or approximately $150 per acre (Ficken and LeWarne, 1988)[6]. Compare this value with a more recent assessment of forest land values among 38 counties in western Washington and Oregon, which found average values of $1,670 per acre (Alig and Plantinga, 2004[7]).

On a global scale, many experts can now show that humans may be depleting the Earth's flow of natural goods and services faster than the flow can be regenerated, and in many areas we are depleting the natural capital that produces this flow. For example, it has been estimated that humans now directly or indirectly appropriate up to 40% of the Earth's Annual Net Primary Productivity (Vitousek et al., 1986; Haberl et al., 2007), dramatically reducing the amount available for other species including those that support humans (such as fisheries). Net Primary Productivity is the total biomass that is produced by ecosystems through photosynthesis, and is the foundation for life on Earth. Other measures present a similar picture: The World Wildlife Fund recently calculated the "Ecological Footprint" of humanity, or the land and sea area that would be needed to sustainably regenerate the resources (and absorb the waste) that humans consume annually. It was found that our current rate of resource consumption and waste disposal requires 1.3 planet Earths - and this "footprint" is rising (World Wildlife Fund, 2008).

Independent of the measure, it appears that our economy today occupies a significant portion of the biosphere. An important reason for this shift in scarcity is that in the past century alone, the per-capita economic production of market goods and services has increased nine-fold (Farley, 2009, citing Delong, 2002). Figures 5 and 6 illustrate the human economy's move from the "Empty World" situation of the past to the "Full World" situation that we live in today.

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[6] Weyerhaeuser's purchase cost him $5.4 million in 1900; this value was converted to 2009 dollars using: http://www.westegg.com/inflation/ (last accessed October 2010).

[7] Original value in this 2004 study was $1,483. This value has also been converted to 2009 dollars using: http://www.westegg.com/inflation/ (last accessed October 2010).

Figure 5: Empty World Situation.

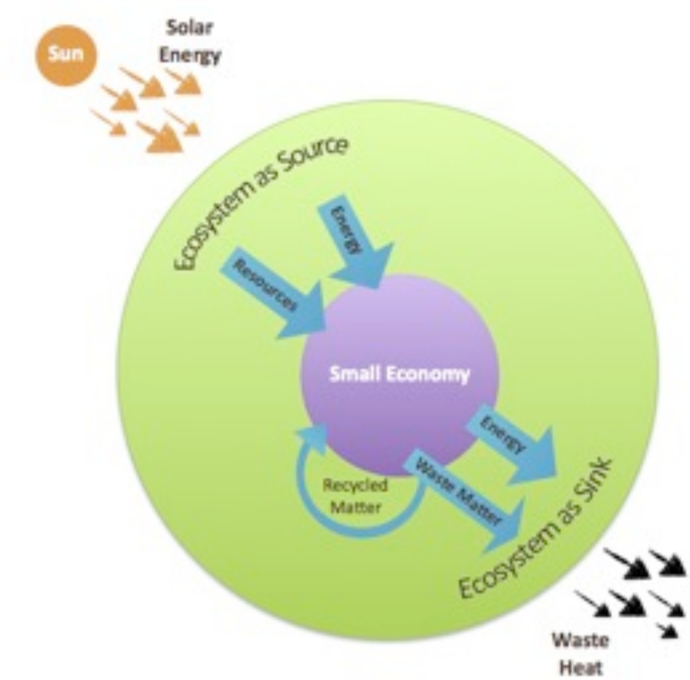
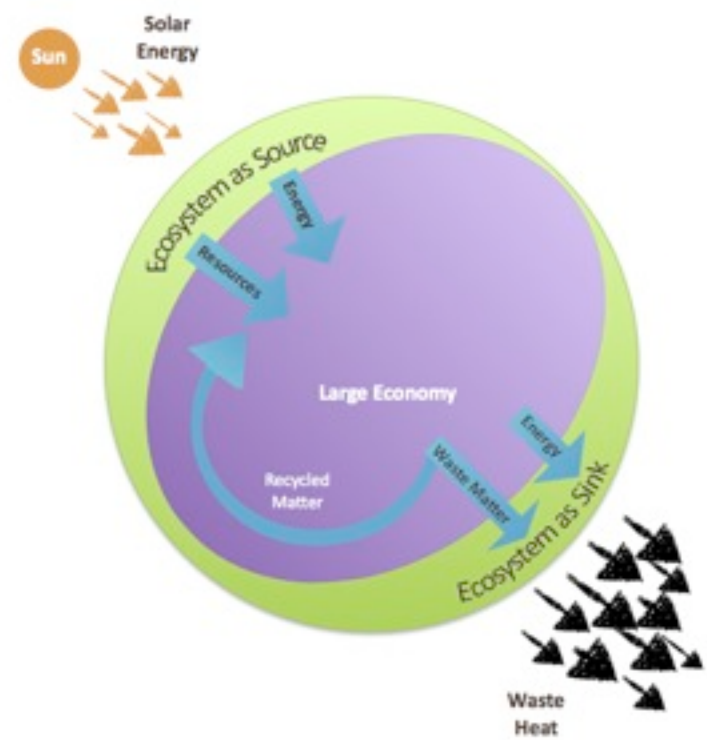


Figure 6: Today's Full World Situation.



Why has the "Shift in Scarcity" been Overlooked?

The success of the industrial revolution has greatly reduced the scarcity of market goods for much of the world's population. However, this has entailed a tradeoff: today, natural goods and services have become scarce. The shift in scarcity, from built capital to natural capital, holds major implications for the way our economy is structured and understood. Recognizing why this shift (on a global scale) has not been noticed can be instructive as we attempt to rebalance natural and built capital, and in addition, human, social and financial capital. Two major reasons are offered as to why the shift in scarcity has been overlooked, though other reasons certainly exist:

- **Exponential Growth of Human Population.** With a constant rate of population growth, the Earth would be expected to grow from half full to completely full in one doubling period- the same period it required to grow from 1% full to 2% full. With improvements in technology and general living standards, the human population has in reality grown exponentially, and doubling periods have shortened. For example, it took about 123 years (1804 - 1927) for the Earth's population to grow from 1 – 2 billion, and just 47 years (1927 – 1975) to then grow from 2 – 4 billion (United Nations, 2000). Not only have human populations grown exponentially, but so has each individual's absolute use of resources. The shift from an "empty world" to a "full world", and a concomitant shift in scarcity, has occurred more quickly than early economic models have been able to adapt.

- **Complementarity versus Substitutability.** If two goods or services are thought of as substitutes in an economic model, then a shortage of one does not limit the productivity of another. By default, the Partial Economy Model has tended to view built capital and natural capital as perfect substitutes, in this way avoiding the problem of scarcity. The false assumption that built capital and natural capital are perfect substitutes can be largely attributed to the failure of the Partial Economy Model to include natural capital explicitly as one of the factors of production (likely because the model was devised while the Earth was still "empty").

  If natural capital is thought of as a complement to built capital (and human, social and financial capital) in the creation of goods and services, as it always must be to varying degrees, then its scarcity constrains the other capitals by definition. For example, dams and levees (grey infrastructure) can provide flood protection services, but only after the majority of floodwater mitigation has occurred in headwater forests, wetlands, and floodplains (green infrastructure). Some natural goods and services, such as oxygen production and carbon sequestration, can be thought of as complements to all types of built capital, because there is no practical built substitute (e.g. all built capital production would cease in the absence of oxygen). In the economy, natural capital is thus, in many respects, an essential complement to built capital.

Ecological Economics: The Whole Economy

The primary goal of ecological economics is to ground economic thinking in the physical reality of today's "full world", a necessary advancement of economic thought. Ecological economics accepts much of the traditional economic theory regarding efficient allocation, but differs in fundamental respects, such as by addressing the problem of scale (i.e. sustainability). Specifically examining the relationship between ecosystems, the economy, and human well-being, ecological economics recognizes that as a subset of nature, our economy is best understood in the context of natural systems and processes (Daly and Farley, 2004).

Ecological economics is recognized worldwide as a tool used to improve decision-making processes at all levels of government. The ecological economic model of the economy, or "Whole Economy" model, illustrated in Figure 7, demonstrates that production of goods and services is tied to five capitals, natural, built, human, social, and financial, and that ecosystem goods and services contribute to human well-being, both directly and by providing natural capital for the production process; the negative feed-back loops from pollution and degradation are also included. In addition, Figure 7 introduces the four guiding principles for a healthy economy: good governance, sustainability, efficiency, and justice, which are displayed in blue. The basic understandings of ecological economics with regard to this model follow.

Figure 7: The Whole Economy Model.

Ecological Economics and the Three Economic Questions

Earlier in this section, three core questions of economics were posed, namely:

1. What ends do we desire?
2. What scarce resources do we need to attain these ends?
3. What ends receive priority, and to what extent do we allocate resources to them?

In light of the Whole Economy model, ecological economics approaches the Three Economic Questions with logic: it reflects deeply on the first two questions before attempting to answer the third question. The solutions that ecological economics has developed are outlined below.

Desired Ends: Human Well-Being

In the context of ecological economics and the Whole Economy Model, human well-being and a high quality of life for the current and future generations represent our desired ends. Human well-being is not a rigidly defined state, but a combination of physical and abstract human ends and needs that differ between individuals and places[8]. Many of these ends can be met on the market,

[8] Psychologist Abraham Maslow, for example, created an often-referenced framework for understanding the different types of human needs, referred to as "Maslow's hierarchy of needs" (Maslow, 1943). At the base of the hierarchy are "physiological" needs such as air, food, and water. Once the basic physiological needs are met, "safety" needs (physical safety, health, financial security etc.) can be attended to. The final three categories of needs are "love and belonging", "esteem" and "self-actualization" (the highest human need).

but many cannot. For example, some basic shared needs may include a dependable supply of food and clean drinking water, physical and financial security, health and friendship, and social bonds. Meeting the suite of human needs, now and into the future, largely depends on understanding the extent of our scarce resources and how they are allocated to different ends.

Scarce Resources: The Five Capitals

The Five Capitals represent our scarce resources- the resources that ultimately go towards human needs and human well-being. The Whole Economy model recognizes that five capitals are essential to economic progress and a high quality of life: healthy natural capital underlies all built, human, social and financial capital, which in turn create the conditions for a healthy and sustainable economy:

- **Natural Capital.** The stock of minerals, energy, plants, animals and ecosystems found on earth that yields a flow of natural goods and services. When taken as one whole system, natural capital provides the total biophysical context for the human economy.

- **Human Capital.** The self-esteem, knowledge acquired through education, technical and interpersonal skills, such as communication, listening, cooperation, and individual motivation to be productive and socially responsible.

- **Social Capital.** The inventory of organizations, institutions, laws, informal social networks, and relationships of trust that make up or provide for the productive organization of the economy.

- **Built Capital.** The 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 (i.e. natural capital) to be converted into a flow of economic goods and services, the products that we typically find in markets.

- **Financial Capital.** Shares, bonds, banknotes, and other financial assets play an important role in our economy, enabling the other combinations of capital (e.g. healthcare, education) to be owned, traded and allocated. Financial capital is based on trust and represents a promise that it will eventually be honored with one of the other types of "real" capital.

Attaining Desired Ends: The Four Guiding Principles

The third question of economics is the least straightforward, namely: *What ends get priority, and to what extent do we allocate resources to them?* While the question cannot be answered directly, ecological economics provides Four Guiding Principles that underlie the long-term attainment of human well-being.

- **Sustainability**. Living within a physical scale that does not destroy the basic natural systems that maintain the economy. Natural systems are part of our "commonwealth," which can be managed sustainably to produce economic benefit to current and future generations, or mismanaged at great cost.

- **Justice.** Fair distribution of public and private gains from natural, built, human, social, and financial goods and services ensures maximum benefit for lowest public investment. Intergenerational distribution is equally important; our children, grandchildren, and future generations should be given fair access to the Earth's stock of mineral and ecological resources.

- **Efficiency**. Careful decision-making regarding how and where resources are moved or invested to produce different suites of goods and services. Consideration of the most efficient balance of built, natural, human, social and financial capital for the types of goods and services we wish to enjoy, and whether or not a particular balance is detrimental to the goal of long-term sustainability.

- **Good Governance.** This principle consists of two elements:

  a. Creation and maintenance of both private and public institutions and groups, policy instruments, systems, and markets that ensure sustainability, justice and efficiency are achieved.

  b. Employing measurements that give an accurate indication of the Whole Economy's health, measuring what our scarce resources are and whether desired ends are being met.

Addressing Inherent Complexity

Importantly, ecological economics is equipped to deal with complexity, which is a physical reality in our economy. Ecological economics recognizes that each of the five capitals are comprised of numerous complex systems that are closely intertwined. Complex systems are characterized by strong (usually non-linear) interactions between the parts, complex feedback loops that make it difficult to distinguish cause from effect, and significant time and space lags, discontinuities, thresholds, and limits (Costanza et al., 1993, citing Rastetter et al., 1992 and von Bertalanffy, 1968).

The concept of resilience, for example, would benefit from ecological economics' better understanding of complexity. Resilience implies the potential of a system to, after disturbance, return to a previous state. A system is assumed to be fragile when resilience is low. Fragile systems tend to be replaced when disturbed; for example, wetlands that are converted to open water produce reduced amounts of ecosystem services and provide less economic value (Gunderson and Holling, 2002). An entire economic system can also collapse without resilience and revert to a less productive one; ecological economics therefore strives to build resilience into economic understanding.

Introduction to Ecosystem Goods and Services

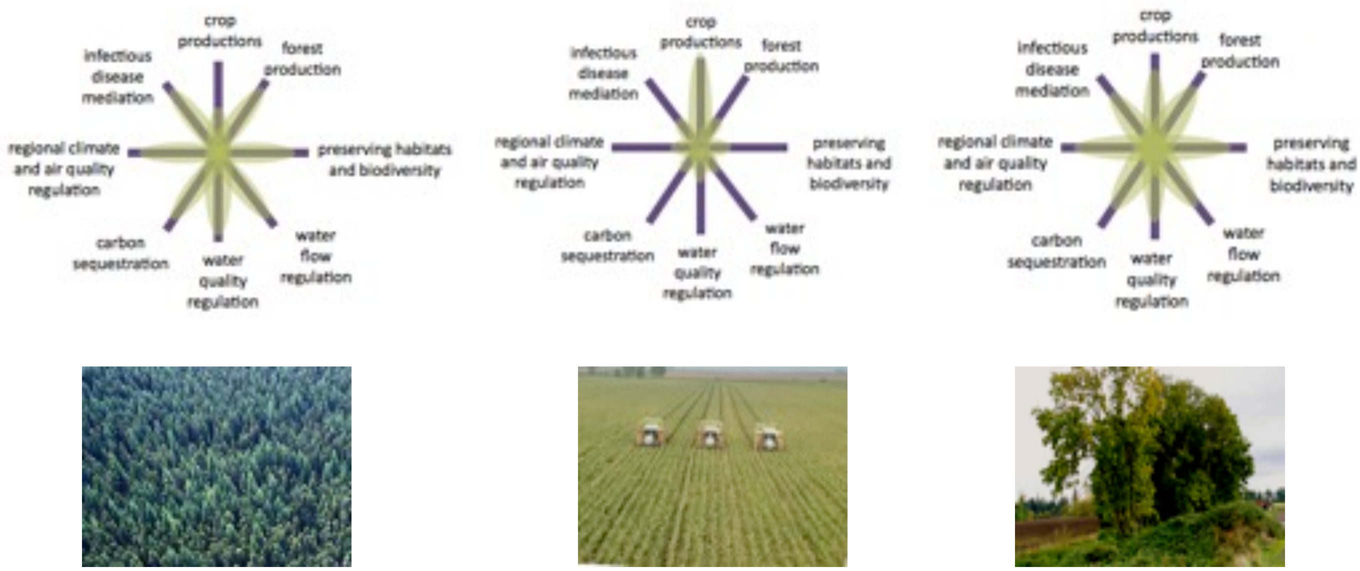
One advantage of the Whole Economy Model is that it can account for the full range of economically valuable benefits that natural capital provides beyond resource extraction, such as carbon sequestration and water filtration. Ecological economics, guided by the Whole Economy Model, has developed an operational framework through which to accurately internalize the value of nature in economic decision making, the "ecosystem service" framework. Ecosystem services were recently given higher prominence in the Millennium Ecosystem Assessment, a project called for in 2000 by then-United Nations Secretary-General Kofi Annan, which was completed in 2005.

The Millennium Ecosystem Assessment set out to examine the worldwide changes in ecosystems that have been occurring, the impacts of these changes 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, utilized the concept of "ecosystem services" to best understand the linkages between ecosystems and human well-being. Today, a number of federal agencies in the United States, including the Environmental Protection Agency and United States Department of Agriculture, house dedicated ecosystem services departments to advance understanding of how ecosystem services can be harnessed to improve long term economic prosperity for the nation.

Our natural environment provides many of the things we need to survive – breathable air, drinkable water, food for nourishment, and stable atmospheric conditions – to name a few. These are what we refer to as "ecosystem goods and services." Ecosystem goods and services are those derived from natural systems that provide benefit to humans. Ecosystems perform many functions, but only functions that provide human benefits are considered ecosystem goods or services. Every ecosystem produces a "suite" of ecosystem services; Figure 8 presents hypothetical examples of combinations of ecosystem goods and services that are produced by different types of land cover.

Figure 8: Suites of Ecosystem Goods and Services Generated by Different Land Cover Types.

Natural Ecosystem | **Intensive Cropland** | **Cropland with Restored Ecosystem Services**



Based on Foley et al., 2005

Healthy, resilient, natural infrastructure, referred to as “natural capital”, is critical to the production of ecosystem goods and services. The natural capital of an ecosystem consists of its individual structural components (trees, forests, soil, hill slopes, etc.) that produce 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 9, and might be likened to the production of cars in a factory: to build a car (a “built” good) requires high quality built capital (e.g. the factory, machines and connection to a power plant), natural capital (e.g. the extracted metal, rubber, food for the workers), human capital (the workers), financial capital (equity to buy the raw materials) and social capital (labor laws and agreements etc.).

Figure 9: The Link Between Natural Capital and Natural Goods and Services.

Ecosystem goods and services are different from the economic benefits provided by labor and capital that we typically value in the economy. Although we might include the dollar value of a levee as an economic asset - as measured by the costs of the workers’ time, fuel, and earthmoving equipment – if we do not include the value of flood protection provided by forests, wetlands, and lakes, then the economic analysis is deeply flawed. These “natural” assets provide as much, or sometimes more, flood protection than built structures and can often be implemented with little or no “capital cost” (the cost of building a levee or building), and low “maintenance costs” (the cost of upkeep)[9].

Ecosystem services clearly provide economic value to our measured economy. When the values of ecosystem services are not counted, their loss is often felt economically. Ecological economics provides the framework to include the real value of these goods and services in economic accounting and decision-making. When we alter environmental conditions, critical ecosystem services are damaged or lost, and must then be replaced by more costly built alternatives that are often funded by taxpayers. If ecosystems are valued as assets, however, the most valuable and cost effective services will not be lost. Otherwise, once lost, many ecosystem goods and services may not be recoverable.

Ecosystem Goods

Ecosystem goods are typically tangible, quantifiable items or flows - such as drinking water, trees for forestry, fish, and food. Most goods are excludable, which means that if one individual owns or uses a particular good, that individual can exclude others from owning or using the same good. For example, if one person eats an apple, another person cannot eat that same apple. Excludable goods can be traded and valued in markets. The quantity of water produced per second or the amount of timber cut in a 40-year rotation can be measured by the physical quantity an ecosystem produces over time. The current production of goods can be valued relatively easily, by multiplying the quantity produced by the current market price.

Ecosystem Services

Ecosystem services are defined as “the conditions and processes through which natural ecosystems, and the species that make them up, sustain and fulfill human life” (Daily 1997). Unlike ecosystem goods, ecosystem services are generally not tangible items that one can see or hold. Flood protection, recreational value, aesthetic value, and storm prevention are a few of the services that ecosystems may provide. Though often more difficult to value because market values rarely exist, ecosystems services have tremendous economic value and are critical both for our quality of life and for economic production (Costanza, 1997; Daily, 1997).

One reason these services may not have known economic values is that, for the most part, ecosystem services are non-excludable. For example, when one person enjoys a view of the Mt. Baker-Snoqualmie National Forest, another person is not prevented from enjoying the same view. Similarly, many non-paying downstream residents may benefit from the flood protection provided by forested land upstream. Because of the challenge associated with valuing and

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[9] Maintenance costs of natural assets are relatively low compared with built assets and often overlooked, despite their importance.

measuring ecosystem services, they have often been ignored. However, in many cases, the value of a service flow may significantly exceed the value of the flow of goods.

For example, a standing forest may be cut down once every few decades to provide an ecosystem good - timber - with revenue generated from the harvest and sales of the wood. However, the same forest, if left standing, might purify the drinking water for a nearby city for centuries, saving the cost of constructing a filtration plant and the additional costs of maintaining the plant each year as it begins to degrade, in addition to providing flood protection, soil erosion control, and many other services.

Many North American cities, including Seattle, Everett, Tacoma, Portland, San Francisco, and Vancouver (B.C.) on the Pacific Coast, and New York and Boston on the Atlantic Coast, have already decided that natural water purification is far more cost effective than other alternatives, and have purchased all or portions of forests near water supply areas to purify the water. Seattle Public Utilities for example purchased a large portion of the Cedar River Watershed over 100 years ago, and through careful management of its forests has avoided constructing a water filtration plant and upfront costs of $200 million. In addition, other ecosystem services such as carbon sequestration, wildlife habitat, soil erosion control, and many more will benefit from this management approach.

Ecosystem Service Valuation

Ecosystem service valuation assigns a dollar value to goods and services provided by a given ecosystem. This allows for proposed management policies to be considered in terms of their ability to improve ecological processes that produce valuable ecosystem goods and services. The full array of ecosystem goods and services produced in the Snohomish Basin are valued in Part IV of this report.

Part III: Ecosystem Services in the Snohomish Basin

Section Summary: *Ecosystem services can be divided into four categories: Regulating, Habitat, Provisioning and Information services. This section provides specific examples of ecosystem services in the Snohomish Basin.*

Categories of Ecosystem Services

The Millennium Ecosystem Assessment, introduced in *Part II: Key Ecological Economic Concepts,* classifies ecosystem services into four broad categories, which describe their ecological role (Millennium Ecosystem Assessment, 2003). Under this framework, both ecosystem goods and services are referred to as "Ecosystem Services", ecosystem goods falling under the "Provisioning Services" category.

- **Regulating Services.** Benefits obtained from the natural control of ecosystem processes. Intact ecosystems in the Snohomish Basin provide regulation of climate, water, soil, flood and storms, and keep disease organisms in check.
- **Habitat Services.** Refuge and reproduction habitat for wild plants, animals and humans. These services contribute to the conservation of biological and genetic diversity and evolutionary processes.
- **Provisioning Services.** Basic goods including food, water and materials. In the Snohomish Basin, 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.
- **Information Services.** Those services that provide humans with meaningful interaction with nature. These services include spiritually significant species and natural areas, enjoying natural places for recreation and learning about the planet through science and education.

Specific ecosystems services exist within each category. These services are identified in Table 1.

Table 1: Ecosystem Services.

	Services	Infrastructure and Processes	Example Goods and Services
Regulating Services		**Maintenance of essential ecological processes and life support systems**	
1	**Gas Regulation**	Role of ecosystems in bio-geochemical cycles	Provides clean, breathable air, disease prevention, and a habitable planet
2	**Climate Regulation**	Influence of land cover and biological mediated processes on climate	Maintenance of a favorable climate promotes human health, crop productivity, recreation, and other services
3	**Disturbance Prevention**	Influence of ecosystem structure on dampening environmental disturbances	Prevents and mitigates natural hazards and natural events, generally associated with storms and other severe weather
4	**Water Regulation**	Role of land cover in regulating runoff and river discharge	Provides natural irrigation, drainage, channel flow regulation, and navigable transportation
5	**Soil Retention**	Role of vegetation root matrix and soil biota in soil retention	Maintains arable land and prevents damage from erosion, and promotes agricultural productivity
6	**Soil Formation**	Weathering of rock, accumulation of organic matter	Promotes agricultural productivity, and the integrity of natural ecosystems
7	**Nutrient Regulation**	Role of biota in storage and re-cycling of nutrients	Promotes health and productive soils, and gas, climate, and water regulations
8	**Water Quality and Waste Treatment**	Role of vegetation & biota in removal or breakdown of xenic nutrients and compounds	Pollution control/ detoxification; Filtering of dust particles through canopy services
9	**Pollination**	Role of biota in movement of floral gametes	Pollination of wild plant species and harvested crops
10	**Biological Control**	Population control through trophic-dynamic relations	Provides pest and disease control, reduces crop damage
Habitat Services		**Providing habitat (suitable living space) for wild plant and animal species**	
11	**Habitat and Biodiversity**	Suitable living space for wild plants and animals	Maintenance of biological and genetic diversity (and thus the basis for most other functions)
12	**Nursery**	Suitable reproduction habitat	Maintenance of commercially harvested species
Provisioning Services		**Provision of Natural Resources**	
13	**Food**	Conversion of solar energy into edible plants and animals	Hunting, gathering of fish, game, fruits, etc.; small scale subsistence farming and aquaculture

14	**Raw Materials**	Conversion of solar energy into biomass for human construction and other uses	Building and manufacturing; fuel and energy; fodder and fertilizer
15	**Genetic Resources**	Genetic material and evolution in wild plants and animals	Improve crop resistance to pathogens & pests
16	**Medicinal Resources**	Variety in (bio)chemical substances in, and other medicinal uses of, natural biota	Drugs, pharmaceuticals, chemical models, tools, test and essay organisms
17	**Ornamental Resources**	Variety of biota in natural ecosystems with (potential) ornamental use	Resources for fashion, handicraft, jewelry, pets, worship, decoration & souvenirs
18	**Water Supply**	Filtering, retention and storage of fresh water (e.g. in aquifers and snow pack)	Provision of water for consumptive use, includes both quality & quantity
Information Services		**Providing opportunities for cognitive development**	
19	**Aesthetic Information**	Attractive landscape features	Enjoyment of scenery
20	**Recreation**	Variety in landscapes with (potential) recreational uses	Travel to natural ecosystems for eco-tourism, outdoor sports, etc.
21	**Cultural and Artistic Information**	Variety in natural features with cultural and artistic value	Use of nature as motive in books, film, painting, folklore, national symbols, architecture, advertising, etc.
22	**Spiritual and Historic Information**	Variety in natural features with spiritual and historic value	Use of nature for religious or historic purposes (i.e. heritage value of natural ecosystems and features)
23	**Science and Education**	Variety in nature with scientific and educational value	Use of natural systems for school excursions, etc. Use of nature for scientific research

Services Valued in this Study

For this study, 15 of 23 identified ecosystem services were valued. Descriptions of the ecosystem services that were valued, including local Snohomish Basin and Puget Sound examples, are provided below.

Gas and Climate Regulation

Gas regulation and Climate Regulation refer to the roles that ecosystems play in regulating the gaseous phase of compounds, organic and inorganic which affect atmospheric composition, air quality and climate regulation. The oxygen that people breathe is a product of photosynthesis from marine plankton and terrestrial plants. Removal of pollutants is another important aspect of gas and climate regulation. Low air quality can cause health care costs to spike as respiratory diseases develop. The regulation of climate is dependent on the composition of the atmosphere. "Greenhouse gases," such as CO2 are transparent to light but trap heat, warming our planet like a greenhouse. Carbon dioxide is removed through carbon sequestration as plants absorb CO_2 to produce roots, shoots, stems and leaves.

Local examples:

- Private, tribal, and government-owned forestlands constitute almost three-quarters of the land area of the Snohomish Basin (Snohomish Basin Salmon Recovery Forum, 2005). This forest cover absorbs CO_2 and captures a great deal of air pollution. Similarly, wetland areas, though their range in the Basin is much smaller than it has been in the past,[10] still sequester significant volumes of carbon every year.
- American Forests (1998) calculated that urban forests remove 78 million pounds of pollutants per year in the Puget Sound area. Based on the value of avoided health care costs and other externalities, the authors valued this gas regulation service at $166.5 million per year for the year of 1996. The extensive forest cover of the Snohomish Basin likely provides a significant amount of gas regulation service, which is very valuable in terms of public health.

Disturbance Prevention

Healthy ecosystems reduce the impact of natural disturbances on humans. Natural disturbances can include floods, storms, tsunamis, and fires. Flood and storm protection in particular are critical to securing economic security for communities, states and nations, as Hurricane Katrina demonstrated in New Orleans. Estuaries and bays, coastal wetlands, headlands, intertidal mudflats, sea grass beds, rock reefs, and kelp forests provide storm protection. These areas are able to absorb and store large amounts of rainwater or water runoff during a storm, in addition to providing a buffer for coastal waves. Estuaries, bays, and wetlands are particularly important for absorbing floodwaters (Costanza et al., in review; UNEP, 2005).

One of the most significant factors in an ecosystem's ability to prevent flooding is the absorption capacity of the land. This is a factor of land cover type (forest vs. pavement, for example), soil structure and quality, and other hydrological and geological dynamics within the watershed. In the Puget Sound, impermeable surface area has increased by over 10% in the past 15 years. The U.S. Geological Survey estimates that urban development leads to increases in flood peak discharges flows of 100-600% for 2-year storm events, 20-300% for 10- year events, and 10-250% for 100-year events (Konrad, 2003).

Retention of forest cover and restoration of floodplains and wetlands provide tangible and valuable ecosystem services: reduced damage from floods to property, lost work time, injury,

[10] For example, only a quarter of historical estuarine wetlands in the Snohomish Estuary remain (Bortleson et al., 1980).

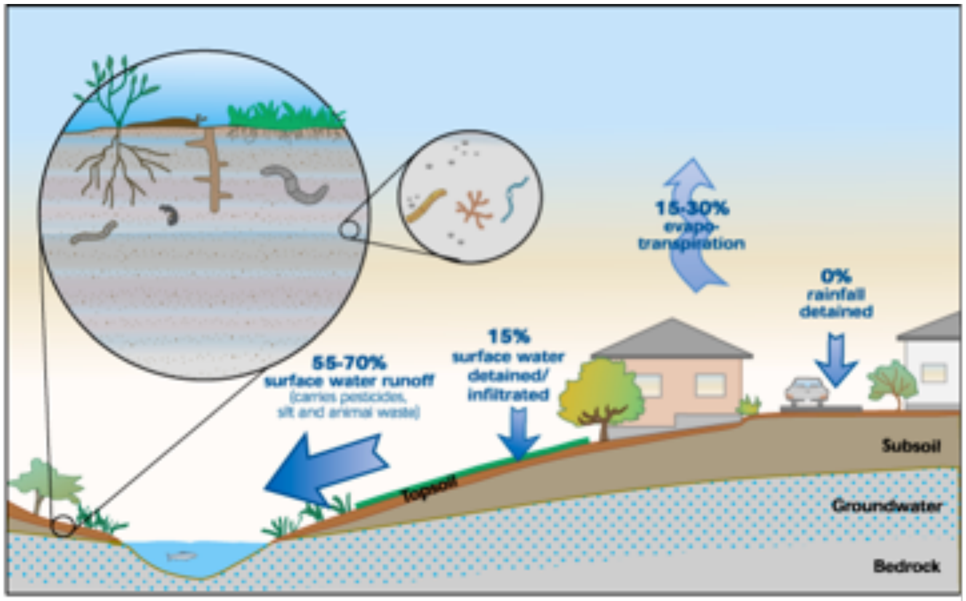
and loss of life. For example, upland forests absorb rainwater, significantly reducing its downhill and peak flows into major stream and river systems. In undeveloped areas of a watershed, typically less than 15% of precipitation reaches streams or rivers as surface runoff, compared with 55-70% in a developed watershed (see Figures 10 and 11 below for a graphic illustration). Today, changes in land use, combined with the potential for higher return frequency for storm events due to climate change, make disturbance regulation one of the most important for the future of economic development in the Snohomish Basin. In order to have productive agricultural and forested lands, protected built capital, and high value, productive ecosystems, flood protection must be effective and efficient.

Local examples:

- The 24-acre North Scriber Creek wetland in Lynwood, Snohomish County, was found by the Department of Ecology to have a flood protection value of $8,000-$12,000/acre/year, and 292 acres of wetland in Renton a flood protection value of approximately $41,000/acre/year (Leschine et al., 1997).

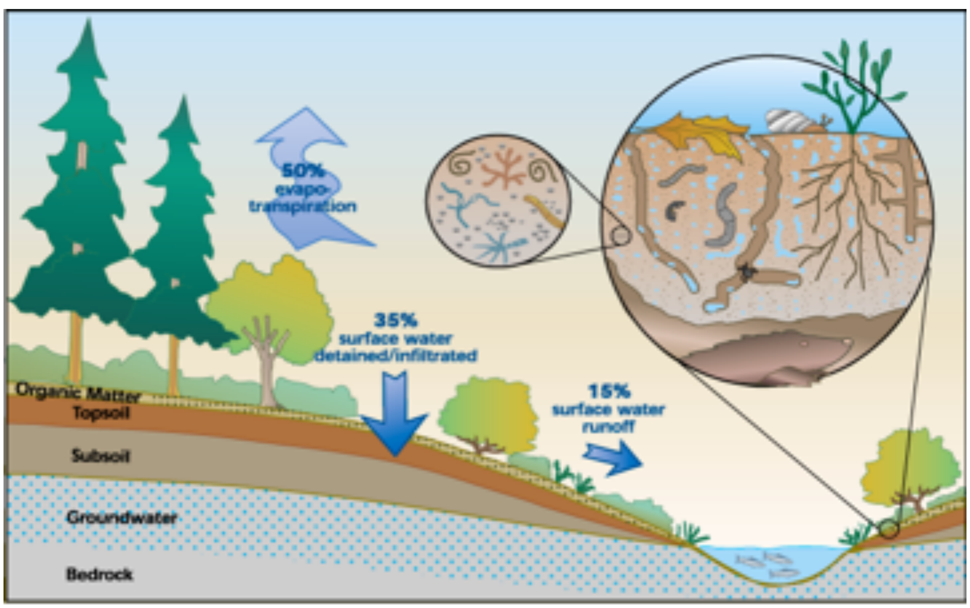
- Some farmers in the Snohomish Basin have completed flood fencing projects as a cost effective, near-term solution to flood hazard mitigation. Flood fencing is an innovative technique developed by Snohomish County Surface Water Management, whereby large logs are vertically driven into the ground along river banks. These logs act as a riparian stand of trees would, trapping large sediment and debris during floods, in this way minimizing bank erosion and damage to property (such as farms) on the floodplain. The logs also provide a refuge to juvenile salmon during high river flows (Snohomish County webpage, 2010).

Figure 10: The Movement of Precipitation in a Developed Watershed.



Source: King County

Figure 11: The Movement of Precipitation in a Forested Watershed.



Source: King County

Water Regulation

This category includes regulation of water flows through the ground and along terrestrial surfaces; and regulation of temperature, dissolved minerals and oxygen. Ecosystems absorb water during rains and release it in dry times, and also regulate water temperature and flow for plant and animal species. The amount and timing of water flow in the Snohomish Basin is important for many reasons; the supply of adequate amounts of cool water at critical times is important for salmon migration, the provisioning of drinking and irrigation water allows for ecosystem goods such as clean drinking water and agricultural products, and the maintenance of adequate water flows generates electricity for hydroelectric dams. Forest cover, riparian vegetation, and wetlands all contribute to modulating the flow of water from upper portions of the watershed to streams and rivers in the lower watershed.

When forested basins are heavily harvested, the remaining vegetation and litter layer on the forest floor absorbs less water. Because the ground's capacity to absorb water is reduced, more water flows over the land and into streams and rivers, contributing to higher peak flows, flood events, erosion and landslide issues, as well as lower low flows in summer months, because the water was not retained in natural systems (Moore and Wondzell, 2005). Figures 10 and 11 illustrate that water regulation is closely linked with floodwater attenuation (i.e. a kind of disturbance prevention).

Local examples:

- The Snoqualmie and Snohomish Rivers have a long history of flooding. Widening the floodway is likely a more effective and less costly approach to flood protection than raising levee heights. The Lower Tolt River Floodplain Reconnection project, at the confluence of the Tolt and Snoqualmie Rivers, set a levee back approximately 800 ft behind the original levee, reconnecting the river with its floodplain and allowing for greater habitat quantity and complexity for salmonids such as Chinook salmon and steelhead trout (Habitat Work Schedule website, 2010). Other ecosystem services will also benefit from this change in water regulation, including disturbance prevention (e.g. flood protection) and aesthetic information (Batker, 2005).

- The Climate Impacts Group has recently published a report on the likely effects of climate change in the Pacific Northwest region (Mantua, Tohver and Hamlet, 2009). Their simulations suggest that climate change will have an effect on the timing and magnitude of annual river and stream flows. This means that in the Puget Sound region, salmon with an ocean-type life history (with a relatively brief freshwater rearing period) are likely to experience a reduction in freshwater survival and productivity because a greater frequency and magnitude of winter flooding will affect egg-to-fry survival rates. A management approach that acknowledges changes in future water flow regimes and builds resilience[11] into natural systems is therefore essential to salmon recovery efforts in the Snohomish Basin.

[11] Resilience refers to a system's (natural or human-designed) capacity to recover after disturbance or its capacity to absorb stress.

Water Supply

Watersheds produce water, including surface water and ground water for large metropolitan areas, wells, industry, and irrigation. The hydrological cycle is affected by structural elements of a watershed such as forests, wetlands and geology as well as processes, such as evapotranspiration and climate. Over 60% of the world's population gets their drinking water from forested watersheds (UNEP 2005). Increasing loss of forest cover around the world has decreased water supply, due to lower ground water recharge and to lower flow reliability (Syvitski, 2005).

Local examples:

- Snohomish County residents receive water captured and largely filtered by natural systems. When the Everett City filter broke down, the EPA allowed the City to continue providing drinking water because the forest filtered water was within clarity parameters, and there was no threat to public safety. A similar filtration breakdown in Milwaukee City caused a massive outbreak of Cryptosporidium Infection to be transmitted through the public water supply, and around 403,000 people developed watery diarrhea (Mackenzie et al., 1994).

- In the Puget Sound, snowpack performs a critical water storage and supply service. Snowmelt in the Puget Sound provides around 70% of drinking water annually (Chang et al., 1987). Current reservoir systems in the Puget Sound largely depend on snowpack to supplement water storage: almost all of the major municipal water systems west of the Cascades have storage to in-stream flow ratios of less than 10% (Hamlet et al., 2001).[12] Snowpack in the Puget Sound may in this way be viewed as essentially a large, inexpensive system of reservoirs. The economic value of snowpack to the Puget Sound population can be assessed by exploring the costs of an alternative storage system, i.e. surface water reservoir construction, and was found to be in the range of $480 million - $39 billion annually (Batker et al., 2010). If the environmental costs of such reservoir systems were included, such as disruption of salmon runs and loss of vegetation, the replacement cost of snowpack might be substantially higher.

Soil Retention

Soil serves a vital function in nature, providing a medium for plant growth as well as nutrients for plants, and habitat for millions of micro and macro organisms. Healthy soils are able to store water and nutrients, regulate water flow, and neutralize pollutants more efficiently than degraded soils (Marx et al., 1999). In this sense, soil retention reinforces a number of other

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[12] Hamlet, A. F., Fluharty, D., Lettenmaier, D. P., Mantua, N., Miles, E., Mote, P., Whitely Binder, L., 2001. Effects of Climate Change on Water Resources in the Pacific Northwest: Impacts and Policy Implications. JISAO Climate Impacts Group, University of Washington.

ecosystem services, including disturbance prevention, salmon habitat, and provisioning of raw materials such as timber.

Natural soil erosion plays an important role in Pacific Northwest ecosystems, allowing fertile soils to be deposited onto floodplains, and providing the gravel required for salmon spawning. Coastal erosion is a natural process along Puget Sound's shoreline, building, maintaining and moving shorelines naturally with interactions of wave energy and sediment deposition. Erosion also creates raw materials for human use: historic gravel deposits are mined in the Snohomish Basin (King County DDES, 2008a; King County DDES, 2008b).

The soil retention properties of ecosystems determine the rate of erosion, and thus soil retention is closely linked with prevention of disturbances such as landslides, which are often caused by excessive erosion and can be attributed to human land use. In many areas, vegetation can help prevent landslides and harmful erosion. The susceptibility of a given slope to erosion is determined by grain-size, soil cohesion, slope gradient, rainfall frequency and intensity, surface composition and permeability, and type of land cover. A forest's organic layers act as a natural sponge, absorbing water during periods of heavy precipitation and preventing erosion. In areas where active forestry occurs, the upper layers of soil are often removed or degraded.

Local examples:

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- Soil retention in Snohomish County is an important ecosystem service, as the sedimentation from large amounts of erosion can be extremely damaging to drinking water quality, siltation and in-stream water quality for fish habitat.[13] Like other counties, Snohomish County has implemented a Shoreline Master Program (SMP), as mandated by the Shoreline Management Act. The Shoreline Management Act was enacted in 1971, in the same year as Washington's State Environmental Protection Act. It was designed to prevent the inherent harm in an uncoordinated and piecemeal development of Washington State's shorelines. Regulation also extends to the banks of rivers and lakes of a certain size, and wetlands associated with those systems. One important function of the SMP is to prevent erosion and sedimentation that would alter the natural function of the water system. In addition to the seven elements that must be incorporated into SMP (shoreline use, economic development, public access, recreation, circulation, historical/cultural/scientific/educational and conservation), Snohomish County has recently added two elements: Agriculture and Implementation (Snohomish County webpage, 2010). King County has also implemented an SMP, incorporating "residential" as an eighth element. This addition recognizes the importance of residential land use along King County's shorelines: the majority of developed- and much of the undeveloped- shoreline in King County is zoned for residential land use

[13] King county Best Available Science Chapter 5: Geologic Hazard Areas - http://www.kingcounty.gov/property/permits/codes/CAO.aspx#best

(King County, 1978).

Soil Formation

Soil is formed over thousands of years through a process that involves parent material, climate, topography, organisms, and time. Soil quality and abundance is critical for human survival, yet human actions can also affect nature's ability to provide high quality soils. From the Snohomish County Soil Survey (United States Department of Agriculture Soil Conservation Service, 1983), five elements influence to type and characteristics of soils.

Parent material is, for the most part, chemically weathered mineral or organic matter that contributes to soil formation. In the Snohomish Basin, most soils were formed from deposits of glacial drift, though some were deposited by till, outwash, and material mixed with volcanic ash.

Topography affects soil formation by changing the drainage and surface flow of rain and runoff. The slope of the land, the ways in which topography dictates water flows and absorption, and solar evaporation are all examples of ways in which topography can relate to soil formation and soil characteristics.

Living organisms contribute to soil formation as they decompose. Plants, microorganisms, earthworms, insects, fungi, and other life forms contribute organic matter and nitrogen. The characteristics of soils drive the types of plant communities in an area; thus, plants can be used as an indicator of soil types. Animals contribute less to this process, but earthworms, insects, and small animals assist with soil aeration and deposit nutrients.

The climate in the Snohomish Basin has three distinct zones: Western (lower elevation 0-800 feet, lower precipitation, a high period of frost-free days, and a mean temperature of 55 degrees F), Central (elevation ranging from 800 – 1,800 ft, slightly more precipitation, fewer frost free days, and an average air temperature of 45 degrees F), and the Eastern region, where elevation is above 1,800 ft, annual precipitation is high, the frost-free period is short, and mean annual air temperature is 42 degrees F. The amount of precipitation and the air temperature are primary factors in the climate's influence on soil formation processes. Because of the colder temperatures and higher precipitation in the eastern area, soils have a distinct surface layer and subsurface layer.

Time is absolutely essential to soil formation. In the Snohomish Basin area, soil-forming processes began following glacial melting, around 12,000 years ago. There are rocky areas in Snohomish County showing glacial scars which have not accumulated any soil. Some types of soils develop more slowly than others, but all develop over the course of thousands of years.

Local examples:

- A number of jurisdictions, including King County, have created outreach programs on building healthy soil, using compost rather than commercial fertilizers that can affect stormwater quality (King County website).

- The Tualco biogas digester near the City of Monroe outputs fibers and liquid as a "byproduct" of the facility's power generation. The liquids are returned to agricultural fields as a nutrient-rich soil amendment, while the fibers are mixed with biosolids to produce a compost mix that can be sold (Smith, 2009). The compost is used by the City of Monroe in public gardening areas around the city. In the near future, biosolids produced by the City of Monroe's wastewater treatment plant will also be used as a feedstock (i.e. input) for compost production at the biogas digester site, reducing the cost of transporting biosolids to other regions and providing further benefits to local soils (personal communication, John Lande, City of Monroe).

Nutrient Regulation

The transfer of nutrients from one place to another and transformation of critical nutrients from unusable to usable forms is an essential ecosystem service. There are 22 essential elements for the growth and maintenance of living organisms. All living things depend on the nutrient cycles of carbon, oxygen, nitrogen, phosphorous, and sulfur in relatively large quantities. These are also the nutrient cycles that human actions have most affected. Silicon and iron are important elements in oceanic nutrient cycles because they affect phytoplankton community composition and productivity. Natural processes facilitate the movement of nutrients and turn them from biologically unavailable forms, such as rocks or gases in the atmosphere, into forms that can be used by other living things. Nutrient cycling is a fundamental precursor to ecosystem and economic productivity, and without functioning nutrient cycles, life on the planet would cease to exist.

Living organisms mediate nutrient regulation. On land, plants depend on biologically mediated breakdown of organic matter to make the nutrients they need for growth available. As plants and plant parts die, they contribute to the pool of organic matter that feeds the microbial, fungal and micro-invertebrate communities in soils. Underground fungal structures can also provide support to living plants – for example young trees may not receive enough light (and therefore nutrients) because mature trees block sunlight, but can draw nutrients from mycorrhizal structures hundreds of yards away (Stamets, 2005). Such communities facilitate the transformation of nutrients from one form to another. Larger animals play a crucial role in nutrient cycles by moving nutrients from one place to another in the form of excrement, and through the decomposition of their bodies after they die. Animals play a role in transporting nutrients between terrestrial and aquatic environments. Salmon and marine birds bring marine nutrients into terrestrial and freshwater ecosystems, enhancing the productivity of these systems throughout several layers of the food web (Polis et al., 1997).

Local examples:

- Salmon enhance local ecosystems in the Snohomish Basin by moving nutrients into our local creeks and rivers. Salmon spend most of their lives in the nutrient-rich North Pacific Ocean, where they accumulate carbon, nitrogen, phosphorous and other micronutrients into their body tissue. When they return to spawn and die, these nutrients are released into the freshwater river system, providing an important "energy subsidy" to nutrient-poor rivers and streams (Merz and Moyle 2006; Willson and Halupka 1995). This process is vital to the biological productivity and health of inland streams and riparian vegetation (Wipfli et al., 1999; Bilby et al., 2003; Kline et al., 1990). It has also been found to elevate the growth rates of young salmon and resident fish, such as trout, resulting in improved survival rates, and greater abundance of fish in following years (Wipfli et al., 2003). Salmon therefore play an important role in cycling nutrients back into the Basin, promoting the health of their habitat, and in turn, the health of their own populations.

Water Quality and Waste Treatment

Microorganisms in sediments and mudflats of estuaries, bays, and nearshore submerged lands break down human and other animal wastes (Weslawski et al., 2004). They can also detoxify petroleum products. The physical destruction of habitat, alteration of food webs, or overload of nutrients or waste products disrupts disease regulation and waste processing services. Alteration of ecosystems can also create breeding sites for disease vectors where they were once non-existent. People can be exposed to disease in coastal areas through direct contact with bacterial or viral agents while swimming or washing in fresh or saltwater, and by ingesting contaminated fish, seafood, or water.

Wetlands, estuarine macroalgae, and nearshore sedimentary biota play a crucial role in removing nitrogen and phosphorous from water (Garber et al., 1992; Weslawski et al., 2004). The removal of these nutrients maintains offshore water conditions that are conducive to healthy native fish and invertebrate biota. The rise of nutrient overload (e.g. through failing septic systems) and hypoxic zones have become a major issue in Hood Canal in recent years (PSAT, 2007). Land use patterns also play an important role. Researchers have found that more agriculturally active and heavily urbanized watersheds contribute three times the nitrogen and phosphorous loads to the Puget Sound than the forested watersheds in the Olympic Mountains (Embrey and Inkpen., 1998).

Local examples:

- Manure runoff from dairy farms along the Snohomish River can compromise the River's ability to support healthy salmon populations. To reconcile the interests of both agriculture and salmon, the Tulalip Tribes, Sno-Sky Agricultural Alliance and Northwest Chinook Recovery recently co-formed a non-profit organization called Qualco Energy, which has built a biogas plant on Tulalip property, near the confluence of the Snoqualmie and Skykomish Rivers. The biogas plant is a pioneering project within the Basin, converting manure from dairy farms into methane gas, which is then used to power a generator. The plant has been running since about 2008, and in addition to keeping dairy farm waste out of rivers and reducing greenhouse gas emission, profits from the sale of electricity will eventually fund local salmon restoration projects (Northwest Indian Fisheries Commission, 2009; Careless, 2009).

- The Puget Sound area has experienced several incidents of shellfish and beach closures due to red tide and amnesic shellfish poisoning in recent years (Woods Hole Observatory, 2006). While the algae that cause toxic blooms are native to west coast waters and toxic blooms can occur as natural events, there are concerns and direct evidence that increasing pollution loads and climate change exacerbate the conditions that lead to toxic blooms (see Rabalais, 2005 for a summary). In 2009 for example, 27 commercial shellfish growing areas were subject to emergency closures due to pollution concerns arising from events such as heavy rainfall, flooding, nearby sewage discharges or spills, and illness outbreaks (Washington State Department of Health, 2010). Reduced access to beaches, fish, and shellfish due to disease has obvious impacts to human health and economic activity in the Puget Sound.

Pollination

Pollination is essential to agricultural crops, trees and flowers. It is the role that insects, birds, mammals and, in some cases, the wind play in transporting pollen grains to fertilize plants. People depend on pollination directly for food and fiber, and indirectly as part of ecosystem productivity. Many plant species would go extinct without animal and insect mediated pollination. Pollination services by wild animals are also crucial for crop productivity for many types of cultivated foods, enhancing the basic productivity and economic value of agriculture (Nabhan and Buchmann, 1997). The importance of wild pollinators to food crops means that wild habitats near croplands are necessary in order to provide sufficient habitat to keep populations of pollinators intact. Some plants have a single species pollinator.

Local example:

- While little is known about the status of many pollinator species in Puget Sound, The Nature Conservancy is finding that the prairie ecosystems around the Fort Lewis area are critical to the health of local insect species, including bees (Washington Conservation Science website). These studies may impact the health of farms and other industries that to this point have taken pollinators for granted.

Biological Control

Healthy ecosystems limit the population of weeds, pests and diseases, protecting human health, crops and livestock. A number of natural predators exist for pest species, which can contribute to control of damages. Natural predators can also play a role in protecting forests from pests. For example through birds consume insects that can prey on trees.

Many exotic pests have recently been introduced to areas beyond their natural range. These new pests have caused annual damage; estimates for this damage in the United States range from $1.1 to $137 billion dollars (Pimental et al., 2000, USOT, 1993, cited in Chapin et al., 2000). Another study estimated that the loss of major crops (wheat, maize and cotton) due to weeds, pests and disease was at least 28% for the years 2001-2003, and found that despite a clear increase in the use of pesticides, the proportions of crop losses have not decreased significantly over the last 40 years (Oerke, 2006).

Local example:

- The emerging field of integrated pest management (IPM) has shown that pests are best managed naturally and, when necessary, treated with pesticides as a last resort. There are also ways to manage crops so as to enhance biological control services. These techniques include crop diversification and genetic diversity, crop rotation, and promoting an abundance of smaller patches of fields (Lichtfouse et al., 2009; Lichtfouse E. et al., 2009; Risch et al., 1983). The Washington State University Snohomish Extension offers resources and training on the newest integrated pest management techniques for Snohomish Basin residents and throughout the state. The Seattle-based non-profit Stewardship Partners, for example, assists Snohomish and King County farmers with the installation of native vegetation areas, providing important bird habitat which, in turn, encourages birds to forage fields for insects.

Habitat and Biodiversity

Biological diversity is defined as the number and types of species and the ecosystems they comprise. It is measured at gene, population, species, ecosystem, and regional levels (Magurran, 1988). Biodiversity must exist for the flow of ecosystem services, and can also be considered an ecosystem service in itself (UNEP 2005). Ecosystems with their full native complement of species tend to be more productive and more resilient to change in environmental conditions or external shocks.

Habitat is the biophysical space formed by (typically natural) processes in which wild species meet their needs. A healthy ecosystem provides physical structure, adequate food availability, appropriate chemical and temperature regimes, and protection from predators. In addition to the physical structure provided to species, food web relationships are important components of habitats which support all species.

One recent meta-analysis of marine data and studies examining the effects of biodiversity on ecosystem services found strong evidence that loss of biodiversity leads to fisheries collapse, lower potential for stock and system recovery, loss of system stability, and lower water quality. The relationship is one of an exponential loss of ecosystem services with declining diversity (Worm et al, 2006). Worm et al. also found that restoration of biodiversity, including the establishment of marine reserves protected from fishing pressures, leads to a fourfold increase in system productivity and a 21% decrease in variability (i.e. an increase in resilience). This study provides the best evidence to date of the direct relationship between biological diversity and ecosystem services in the marine environment.

Local examples:

- The Puget Sound is home to a high diversity of kelps (23 species) and one species of eelgrass. Both kelp (though significant losses have occurred) and eelgrass exist in the Snohomish River Delta, providing important habitat and nursery functions for a large number of commercially important species, including salmon, crab, abalone, and juvenile rock fishes (Mumford, 2007).

- The Snohomish Basin and Puget Sound are home to a rich diversity of species and habitats; however, most terrestrial and aquatic habitat in the Snohomish River Basin has suffered degradation through physical alteration caused by development, conversion from a natural to a heavily managed land function, logging, pollution, or the impact of invasive species (Buchanan et al., 2001; EPA, 2007; Olson et al. 2001). Currently, more than 21 species in the Puget Sound have been listed as federally threatened or endangered (Puget Sound Partnership, 2009). Not only have habitat areas been lost, but the processes essential to habitat formation and function have been impacted as well.

Food

Providing food is one of the most important functions of ecosystems. Agricultural lands are our primary source of food; farms are considered modified ecosystems, and food is considered an ecosystem good with labor and built capital inputs. In traditional economic analyses, agricultural value is measured by the total market value of crops produced. While this measure is useful, market value is only a small portion of the total value agricultural lands provide through pollination, carbon sequestration, aesthetic value, and other services. Marine ecosystems are the largest sources of food from wild ecosystems. Globally, fish and seafood provide the primary source of protein to one billion people. Fishing and fish industries provide direct employment to some 38 million people (UNEP, 2005).

Local example:

- Agriculture in the Puget Sound Basin produced $1.1 billion worth of crops and livestock in 2002, the latest year for which data is available (USDA, 2002). Berries, peas, potatoes, flower bulbs, seeds, and dairy products are important agricultural commodities in the Puget Sound Basin. Berries are especially high value products for the region.

- Agricultural land contributes significantly to value in the Snohomish Basin, and includes equine, nursery, pasture, and market crop uses. The ecosystem service valuation tool used in this report includes food value along with available ecosystem service values in its full watershed valuation.

Aesthetic

Aesthetic value, as an ecosystem service, refers to the appreciation of and attraction to beautiful natural land and seascapes. The existence of National Seashores, State and National Parks, Scenic Areas, and officially designated scenic roads and pullouts attest to the social importance of this service. There is also substantial evidence demonstrating the economic value of environmental aesthetics through analysis of data on housing markets, wages, and relocation decisions (Palmquist, 2002 and see studies included in valuation results). Degraded landscapes are frequently associated with economic decline and stagnation (Power, 1996).

Local examples:

- The Snohomish Basin's beaches and views of water, forests, mountains and farmland are of major importance to the cultural and economic character of the Basin. In 2009, the U.S. Congress designated the Wild Sky Wilderness Area, an area covering over 106,000 acres of forested mountains in the Upper Skykomish River Valley. Surrounding municipalities have begun investing in the recreational economy, as well as in real estate that boasts scenic vistas of the area.

Recreation

Recreation is related to, but not totally encompassed by, aesthetic values. People travel to beautiful places for vacation, and engage in activities such as recreational fishing, scuba diving, surfing, kayaking, whale and bird watching, boating, sail boarding, hunting, skiing, snowboarding, enjoying local seafood and wines, and beachcombing. Such activities all require healthy ecosystems, fish, beaches, snow and other environmental attributes. Storm protection, shoreline stabilization, and waste treatment are also important ecological services associated with recreation and tourism because they help keep tourists safe and protect both private and public infrastructure needed for the tourist industry.

While teasing out the direct monetary contribution of the ecosystems themselves to the recreation and tourism economy, there is no doubt that attractive landscapes, clean water, and healthy fish and wildlife populations provide a necessary underpinning to this sector of the economy. Several studies of nature-related recreation are included in the ecosystem service value analysis of the following section.

Local examples:

- The Snohomish Basin provides for hiking, boating, biking, fishing, hunting, wildlife watching, swimming, camping, skiing and other recreational activities. Jetty Island kite sailing is nationally recognized and provides a training ground for the stronger winds of the Columbia Gorge, Tofino, B.C. and Howe Sound. In June 2010, Jetty Island was host to the Jetty Jam, a two day event involving competitive kite boarding and paddle boarding races, kite boarding demonstrations and live music.

- Recreation and tourism, like aesthetics, is an important part of the link between ecosystem services and the Puget Sound's economy: nearly 80% of the state's revenue generated by tourism is generated in the Puget Sound (State of Washington OFM, 2007), and more than half of recreational salmon that are caught in Washington State are from Puget Sound (Puget Sound Partnership, 2007).

Spiritual and Religious Value

Many natural areas have special importance to native people from a spiritual perspective, as evidenced by indigenous traditions, stories and art depicting salmon and other marine organisms and watershed residents. Non-native people also tend to feel an emotional or spiritual connection to landscape in which they live. Spiritual and religious values are very difficult to assess monetarily, as there is no real way to measure their quantity or importance across individuals. One way to gain insight is to ask people how much they would be willing to pay to protect a given species or area.

The use of "willingness to pay" surveys for natural goods and services, such as protection for whales or spotted owls, reveals that many people rank the protection of nature above additional material gains. That is to say, they would choose protection over a monetary reward. Some respondents to such survey instruments give "protest bids" which indicates that they are not willing to put a finite price on saving wildlife or wild places (see Spash, 2005 for a review).

Local examples:

- The Snohomish Basin has played an important role in the physical, social, cultural and spiritual identity of the Snohomish Basin and the Pacific Northwest for millennia. Salmon harvests, for example, have always been a central part of the people of the Tulalip Tribe's way of life. In the spring, the Tulalip Tribes traditionally hold ceremonies to celebrate the return of salmon spawning runs. Throughout the year, abundant salmon runs have always been a mainstay of tribal culture and religion. This was recognized in the Treaty of Point Elliot[14], but since the treaty was signed, populations of salmon and other fish species in the Snohomish Basin have greatly declined[15], which has led to a virtual disappearance of fish during the early part of the fishing season, preventing the Tulalip Tribes from holding the traditional early-season ceremonies. Just a small increment of growth in the Snohomish Basin's salmon production may bring harvestable fish during April, and would thus have a high value to the Tulalip Tribes, both spiritually and culturally. The specific spiritual and cultural value of the Snohomish Basin are not quantified in this study; however,

[14] On signing the treaty, the Tulalip and other tribes were guaranteed the right to take fish in their usual and accustomed fishing places and the United States acknowledged their responsibility to honor the treaty by ensuring that abundant fish reserves were not compromised.

[15] In the case of Skykomish and Snoqualmie Chinook salmon, populations are at 3.3% and 3.8% of historic equilibrium abundance respectively (Snohomish County Public Works Department 2005).

the Tribes have been active participants in working with the community on restoring these runs, and they have sacrificed a significant amount of harvest to bring fish populations back in order to lower risk of extinction.

Services not Valued in this Study

Following are examples of ecosystem services that were not valued in this report due to lack of suitable primary studies that could be applied to the Snohomish Basin, cost data, or there are values of goods/services that cannot be specified to the watershed. However, these services clearly hold value.

Raw Materials

Raw materials include biological materials used for medicines, fuel and fiber, art, and construction materials from timber to gravel. Washington State produced 34 billion board feet of commercial timber harvest in 2006, mostly from State and private lands (WDNR, 2006). Other important goods that ecosystems produce include petroleum, lime, wood, fibers for clothing, and ornamental and medicinal products.

In the Snohomish Basin, raw materials such as timber, gravel, and medicine are readily measurable and marketable. Because the Basin is not itself a political jurisdiction however, scant data on raw materials exists that is specific to the watershed.

Primary Productivity

Primary productivity is another supporting service upon which all other ecosystem services depend. It refers to the conversion of energy from sunlight into forms that living organisms use. Marine and land plants perform this function, using the sugars that are products of photosynthesis for their own respiration. Human life depends directly on primary productivity through consumption of food as crops, wild plants, seaweed, fish and seafood, and livestock.

Humans appropriate over 40% of the planet's terrestrial primary productivity, and this share is increasing – with tremendous ecological implications for the rest of the planet's organisms and energy budget (Vitousek et al., 1986; Pimm, 2001). One likely outcome of greater consumption of primary productivity is the loss of biological diversity, which, as discussed above, would have severe consequences on the delivery of many other ecosystem services. Terrestrial primary productivity comes mainly from forests in Western Washington, but ecosystem types such as grasslands and meadows can also contribute, albeit at a lower rate. Loss of forests to development decreases primary productivity[16].

Marine primary productivity comes from wetland plants, macro-algae, and sea grasses in the coastal and near shore environment, and from phytoplankton in the continental shelf and deep-sea waters. Most marine primary productivity occurs in the coastal zone out to the farthest

[16] Of course, since humans began to use fossil fuels, the number of people and amount of consumption has far exceeded what would have been possible operating only on solar energy flows that drive photosynthesis.

extent of the continental shelf. About 8% of total primary productivity of ocean ecosystems supports human fisheries. However, when the calculation is confined to parts of the ocean where most primary productivity and fish catches occur, the number approaches the productivity of terrestrial systems, 25-30% (Pauly and Christensen 1995, Pimm, 2001).

When humans consume most ocean primary productivity in the form of fish and seafood, less productivity will be left to fuel the remainder of the food web and all the ecological processes that it drives (Pimm, 2001). Whereas fish harvests in the past were focused primarily on the top food-web fish, like cod, as demand has grown and many fisheries have collapsed, fishing pressure has been increased on smaller species like mackerel, herring and anchovies. These actions, often called "fishing down the food chain," place additional pressure on top predator fish by removing their food supply. In addition, climate change has large implications for ocean productivity due to changes in currents, upwelling, and changes in water chemistry (Orr et al., 2005).

Scientific and Educational

The number of educational and research institutions devoted to studying marine and terrestrial environments shows scientific and educational importance of ecosystems. Government, academic, and private resources are all devoted to formal study of ecosystems in the Puget Sound Basin. Such pursuits benefit people through direct knowledge gained for subsistence, how systems work, safety, and commercial purposes. Scientific and educational institutions devoted to both marine and terrestrial environments also provide locally significant employment. These institutions include Battelle Northwest, University of Washington biology and forestry schools, The Pacific Northwest Research Station of the U.S. Forest Service, and NOAA Pacific Fisheries Science Center's Research Station in Mukilteo.

Part IV: Valuation of the Snohomish Basin

Section Summary: *The economic value of ecosystem services generated in the Snohomish Basin was estimated using benefit transfer methodology. The results indicate that ecosystem goods and services within the Snohomish Basin generate at least **$383.1 million to $5.2 billion** in economic value annually, and if treated as a traditional economic asset would have a value of between **$13.2 billion and $180.1 billion**, based on a 2.7% discount rate over 100 years. The reliability, limitations, and possible sources of error for this ecosystem service valuation are outlined at the end of this section.*

Summary of Valuation Steps

This valuation of ecosystem services provided by nature in the Snohomish Basin can be divided into the following steps:

- **Step 1: Quantification of Land Cover Classes:** Geographic Information Systems (GIS) data is used to assess the acreage of each land cover class within the Basin. Examples of land cover classes include: pasture, estuary, urban green space and riparian forest. Land cover classes were chosen based on the ability to derive ecosystem valuation data for that type of class.

- **Step 2: Valuation of Land Cover Classes:** The suites of ecosystem services provided by each land cover class are identified. The value of a particular ecosystem service provided by a particular land cover class is determined by referring to a valuation study (on a comparable study site) in a peer-reviewed journal, and can only be valued where such a previous study exists. Each land cover class is assigned a total high and low annual per-acre value for its ecosystem services, calculated as the sum of the high and low annual values of the suite of (valued) ecosystem services that are provided by that land cover class.

- **Step 3: Valuation of the Snohomish Basin:** The total high and low annual values of ecosystem services for a particular land cover class is multiplied by the acreage of that land cover class within the Basin to arrive at total high and low annual values. The total high and low values of all land cover classes are then summed to arrive at a total annual value for all valued ecosystem services provided by the Snohomish Basin.

- **Step 4: Net Present Value Calculations:** Net present values are calculated for the Basin over 100 years at two discount rates: 0% and 2.7% (no discount, and the U.S. Army Corps of Engineers rates, respectively).

Step 1: Quantification of Land Cover Classes

Geographic Information Systems (GIS) data is used to assess and categorize the land cover on the ground in the Snohomish Basin. This data is gathered through aerial or satellite photography and can be classified according to several classification systems (or "layers"). Figure 12 graphically depicts the distribution of land cover within the Snohomish Basin.

Earth Economics maintains a database of peer-reviewed valuation studies organized by land cover class, which require GIS data from several different layers. For this valuation, the Snohomish Basin was divided into 15 land cover classes using GIS data provided by Snohomish County. Table 3 presents the final land cover classes and acreages that comprise the Snohomish Basin as categorized for this report, and a description of the layers(s) and rationale employed to obtain the acreage values.

Snohomish County's 2006 Landsat/Landcover (see Table 2), which divides land cover into 11 basic classes, was used as the foundational GIS layer. Several other layers were then combined with this layer using specific rules to yield 15 final land cover classes. Other layers included: Snohomish County Eelgrass layer; Snohomish County Waterbodies and Watercourse Layers; National Wetlands Inventory (NWI) layer; King and Snohomish County Agricultural layer; and the King and Snohomish County Urban Growth Area boundaries. The following points are noteworthy:

- **Agricultural Lands.** The King and Snohomish County Agricultural Lands layer contained a number of sub-categories that did not strictly match the Earth Economics definition of Agriculture and so was divided among three classes for this valuation: Agriculture (Agricultural Lands sub-categories used: market crops, nursery, tree farm, berries, grain, orchard, poultry, pumpkin patch/corn maize, seed crops and sod farm); Pasture (Agricultural Lands sub-categories used: horse/equine, livestock/forage, managed field/grassland, unmanaged, fallow, and forage); and Wetland (Agricultural Lands sub-categories used: marsh or wetland preserve, too wet to farm).

- **Riparian Buffer.** The acreage values for riparian buffer zones were not included in any of the datasets, but are critical to habitat and other ecosystem functions. A 50 foot buffer on each side of the stream was applied to delineate riparian buffer zones along streams and rivers for forest (Landsat/Landcover 1,2 or 3- see Table 2). In order to avoid double counting, riparian buffer zone acreage was removed from the total acreage for Forest.

Figure 12: Land Cover Classes within the Snohomish Basin.

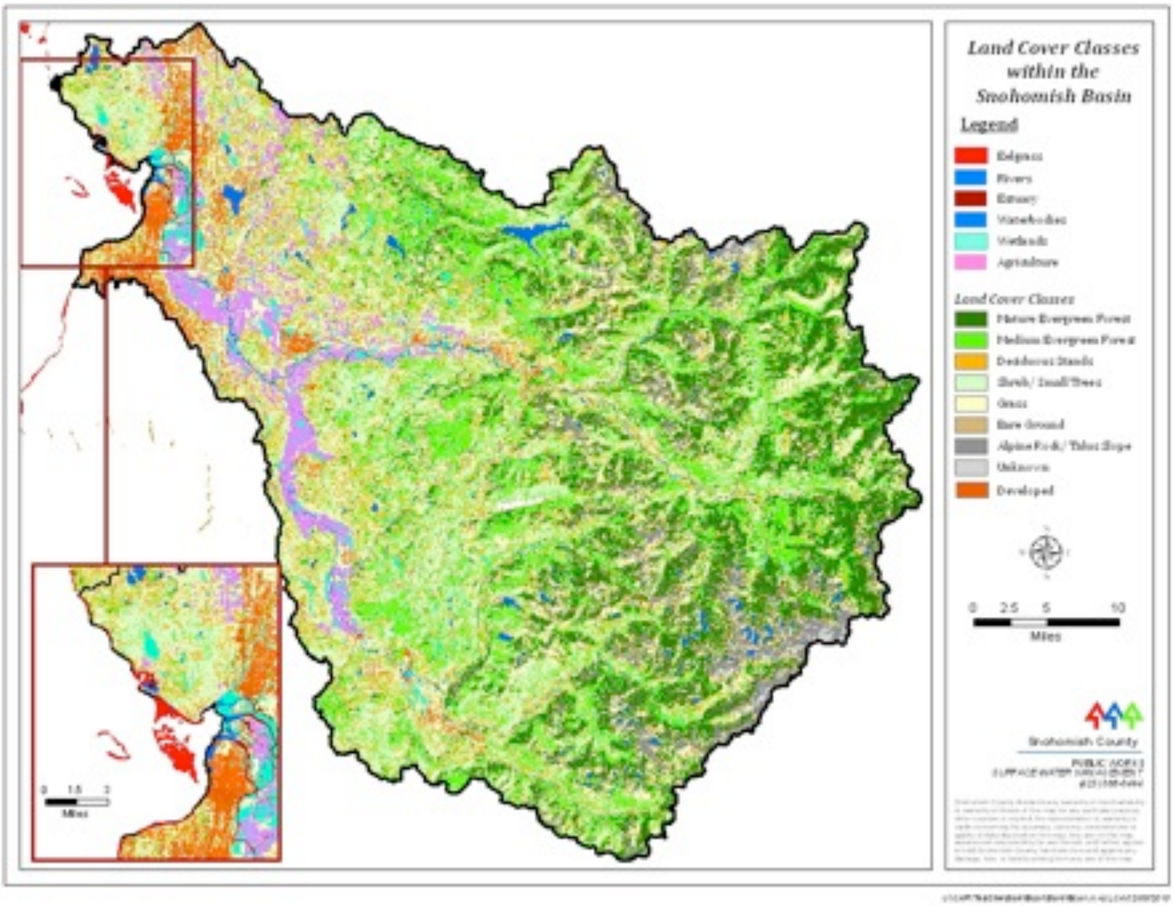


Table 2: Snohomish County 2006 Landsat/Landcover Data.

Landsat/Landcover Identifier Code	Basic 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

Table 3: Total Acreages by Land Cover Class in the Snohomish Basin.

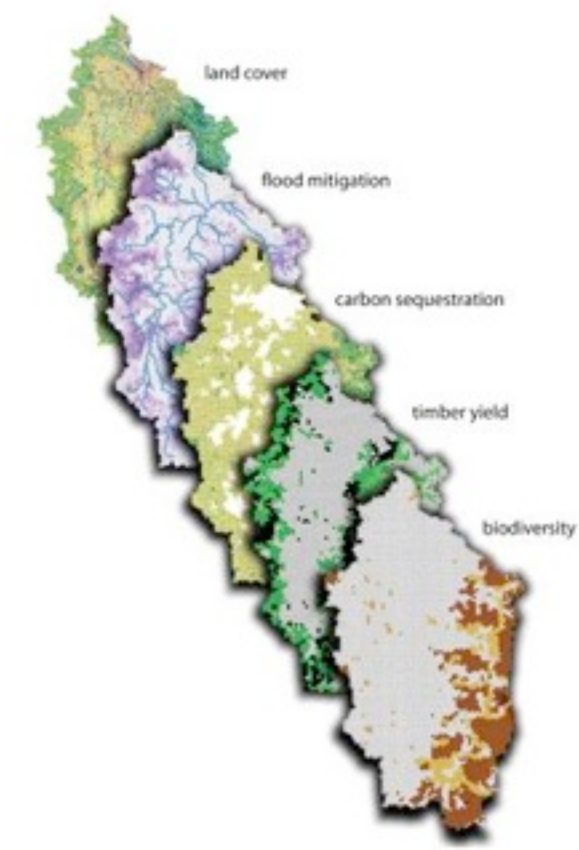
Land Cover Class	Acreage	Data Source(s)/Layers Used and Rationale
Agriculture	6,232	King and Snohomish County Agricultural layers (sub-categories: nursery, tree farm, berries, grain, orchard, poultry, pumpkin patch/corn maize, seed crops and sod farm market crops).
Eel Grass Beds	1,168	Snohomish County Eelgrass layer.
Estuary	1,162	Waterbody area east of SR 529 to the beginning of Ebey Slough.
Forest		
Forest- Mid Successional	324,585	Landsat/Landcover 2 and 3, minus riparian 2 and 3, minus Landsat/Landcover Urban Green Space 2 and 3.
Forest- Late Successional	197,807	Landsat/Landcover 1 minus riparian 1 minus Landsat/Landcover Urban Green Space 1.
Grasslands/Rangelands	142,822	Snohomish Landsat/Landcover 5.
Lakes/Rivers	19,401	Waterbody and watercourse layer minus estuary area.
Marine	2,325	Waterbody area west of SR 529 and NWI wetlands classes as Marine wetlands.
Pasture	35,874	King and Snohomish County Agricultural layer (sub-categories: horse/equine, livestock/forage, managed field/grassland, unmanaged, fallow, and forage).
Riparian Buffer	34,226	Landsat/Landcover 1,2,3 within a 50 ft riparian buffer.
Shrub	295,102	Landsat/Landcover 4 minus Urban Green Space Landsat/Landcover 4.
Urban Green Space	21,264	Landsat/Landcover 1,2,3,4 within the Snohomish County Urban Growth Area boundary.
Wetland	26,444	NWI and wetlands from Agricultural Lands (sub-categories used: marsh or wetland preserve, too wet to farm).
Barren/Developed	85,579	Anything not classified.
Perennial Ice/Snow	3,149	Snohomish Landsat/Landcover 11.
Total	**1,197,140**	

Step 2: Valuation of Land Cover Classes

Ecosystem Services Provided by Each Land Cover Class

The spatial distribution of goods and services produced in a region's economy can be mapped from a bird's eye view. Mapping the different goods and services provided by factories, restaurants, schools and businesses would provide a view of the economy of that region. A barber shop would represent the service of a haircut, and a Boeing plant would represent the good of a commercial airliner and perhaps a number of services. Each piece of land in the region, from roads to supermarkets, could be linked to one or more goods and services.

Figure 13. Example of Different Suites of Ecosystem Services Provided by Different Land Cover Types.



Source: Erik Nelson (Stanford University, Palo Alto, CA) and Heather Tallis (Stanford University, Palo Alto, CA)

For this valuation, Earth Economics measured the distribution of ecosystem services throughout the Snohomish Basin. Each land cover class, from wetland to mature forest to eelgrass, is known to provide humans with its own "suite" of economically valuable goods and services. For example, a wetland provides ecosystem services such as disturbance regulation, climate regulation and soil formation, while eelgrass also provides disturbance regulation and climate regulation, but not soil formation. Figure 13 illustrates the way ecosystem services can be "stacked" on a watershed landscape, in this case the Willamette Basin in Oregon. The bottom layer, "land cover", represents the land cover classes, each of which can produce a range of ecosystem services. Some land cover classes can be seen to produce both flood mitigation (i.e. disturbance regulation and/or water regulation in this report) and carbon sequestration (i.e. gas regulation and/or climate regulation in this report), while others produce only flood mitigation.

Annual Flow of Value

Nature in the Snohomish Basin generates a flow of value, analogous to an annual stream of income. As long as the natural capital (i.e. natural infrastructure) of the Basin is not depleted, this flow of value will likely be provided into the distant future. In the present valuation, the units for this flow of value are expressed in $/acre/year, which represents the dollar value generated by a single ecosystem service on a particular land cover class. For example, a typical acre of old-growth forest might provide $9.61 in water regulation (an ecosystem service) benefits every year.

The annual per-acre values of the full suite of ecosystem services produced by a particular land cover class, when combined, yield a total $/acre/year value for that land cover class. To determine the total annual value, rather than the per-acre value, being generated by all the areas of a particular land cover class within the Basin, the $/acre/year value for the land cover class is multiplied by the total acreage, resulting in a $/year value. In the case of old-growth forest, this means combining all of its known ecosystem service values (i.e. water regulation, pollination, recreation etc.) and then multiplying that value by the number of acres of old-growth forest in the Snohomish Basin for a value in $/year.

In determining an annual flow of value for each land cover class, it is important to begin with accurate values for individual ecosystem services. Although the full suite of ecosystem services are never bought and sold on a market, and most services typically lack a market value, Earth Economics is able to assign the initial dollar value for ecosystem services (in $/acre/year) to a number of ecosystem services within each land cover class by "transferring" values from our database of peer-reviewed academic studies and journal articles.[17] This approach is known as "benefit transfer".

Benefit Transfer Methodology

Benefit transfer is a widely accepted economic methodology used to determine a dollar value of goods and services provided by nature in a study site. Benefit transfer is the method of identifying high-quality primary studies in the scientific literature that calculate the value of ecosystem services and applying them to a study site- in this case the Snohomish Basin. Earth Economic selects primary valuation studies based on sites that have key comparable attributes to the Snohomish Basin.

While original studies are desirable for context and accuracy, such data are often cost prohibitive and simply not available. Conducting original empirical work for all services and all ecosystem types in a study area would entail over 100 primary ecosystem service valuation

[17] Agriculture and Pasture were the only land cover classes in this study to be assigned an ecosystem value that was calculated in-house, because primary study values were not available to represent the Basin-specific, economically valuable food production services of Agriculture and Pasture in the Snohomish Basin that are sold in the market, including livestock, poultry, and market crops. To determine an *approximate* value for ecosystem services generated by Agriculture and Pasture, USDA's 2007 census figures on total agricultural sales in Snohomish and King Counties were obtained. Next, that value was divided by the total number of acres in agriculture (also obtained from the USDA census) in both Snohomish and King Counties, to yield an average $/acre/year value for agriculture between the two counties, which was used as the "food" value for agriculture in the valuation.

studies. Benefit transfer methodology is similar to a house appraisal, where an appraiser compares the sale price of other houses with similar attributes (such as location or number of bedrooms). Initially determining a range of possible values for the house, the appraiser will typically select an estimated sale price for the house being appraised. Similarly, the results of a benefit transfer study use values derived from studies of ecosystems with similar attributes in comparable locations to the site in question.

Many individual valuation studies also include low and high estimates. All of the lowest estimates from each list of studies for each ecosystem service within a cover type were totaled to provide a low estimate and the same procedure was used to establish the high estimates. The estimates were not averaged. This approach results in a larger range than would be the case if all low (high) estimates within a land cover class/ecosystem service combination were first averaged prior to aggregating across ecosystem services within a land cover class.

Including the full range of values is appropriate in this valuation and advantageous in many respects. Importantly, a range mitigates the level of uncertainty inherent in primary valuation studies by reducing sampling errors. In other words, including the full range of values that exist in the literature, rather than taking an average or arbitrary value, ensures that the true value is likely to be captured. Even where a single value is presented in a primary study and known to be relatively accurate, benefit transfer is a comparison between two different sites and they are unlikely to match in all respects.

Also, the nature of ecosystems and societies will ensure the true value of ecosystem services for a given location (or price, if applicable) is in constant flux. This same rule applies to a house appraisal. Although a real estate appraiser can suggest a *likely* sale price for a house (by selecting a value from within a range), its *final* sale price will depend on the housing market, consumer preferences, the physical condition of the house and other factors. Eventually, however, the wide range in ecosystem service values can be expected to narrow somewhat as more recent and accurate primary studies are completed and added to the database.

Primary studies that were applied to the present valuation are published in peer reviewed economic academic journals, which may arrive at values for an ecosystem service using one of a variety of accepted valuation methods. As Table 4 shows, valuation methods typically used in primary studies can 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 inland 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 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.

Gaps in Primary Studies

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 class could be assigned a known value from the database. For example, the land cover class Agriculture has only been valued for three ecosystem services, when agricultural lands clearly provide climate regulation, nutrient cycling, and a number of other important benefits. Similarly, forests provide the full range of ecosystem services but can only be valued for five services in this study.

A simplified matrix that summarizes the suite of ecosystem services known to be produced by each land cover type, compared with those that were actually valued in this study, is provided in Table 5, indicating that a large number of ecosystem services (for each land cover class) have yet to be valued in a primary study. Such omissions are likely to reduce the value estimates for land cover classes, because the values of individual ecosystem services are counted in an additive fashion to arrive at a total value for a given land cover class. As further primary studies are added to the database, the combined known value of ecosystem services in the Snohomish Basin will rise.

Table 5: Ecosystem Services Valued and/or Identified in the Snohomish Basin.

	Agriculture	Beach	Eel grass beds	Estuary	Forest - Mid	Forest - Late	Grasslands/Rangelands	Lakes/Rivers	Marine	Pasture	Riparian buffer	Shrub	Urban green space	Wetland	Barren/Developed	Perennial Ice/Snow
Provisioning Services																
Food	x															
Raw Materials																
Genetic Resources																
Medicinal Resources																
Ornamental Resources																
Water Supply				x	x			x	x		x			x		
Regulating Services																
Gas Regulation						x	x				x	x	x	x		
Climate Regulation																
Disturbance Prevention											x			x		
Soil Retention							x									
Water Regulation						x	x				x		x	x		
Biological Control					x		x									
Water Quality and Waste Treatment							x							x		
Soil Formation										x						
Nutrient Regulation																
Pollination																
Habitat Services																
Habitat and Biodiversity				x	x	x		x			x	x		x		
Nursery																

Provisioning Services																
Aesthetic Information	x			x	x						x			x		
Recreation	x			x	x	x		x		x	x	x	x	x		
Cultural and Artistic Information																
Science and Education																
Spiritual and Historic Information											x			x		

[light blue box] Ecosystem service produced by land cover class but not valued in this report

[x] Ecosystem service produced by land cover class and valued in this report

[white box] Ecosystem service <u>not</u> produced by land cover class

Example: Valuing Two Land Cover Classes

The benefit transfer process is perhaps best illustrated with an example involving just two land cover classes. Agriculture and Estuary will be used as examples. In Step 1 of this valuation, the acreages for Agriculture and Estuary were found (using GIS) to constitute 2,561 and 1,162 acres of the Snohomish Basin respectively. In Step 2, where appropriate, the suite of ecosystem services provided by each land cover class was identified and assigned values from the Earth Economics database. Table 6 displays the results of this process; Agriculture was valued for only three of the 20 ecosystem services it is known to provide, while Estuary was valued for four of a possible 19.

Combining the high and low values for all ecosystem service values in a land cover class yields an annual per-acre value, which is then multiplied by the acreage to arrive at a total annual value for that land cover class. To arrive at the low value for Estuary, for instance, $176.23/acre/year (the combined low values of ecosystem services provided by Estuaries) was multiplied by 1,162 acres for a total value of $204,779/year. In other words, all of the estuaries that exist in the Snohomish Basin together generate at least $204,779 in value every year. The combined high values of ecosystem services for Estuary is $2,230.29, and if multiplied by 1,162 acres indicates that estuaries in the Basin generate as much as $2,591,597 in economic value each year- and this value may grow as more ecosystem services are added to the database.

Table 6: Total Annual Ecosystem Service Values for Agriculture and Estuary in the Snohomish Basin.

	Agriculture ($/acre/year)		Estuary ($/acre/year)	
Ecosystem Service	Min.	Max.	Min.	Max.
Food	$2,051.16	$2,051.16		
Raw Materials				
Genetic Resources				
Medicinal Resources				
Ornamental Resources				
Gas Regulation				
Climate Regulation				
Disturbance Prevention				
Soil Retention				
Water Regulation				
Water Supply			$5.90	$217.92
Biological Control				
Water Quality/Waste Proc.				
Soil Formation				
Nutrient Regulation				
Pollination	$2.40	$12.10		
Habitat and Biodiversity			$11.55	$1,385.51
Nursery				
Aesthetic Information	$24.30	$24.30	$157.42	$157.42
Recreation			$1.36	$469.44
Cultural/Artistic Info.				
Science and Education				
Spiritual/Historic Info.				
TOTAL ($/acre/year)	$2,077.86	$2087.56	$176.23	$2,230.29
ACREAGE	6,232	6,232	1,162	1,162
TOTAL ($/year) – rounded to nearest $thousand	**$12,949,000**	**$13,010,000**	**$205,000**	**$2,592,000**

Step 3: Valuation of the Snohomish Basin

Having determined the acreages of each land cover class and the annual flow of economic benefits they produce, the annual value of ecosystem services provided in the Snohomish Basin can now be calculated. The annual value for the Basin, like those of individual land cover classes, is expressed as a range. Thus, the low annual values of each land cover class are summed to arrive at a total low value for the Basin, and the total high value is reached by summing the high annual values of each land cover class. Table 7 summarizes the complete valuation process. The table includes each land cover class with its acreage and value, and the total value for all lands within the Snohomish Basin. **Results indicate that nature in the Snohomish Basin generates at least $383 million to $5.2 billion in goods and services to humans every year.** More detailed information on the primary studies used in this benefit transfer is listed in *Appendix C. Value Transfer Studies Used by Land Cover Type.*

Table 7: Ecosystem Service Valuation Summary.

		Total by Land Cover Class ($/acre/year)		Total by Land Cover Class ($/year)	
Cover Type	Acres	Low	High	Low	High
Agriculture	6,232	$2,077.86	$2,077.86	$12,949,223.52	$13,009,674.92
Eel grass beds	1,168	$7,244.64	$20,286.83	$8,461,739.52	$23,695,017.44
Estuary	1,162	$176.23	$2,230.29	$204,779.26	$2,591,596.98
Forest					
Forest – Mid	324,585	$79.91	$1,677.28	$25,937,587.35	$544,419,928.80
Forest – Late	197,807	$106.55	$2,236.37	$21,076,335.85	$442,369,640.59
Grasslands/Rangelands	142,822	$96.35	$96.35	$13,760,899.70	$13,760,899.70
Lakes/Rivers	19,401	$92.92	$25,443.38	$1,802,740.92	$493,627,015.38
Marine	2,325	$259.34	$431.16	$602,965.50	$1,002,447.00
Pasture	35,874	$2,084.11	$2,093.81	$74,765,362.14	$75,113,339.94
Riparian Buffer	34,226	$229.57	$29,046.31	$7,857,262.82	$994,139,006.06
Shrub	295,102	$7.90	$1,200.35	$2,331,305.80	$354,225,685.70
Urban green space	21,264	$1,293.84	$4,743.10	$27,512,213.76	$100,857,278.40
Wetland	26,444	$7,025.78	$82,466.48	$185,789,726.32	$2,180,743,597.12
Barren/Developed	85,579			0	0
Perennial Ice/Snow	3,149			0	0
Totals (rounded to nearest $million)	1,197,140			$383,000,000	$5,227,000,000

Step 4: Net Present Value Calculations

Results

The previous three steps describe the method used to quantify the flow of benefits provided by nature in the Snohomish Basin. The ecosystems which produce flows of economically important services can be thought of as a (natural) capital asset. 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 traditional capital asset (or project) can be approximately calculated as the net present value of its future benefits. It must be noted, of course, that calculating the net present value of ecosystems is an exercise, analogous but not identical to the net present value of an asset that can be bought and sold.

If the "natural capital" of Snohomish Basin were treated like an economic asset, the asset value of the natural systems would be between **$13.2 billion and $180.1 billion, valued at a 2.7% discount rate over the next 100 years. At a 0% discount rate, the Basin's asset value is estimated at $38.3 billion to $522.7 billion**. Calculations of the net present value of the flow of ecosystem services indicate that intact natural systems of the Snohomish Basin provide enormous value to society in the short and long term. We enjoy (and require) some of this value now, such as the supply of drinking water, but through time future generations will cumulatively receive very large economic benefits from functioning natural capital. Background information on Present Value, Net Present Value, and Discounting is provided below.

Present Value

Assets that provide value across time require a method for comparing their future and present benefits. The estimated stream for future income is converted to a "present value" by using a discount rate, usually based on the prime rate or other factors. The *net* present value of a project refers to the sum of its present value each year over a given number of (discounted) years into the future, 100 years in this valuation. "Present value maximization" is an often-used approach to treating benefits provided across time, but giving the greatest weight to the present, which is the goal used in most economic analysis. As both a goal and a method for treating value across time, it is called the Present Value Criterion. Since the goal is maximizing "present" value, value provided in the future is worth less than value provided closer to the present.

Net Present Value and Discounting

Calculating the (net) present value of an asset in traditional economics requires the use of a discount rate. For example, the Army Corps of Engineers use a 2.7% discount rate for large projects, which lowers the value of the benefits by 2.7% every year. Seattle Public Utilities and some other institutions use a 5% discount rate for capital construction projects.

A discount rate is designed to control for the following:

1. **Pure time preference of money/ opportunity cost of investment**. The rate at which people value what they can have now, compared with putting off consumption or income until

later. For example, a person would rather have a dollar today than a dollar in one year's time, because they could invest the dollar today in a 'risk-free' investment such as US treasuries and receive at least a small return. Thus, a dollar in one year's time has a present value of less than a dollar.

2. **Depreciation.** Built assets such as cars and levees tend to fall apart and lose functionality due to wear and tear, causing their value to decline. Discounting can be adjusted for different types of assets.

Due to the unique nature of ecosystem services, the issue of how to treat this stream of renewable benefits provided across generations is a difficult issue. Using a discount rate assumes that the benefits humans reap in the present are more valuable than the benefits provided to future generations. Discounting therefore favors the selection of projects that provide benefits in the present and push costs into the discounted future. Discounting is more appropriate for built goods that will deteriorate and provide less or no value in the future, such as a car.

The bias toward present value and discounting of future value can result in market failures or perverse "unsustainable" decisions where renewable resources are liquidated for short-term gain at much greater long-term costs. For this reason, traditional present value maximization biases are known to be inter-generationally inconsistent and inefficient over the long-term if limits are not considered. For example, maximizing short term profit by using cheap fuel, like coal, does not account for long term costs to human health and climate regulation.

Renewable resources should be treated with lower discount rates than built capital assets because they provide a rate of return over a far longer period of time, potentially thousands of years or longer. Forests, for example, continue to develop in complexity and value over time, even with little or no human maintenance. Natural events, such as forest fires, may reduce some types of value on the short term, but play highly valuable regulation role in the longer term.

The understanding that ecosystem function and values typically appreciate, rather than depreciate, has profound implications for how nature is treated across time. Most of the benefits that a natural asset- such as Snohomish Basin- provides reside in the distant future, whereas most of the benefits of built capital- such as a building- reside in the near-term, with few to no benefits provided into the distant future. Both types of assets are of course important to maintain for a high quality of life, but each asset operates on a different time scale. It would be unwise to treat our time preference for a forest like we treat that of a building, just as we would not treat our time preference for a building like we treat that of a disposable coffee cup.

A net present valuation was also performed using a zero percent discount rate. The use of a zero percent discount rate indicates that the value ecosystems will provide in a 100-year span is equal throughout that period. In other words, a glass of water consumed today would have the same present value as a glass of water consumed by somebody in 50 or 100 years. A zero percent discount rate better recognizes the renewable and essential nature of ecosystem services, and that people in the future will place at least the same value on ecosystem services as we do today- perhaps a greater value as their scarcity increases. However, the use of a zero percent discount rate is also flawed, because it would set the value of ecosystem services as infinite.

Current ecological economics literature yields a healthy discussion on whether or not to use discount rates and what rate should be applied to calculate the value ecological assets over time (Azar and Sterner, 1996). A variety of alternatives to standard exponential discounting, including the use of declining discount rates (Newell and Pizer, 2003) and "intergenerational" discounting, both of which allow the assignment of different, presumably lower, discount rates for future generations versus the current generation (Sumaila and Walter, 2005). For simplicity, only a 2.7% and a 0% discount rate were used in this valuation.

Study Limitations

The results of this first attempt to assign monetary value to the ecosystem services rendered by the Snohomish Basin have important and significant implications on the restoration and management of natural capital in the Basin. Valuation exercises have limitations that must be noted, although these limitations should not detract from the core finding that ecosystems produce significant economic value to society. 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 accounts 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 and only using 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 Snohomish Basin 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 and no less justified than their use in other “macroeconomic” contexts, for instance, developing economic statistics such as Gross Domestic or Gross State Product. This study’s estimate of the aggregate value of the Snohomish Basin’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 were 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, a major indicator of ecosystem health – and 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 performed. The approach is similar to determining an asking price for a piece of land based on the prices for “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 in fact conceive of an exchange transaction in which, for example, all or a large portion of a watershed was sold for development so that the basic technical requirement, that economic value reflect exchange values, could in principle be

satisfied. Even this is not necessary if one recognizes the different purpose of valuation at this scale – a purpose more analogous to national income accounting than to estimating exchange values (Howarth and Farber 2002).

In this report we have tried to display 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.

That the value ecosystems provide to people exceeds the gross world product should, with some reflection, not be so surprising. 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, 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.

- **Increase 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), and if the Snohomish Basin'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. Techniques called multi-criteria decision analysis are 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 foregoing development or exploitation are counted against non-quantified environmental concerns.

GIS Limitations

- **GIS Data.** Since this valuation approach involves using benefits 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 the reliability, both in terms of categorical precision and accuracy, of the land cover maps used in the benefits transfer.

  Accuracy: In the first place, the source GIS layers are assumed to be accurate but may contain some minor inaccuracies due to land use change since the data was sourced, inaccurate satellite readings and other factors.

  Categorical Precision: Secondly, 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 Snohomish Basin, so the "riparian buffer" cover class was applied to all forest and layers (i.e. forest cover) within 50ft of the "Waterbody and Watercourse" layer. This process is likely to produces some inaccuracies in final acreage values for each land cover class and thus affect the final dollar valuation of the Snohomish Basin.

- **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 systems dynamics 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 since 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 Snohomish Basin 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 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 on overall. At this point, however, it is impractical to know how much higher the low and high values would be.

Part V: Applications of Study Findings

Section Summary: *Natural capital is the green infrastructure that produces nature's goods and services, and as it becomes scarcer its value will increase. Economies cannot exist without the goods and services nature provides and become crippled when regional natural systems are degraded. The long-term health of the Snohomish Basin and the Puget Sound region depends upon our ability to make wise choices and investments that increase the productive capacity of the Basin's natural capital. Information on how to positively understand and apply the results of this study are in bold text:*

Investing in the Future

The term "investments" describes the choices we make today with regard to economic planning. An economy is the product of previous decades of investment; today's investments determine the nature of tomorrow's economy, and future generations will benefit or suffer from the choices made today. When Seattle Public Utilities invested in the Cedar River Watershed, they were thinking of not only the short term costs and benefits of using the watershed to filter water, but also the long term investment which, in the case of the Cedar River, has vastly increased in both production and monetary value over time.

The substantial economic value currently being generated in the Basin demonstrates that nature is an investment worth maintaining, and that while the Basin's economy is already closely intertwined with its natural foundations, much can be done to further account for the natural goods and services that are produced for greater overall well-being in this Whole Economy.

As natural systems in the Snohomish Basin become fragmented and scarcer, it is imperative to consider both the retention (conservation) and the restoration of these systems as a key investment in the future economy as supported by a green infrastructure.

Decision Support

This study provides an appraisal dollar value for the ecosystem goods and services in the Snohomish Basin. The appraisal values identified in this study are defendable and applicable to decision-making at every jurisdictional level.

This study provides decision-makers an opportunity to shift from addressing issues and challenges at a very local (single-issue) scale, to taking an integrated approach to developing a sustainable green economy in which natural capital is known as a safe investment that maintains or increases its value over time.

Watershed Characterization

Watershed characterizations, salmon habitat plans and other watershed-based analysis should be informed by ecosystem service analysis. It is also important that State and Federal agencies, particularly the Department of Natural Resources and Department of Ecology and the Army Corps of Engineers (all of which have supported ecosystem service analysis and valuations in the past for specific projects) adopt this analysis as a normal part of operations. Training for private firms including consulting companies, government agencies and non-profits in ecosystem service analysis should proceed at a rapid pace.

Economic benefits provided by natural systems are important and need to be valued. These improvements in economic analysis, which promote better investment, are informed by ecosystem services. The mapping of ecosystem services on the landscape, their provisioning, beneficiaries and impediments inform how institutions should be set up and how incentives and funding mechanisms should be created.

Decision makers should understand that ecosystem services are crucial to solving many of our economic sustainability issues in the Snohomish and Puget Sound Basins, and incorporate economic impacts of natural systems into characterization and general investigation studies.

Cost-Benefit Analysis

All federal and state agencies, cities, counties and many private firms utilize cost/benefit analysis to make investment decisions in areas such as health care, levee construction, education, road building, economic development, tax breaks and others. If cost/benefit analysis is flawed, investments will be flawed. A fish processing plant counts as an asset in cost/benefit analysis, yet federal rules dictate that the system that actually produces the fish does not count as an asset and cannot be valued in the analysis.

In the US, the federal rules for cost/benefit analysis are currently under consideration for significant changes. Proposed changes include the valuation of ecosystem services. It is uncertain how long this will take but it is Earth Economics' experience that when local and regional jurisdictions, such as counties, factor natural capital into cost/benefit analysis, better, more informed decisions result.

When working with federal agencies on shared projects, jurisdictions have an opportunity to take a leadership role; the Army Corps of Engineers will grant exemptions to include the values of natural systems in cost/benefit analysis to ensure natural systems are considered along with built infrastructure for a more complete and accurate flood risk management plan and strategy.[18]

Project Prioritization

Criteria for selection and prioritization of capital infrastructure projects need to reflect the goals of the communities and the policies of local jurisdictions.

Though not a comprehensive list of criteria, some questions driven by ecosystem services-related policies include:

- **Does the project enhance natural processes?**

[18] The first exemption granted by the Army Corps of Engineers occurred in 2009 as a result of an Earth Economics study which highlighted scientific work done by the University of Louisiana and informed jurisdictional leaders and Army Corp staff about the hurricane and flood protection value of wetlands on the Louisiana Coast.

- **Do the project impacts enhance or degrade associated ecosystem services (such as habitat or water quality) at the site-specific or regional scales?**

- **How are the benefits (safety, health, economic and ecological) of this project distributed?**

Environmental Impact Statements

In Washington State, environmental impact statements (EIS) often have an effect on project design and thus investment by identifying actions that reduce the negative environmental impacts or enhance restoration. One of the fundamental challenges of environmental impact statements is the lack of an economic interface. In other words, environmental damages can be quantified in scientific terms, but this has no common language with project financing, which is denominated in dollars. Ecosystem service identification and valuation often strengthens what is the weakest area of environmental planning and analysis: the economic implications and value provided by restoration projects.

In 2010, Earth Economics provided the first economic section in an environmental impact analysis for Snohomish County's Smith Island restoration project. Three scenarios were examined for ecosystem service enhancement and valuation. Providing this information allows for a stronger understanding of the economic benefits the project provides. Identifying the dollar value of ecosystem services enhanced by the project and provided to the public also strengthens the capacity for funding proposals.

Private and public institutions should include an ecosystem service analysis to strengthen environmental impact assessments. Policy makers in Washington State should lead the nation in requiring ecosystem service analysis in all applicable environmental impact statements.

Land Use Policy and Management

One of the biggest environmental threats to North Puget Sound is the loss of forest. We have been losing forest at a rate of 26 acres/day since 1990, the highest rate in Washington (University of Washington School of Forest Resources, 2009). There are over a quarter of a million acres of forest in the region "at risk" of being lost. Currently, approximately 5.7 million acres are owned by small private landowners (<5000 acres). The tax burden of forest ownership is a great burden on small landowners, because taxes are based on the "highest and best use" of the land. The cost of land taxes makes forestry less viable, and puts pressure on small landowners to convert forestlands into real estate development and other uses.

This study indicates that certain land cover types have higher value than others, and where the choice exists in land use planning, the higher-value land cover types should be maintained or increased. The role of private landowners should not be underestimated: the rate of (especially low-land) forest conversion must be slowed down, and incentives and education should continue to be provided for small forested landowners to keep their property forested and healthy.

Internal Policy and Procedure Revamp

To shift private and public investment toward green infrastructure, buildings, and investment, requires that natural capital be recognized as a capital asset that is measurable within standard accounting systems. The creation of Seattle Public Utilities (SPU) more than a century ago was a visionary and successful institutional development. Purchasing a watershed secured to provide and filter the water supply for the city in perpetuity was a radical and expensive idea at the time. Had the Seattle City Council required a threshold rate of return on investment, it would likely never have justified this daring project. The goal of the investment was not to maximize "net present value," but to provide safe and reliable drinking water for the people of Seattle forever. Consider one important advantage of a valued economic asset: you can justify investments in it.

Decision makers for local jurisdictions and tribes should consider an 'Accounting Review' of existing capabilities to implement natural capital accounting within Basin. From this, accounting recommendations for incorporating ecological economics and ecological accounting methods, procedures and auditing recommendations for "No Net Loss" policy compliance of Shoreline Master Program as well as policies designed to retain agriculture and natural resource lands can be developed and implemented.

Development of Funding Sources

Application of Results to Grant Writing

The values included in this report are not spatially explicit but provide reference values for some of the ecosystem services that are produced by comparable ecosystems to those in the Snohomish Basin. A riparian restoration group, for example, might like to apply for grant funding that would restore 100 acres of shrub/scrub to riparian forest. Using the values found in this appendix as a reference, they can perform a simple calculation to show the increase in economic value generated by that land, thus showing an economic return on investment to the region in addition to the ecological Return on Investment (ROI).

Arguments can be borrowed from the discussion in this report to strengthen grant applications. If it is a long term project being considered, a simple ecosystem service valuation, using reference values from this report, may be used to show the long term return on investment. If funding for a project involving improvement to ecosystem services is already secured, the concepts and valuation can be used to build broad-based support for the project.

Green Jobs Analysis

Ecosystem services and jobs are closely connected. Jobs analysis (i.e. number of jobs created) is increasingly important in securing funding, and is part of many federal applications. An examination of jobs created by capital and restoration projects that improve natural systems generally looks at how many construction jobs are created by moving earth or planting native vegetation. Yet most restoration projects also provide quantifiable ecosystem goods and services, which have economic importance and provide an increase in sustainable, well-paid jobs. Establishing an increase in permanent employment is far more important than providing temporary jobs, and federal agencies recognize and measure this accordingly. Earth Economics has helped agencies in the past secure project funding by linking projects to green jobs development.

Restoration projects can and should be effectively linked to economic growth and sustainability.

Watershed Investment Districts

As our region has become more crowded, so have our tax districts. Inevitably, there can be conflicts. In the Green River Valley over a dozen stormwater districts, previously invested millions of dollars to build stormwater systems that generally get water out of cities and into the main stem of the river as fast as possible. Prior to 2008, there was a flood district positioned at the lower reaches of the river, which received higher peak flows every year as impermeable surfaces and stormwater systems expanded, contributing to greater flooding. The flood district invested in higher levees, which were increasingly damaged by higher peak water flows. This type of infrastructure conflict is part of a cycle that is unhealthy for humans, salmon, the economy and the environment.

The work accomplished by Water Resource Inventory Area 9 (WRIA 9) with Earth Economics in the Green River Valley demonstrates an impressive, innovative approach for adding a new level of rationality to our existing tax district structure. WRIA 9 is charged with salmon restoration and encompasses the cities of the Green River Valley from Seattle to Black Diamond. Along with Vashon Island, Seattle Public Utilities, the King Conservation District, King County, Boeing Corporation and other stakeholders, WRIA 9 is likely leading the charge in the state by boldly proposing a path to better coordinate and rationalize watershed-based tax districts (currently called "Watershed Investment Districts") as part of their effort to restore salmon populations.

Snohomish Basin leaders should facilitate discussions about institutions and improvements that help coordinate and rationalize current tax districts. Ecosystem services can be a guide for improvement by setting a context wherein alternatives and tradeoffs may be evaluated, illustrating what happens across governmental priorities (e.g. when deciding on the optimal balance of natural and built capital in stormwater investments).

Towards a Sustainable and Desirable Future

Our infrastructure can be further integrated to satisfy multiple goals (e.g. sustainability, salmon recovery and flood protection) to provide a better return on investment. In the case of salmon recovery, natural capital (floodplains and deltas) is utilized along with built capital (levees and reducing fish blockages), increasing the provision of a range of other ecosystem services. A successful salmon plan improves confidence in the system and social bonds; improves natural capital; builds sustainable communities, all contributing to human well-being. Understanding where and how to invest in a watershed is essential to improvement in the five capitals and the goal of human well-being.

Snohomish Basin leaders can use the concepts, values and recommendations presented in this study to begin incorporating ecosystem services into agency goals, metrics, indicators, assessment and general operations. For example, when developing budgets and program planning, writing grant applications to secure federal and outside funding, examining policies and accounting practices, reporting and aligning to Puget Sound health indicators, and development review and permitting process in rural areas.

Part VI: Conclusion

There are many ways in which the economy of the Snohomish Basin - and the quality of life for its citizens - depends upon functioning ecosystems. When natural systems are healthy, they provide vast amounts of economic value at a relatively low cost; once degraded, natural systems require investments such as the installation of "built infrastructure" which depreciates over time. When functioning natural systems are compromised, often a new tax district is created with typically a narrow focus on the partial flow of a single ecosystem good or service, such a flood protection.

This report provides an appraisal valuation of ecosystem services in the Snohomish Basin, quantifying the economic value supplied by nature in the Basin every year. The results are compelling: by protecting against flooding, assuring water supply, buffering climate instability, supporting fisheries and food production, maintaining critical habitat, providing waste treatment, and additional benefits **Snohomish Basin ecosystems are providing between *$383.1 million to $5.2 billion* in benefits every year.**

Ecosystem services may also be treated like an economic asset, providing a stream of benefits over time, similar to a bridge or other capital infrastructure. Valued as such, a discount rate may be applied to these services, allowing for calculation of the present value of these systems. If treated like an asset with a life span of 100 years, **the present value of the Snohomish Basin would be between $13.2 billion and $180.1 billion**, using a 2.7% discount rate.

Though a snapshot in time, these appraisal values are defendable and applicable to decision-making at every jurisdictional level. Ecosystem Service Valuations can aid effective and efficient natural resource management. This study also introduces a Whole Economy model to explicitly link the regional economy to the watershed, and can also be used to help guide advancements towards a sustainable green economy by shifting investments towards achievement of the ideal balance of five capitals: natural, built, human, social and financial.

Quantification of tradeoffs among ecosystem services and their interactions with human well-being are now among the most pressing areas of concern in the Snohomish Basin. Basin leaders can use the concepts and values presented in this study to begin incorporating ecosystem services into agency goals, metrics, indicators, assessment and general operations. For example, ecosystem service values should be considered when developing budgets and program planning, grant applications to secure federal and outside funding, examining policies and accounting practices, reporting and aligning to Puget Sound health indicators, and development review and permitting processes in rural areas.

We have an excellent opportunity to begin developing measures and indicators that can provide the data and information needed to support policy discussions about the tradeoffs among many potential investments of public and private money, investments that ultimately affect human wellbeing. Seizing the opportunity and rising to the challenge will ensure a sustainable and desirable future for all Snohomish Basin residents.

Appendix A: Report References

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Appendix C: Value Transfer Studies Used by Land Cover Type

Land Cover	Ecosystem Service	Author(s)	Minimum ($/acre/year)	Maximum ($/acre/year)
Agricultural lands	Aesthetic	Bergstrom, J., Dillman, B. L. and Stoll, J. R.	$24.30	$24.30
	Pollination	Robinson, W. S., Nowogrodzki, R. and Morse, R. A.		$12.10
		Southwick, E. E. and Southwick, L.	$2.40	
	Food	Earth Economics In-house calculation	$2,051.16	$2,051.16
Totals			***$2,075.46***	***$2087.56***
Eel grass beds	Nutrient Cycling	Costanza et al. 1997	$7,244.64	$20,286.83
Totals			***$7,244.64***	***$20,286.83***
Estuary	Aesthetic	Johnston, R. J. et. al.	$157.42	$157.42
		Farber, S. and Costanza, R.	$11.55	
		Johnston, R. J. et. al.		$1,385.51
	Recreation	Johnston, R. J. et. al.		$469.44
		Whitehead, J. C., Hoban, T. L. and Clifford, W. B.	$1.36	
	Water Supply	Bocksteal, N. E., McConnell, K. E. and Strand, I. E.		$217.92
		Whitehead, J. C., Hoban, T. L. and Clifford, W. B.	$5.90	
Totals			***$176.23***	***$2,230.29***
Forest	Gas & Climate Regulation	Bagstad, K and Boumans, R. 2008 (unpublished)	$32.27	$841.50
	Habitat Refugium & Nursery	Garber et al. 1992		$684.48
		Haener, M. K. and Adamowicz, W. L.	$1.52	

	Pollination	Hougner, C. 2006	$62.97	$62.97
	Recreation	Bishop, K.		$637.81
		Boxall, P. C., McFarlane, B. L. and Gartrell, M.	$.18	
	Water Regulation	Loomis, J.B. 1988	$9.61	$9.61
Totals			***$106.55***	***$2,236.37***
Grasslands/Rangelands	Biological control	Pimentel et al. 1995	$12.66	$12.66
	Gas & Climate Regulation	Costanza et al. 1997	$3.85	$3.85
	Pollination	Pimentel et al. 1995	$13.77	$13.77
	Soil Erosion control	Costanza et al. 1997	$15.97	$15.97
	Soil Formation	Costanza et al. 1997	$.54	$.54
	Water Quality	Pimentel et al. 1995	$47.91	$47.91
	Water Regulation	Costanza et al. 1997	$1.65	$1.65
Totals			***$96.35***	***$96.35***
Lakes/Rivers	Habitat Refugium & Nursery	Knowler, D. J. et. al.	$58.89	
		Streiner and Loomis 1996		$1,479.84
	Recreation	Loomis et al. 2002		$23,120.10
		Patrick, R. et. al.	$1.69	
	Water Supply	Piper, S.	$32.34	
		Ribaudo, M. and Epp, D. J.		$843.44
Totals			***$92.92***	***$25,443.38***
Marine	Water Supply	Soderqvist, T. and Scharin, H.	$259.34	$431.16
Totals			***$259.34***	***$431.16***
Pasture	Recreation	Boxall, P. C.	$.03	$.03
	Soil Formation	Pimentel, D.	$6.22	$6.22
	Food	Earth Economics In-house calculation	$2,051.16	$2,051.16
	Pollination	Southwick, E. E. and Southwick, L.	$2.40	
		Robinson, W. S., Nowogrodzki, R. and Morse, R. A.		$12.10
	Aesthetic and Recreational		$24.30	$24.30

Totals			***$2,084.11***	***$2,093.81***
Riparian Buffer	Aesthetic	Kulshreshtha, S. N. and Gillies, J. A.	$50.96	$50.96
	Cultural & Spiritual	Greenley, D., Walsh, R. G. and Young, R. A.	$4.67	$4.67
	Disturbance Regulation	Rein, F. A.	$53.39	$235.73
	Gas & Climate Regulation	local estimate	$99.00	$990.00
	Habitat Refugium & Nursery	Kahn, J. R. and Buerger, R. B.	$.26	
		Knowler, D. J. et. al.		$269.91
	Recreation	Bowker, J. M., English, D.B. and Donovan, J.A.		$14,297.09
		Greenley, D., Walsh, R. G. and Young, R. A.	$8.57	
	Water Regulation	Faux et al. 1999		$182.87
		Rein, F. A.	$7.56	
	Water Supply	Mathews, L. G., Homans, F. R. and Easter, K. W.		$13,015.08
		Rich, P. R. and Moffitt, L. J.	$5.16	
Totals			***$229.57***	***$29,046.31***
Shrub	Gas & Climate Regulation	In house calculation	$6.20	$62.30
	Habitat Refugium & Nursery	Haener, M. K. and Adamowicz, W. L.	$1.52	
		Kenyon, W. and Nevin, C.		$500.24
	Recreation	Bishop, K.		$637.81
		Boxall, P. C., McFarlane, B. L. and Gartrell, M.	$.18	
Totals			***$7.90***	***$1,200.35***
Urban Green Space	Gas & Climate Regulation	McPherson, E. G.		$874.79
		McPherson, E. G., Scott, K. I. and Simpson, J. R.	$26.81	
	Recreation	Tyrvainen, L.	$1,261.31	$3,697.42

	Water Regulation	American Forests		$170.89
		McPherson, E. G.	$5.72	
Totals			***$1,293.84***	***$4,743.10***
Wetland	Aesthetic	Doss, C. R. and Taff, S. J.		$4,626.73
		Gund Database	$68.09	
	Cultural & Spiritual	Anderson, G. D. and Edwards, S. F.	$246.86	$246.86
	Disturbance Regulation	Farber, S.	$4.88	$4.88
	Gas & Climate Regulation	Roel calculation for LA	$29.43	$267.43
	Habitat Refugium & Nursery	Allen, J. et. al.		$12,537.14
		Lynne, G. D., Conroy, P. and Prochaska, F. J.	$1.17	
	Recreation	Allen, J.		$9,347.33
		Farber, S.	$8.75	
	Water Quality	Breaux, A., Farber, S. and Day, J.	$109.78	$17,673.84
	Water Regulation	Thibodeau, F. R. and Ostro, B. D.	$6,357.71	$6,357.71
	Water Supply	Allen, J. et. al.		$31,404.56
		Lant, C. L. and Tobin, G.	$199.11	
Totals			***$7,025.78***	***$82,466.48***

EARTH ECONOMICS

What is your planet worth?