A New View of our Economy:

Nature's Value in the Snoqualmie Watershed

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EARTH
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Executive Summary

This study examines the economic value of the natural goods and services provided by the Snoqualmie Basin's forests, streams, wetlands, grasslands, and agricultural lands. The Snoqualmie Basin's natural goods include fish, drinking water, and agricultural products. Services include flood protection, drinking water filtration, local weather and climate stability, aesthetic value, and recreation. These goods and services have not previously been accounted for in economic analysis, and as this report indicates, they represent significant value within the watershed. Valuation of "natural" capital is important because it helps the public and decision makers decide how to allocate budgets for conservation and restoration and integrate with economic development improving current and future planning decisions. Investing in conservation and restoration efforts that enhance these goods and services will provide lasting benefit to the local economy and community at comparably low cost, given their immense value.

Annual Value of the Snoqualmie Basin

This report uses several methods to estimate the value of goods and services provided by natural systems in the Snoqualmie Basin. The "benefit transfer methodology", which is based on peer-reviewed academic journal articles and research in the Snoqualmie Basin, found that the Snoqualmie Basin provides between roughly $265 million - $2.5 billion per year in benefits. The wide range reflects uncertainty and the value will narrow and total value will rise as additional primary studies are completed and valuation gaps are closed.

Natural systems in the Snoqualmie Basin provide an annual flow of benefits of at least 265 million dollars.

Asset Value of the Snoqualmie Basin

From the annual benefit of these natural goods and services, an estimate analogous to an asset value can be calculated. The watershed can be seen as an economic asset producing a flow of benefits, just as a building is an asset that may be rented out for a flow of benefits. If the "natural capital" of the Snoqualmie Basin were treated like "built capital" economic assets, which depreciate over time, the asset value of the natural systems would be between $9 billion and $86 billion at a 2.7% discount rate over 100 years. These are conservative estimates. Valuation of additional ecosystem services and a more refined analysis will result in higher values. This is a new field. Reporting the full range better expresses inherent uncertainty, however, the lower number represents a solid basement value. It can be adopted for policy applications.

Natural capital differs significantly from built capital. While most natural systems are self-maintaining, almost all built capital eventually falls apart. This distinction justifies use of a different approach for discounting the future value of watershed benefits when estimating their asset value. The use of a zero percent discount rate reflects the fact that the value that these ecosystems will provide in a 100- year span is at least constant throughout that period. In other words, a gallon of water consumed today would have the same value as a gallon of water consumed in year 100.

This scenario better recognizes the renewable nature of ecosystem services and the benefit they will provide for future generations. Using a zero discount rate for 100 years provides an asset value for ecosystem services in the Snoqualmie Basin of $26 billion to 250 billion. A watershed provides far more value across time than most built capital, as reflected by this higher asset value.

When measured as an asset over 100 years, the Snoqualmie Watershed is worth at least $9 billion at a 2.7% discount rate, or $26 billion at a 0% discount rate.

Although rendered for free in terms of market price, these natural services have high economic value. Furthermore, the majority of economic value provided by ecosystems is produced as economically non-excludable services for landowners as well as members of the general public. This means that one person's use of these services does not diminish their use for another person – the water filtration and air quality services provided by a healthy forest are available to all. Because we do not often buy or sell ecosystems and their services, watersheds have often been treated as having zero economic value, and society has underinvested in them. When free flood protection provided by natural systems is lost, tax districts must be formed and extensive levee systems must be built to replicate the lost natural flood protection. When the levee system fails, as it did during Hurricane Katrina, the costs are devastating. Economics is now advancing to include the value of natural systems, which can help avoid unnecessary and extensive costs.

In order to better protect the immense value in the Snoqualmie Watershed, local, state, and federal jurisdictions have a critical role to play in securing a sustainable and prosperous economy. In a full-world scenario this requires meeting four important economic goals:

1. **Sustainable Scale -** Determining proper relationships between economies and the physical limits of a natural system.
2. **Fair Distribution -** Fairly assigning costs to those who benefit from or cause harm to natural systems, and fairly allocating public and private gains from ecosystem goods and services.
3. **Efficient Allocation-** Making careful decisions about how and where resources are moved or invested, and efficiently balancing built, natural, human, and social capital for the types of goods and services we wish to enjoy**.**
4. **Good Governance -** Creating and maintaining private and public institutions, systems, and markets, is essential to achievement of goals 1 – 3. Restoring the

> Snoqualmie Basin is critical to improving quality of life and to securing sustainability, fairness, and economic progress in the Snoqualmie and the broader Puget Sound Region.

This report quantifies the value of ecosystem goods and services provided by the Snoqualmie Basin in measurable, discreet terms. The value of the economic benefits that the Snoqualmie Basin provides is enormous. The economic value of the Watershed is likely larger than the built economic assets that it contains. This conclusion may be surprising, but as this report demonstrates, it makes sound economic sense.

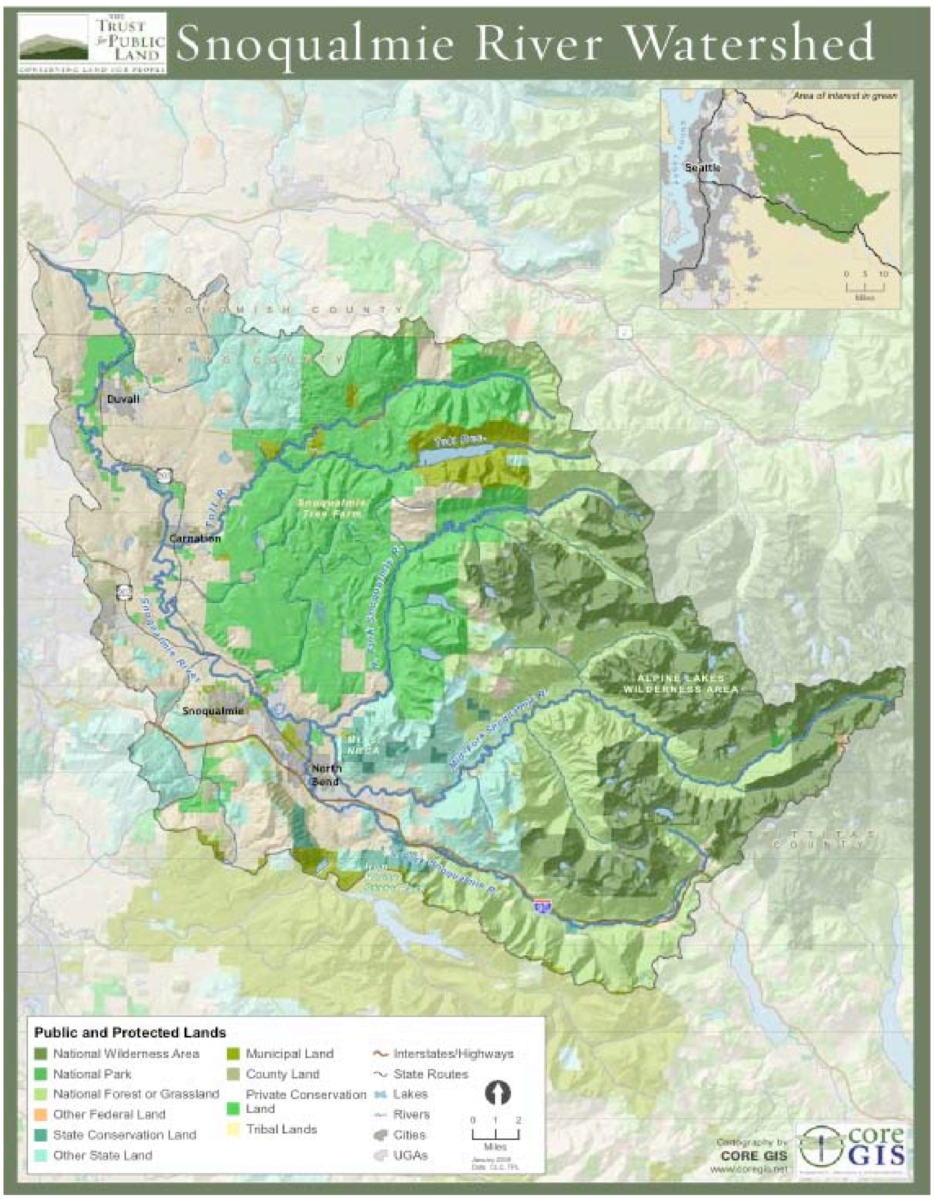
Introduction

The Snoqualmie Watershed

Natural Resources - Summary

Nestled between the Cascade Foothills and the increasingly urban areas of Redmond, Sammamish, and Issaquah, the Snoqualmie Watershed covers 443,909 acres or 692 miles, largely in King County with a small portion in Snohomish County. The vast majority of the land is in forestry, agriculture, or rural residential uses, as shown in Figure 1.

Figure 1: Snoqualmie Basin Map



Source: Trust for Public Land and CORE GIS

Roughly 75% of the Watershed is within the Forest Production District (FPD).[1] The Snoqualmie River and its tributaries provide water for agricultural uses, drinking, and habitat for fish and other species.

The economy of the Snoqualmie Valley was historically grounded in the heavy Chinook and Coho salmon runs that sustained Native Americans and later, settlers. By the mid 20th century, the economy had turned from fishing to farming and forestry. Today, the economy still relies on goods such as fish and timber, but has expanded due to rapid population growth and commercial and industrial development. The Snoqualmie Basin is home to many working agricultural lands and vibrant local communities, and is also known for its abundant recreational opportunities.

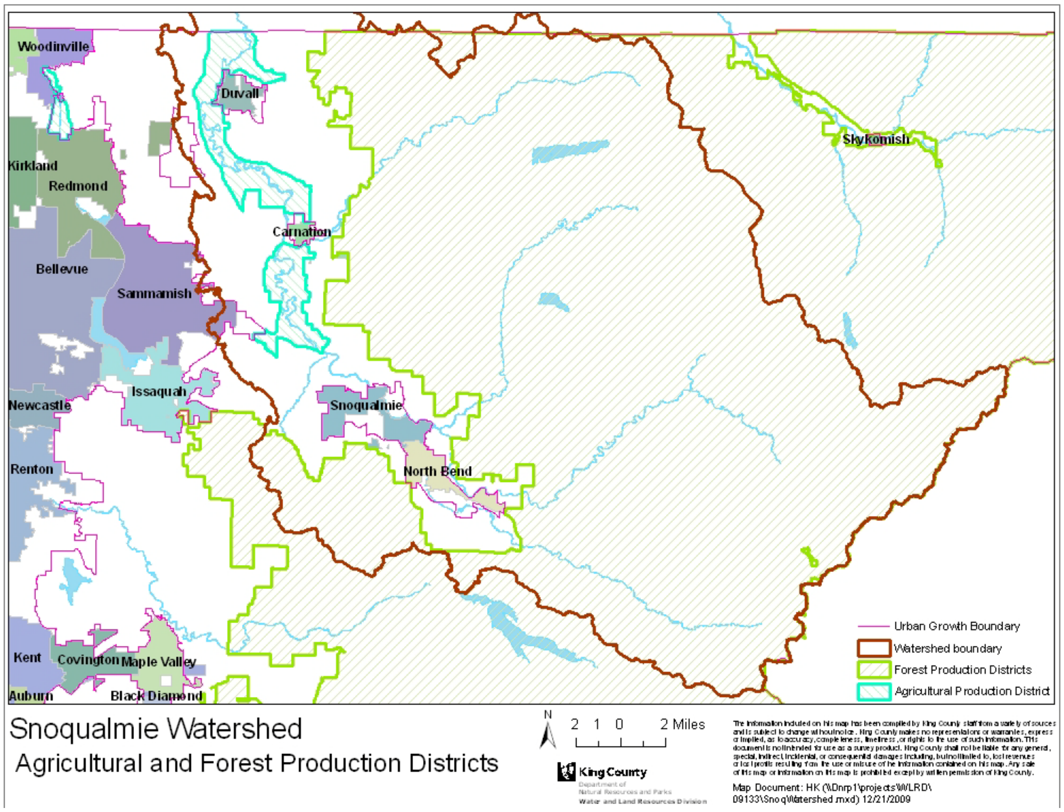
Natural Resources - Detail

The Snoqualmie Basin supports wild populations of coho, Chinook, chum, and pink salmon, as well as steelhead, cutthroat, rainbow, and bull trout – and is among the best remaining fish habitat in King County.[2] However, habitat has been severely impacted in recent years. During the 1980’s, salmon runs along the Snoqualmie and Skykomish Watersheds provided one third of the wild coho salmon entering the Puget Sound (King County 2010c). Today Snoqualmie Chinook Salmon populations are below five percent of their historical levels (SWF et al., 2006). Puget Sound-wide, Chinook salmon and bull trout are listed as threatened under the Endangered Species Act (ESA), which mandates protection of habitat and restoration to 70% of historical levels for populations at risk species. This listing has caused increased efforts to protect and restore populations and avoid federal penalties.

Agricultural production includes hay and forage, tree farms, and market produce crops. The Snoqualmie Watershed is an important resource in Washington’s landscape for food, recreation, forestry, fish, and many other valuable natural amenities. These interests are increasingly coordinating to increase mutual benefits from land stewardship, which will ultimately increase the economic viability and desirability of the Snoqualmie Watershed. Figure 2 shows the amount of land in the basin that is in the Forest Production District and Agricultural Production District (Source: King County GIS).

[1] A Forest Production District is a county's designated forestland of long-term commercial significance.
[2] Salmon Conservation in the Snoqualmie Watershed

Figure 2: Snoqualmie Watershed Agricultural and Forest Production Districts



The Snoqualmie's Changing Landscape and Local Management

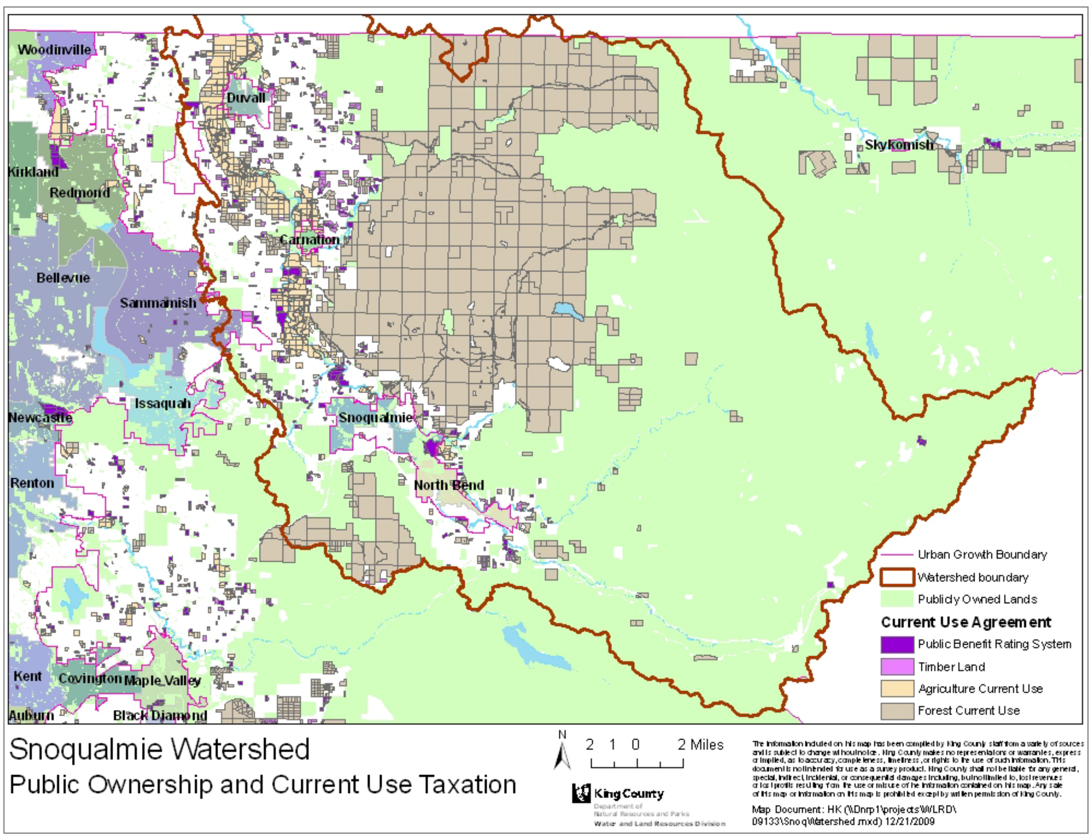
The Snoqualmie watershed has been severely impacted by development over the past half a century. The watershed's population nearly doubled from 1980 to 1999, reaching 38,000 in that year. Though today the watershed population is around 40,000, it may swell to 70,000 by 2020 (Solomon and Boyles, 2002). This growth, in the Snoqualmie Watershed and throughout the Puget Sound, has already begun to affect ecological production. The 1999 listing of Puget Sound Chinook salmon and bull trout as threatened species under the ESA is one example. Chinook salmon populations in the Snoqualmie are currently below 10% of historical levels (SWF 2010).

This dramatic decline in population is in part due to dramatic changes on the landscape; roughly 60% of the banks of the Snoqualmie and Snohomish Rivers have little or no riparian vegetation, and nearly 30% of Snohomish Basin floodplain tributaries have been channelized (King County 2010). These changes have had serious consequences for both environmental health and human wellbeing, including direct economic losses in forgone fisheries productivity, lost recreational value, and increased storm and flood damage.

Fortunately, many entities within the Snoqualmie Basin are already hard at work to improve its future, though there is still no comprehensive vision for what local targets should be or how to best accomplish environmental restoration. Increasing ecosystem productivity - while at the same time accommodating growing population and protecting working forests and agricultural landscapes - is a complex undertaking that will require continued collaboration between local entities.

King County allows property tax exemptions within a number of key sectors, including forestry and agriculture. These "current use/open space" exemptions allow for the land to be taxed according to its current use, instead of by its "highest and best use". Exempt lands include farm and agricultural land, timberland, and some other open space uses. This potential for tax relief encourages private stewardship of land and helps to preserve working lands in the face of increasing development pressures. Figure 3 shows land in the watershed that is either public or participating in current use taxation exemptions.

Figure 3: Snoqualmie Watershed Public Ownership and Current Use Taxation



Though recent budget challenges have limited funding for many programs, the King County Water and Land Resources Division has many highly innovative and effective programs to improve flood protection, provide landowner stewardship education and incentives, promote transferrable development rights (TDRs), and other forestry and agriculture programs. Additionally, King County implemented the Washington State Growth Management Act after it passed in 1990, which has led much of the watershed to become designated as rural resource lands. Every four years as the King County Comprehensive Plan is updated, rural land along the Urban Growth Boundary (UGB) is evaluated for conversion because of increasing population pressure, economic, and political demands. The success of these efforts may hinge upon development and execution of a comprehensive plan to protect the rural resources and improve the quality of life in the Snoqualmie Basin.

Objectives of this Study

This study uses a "natural capital" approach to policy and asset management, identifying and estimating the value of those goods and services produced by natural capital in the Snoqualmie Basin. This ecosystem service valuation builds off recent studies conducted by Earth Economics, including a valuation of the entire Snohomish Basin.

As part of the project, Earth Economics (EE) has collaborated with Stewardship Partners (SP) and the Trust for Public Lands (TPL), two organizations with a long history of successful programs in the Watershed, and Partnership for Rural King County (PRKC), an organization based in the Snoqualmie Valley that promotes sustainability through landowner education and participation in the public policy process. This work and collaboration was made possible through generous funding from the Bullitt Foundation.

While ecosystem and resource management decisions typically focus on "built capital" and financial assets, residents and businesses in the Snoqualmie Basin are critically dependent not only on built facilities but also on "natural capital" for water, drainage, electricity, flood protection, recreation, agriculture, and other benefits. Watersheds and other ecosystems are capable of providing a full range of 23 identified categories of ecological goods and services (see list on page 27). An understanding of the relationships between watershed ecosystem health and the provisioning of these goods and services can better inform a visioning process for restoration in the Snoqualmie Basin.

The Snoqualmie Basin needs a watershed-wide vision for habitat restoration and economic progress. This vision must be connected to investment within the Watershed via economic analysis. The intent of this study is 1) to help inform the Snoqualmie Watershed visioning process that the Trust for Public Lands and Stewardship Partners are currently helping coordinate within the Basin, and 2) to create practical tools and information for conservation.

Effective promotion of healthy ecosystems, communities, and economies requires the application of science-based economics in a real and globally significant bioregion like the Puget Sound. The approach and strategies outlined in this report are designed to be replicable, in the aim of shifting investment and policy towards protection and restoration of ecological resources. Our goal is to provide a more stable and sustainable foundation for future economic and societal progress.

Study Approach

The study utilized current Geographic Information System (GIS) data provided by CORE GIS to gather land cover class information. Land cover classes included wetlands; rivers and lakes; pasture; agriculture; urban green space; early, pole, mid, and late forest; and more. The suite of ecosystem services provided by each of these land cover types was then valued to the fullest extent possible using peer reviewed academic journal articles. Each service was valued using the lowest value available in the literature as well as the highest value, to provide the most accurate range of possible value. To get a sense of value over time, the present value (PV) was then calculated over different time horizons from the estimates of the annual flow of ecosystem benefits.

While this study stands as the most comprehensive valuation to date, it is also dramatically incomplete. Of the 23 identified categories of ecosystem services, only 12 could be valued and of these 12, none were fully valued across all ecosystem types. For example, we valued 8 ecosystem services for grasslands, but only 2 for agricultural lands. This reflects the fact that ecosystem service valuations are on the cutting-edge of economic analysis, and original valuation studies are still limited. A better understanding of the natural capital value of the Snoqualmie Basin requires more primary ecosystem service valuation studies. There are few ecosystem service valuation studies from the Snoqualmie Basin; so many of the studies used are taken from other regions.

This report is organized as follows: **Part 1** provides a “new view” of the economy with a discussion of ecosystem goods and services and some basic ecological economic concepts. **Part 2** provides information on existing ecosystem services within the Snoqualmie Watershed. **Part 3** consists of the Snoqualmie Basin ecosystem service valuation and calculations of net present value, a figure analogous to an asset value. We also discuss the flaws in this methodology and the research needed to improve our understanding of the economic role of natural capital and healthy ecosystems. **Part 4** reviews the implications of these results for restoration efforts, including policy implications and potential funding mechanisms.

Part I: What is ecological economics?

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". Ecological economics places our economy within natural systems and includes the real value that our natural, functioning ecosystems produce. When we alter environmental conditions, these services are often lost, and must be replaced by costly built alternatives. In many cases, once lost, ecosystem goods and services cannot be recovered.

The scientific field of economics has advanced significantly in recent years in ways that improve our ability to quantify the value and impacts of resource management strategies. A great deal of research since 1985 has focused on developing and refining methods, tools, and techniques for measuring the value produced by natural systems. These include new concepts such as "natural capital" and new techniques including ecosystem service valuation.

Natural Capital

Ecosystems and natural resources, or natural capital, have previously been viewed as virtually limitless compared to human-built capital. In the past, they were considered as "free" and therefore of no value. Given the increasing scarcity of healthy ecosystems, the valuation of natural capital helps decision makers identify costs and benefits, evaluate alternatives, and make effective and efficient management decisions. Excluding natural capital in asset management can result in significant losses, increased costs, and decreases in efficiency and community benefit.

Natural capital is comprised of geology, nutrient and water flows, native plants and animals, and the network of natural processes that yield a continual return of valuable benefits (Daly and Farley, 2004). Natural capital contributes to our economy and quality of life in many ways that are not currently included in policy considerations – for example by providing water, natural water filtration, energy, flood control, recreation, natural storm water management, biodiversity, and educational opportunities. Consideration of the Snoqualmie Basin and other ecosystems as natural capital helps provide a more complete view of ecosystem health and the production of valuable benefits.

Ecosystem Goods and Services

Ecosystem goods and services are those that are derived from natural systems, which provide benefit to humans. There are many things that ecosystems do, but if it does not provide a benefit to people, it is not considered an ecosystem good or service.

Economic benefits come in many different forms – wheat, medical services, and entertainment, for example. Goods are tangible items you could see or touch, like a table, car, or board of timber. Services are things you see or touch, like recreation and biodiversity. The following table provides examples of ecosystem goods and services provided by the Snoqualmie Basin.

Table 1: Ecosystem Goods and Services

Ecosystem Goods	Ecosystem Services
• Food (crops, milk, salmon, beef) • Construction materials (timber, gravel) • Clean drinking water • Medicinal resources (Taxol from the Pacific Yew tree)	• Clean air • Flood protection • Natural pollination of crops • Stable climatic conditions • Recreational opportunities • Biodiversity and habitat for plant and animal species

Ecosystem Goods

Ecosystems provide a variety of useful goods like water, timber, and fish. Most goods are excludable; if one individual owns or uses a particular good, that individual can exclude others from owning or using the same; if one person eats an apple, another person cannot eat that same apple. Excludable goods can be traded and valued in markets. The production of goods can be measured by the physical quantity produced by an ecosystem over time, such as, the volume of water production per second, the board feet of timber production in a 40-year rotation, or the weight of fish harvested each year. The current production of goods can be easily valued by multiplying the quantity produced by the current market price. This production creates a flow of ecosystem goods over time.

Ecosystem Services

Ecological 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). Ecosystems provide a variety of services that individuals and communities use and rely upon, not only for their quality of life, but also for economic production (Daily, 1997; Costanza et al., 1997). Ecosystem services are measurable benefits that people receive from ecosystems. Ecosystems produce goods and services as a result of ecosystem process, function, and structure.

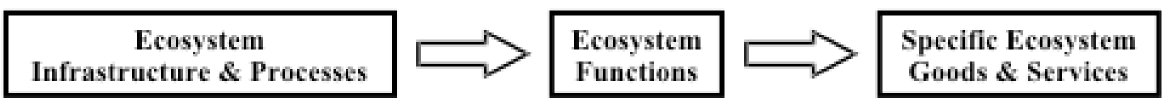
The stream of services provided by an ecosystem is referred to as a “service flux.” A flow of goods can be measured in quantitative productivity over time, while a service flux is generally more difficult to measure and value. Ecosystem services are, in many cases, non-excludable services. For example, when one person enjoys a view of the Mt. Baker-Snoqualmie Forest, it does not prevent another person from enjoying the same view - unless congestion develops. Similarly, all downstream residents benefit from the flood protection provided by forested land upstream. As a result of this non-excludability, most ecosystem services are not sold in markets.

Ecosystems and Value Production

Ecosystems are comprised of individual structural components (trees, forests, soil, hill slopes, etc.) and dynamic processes (water flows, nutrient cycling, animal life cycles, etc.) that create functions (water catchment, soil accumulation, habitat creation, etc.) that generate ecological goods and services (salmon, timber, flood protection, recreation, etc.).

Figure 4 below summarizes these relationships in a simplified diagram. Ecosystem infrastructure has particular physical components within given boundaries of the ecosystem. The infrastructure itself is dynamic, as biotic structures migrate and abiotic components flow through the watershed, often via air or water. These functions vary widely in spatial boundaries (oxygen migrates globally, spawning habitat is locally confined). Thus ecosystems may provide benefits that extend globally (carbon sequestration) or locally (drinking water production). These structures, processes, and functions combine to produce economically valuable goods and services.

Figure 4: Relationship of Ecosystems to the Goods and Services Produced



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 the full diversity of valuable ecosystem goods and services. In the Snoqualmie Basin, restoration efforts would protect and reestablish not only the ecological processes necessary for narrow interests, such as Chinook salmon, but also a much broader set of ecosystem processes, functions, and ultimately ecosystem services.

The Value of Ecosystem Services Relative to Ecosystem Goods

While the value of a service flux may be more difficult to measure, its value may, in many cases, significantly exceed the value of the flow of goods. A study of Philippine mangroves showed that the services of storm protection and nursery functions produced several times the value of shrimp aquaculture operations that replaced the mangrove ecosystems (Boumans et al., 2004).[3]

Integrated Ecosystems

A heart or lungs cannot function outside the body. Neither can the human body function without a heart and lungs. Good health requires organs to work as part of a coordinated

[3] 85% of commercial fish species are dependent on the mangroves for a period of time within their lifecycle.

system. The same is true for ecosystems. Interactions between the components make the whole greater than the sum of its individual parts. Each of the physical and biological components of the watershed, if they existed separately, would not be capable of generating the same goods and services provided by the processes and functions of an intact watershed system (EPA, 2004). Ecosystem services are systems of enormous complexity. Individual services influence and interact with each other, often in nonlinear ways (Limburg et al., 2002).

Value Production "In Perpetuity"

Healthy intact ecosystems are self-organizing (require no maintenance) and do not depreciate. They can provide valuable ecological goods and services on an ongoing basis "in perpetuity" and without cost to humans. A forest provides water control, flood protection, aesthetic and recreational values, slope stability, biodiversity and other services without maintenance costs. This differs from human-produced goods and services (cars, houses, energy, telecommunications, etc.) that require maintenance expenditures, depreciate, and usually end up discarded, requiring further energy inputs for disposal or recycling.

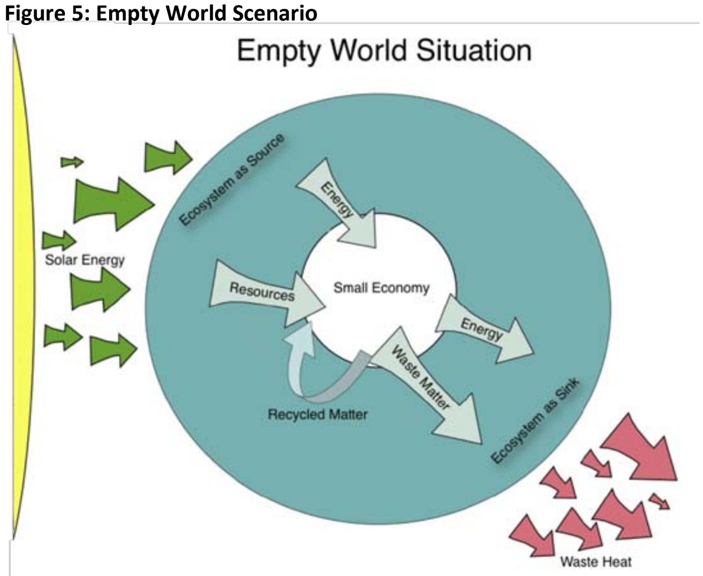
Destruction of ecosystem functions disrupts an ongoing flux of valuable ecological services. Filling flood plains increases flooding. When an ecosystem's free natural flood prevention functions are destroyed, flood damage will exact continuing costs on individuals and communities who must either suffer flood damage or pay for engineering structures and storm water infrastructure to compensate for the loss of flood protection. Without healthy ecosystems, taxpayers, businesses and governments incur damage or costs to repair or replace these ecosystem services. When ecological services are restored, the reverse dynamic can occur.

Natural Capital and Economics

A century ago, forests, waters, fish and other resources seemed virtually unlimited. There were few people, and the size of the economy relative to the natural systems that supported it was small. Figure 5 shows this "Empty" world economy, where human labor is limited and natural resources are abundant.

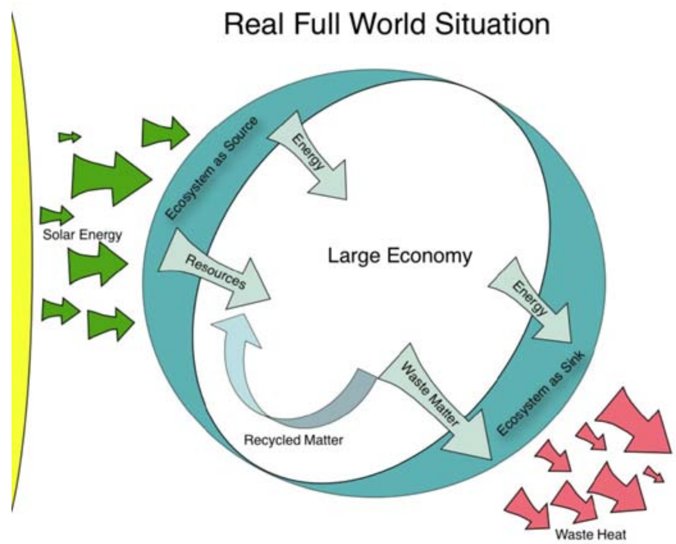
Figure 6 illustrates what happens when the economy expands relative to the size of the natural systems that sustain and maintain it.

Figure 5: Empty World Scenario



As the economy expands, ecosystems are impacted by its increasing size and demands. In the last century, local, national, and global economies have shifted from a seemingly empty world of unlimited and stable resources and natural systems - to a full world scenario where natural resources are limiting factors, and even global systems like climate and ozone protection can be disrupted.

Figure 6: Full World Scenario



Many parts of the world are already responding to the effects of economic expansion on the environmental resources upon which all humans depend. For example, in 1987, countries around the world recognized that banning chemicals known to damage the earth's ozone layer would lead be economically better than risking continued damage, and the Montreal Protocol was signed. Although there was some cost to adjust to this new rule, the natural system that was protected – our atmosphere – is infinitely more valuable.

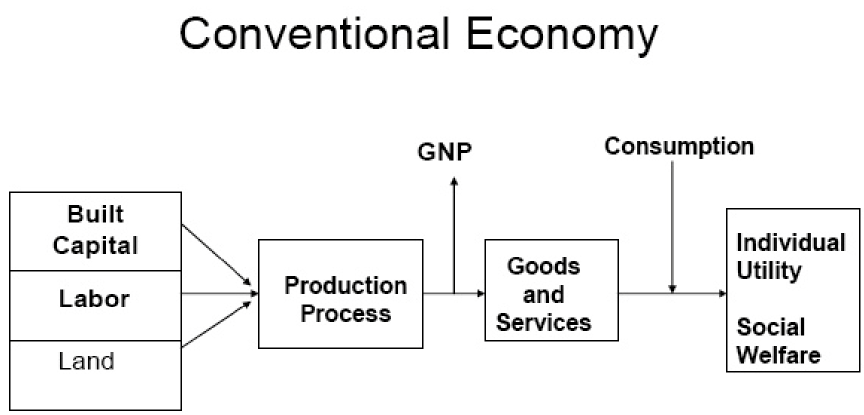
A great deal of our natural capital is still at risk. The fields of economics and public policy must adopt to adjust to this new paradigm. In today's full world scenario, we need management approaches that protect the natural value up which our economy and quality of life rely.

Ecological Economics: Leveraging Capital to Build Sustainable Economies

Economics was heavily influenced during the industrial revolution, when some regions began to enter a full world scenario. Economics focused on increasing the production of manufactured goods and built capital above all else. This approach has yielded a highly productive market system for manufactured capital, which we measure using Gross National Product (GNP).

Ecological Economics aims to combine traditional economics and ecology so that decision-makers and local citizens can pursue a more diverse set of goals. There are many things that we care about beyond manufactured products. In fact, a great deal of research suggests that things like leisure time, equality, and healthy relationships with other people contribute significantly to happiness (Easterlin, 1995; Easterlin, 1974; Graham, 2005). Traditionally, economics has provided a poor measurement of these components. Built capital and human capital (labor) have been the primary "factors of production." Land and other ecological resources are only occasionally included in economic analysis. Figure 7 provides a sketch of this perspective.

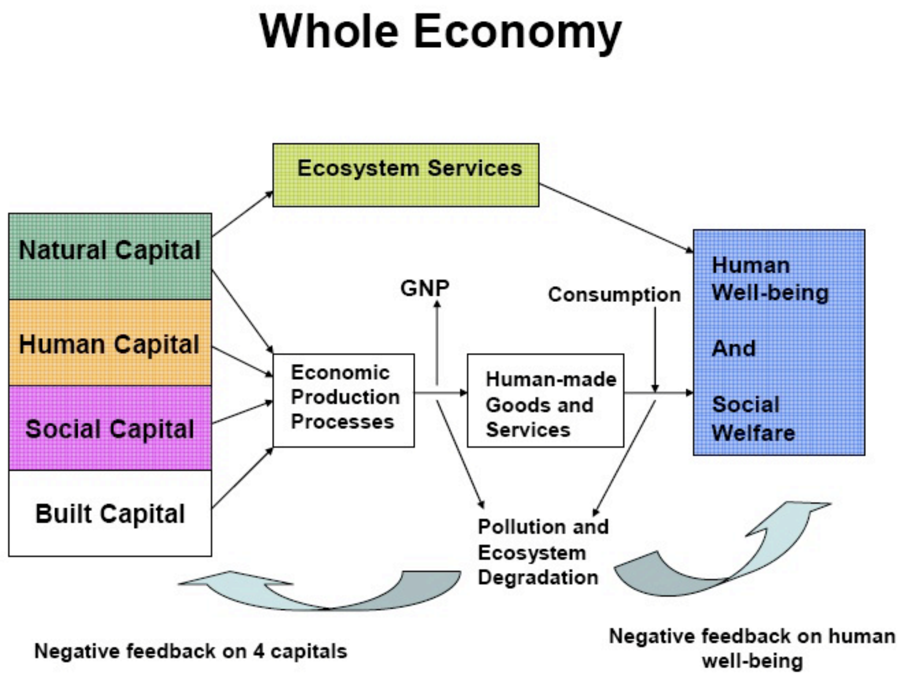
Figure 7: Traditional Economic Model



Natural capital is often thought of as something that human-built alternatives can replace. In many cases, however, built capital cannot replace natural capital. When water becomes polluted and natural systems are not available to filter it, it is possible to build a water filtration plant so that drinking water is still available. In many cases, however, built capital cannot replace natural capital. If a species becomes extinct, their genetic variance will be lost forever. Natural capital and built capital are often used together as complements (Daly and Farley, 2004). Fishing boats, which are human built capital, are useless without fish (natural capital), and both are required to provide fish for human consumption.

Figure 8 illustrates a more robust vision of the economy, which takes into account four types of capital (see definitions below), as compared to the traditional model, which includes only built capital, labor, and land. The recent economic recession has highlighted the importance of a fifth capital: financial capital.

Figure 8: Ecological Economic Model of the



Economy

Five Capitals

The field of economics needs to be updated to reflect 21st century realities. There are five capitals we must consider in order to accurately portray our current economic reality.

Natural Capital: The earth's stock of organic and inorganic materials and energies, both renewable and nonrenewable, as well as the planetary inventory of living biological systems.

When taken as one whole system, natural capital provides the total biophysical context for the human economy. Nature provides resources, energy, and ecosystem functions that allow for natural and human production, along with services that purify and recycle waste products. Human wellbeing depends on these resources and services.

Built Capital: Infrastructure including technology, machines, structures, tools and transport that humans design, build and use for productive purposes.

All built capital is made from natural capital. Along with human capital, our built capital is what directly allows raw materials to be converted into goods and services.

Human Capital: Human labor, knowledge acquired through education, and interpersonal skills, such as communication, listening, cooperation, and individual motivation to be productive and socially responsible.

It is well recognized that education and training are essential to economic progress, innovation and a high quality of life.

Financial Capital: Shares, bonds, banknotes, and other financial assets.

Financial capital plays an important role in our economy, enabling the other types of Capital to be owned and traded. However, it has no real value itself. Financial capital represents a promise in the place of one of the other types of "real" capital.

Social Capital: Social capital is 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.

Without a functioning society in which people respect each other and have some concern for the wellbeing of others, most economic activity would be impossible.

Goals for Resilient, Prosperous, and Balanced Economies

Our economy must carefully balance each of these types of capital. In order to do so, the many stakeholders within the Snoqualmie Basin must consider the following goals:

- **Sustainable Scale:** Recognition of the physical limits of natural systems - which contain and sustain the economy - and determination of the proper relationship between economies and those limits.

- **Fair Distribution:** Costs of provisioning and restoring ecosystems are fairly assigned to those who benefit from, or cause harm to them. Additionally, public and private gains from ecosystem goods and services are fairly allocated.

- **Efficient Allocation:** 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.

- **Good Governance:** Creation and maintenance of private and public institutions, systems, and markets. This is critically important to achieving goals 1-3. Markets lacking sufficient oversight tend to produce market failure, which is inefficient.

How can markets achieve these goals?
Markets allocate resources for the production of large quantities of goods and services, and then distribute these goods and services to people, firms, and governments. Markets work well for many types of built capital and often determine land use and management patterns, which in turn limit or enhance provisioning of natural capital. In order to obtain an appropriate mix of both built capital and natural capital, the economic value of ecosystem goods must be incorporated into market decisions. Additionally, markets need regulation and oversight to prevent market failures. If markets do not include all costs of production in their price, they become “distorted” and inefficient.

For example, coal-fired power plants produce air pollutants like sulfur dioxide, mercury, carbon dioxide, and particulates. However, the owner of the power plant emitting pollution only pays the costs for constructing and maintaining the production facility. Meanwhile, the costs to society are immense. According to a recent study from the National Academy of Science, the cost of coal to human health, grain crops, timber yields, buildings, and recreation was $62 billion dollars, or 3.2 cents per kilowatt-hour (National Academies press release 2009).This figure is an underestimate because we have not established reliable systems for valuing damage to ecosystem services--they are rarely included in estimates of this kind. If climate impacts were taken into account, the cost would rise by at least 0.1 to 10 cents per kilowatt-hour (National Academies press release 2009). Unfortunately, these costs are not yet included in the market price of the product, so there is no incentive to reduce them. Instead, it is taxpayers and future generations who will bear the burden of these costs.

In order to correct such inefficiencies and provide goods and services at the lowest cost to society, the proper institutions must be in place. Government institutions need to operate at the scale of the issue or problem they are meant to address, and must be provided with sufficient powers and resources to achieve their mission. The recently created Puget Sound Partnership is an institution at the scale of Puget Sound for protecting and restoring Puget Sound. The State Department of Ecology is at the scale of the state and provides a critical role to ensure that development is responsible and provides a net benefit.

Natural Capital Management in the Snoqualmie Basin
Healthy ecosystems are self-maintaining; they have the potential to provide an ongoing output of valuable goods and services in perpetuity and to appreciate in value over time. In contrast, built structures and other man-made capital have a tendency to depreciate in value over time, and require significant financial inputs for operations and maintenance. Incorporating natural capital within a visioning process for the Snoqualmie Basin will

enhance the capacity of ecosystems to produce economic value and community benefit. Minimal investment and support for proper management of these assets will continually bring large returns by way of ecological goods and services.

Public and private landowners in the Snoqualmie Basin have a unique opportunity to understand the full economic importance of ecosystems as providers of services. The provisioning and filtration of water is a good example. Standing forests can naturally purify water to drinking water standards. A number of cities in the United States, including Seattle, Everett, Portland, San Francisco, Vancouver and Tacoma, have already decided that the value of this service flow - water purification - is far more valuable than other alternatives, and have purchased all or portions of forest lands near water supply areas to purify the water. As an added benefit, other ecosystem services such as carbon sequestration, wildlife habitat, soil erosion control, and many more will benefit from this management approach.

Ecosystems in the Snoqualmie Basin can be managed in a way that optimizes the aggregate value of goods and services with potential to benefit current and future generations. For example, local farmers can contribute to positive environmental outcomes through riparian planting and other land management techniques. This type of private action is already occurring through programs offered by Stewardship Partners, the Trust of Public Lands, the Partnership for Rural King County, and many other groups.

Part 2: Ecosystem Services in the Snoqualmie Watershed

The Snoqualmie Watershed is an appropriate geographic area for economic development planning because it encompasses a natural boundary for water and natural systems, as well as natural boundaries for human communities. In determining how to fundamentally improve our quality of life and economy, it is critical to understand that the economy and healthy people and communities reside within a watershed and depend upon the natural systems it provides.

Watershed Management

There are many active stakeholders in the Snoqualmie Watershed, including local government, non-profits, and citizens groups. Both King and Snohomish County invest critically to natural resource management in the Watershed. These diverse groups are working together to help move towards development of a cohesive watershed strategy. Along with our partners on this project, the Trust for Public Lands and Stewardship Partners, we are supporting a stakeholder process to help develop a localized, long-term vision for the Snoqualmie Watershed. The following section provides a cursory review of current actors involved with watershed management in the Snoqualmie Watershed

Snoqualmie Watershed Stakeholders

The Snoqualmie Watershed contains many active groups of local citizens and organizations dedicated to improving the quality of life within the watershed. The following section will briefly describe some of the current government and citizen-driven efforts in the Watershed.

Federal Stakeholders

Several federal agencies are active in the Snoqualmie Watershed, including the US EPA, the United States Geological Survey (USGS), and the Army Corps of Engineers. These agencies collectively provide a number of environmental services. For example, the USGS collects a wide array of water quality and streamflow data from 18 gauges in the Watershed. This information is used to help identify trends in the Snoqualmie River Basin and to inform various stakeholders and management approaches in the Watershed. The USGS has also developed advanced tools such as a live flood-modeling tool, FloodPath, which allowed users to foresee likely flood levels on their property during flooding in January 2009 (USGS 2009).

The Federal EPA recently funded a highly focused community stewardship pilot in two sub-basins of the Snoqualmie: the Raging River and the Patterson Creek basins. This project, called Stewardship in Action, provides resources and tools to community groups and landowners environmental improvements to private land from September 2009-September 2011. Additionally, the EPA is operating the Puget Sound Estuaries Program, under the National Estuary Program, established by Congress in 1987.

The Army Corps of Engineers manages much of the flood control infrastructure along the rivers, primarily levee repairs and other basic maintenance. Along with the routine repairs made to levees along the Snoqualmie River, the corps is involved in the "Snoqualmie 205 Project" with the City of Snoqualmie and King County. This flood study has thus far led to flood damage reduction strategies such as channel widening upstream of Snoqualmie Falls and removal of an abandoned bridge.

State and Local Government

The Department of Ecology (DOE) manages watershed planning in Washington State. The DOE provides maps of the Snohomish Watershed, including land cover/ land use, topography, water bodies, population density, and major public lands. In 2008, the DOE conducted water quality studies along the Snoqualmie River, including fecal coliform bacteria, dissolved oxygen, ammonia-nitrogen, and pH total maximum daily load. The DOE is currently developing a temperature study (DOE website 2010).

The Snoqualmie Watershed is largely in King County, with a small portion of land in Snohomish County. Kittitas County borders the watershed to the Southeast. Many County groups from both King and Snohomish Counties are involved in the Snoqualmie, including watershed forums, conservation districts, and county natural resource departments. The Snohomish Conservation District works with farmers and landowners to protect water quality, promote fish and wildlife habitat, and address other issues as needed (SCD website 2010). Additionally, Snohomish County has completed a stream habitat evaluation along the entire Snoqualmie-Skykomish Watershed (Neuman, 2002). The King Conservation District enables the Snoqualmie Watershed Forum to allocate a portion of funding for habitat protection, restoration, and stewardship projects in the Snoqualmie Valley through grants.

Other state and local actors include the Snoqualmie Ranger District and the Snoqualmie Watershed Forum.

Snoqualmie Tribe

The Snoqualmie people are a Coast Salish Native American Tribe that has inhabited the Snoqualmie Valley for at least 2000 years, as evidenced by archeological findings (King County DDES, 2001). The Snoqualmie have always depended on the area's abundant ecosystem goods and services - hunting deer and elk, fishing for salmon and other species, and collecting medicinal and cultural resources from other plants and animals. The Snoqualmie also associate many landscape features with stories of creation; these lands are often considered sacred. Some parts of the watershed with historical cultural significance, including Snoqualmie Falls, continue to be incorporated into tribal ceremonies and activities. In a personal communication with Matt Baerwalde, Water Quality Manager of the Snoqualmie Tribe DENR, he tells that the Snoqualmie people do not think of themselves as "inhabiting" the valley; rather, they *are* the Basin.

In 1855 the Snoqualmie signed the Point Elliott Treaty, under which the Tribe surrendered land between the Snoqualmie Pass and Marysville, and gained federal recognition. In 1953, the Tribe lost federal recognition, as they no longer held a federally reserved base. Following an unsuccessful attempt to create a reservation near the Tolt River, their ancestral lands, the Snoqualmie and Skykomish Tribes filed a claim to recover the lands previously ceded to the US government. This claim was rejected by the Indian Claims Commission in 1961; then later reversed in the court of appeals. In 1968 a settlement agreement was reached, whereby the US government offered $257,689 to the two Tribes.[4] Finally, in 1999, the Snoqualmie's status as a federally recognized tribe was reinstated.

Today, the Snoqualmie Tribe numbers around 650 members. The Tribe is currently managing a number of restoration and monitoring activities within the Snoqualmie Basin. One project is a 5.2-acre riparian restoration at Fall City Community Park, on King County property. This involves replacing non-native, invasive species with native plants, and will result in a buffer that extends more than 30 meters. With increased funding, this restoration will then add an additional 9 acres of vegetation to the riverbank, another important step towards absorbing floodwaters before they have a chance to build up downstream. The Snoqualmie Tribe also manages smaller restoration projects on their 60-acre reservation property, including a new nature trail. This will be a welcome addition to the surroundings of the recently constructed casino.

Non-profits and Partners

There are also many non-governmental groups at work within the watershed. Our partners on this project, TPL and SP, each have important programs at work in the area. The Partnership for Rural King County was also a project partner.

The Bullitt Foundation has also contributed to our work in the watershed, by funding this report.

[4] http://www.goia.wa.gov/Tribal-Information/Tribes/snoqualmie.htm

Ecosystem Services and Value in the Snoqualmie

In 2001, an international coalition of scientists within NASA, the World Bank, the United Nations Environmental Program, the World Resources Institute, and others initiated an assessment of the effects of ecosystem change on human wellbeing. The product of this collaboration was the Millennium Ecosystem Assessment, which classifies ecosystem services into four broad categories describing their ecological role (MEA 2003). Ecological economists generally use these same categories.

- **Provisioning services** provide basic materials; mostly ecosystem service goods. Forests grow trees that can be used for lumber and paper, berries and mushrooms for food, and other plants for medicinal purposes. Rivers provide fresh water for drinking and fish for food. The waters of the Puget Sound provide fish, shellfish, and seaweed. Provisioning of these goods is a familiar service provided by nature, and is easiest to quantify in monetary terms (Farber et al., 2006).

- **Regulating services** are benefits obtained from the natural control of ecosystem processes. Intact ecosystems provide regulation of climate, water, soil, and keep disease organisms in check. Degraded systems propagate disease organisms to the detriment of human health (UNEP, 2005).

- **Supporting services** include primary productivity, nutrient cycling and the fixing of CO2 by plants to produce food. These services are the basis of the vast majority of food webs and life on the planet.

- **Cultural services** are those 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.

Within each category, there are many more specific ecosystems services. These services are identified in the following table.

Table 2: Table of Ecosystem Services

Service	Definition
Provisioning	
Drinking Water	Water for human consumption
Food	Biomass for human consumption
Raw Materials	Biological materials used for fuel, art and building. Geological materials used for construction or other purposes
Medicinal Resources	Biological materials used for medicines
Regulating	
Gas and Climate Regulation	Regulation of greenhouse gases, absorption of carbon and sulfur dioxide, and creation of oxygen, evapotranspiration, cloud formation and rainfall provided by vegetated and oceanic areas
Disturbance Regulation	Protection from storms and flooding, drought recovery
Soil Erosion Control	Erosion protection provided by plant roots and tree cover
Water Regulation	Water absorption during rains and release in dry times, temperature and flow regulation for plant and animal species
Biological Control	Natural control of pest species
Water Quality and Waste Processing	Absorption of organic waste, filtration of pollution
Soil Formation	Formation of sand and soil from through natural processes
Supporting	
Nutrient Cycling	Transfer of nutrients from one place to another; transformation of critical nutrients from unusable to usable forms
Biodiversity and Habitat	Providing for the life history needs of plants and animals
Primary Productivity	Growth by plants provides basis for all terrestrial and most marine food chains
Pollination	Fertilization of plants and crops through natural systems
Cultural	
Aesthetic	The role which natural beauty plays in attracting people to live, work and recreate in an area
Recreation and Tourism	The contribution of intact ecosystems and environments in attracting people to engage in recreational activities
Scientific and Educational	Value of natural resources for education and scientific research
Spiritual and Religious	Use of nature for religious or historic purposes (i.e., heritage value of natural ecosystems and features)

Based on Daly and Farley 2004 and de Groot 2005

These are the primary categories of ecosystem services, and are discussed below. It should be kept in mind that these can be further broken down into sub-categories. For example, recreation contains boating, fishing, birding, hiking, hunting, swimming and other activities. Every year, ecosystem services are added to the more detailed categories.

The description of each service includes a special “Spotlight on Snoqualmie” section within an orange box.

Provisioning Services

Fresh Water

Watersheds provide fresh water for human consumption and agriculture; 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). Some Snoqualmie Basin residents are among these. 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).

The Puget Sound Basin is heavily influenced by its proximity to the Pacific Ocean and the Olympic and Cascade Mountains. Local ecosystems capture precipitation in the form of rain and snow. Water is filtered through forests and other vegetation (See Water Filtration and Waste Processing), to produce clean ground water and surface water.

In the Snoqualmie Basin, nearly 90% of private, municipal, industrial, and agricultural water comes from groundwater sources. Most of this water comes from wells, which are treated with fluoride and chlorine. Much of the groundwater is incorporated into the East King County Groundwater Management Area, which covers 225 miles of land in or near the Snoqualmie River Valley. A Groundwater Protection Committee met from 2002-2004, at which time the Committee disbanded.

Although local, short-term demand for water withdrawal is predicted to remain fairly stable in the Snoqualmie Basin, experts predict pressure from elsewhere in the Puget Sound will contribute to increasing water demand. Additionally, Washington State climate change predictions indicate that prolonged droughts and decreased snowmelt might exaggerate low-flow summer conditions (EKCRWA 2007). Currently, there are some projects to alter stream flow in the Snoqualmie Watershed, both for human use and for aquatic species. This work is discussed in the section on “Water Regulation”.

Food

Food includes biomass for human consumption, provided by a web of organisms and a functioning ecosystem. Providing food is one of the most important functions of marine 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, 2006).

Agricultural land also provides a great deal of food value. Agricultural lands 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, 2004). Berries, peas, potatoes, flower bulbs, seeds, and dairy products are the major economic yields of Puget Sound farms. Berries are especially high value products for the region.

Historically, the Snoqualmie Valley has been an area rich in natural resources. Before settlers arrived, the area supplied deer, mountain goats, edible bulbs and plant roots, berries, and above all, abundant salmon. The Snoqualmie Tribe managed the prairie's productivity with occasional burns. Arriving settlers later developed a large hops industry in the 1880's, which flourished until the late 1890's. Other agriculture filled its place until the 1960's, when agriculture in the valley declined (King County website, 2010).

Today, the Snoqualmie Agricultural Production District (APD) covers 14,000 acres, largely located along main-stem rivers and along lowland tributaries. Over 4,500 acres of this land has been protected under the Farmland Preservation Program (King County 2010). According to a 2003 survey by King County, approximately half of total agricultural activity in the Snoqualmie Basin is located within the APD. These lands provide both local and national food, as well as local employment and ecosystem benefits. Livestock and dairy farms cover the largest amount of acreage (4,300 acres of forage lands for livestock), with other significant uses including produce, tree farms, corn, and nurseries (Kaje, 2009).

Additionally, agricultural lands, both active and fallow, provide aesthetic and cultural value. The King County Conservation District assisted with the purchase of the historical Meadowbrook farm, which remains as an open space corridor in the Valley. The King County Historic and Scenic Corridors Project helped develop the West Snoqualmie River Road Heritage Corridor, which capitalizes on historical corridor features as well as views of agricultural lands such as cut flower fields and pastures, and historic architecture such as dairy farmsteads and barns (KCDOT, 2009).

The Snoqualmie Basin has a large amount of critical salmon habitat, which traditionally provided a valuable food source to the Snoqualmie Tribe and others. The details of the habitat and non-commercial values will be discussed in later sections.

However, agricultural production, particularly cattle operations, can degrade water quality and fish habitat when not properly managed. One of our partners on this project, Stewardship Partners, with support from King County, has helped many farms within the Snoqualmie Valley improve practices to reduce negative environmental effects. Through activities such as planting riparian vegetation, both the value of this farmland is increased, and the local economy is enhanced. Better salmon habitat will provide greater return in commercial fishing, local food, and draw recreational and sports fishers as tourists.

Raw Materials

Raw Materials include biological materials used for medicines, fuel, art and building; geological materials used for construction or other purposes.

Washington State produced 34 billion board feet of commercial timber harvest in 2006, mostly from State and private lands (WDNR, 2006). Federal lands have been extensively harvested in the past but environmental, social, and legal limitations were reached on these lands by the early 1990s; they now account for a small portion of the regional timber harvest (Swedeen, 2004). Other important goods that ecosystems produce include petroleum, lime, wood, and medicinal products.

The Snoqualmie Basin contains a great deal of working forestlands, with over 75% of its land in the Forest Production District. Trees have been harvested from the area from the late 1800s to the present. Logging of old-growth timber peaked in the 1920s, so there are no old growth stands remaining, and most of the current forest is third or fourth generation growth. Timber production is still active in the area, and about twenty mining claims (primarily for quartz crystals) are still active in the nearby National Forest. The Snoqualmie Valley also has a significant amount of land in tree farms.

Regulating Services

Gas and Climate Regulation

Ecosystems help to regulate the gaseous portion of nutrient cycles that effect atmospheric composition, air quality and climate regulation. This process is facilitated by the capture and long-term storage of carbon as a part of the global carbon cycle. Forests and individual trees play an important role in regulating the amount of oxygen in the atmosphere and in filtering pollutants out of the air, including removal of tropospheric ozone, ammonia, sulfur dioxide, nitrogen oxide compounds (NOx), carbon monoxide, and methane.

Carbon sequestration is a specific and important type of gas regulation. Forests, agricultural lands, wetlands, and marine ecosystems all play a role in carbon sequestration. Undisturbed old growth forests have very large carbon stocks that have accumulated over thousands of years. Replacing old growth forests with new trees results in net carbon emissions caused by the loss of hundreds of years of carbon accumulation in soil carbon pools and large trees (Harmon, 1990).

Maintaining a climate within a stable range is increasingly a priority for local, federal, and international jurisdictions. The role of forests and other ecosystems in controlling Greenhouse Gases (GHGs) – those that contribute to global warming – is essential to the continuation of life on earth. However, carbon sequestration is not the only value provided by gas and climate regulation. American Forests (1998) calculated that urban forests remove 78 million pounds of pollutants per year in the Puget Sound area. Low air quality can cause health care costs to spike, as respiratory diseases develop. In the Puget Sound, the gases sequestered by forests saved $166.5 million per year in avoided health care costs and other costs in 1996. The extensive forest cover of the entire Puget Sound Basin thus likely provides a significant amount of gas regulation services that is very valuable in terms of public health.

Managed forests have the potential to sequester nearly as much carbon as old growth forests, but this requires longer rotations than current industrial standards and other changes (Harmon and Marks, 2002). Agricultural soils can also sequester more carbon when certain techniques are used, including crop rotations, livestock waste disposal, and conservation tillage, especially no-till (West and Post, 2002; Tweeten et al, 1998). Because these types of practices could provide significant global value - $8 to $59 per ton by some estimates – there is increased interest in including agricultural lands in carbon trading markets, with farmers receiving payments for their sequestration. The potential of this market and others related to agricultural lands will be discussed in the section on funding mechanisms.

The Snoqualmie Basin still contains a great deal of forested land, though working forests and farmland could play a larger role in climate and gas absorption in the Snoqualmie Watershed. Payments to farmers may someday incentivize no-till agriculture and longer forest rotations for working forests. Additionally, some cities, such as Snoqualmie, have taken measures to improve sustainability. The city expects to save $1,000 annually in stormwater costs from urban tree planting; and these trees will likely also contribute to additional carbon sequestration.

Disturbance Regulation

Estuaries and bays, coastal wetlands, headlands, intertidal mudflats, seagrass 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 against coastal waves. Estuaries, bays, and wetlands are particularly important for absorbing floodwaters (Costanza et al., 2008); UNEP, 2005).

Today, changes in land use, combined with the potential for higher frequency storm events due to climate change, make this service one of the most important for the future of economic development in the Snoqualmie Watershed. In order to have productive agricultural and forested lands, protected built capital, and high value, productive ecosystems, flood protection must be effective and efficient. Given that significant infrastructure can be damaged during large storm events, tourism and recreation could be harmed as well.

One of the most significant factors in an ecosystem's ability to prevent flooding is the absorption capacity of the land. This is determined by land cover type (forest vs. pavement), soil 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 USGS 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). One recent study in Renton found that wetlands provide over $40,000 per acre of flood damage protection (Leschine, 1997). Another pilot study in King County demonstrated that flood hazard reduction projects in the floodplain and Cedar River could avoid $468 to $22,333 per acre per year in damages to homes and county flood control facilities (Swedeen and Pittman, 2007).

The retention of forest cover and restoration of floodplains and wetlands provides a tangible and valuable ecosystem service. Most notably, it reduces the devastating effects of floods, which include property damage, lost work time, injury, and loss of life. Unfortunately, Puget Sound estuaries have lost about 60% of their salt marshes since European settlement (Buchanan et al., 2001). Wetlands and intact riverine floodplains, including riparian forests, absorb the increased river flows that result from storm events and high snowmelt. Upland forests also absorb rainwater, reducing surface runoff into major stream and river systems. Greater over-land water flows during winter storms cause more flood damage when wetlands are lost, riparian areas are disconnected from rivers and streams, or forestland is replaced by houses and commercial development (Kresch and Dinicola, 1997).

Prior to its recent settlement and industrial development, the Snoqualmie Basin experienced regular storms and flooding, just as it does today. Without any concrete levees, wetland and riparian vegetation was forced to adapt to these regular natural disturbances. An array of complex plant communities arose, which withstood natural disturbances by absorbing their energy. During storms old growth forests soaked up a great deal of water, allowing only a low level of surface runoff. Flooding was further buffered by large tracts of wetland and riparian vegetation which served as a sink for excess water and prevented buildup of water downstream.

Today, existing forest within the Snoqualmie Basin has become increasingly fragmented, partly due to pressures such as land use value increases, changing ownership patterns and residential development (King County WLR, 2010; McCaffrey, 2004). Riparian vegetation and wetlands are following similar trends of fragmentation and altered hydrology (Catchpole and Geggel, 2009a). As a result, the watershed's ability to absorb the energy of natural disturbances has been significantly reduced.

In the Snoqualmie Basin, urban areas line the riverbanks - often in areas that are natural floodways. It was recently estimated that a 100-year flood along the Snoqualmie River would displace approximately 1600 residents in Snoqualmie alone and cost more than $29 million (King County Flooding Services, 2010). Also, the close proximity of urban areas to natural floodways means that during a flood there is a greater likelihood that floodwaters will pick up land-based pollutants such as industrial and residential chemicals, manure, and agricultural fertilizer (Kaje, 2009).

If global temperatures continue to rise, models predict that the Pacific Northwest will experience wetter winters and drier summers (Mote and Salathe, 2009). In Puget Sound watersheds, snowpack is likely to decrease, while rain will increase (Elsner et al, 2009). A reduction in upland vegetation, along with these climatic changes, will result in an increase in rain-on-snow events, further adding to the severity of surface water buildup, flooding and landslides (Coffin and Harr 1992).

Residents in the Snoqualmie Basin understand that storms and flooding are regular events in the Watershed, and employ a variety of strategies to reduce the stress and danger that comes from such disturbances. After the 2006 floods in Snoqualmie, for example, 90 residents applied to have their houses raised, while 12 applied to have their houses bought out (Catchpole and Geggel, 2009b). Local government continues to maintain flood levees along key riverbanks, but is more often beginning to implement non-traditional flood protection measures, such as levee setbacks and the planting of riparian vegetation along riverbanks (Catchpole and Geggel, 2009b). Policies that recognize the Snoqualmie River's natural tendency to flood will save money in the long term. The following page shows photographs of past flooding in the Snoqualmie Basin.

Figure 9: 2006 Flooding in the Snoqualmie

Top left: Flooding on Silva Street, Snoqualmie; **Top Right:** Flooded farmhouse, Snoqualmie Valley; **Bottom photo:** Flooded roadways. Photo Credit: Snoqualmie Nation, Snoqualmie Joe.

Soil Erosion Control

Natural erosion and landslides provide sand and gravel to streams, creating habitat for fish and other species. Additionally, these processes can move Large Woody Debris (LWD) through the process of recruitment, which are needed for healthy aquatic processes. However, if too many areas become unstable, too much LWD will be deposited, causing unnatural jams that damage habitat and infringe on recreational activity.

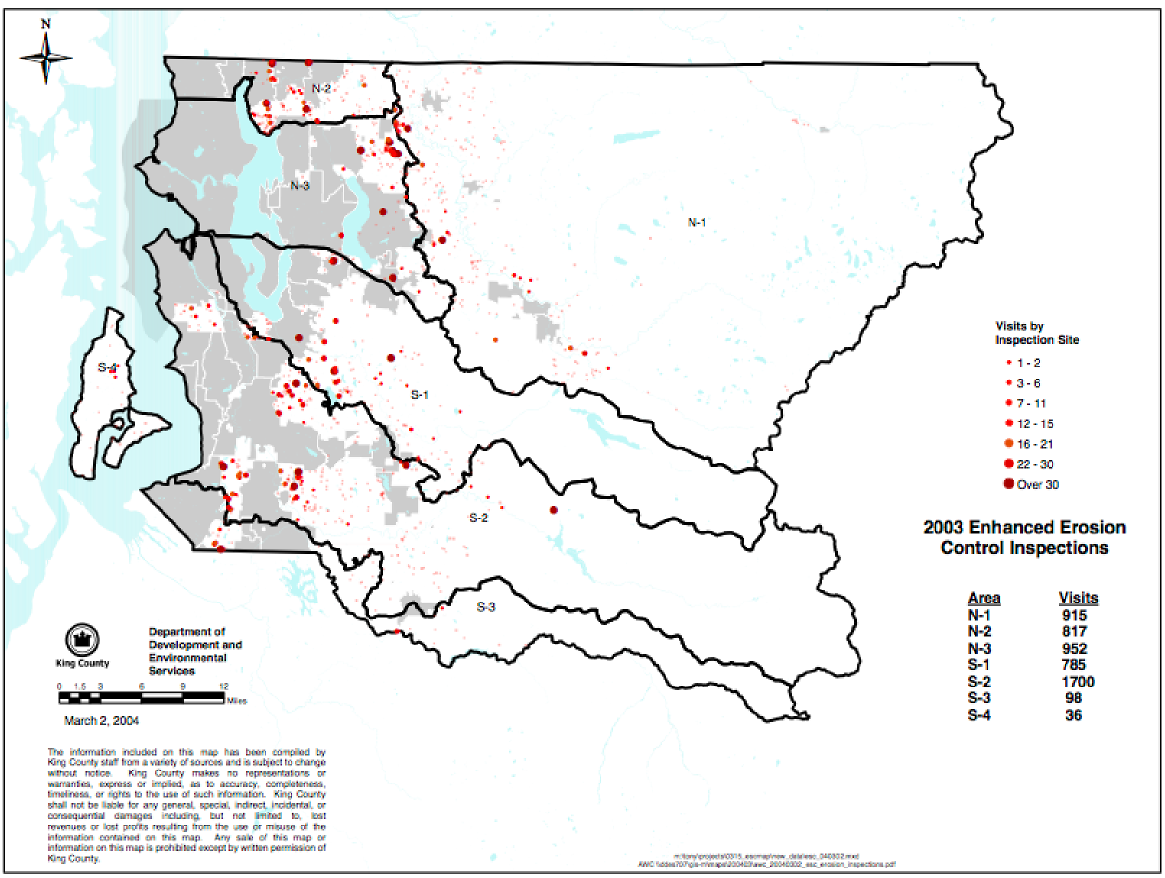
Natural erosion protection is provided by plant roots and tree cover. Soil erosion control is closely linked with disturbance prevention. While the absorption capacity of the land will largely determine floodwater levels, the retention of this water can play a significant role in preventing landslides and other damaging forms of erosion. Sedimentation from a large number of landslides can harm salmon habitat.

On the other hand, human alteration of shoreline and stream corridors can prevent the type of natural erosion upon which salmon and other species depend. Forested and vegetated areas naturally provide stability and erosion control, while impermeable built surfaces or deforested areas cannot retain soil well. Human activities may not only affect an area's ability to retain soil, but can also increase the flow of water that may mobilize soil particles. Accidental surface-water discharges or increased storms related to climate change can both increase erosion risk.

Erosion control in the Snoqualmie Watershed is an important service, as the sedimentation from large amounts of erosion can be extremely damaging to downstream water quality and fish habitat (KCDES et al., 2004). Erosion Hazard Areas were mapped by King County beginning in the late 1980s. The susceptibility of a given slope is determined by grain-size, soil cohesion, slope gradient, rainfall frequency and intensity, surface composition and permeability, and type of land cover (Kresch and Dinicola, 1997).

The best management in the Snoqualmie Basin will be to allow for natural erosion while protecting habitat and built value by avoiding development and deforestation in areas that are at risk of severe erosion or landslides. Areas most often visited by King County officials are shown in the map below, Figure 12.

Figure 10: King County Erosion Control Inspections, 2003.



Source: King County Department of Development and Environmental Services

Water Regulation

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 Puget Sound 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.

Agricultural and urban development often results in lost forest cover or riparian vegetation. This shift in land cover is among the most important causes of a smaller fresh water flow to coastal wetlands and bays. When forested basins are heavily harvested, they become dominated by recently clear-cut or young stands, causing the remaining vegetation and litter layer on the forest floor to absorb less water. More water then flows over land into streams and rivers, contributing to higher peak flows, flood events, erosion and landslide issues (Moore and Wondzell, 2005). Heavy harvesting also reduces the ability of forests to slowly release water during dry summer months and moderate stream temperatures. The soil from erosion entering streambeds injures fish and fills spawning beds. These cumulative effects can damage built and natural capital.

Coastal freshwater wetlands form a salinity gradient with saltwater marshes and the ocean. These freshwater wetlands keep salt water from intruding on coastal freshwater supplies, both at the surface and in aquifers (UNEP, 2005). Alteration of hydrology by diverting water from estuaries is considered to be a major threat to coastal areas (Pringle, 2000). Hypersalinization can occur when too much fresh water is prevented from reaching estuaries, threatening fresh water supplies, habitat, and other services.

As was discussed in the section on Drinking Water, ecosystems are able to naturally both supply and then filter clean water for human use. One way to understand the economic value of intact watersheds is to compare it to the cost of building and maintaining water supply and treatment facilities. To the extent that loss of ecological systems results in reduced supply, value can also be ascertained through the cost of having to import water from elsewhere. These are examples of what economists call replacement costs (see section on Valuation Methods).

A wide variety of stream-flow augmentation techniques have been adopted in the United States, Great Britain, and elsewhere. In order to balance human desire to maximize water supply with other services such as water regulation and habitat, these types of management techniques must be carefully evaluated regarding their impact on water flows elsewhere in the watershed. Much of the science behind stream-aquifer relationships and other hydrologic relationships within the watershed are still not fully understood, and will greatly impact our ability to protect other ecosystem services as we utilize this valuable one.

Currently, the East King County Regional Water Association (EKCRWA) - in conjunction with the Department of Ecology (DOE) and Seattle Public Utilities (SPU) - is pursing projects to impact ground and surface water resources in the Snoqualmie Basin, documented in an extensive Streamflow Enhancement Report produced in 2007. Studies in the 1980s and 1990s indicated that East King County might experience future water shortages, sparking an investigation by the EKCRWA. This work has analyzed the potential of various stream flow augmentation techniques in the Snoqualmie Basin, specifically the Snoqualmie Aquifer Regional Water Supply Project.

The project would deliver water from the upper Snoqualmie Basin to the regional supply system. However, since such action could jeopardize flows needed for salmon and other species, the EKCRWA has proposed managing ground water together with surface water, so that groundwater would be withdrawn from wells in the upper Middle- and South Fork basins, added to the Snoqualmie River as it flows through Duvall, and withdrawn once past critical salmon areas.

Additionally, high temperatures during summer months threaten aquatic populations, and temperature is now the largest water quality concern in the mainstem of the Snoqualmie River (Kaje, 2009). Future conditions may vary due to climate change, including reduced snowmelt and lower summer flows. New water management strategies will need to be developed to meet both increasing human demand and increasing pressure to restore and protect salmon and other aquatic species.

Pollination

Pollination supports wild and cultivated plants, which are an important supply of food for people. Pollination also plays a critical role in ecosystem productivity. Many plant species, and the animals that rely on them for food, would go extinct without animal and insect mediated pollination. Pollination services 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). Wild habitats near croplands are necessary in order to provide sufficient habitat to keep populations of pollinators, so vital to crop production, intact. The loss of forestlands and native shrubby riparian areas in suburbanizing rural areas has a negative impact on the ability of wild pollinators to perform this service.

Pollination drives many of the ecosystem services provided by the Snoqualmie Basin. Agriculture, for example, relies heavily on pollination. Insect-pollinated market crops were valued at approximately $20 billion to the U.S. economy in 2000 (Morse and Calderone, 2000). The Snoqualmie Valley Agricultural Production District (APD), found within the Snoqualmie Basin, is the second largest APD in King County. In terms of acreage, its market crops account for around half of the King County total (this includes flowers) (KCDNRP and KCAC, 2009), many of which rely on natural pollinators. Livestock make up around a third of the valley's APD, and is indirectly reliant on pollinators, in that forage crops such as alfalfa are grown with the help of pollinators. Pollinators also ensure that local flowering plants are able to reproduce. These plants in turn provide us with a number of ecosystem services, such as breathable air, and some of the natural beauty that attracts visitors to the Snoqualmie Basin.

Biological Control

Biological Control is the ability of ecosystems to limit the prevalence of crop and livestock pests and diseases. A wide variety of pest species destroy human agricultural crops, reducing worldwide harvest by an estimated 42%, thereby causing a loss of $244 billion dollars each year (Pimentel et al., 1997). A number of natural predators for pest species contribute to natural control of damages. These predators also play a role in protecting forests from pests. Birds, for example, are a natural predator of some harmful insects. Unfortunately, many exotic pests, for which no natural predators exist, have been introduced to areas beyond their natural range. These new pests have caused annual damage ranging from $1.1 to $134 million dollars in the United States alone (Chapin et al., 2000).

In recent years, humans have turned increasingly towards pesticides to control crop losses. While pesticides can reduce the risk of specific pest attacks, they can also harm natural predator populations and lead to resistance among pests, making them even more difficult to control in the future. Overuse of pesticides is also known to reduce provisioning of some other ecosystem services, particularly water quality. While there may be a role for pesticide control in agricultural practice, 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 (Dordas, 2009; Risch et al., 1983).

Because the Snoqualmie Basin has a substantial agricultural community, there is ample opportunity to improve the use of biological control measures to assist farming practices. There are a number of resources are available; The National Sustainable Agriculture Information Service provides both English and Spanish language information on sustainable farming, including pest management approaches. The Snoqualmie Basin was also home to Stewardship Partner's pilot "Salmon Safe" Program, which requires farm owners to adopt natural pest control methods and increase diversity (Stewardship Partners, 2010).

Water Quality and Waste Processing

Microorganisms in sediments and mudflats of estuaries, bays, and nearshore areas 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 and waste products disrupts disease regulation and waste processing services. Changes to ecosystems can also create breeding sites for disease vectors where they were previously 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. The recent rise of cholera outbreaks in the southern hemisphere is associated with degradation of coastal ecosystems (UNEP, 2006).

The Puget Sound area has had 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 is evidence that increasing pollution loads and climate change exacerbate the conditions that lead to toxic blooms (see (Rabalais, 2005) for a summary). Many areas in Puget Sound also have health advisories due to high bacteria counts from human and domestic animal waste, especially in late summer, and many shellfish harvest areas have been closed as a result (PSAT, 2007). Reduced access to beaches, fish, and shellfish due to disease has obvious impacts to human health and economic activity in the Puget Sound counties.

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 native fish and invertebrate biota. The rise of nutrient overload and hypoxic zones caused by a combination of agricultural run-off, failed septic systems, and the dumping of fish carcasses have become a major issue in Hood Canal in recent years. 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).

Water Quality in the Snoqualmie Watershed has remained relatively high, but there may be reason for concern as conditions change in the coming years. A 2009 report produced by King County, "Snoqualmie Water Quality Synthesis", found that growing population, changing land use, and climate change may all present threats to water quality. Population growth will require additional waste processing and sewage facilities, though it is possible that some natural management approaches could be used. Growing urban and rural populations will also add development pressure to wetlands, forests, and riparian areas. However, there are some positive trends as well. Agricultural land uses have diversified in recent years, moving away from historically common dairy farming, which may help water quality.

Thus far, nutrient inputs to the mainstem have been small enough that the River continues to meet state standards, though many sites occasionally exceed fecal coliform bacteria limits. A number of tributaries have consistent water quality problems, especially Kimball, Patterson, Ames, Cherry, and Tuck Creeks. Problems include high temperature, excessive bacterial load largely due to livestock operations and septic system failures, low pH, and low dissolved oxygen. Some of the current conditions likely result from long-term changes in soil and drainage patterns resulting from past conversion of forest to agricultural land and logging practices. Still, the findings of the 2009 report support previous sections of this document: Intact wetlands and forests are the best defense against water quality degradation. Local jurisdictions should place a premium on protecting these assets in perpetuity. They also reduce flooding and bank erosion while sustaining the aesthetic beauty of rural communities.

Supporting Services

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. The following section draws on information from the Snohomish County Soil Survey (USDASCS, 1983).

There are five significant factors in soil formation:

- Parent material is for the most part chemically weathered mineral or organic matter that contributes to soil formation. In Snohomish and King Counties, most of the soil was formed from deposits of glacial drift, though some was 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 type of plants in an area can determine characteristics of the soil. Animals contribute less to this process, but earthworms, insects, and small animals assist with soil aeration and deposit nutrients.

- The climate in Snohomish County has three distinct zones: Western (lower elevation, 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 (elevation above 1,800 ft, high annual precipitation, short frost-free period, 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 area, soil-forming processes began following glacial melting, around 12,000 years ago. Some types of soils develop more slowly than others, but all develop over the course of thousands of years.

Nutrient Cycling

There are 22 elements essential to the growth and maintenance of living organisms. While some of these elements are needed only by a small number of organisms, or in small amounts in specific circumstances, all living things depend on the nutrient cycles of carbon, nitrogen, phosphorous, and sulfur in relatively large quantities. These are the cycles that human actions have most effected. Silicon and iron are also important elements in ocean nutrient cycles because they affect phytoplankton community composition and productivity. It is living things that facilitate the movement of nutrients between and within ecosystems and which turn them from biologically unavailable forms, such as rocks or the atmosphere, into forms that can be used by others. Without functioning nutrient cycles, life on the planet would cease to exist.

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. These 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. Forests also play a significant role in global nutrient cycles; they hold large volumes of basic nutrients and keep them within the system, buffering global flows. Deforestation has played a large part in altering global carbon and nitrogen cycles (Vitousek et al., 1997).

The marine environment plays a central role in all major global nutrient cycles. Marine organisms fix nitrogen and take up carbon, phosphorous, and sulfur from the water or from other organisms. Much of the mass of these macronutrients is deposited in sediments where it is either stored for the long term or taken back up to surface waters by upwelling. The ability of marine environments to cycle nutrients can be negatively affected but nutrient overloads, which result largely from human actions that cause water pollution such as fertilizer runoff.

The removal of forests, riparian areas, and wetlands has had a significant effect on nutrient cycles. These ecosystems trap and retain nutrients that would otherwise run off into streams and rivers, and eventually end up in the ocean. A combination of increased use of fertilizers and the loss of the buffering capacity of these ecosystems has led to fresh water, estuarine, and ocean systems suffering nutrient overloads which lead to large blooms of phytoplankton. Loss of commercially, recreationally, and culturally important fish species has occurred as a result. The number of marine dead zones in the world has doubled every decade since the advent of nitrogen fertilizers after World War II (UNEP, 2005). The presence of these dead zones is a clear indication that global nutrient cycles have been severely altered by human actions.

Nutrient cycling is a supporting service because many other services depend on it. Given that ecosystem productivity would cease without it, production is impaired when these cycles become significantly altered. Nutrient cycling is a fundamental precursor to ecosystem and economic productivity. This fundamental role cannot be fully substituted by human-made solutions, and operates at multiple, overlapping scales, so it is difficult to arrive at an accurate economic value for these services, and is often undervalued (Farber et al., 2006). Given that nutrient cycling is fundamental to the operation of life on the planet, it is important that biological science inform policy that will protect this critical service.

Biodiversity and Habitat

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). For all ecosystems, biodiversity is both a precondition of the flow of ecosystem services and an ecosystem service in itself (UNEP, 2006). It is a precondition because ecosystems, with their full native complement of species, tend to be more productive and more resilient to change in environmental conditions or external shocks. Biodiversity is also an ecosystem service in itself because novel products have been derived from genetic and chemical properties of species, it provides a secure food base (multiple sources of food with different seasonal availability), and people ascribe value to it simply for its existence. Likely one of the more diverse areas in North America, the Puget Sound Basin is home to a rich diversity of species and ecosystems.

Habitat is the biophysical space and process 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. Habitat may provide refugium and nursery functions; A refugium refers to general living space for organisms, while nursery habitat is specifically habitat where all the requirements for successful reproduction occur (De Groot et al., 2002). In addition to the physical structure provided to species, food web relationships are important components of habitats that support all species. For instance, food webs based on kelp and eelgrass beds provide the conditions necessary for salmon, crab, sea cucumbers, and sea urchins – all commercially important species in the Puget Sound (Mumford, 2007).

A recent assessment found that there are at least 7,013 species, including animals (vertebrate and invertebrate), flowering plants, fungi, and marine algae in the habitat types of the Puget Sound Basin (CFBD and FSJ, 2005). Given that little is known about some invertebrates and most microorganisms, the total is likely much higher. Western Washington forests are home to 82 species of mammals, 120 bird species, 27 amphibian species, 14 reptile species (Olson et al., 2001), and several thousand invertebrate species including fresh water mussels, insects, and arthropods (FEMAT, 1993). All seven species of salmonids found in the Puget Sound use forested streams and rivers for part of their life cycle. Many forest species depend on, or are at their highest abundance, in late-successional or old growth forests (FEMAT, 1993; (Carey, 1996).

Habitat areas in the Puget Sound Basin have widely suffered degradation due to development, conversion from a natural to a heavily managed type, logging, pollution, or the impact of invasive species (Buchanan et al., 2001; EPA, 2007; Olson et al. 2001). Loss of non-federal forestlands to residential and commercial development has been occurring at a yearly rate of 1.04% from 1988 through 2004 (Bradley et al., 2007). Toxic and biological pollution continue to pose a threat to nearshore and pelagic habitats and their associated species in the Puget Sound (PSAT, 2007).

A 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). In contrast, 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 stability). This study provides the best evidence to date of the direct relationship between biological diversity and ecosystem services in the marine environment.

At a global scale, the loss of biodiversity in all ecosystems through over-harvest, habitat degradation and loss has been substantial in marine and coastal ecosystems, forests, grasslands and agricultural systems. This has large implications for maintenance of ecosystem services (UNEP, 2005, 2006). Over-fishing and habitat loss have affected Puget Sound's fish stocks; urbanization and industrial development have led to the loss of large portions of historical forest and wetland cover; and pollution and land loss to residential and commercial development continue to threaten the continued persistence of many species and ecosystems. There are currently 17 species listed as federally threatened or endangered that live in the Puget Sound Basin, though the Center for Biodiversity (2005) estimates that there are at least 285 species that are critically imperiled.

Habitat contributes significantly to other ecosystem services, namely, fisheries, recreation through wildlife watching, and cultural or spiritual values, which are often expressed though people's willingness to pay for protection of natural areas and through public or private expenditures on acquiring and protecting habitat.

The US Fish and Wildlife service lists species as "endangered" or "threatened", in order to assure protection of these species under the Endangered Species Act. In the Snoqualmie Basin, listed species that are likely present include bald eagles, Chinook salmon, bull trout, steelhead, northern spotted owls, and marbled murrelets.

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 crops, wild plants, seaweed, fish and seafood, and livestock.

In the past, we depended mainly on the direct energy flow from food consumption to conduct the work of survival. Then we used the help of draft animals and simple machines. At the onset of the industrial age, humans increasingly depended on fossil fuels, which are ancient stored energy from photosynthesis. Since humans started to perform work with the use of fossil fuels, the number of people and amount of consumption has far exceeded what would have been possible just by operating on current energy flows. Humans appropriate over 40% of the planet's terrestrial primary productivity. This share is increasing – with massive ecological implications for the rest of planet's organisms and energy budget (Vitousek, 1986). One likely consequence is a loss of biological diversity, which, as discussed above, would have severe consequences on the delivery of many other ecosystem services.

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). Again, if humans consume most ocean primary productivity in the form of fish and seafood, not much will be left to fuel the remainder of the food web and all the ecological processes that it drives (Pimm, 2001).

Terrestrial primary productivity comes mainly from forests, but ecosystem types such as grasslands and meadows also contribute, although at a much lower rate. Loss of forests to development decreases primary productivity. Such loss is an issue in the Puget Sound Basin, especially in the suburbanizing fringe.

Marine primary productivity comes from wetland plants, macroalgae, 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 extent of the continental shelf. Due to changes in currents, upwelling, and changes in water chemistry, which may affect the ability of diatomaceous phytoplankton to form calcerous shells, climate change has large implications for ocean productivity (Orr et al., 2005).

Cultural Services

Aesthetic

Aesthetic value, as an ecosystem service, refers to the appreciation of and attraction to beautiful natural land and seascapes (De Groot et al., 2002). 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). Puget Sound's islands, rocky beaches, and views of water, forests and mountains, are of major importance to the cultural and economic character of the region. There is also evidence substantiating the view that degraded landscapes are associated with economic decline and stagnation (Power, 1996).

Recreation and Tourism

Ecosystem features like biological diversity and clean water attract people to engage in recreational activities, and can also increase property values or attractiveness for business. Tourism and recreation are related to, but not totally encompassed by, aesthetic values. People travel to beautiful places for vacation, but they also engage in specific activities associated with the ecosystems in those places. Recreational fishing, scuba diving, surfing, kayaking, whale and bird watching, hunting, enjoying local seafood and wines, and beachcombing are all activities that would not occur or be thoroughly enjoyed without intact shorelines, healthy fish and wildlife populations, clean water and without the aesthetic quality of the area. 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.

Tourism and recreation, significant parts of nearly all coastal economies throughout the world, are both a blessing and a curse. Development designed to attract tourists has been a major source of degradation in coastal environments causing water quality and habitat degradation (UNEP, 2006). Too much recreational fishing pressure and too many whale-watching boats can also put excessive pressure on the species that attract people in the first place. The concept of ecotourism has arisen in part to deal with these issues. It is, however, an incomplete solution to date (UNEP, 2005; 2006).

Recreation and tourism are, like aesthetics, 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 (Office of Financial Management, 2007). More than half of recreational salmon that are caught in Washington State are from Puget Sound (Puget Sound Partnership, 2007).

Recreational fishing brings in substantial revenue to the state (approximately $854 million in 2001 according to the Washington Department of Fish and Wildlife (2002)), and thus to the Puget Sound area. Healthy, fishable salmon populations are therefore important to the tourist economy. Scuba diving, kayaking, bird watching, hiking, climbing, and nature photography draw people, both residents and visitors, to the natural areas of the watershed.

The Washington Department of Fish and Wildlife calculated that wildlife watching in Washington State brought in $980 million in 2001 (WDFW, 2002). It is interesting to note that in the year for which these spending statistics were reported, non-consumptive wildlife viewing accounted for more than double the expenditures for hunting, and exceeded spending on recreational fishing by nearly $130 million. Although not all of this spending occurred in the Puget Sound Basin, statistics on the proportion of overall tourism revenue generated in Washington that comes from Puget Sound indicates that more than half of this was likely spent in the region.

The State of Washington has also invested in ensuring that people have public access to the 35 State Parks located in the region. Washington does not charge users fees for these parks, indicating that it is willing to spend considerable fiscal resources to support outdoor recreation.

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 described below.

The aesthetic value of the Snoqualmie Valley plays a big part in attracting and retaining residents, even in the face of regular flooding (Catchpole and Geggel, 2009b). Snoqualmie Falls alone is estimated to attract 2.2 million visitors each year, making it the second most-visited attraction in Washington State after Mount Rainier (City of Snoqualmie, 2009). People visit throughout the year, engaging in activities such as skiing, hiking, kayaking and fishing (Snoqualmie Valley CoC, 2010). The Valley's natural and social capital give it even greater potential as a tourist destination, and King County is eager to promote it more actively as a place to stay (Catchpole, 2010).

The population explosion in the City of Snoqualmie is a testament to this popularity. Between 2000 and 2009, thanks to an increase in available housing, the city's population grew by 496.6%, making it the fastest growing city in Washington State for that period (PSRC, 2009).

Scientific and Educational

Ecosystems are the subject of much scientific study for both basic knowledge and for understanding the contribution of functioning ecosystems to human wellbeing.

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, safety, and commercial purposes. The study of natural systems is also an important intellectual pursuit for helping people understand how complex systems work. Scientific and educational institutions devoted to both marine and terrestrial environments also provide locally significant employment. These institutions include Batelle 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.

The Snoqualmie Basin generates significant employment for scientific monitoring, research, educational and restoration activities. For example, salmon and stream restoration projects bring in federal, state, county and private funding, while educating the broader community in the science and value of healthy streams. The valley is also providing important insights into flood control management, as a part of the King County Flood Control District. The area is effectively a “living laboratory” for flood control measures, and the high frequency of flood disasters has forced King County to develop one of the nation’s most progressive flood management strategies (King County DNRP, 2010). Insights gained here will not only save money for residents of the Snoqualmie Basin in the future, but will also gain statewide and international attention if they succeed, helping other jurisdictions to reduce the costs involved in flood protection.

Spiritual and religious

Ecosystems and their components play a role in the spiritual beliefs of people. These values do not lend themselves well to economic quantification. Other aspects of the linkage between ecosystem and culture include the spiritual significance that individuals and societies place on nature, and the scientific and educational value derived from studying natural systems. The watershed is especially important to the Snoqualmie Tribe from a spiritual perspective, as evidenced by their traditions around salmon and other marine organisms, and by their art and stories.

Individuals of non-native origin also express the spiritual value of nature through various means. One important aspect of attempting to ascribe economic value to spiritual significance should be noted here. The use of willingness to pay surveys (see below for definitions) for things like saving whales or spotted owls reveals that many people are unwilling to trade money or tangible goods for the loss of species or places; they rank the protection of nature above many aspects of material well-being. Some respondents to such survey instruments give “protest bids” which indicates that they are not willing to put a price on saving wildlife or wild places (see Spash 2005 for a review).

A number of natural features within the Snoqualmie Basin are linked to the creation stories of Snoqualmie Tribe.

Part 3: Valuation of the Snoqualmie Watershed

Study Approach

The methodology of value transfer was used to conduct this economic valuation. Conducting original studies for every ecological service on every site for every vegetation type is cost and time prohibitive; instead, researchers developed a technique called benefit or value transfer, which is a widely accepted economic methodology wherein the estimated economic value of an ecological good or service is determined by examining previous valuation studies of similar goods or services in comparable locations.

This valuation is akin to a house appraisal where an appraiser considers the valuations (sales) of houses in different locations and specific aspects of the house and property being appraised. The number of bedrooms, condition of the roof, square footage, and view are additive values for estimating the full value of the house. These additive values provide different services and contribute to the total value of a house.

An acre of forestland provides water regulation and filtration, aesthetics, flood protection, and habitat. One study may establish the value per acre of watersheds for drinking water filtration. Another study may examine the value per acre of wildlife habitat. To determine the full per acre value provided by a vegetation type, ecosystem service values are summed up and multiplied by the acreage.

Valuation Techniques

The valuation techniques utilized to derive the values in the database were developed primarily within environmental and natural resource economics. As Table 3 indicates, these techniques include direct market pricing, replacement cost, avoided cost, factor income method, travel cost, hedonic pricing, and contingent valuation.

- ***Direct use value*** involves interaction with the ecosystem itself rather than via the services it provides. It may be consumptive use such as the harvesting of trees or fish, or it may be non-consumptive such as hiking, bird watching, or educational activities.

- ***Indirect use value*** is derived from services provided by the ecosystem when direct values are not available. This may include the removal of nutrients, providing cleaner water downstream (water filtration), or the prevention of downstream flooding. Studies may derive values from associated market prices such as property values or travel costs. Values can also be derived from substitute costs like the cost of building a water filtration plant when natural ecosystem filtration services are disturbed and fail. Contingent valuation is an additional method that entails asking individuals or groups what they are willing to pay for a good or service.

Table 3: Valuation Methodologies

Avoided Cost (AC): services allow society to avoid costs that would have been incurred in the absence of those services; storm protection provided by barrier islands avoids property damage along the coast.
Replacement Cost (RC): services can be replaced with man-made systems; nutrient cycling waste treatment provided by wetlands can be replaced with costly treatment systems.
Factor Income (FI): services provide for the enhancement of incomes; water quality improvements increase commercial fisheries catch and the incomes of fisherfolk.
Travel Cost (TC): service demand may require travel, which has costs that reflect the implied value of the service; recreation areas can be valued at least by what visitors are willing to pay to travel there, including the 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.

Adapted from Farber et al 2006

Present Value Calculation and Discounting

The assessment and management of ecosystem service flows earned over generations is a difficult challenge. The stream of benefits can reflect current costs of capital or other financial opportunity costs, but due to discount rates, we tend to undervalue benefits that will be received in the future or by future generations. The discount rate assumes that the benefits we harvest in the present are worth more than the benefits that are provided for future generations, a view that those in the future may not share.

Discount rates that are used in public land management project appraisal can be based on a variety of rate sources including the prime rate of interest, the market rate of interest, and inferred social discount rate. This report provides net present value (NPV) calculations with the two discount rates of 3% and 0%.

The tendency of discounting for present value maximization historically encourages decision makers to select projects that pull short-term benefits into the present and push costs into the discounted future. Over the long-term, this increases the risk of amplifying intergenerational inequities. In economic terms, potentially unsustainable management practices will tend to liquidate renewable resources for short-term gain at much greater long-term expense or loss of value.

Ecological economists solve this dilemma by defining a sustainable scale for the use of ecosystem services, one where basic ecosystem services within a watershed are kept intact. This ensures ecological sustainability where future generations are not left with an unviable set of ecological systems. The vast majority of value provided by a healthy ecosystem is held in the indefinite future. Today, we reap a thin annual slice of benefits from this continuous stream of the 23 categories of ecosystem goods and services.

Ecosystems are assets, a form of wealth. Many ecosystem services are necessary for our survival: oxygen production, waste decomposition, and storm protection to name a few. This asset of natural capital provides a stream of benefits that current and future generations require. This is unlike non-renewable resources, such as burning gasoline, or human-built capital like a new car. They burn up, are used up, or depreciate to eventually become waste, requiring further energy inputs for recycling. The primary benefits of non-renewable and human-built capital are held closer to the present. This is an important distinction between natural and human-built capital. In addition, value is not fixed in time; the values of many ecological services rapidly increase as they become increasingly scarce (Boumans et al. 2002).

Healthy ecosystems are self-organizing, often not requiring maintenance. They do not depreciate, can provide goods and services potentially in perpetuity, and hold vast amounts of value in the distant future. As a result, it is important to illustrate the value of these ecosystem services by considering their value without discounting.

A calculation of value produced by the Snoqualmie Basin using a zero discount rate was used to provide a glimpse of how the Basin's residents would see the stream of future ecosystem service benefits. Ecosystem services have, in fact, increased in value at an accelerating rate as they have become increasingly scarce. This is expected to continue with current development projections in the area. Thus, the true value of these services may be much larger.

Study Limitations

This study provides a best-possible first estimate of the economic value of the ecological goods and services generated within the Snoqualmie Basin. The study, based primarily on value transfer and not on original research of each ecosystem service within the basin, should be regarded as the best first estimate but also have the potential for improved accuracy from further research.

While a number of study limitations should be kept in mind when considering the results, these limitations do not detract from the fact that ecosystem services provide high value. Restoration in the Snoqualmie Basin is better informed with fact-based estimates rather than an implicit assumption of zero value. Limitations to this evaluation include the following:

1. Incomplete coverage is perhaps the most serious issue. Not all ecosystems have been well studied or valued. This results in a serious underestimate of the value of ecosystem services.
2. Current price distortions and externalities also tend to result in an underestimate of ecosystem service values.
3. Estimates based on willingness-to-pay depend on people's knowledge base, which is limited concerning ecosystem services.
4. As the sources of ecosystem services become more limited, the valuations likely underestimate shifts in the relevant demand curves. If the Puget Sound Basin's ecosystem services are scarcer than assumed here, their value has been underestimated in this study.
5. Conversely, there is the potential that ecosystems identified in the GIS analysis are fully functioning to the point where they are delivering the values that are assumed in this report. This may result in an over-estimate of current value.
6. The valuation assumes smooth responses to changes. If ecosystems approach thresholds of collapse higher values for affected services would be produced.
7. If a threshold is passed, valuation is out of the "normal" sphere of marginal change and larger scale social and ethical considerations dominate, such as an endangered species listing.
8. Bias can be introduced in choosing the valuation studies, as in any appraisal methodology. The use of a range partially mitigates this problem.
9. This method assumes spatial homogeneity of services within ecosystems. 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.
10. This analysis is a static, partial equilibrium framework that ignores interdependencies and dynamics. New models that are dynamic are being developed.
11. The value estimates are not necessarily based on sustainable use levels. Limiting use to sustainable levels would imply higher values.

12. The approach does not fully include the "existence" value of ecosystems.

If these problems and limitations were addressed, the result would most likely be significantly higher values. At this point, however, it is impossible to know how much higher the low and high values would be.

Snoqualmie Watershed Valuation

The ecological goods and services produced by each land cover type in the Snoqualmie Basin were estimated utilizing the methodological approach outlined in the previous section. The following sections and tables discuss this in more detail.

These estimates are based on the range of values for these land covers conducted outside of the Snoqualmie Basin. As cursory estimates based on benefit transfer methodology, they provide an estimated range. A specific study or set of studies should be conducted in the Snoqualmie Basin to narrow the range in values.

Our analysis depends on categorization of each type of land cover into a form that matches our database of values and studies that have been done on ecosystem services. Table 3 summarizes the land cover classes and acreage for each class in the Basin. The most recent (2001) National Land Cover Data (NLCD) from the U.S. Environmental Protection Agency defines cover types and estimates area coverage. CORE GIS provided GIS data through a contract with the Trust for Public Lands.

Table 4: Snoqualmie Basin Land Cover Summary

Cover Type	Acres
Barren land	9,373
Cultivated Crops	992
Deciduous forest	10,044
Developed, High intensity	220
Developed, Low intensity	10,922
Developed, Medium intensity	2,065
Developed, Open space	17,309
Emergent herbaceous wetlands	2,109
Evergreen forest	234,373
Grassland/Herbaceous	16,528
Mixed forest	64,691
Open water	4,484
Pasture/Hay	9,560
Perennial ice/snow	370
Shrub/Scrub	51,514
Woody wetlands	9,353
Totals	**443,909**

In some cases, our data needs are more specific than the information provided by the NLCD. For example, the value of forest can vary widely depending on how old it is. A recently clear-cut forest is less able to absorb and retain water, sequester carbon, and perform other valuable services. We therefore use information on tree stand size from the Interagency Vegetation Mapping Project to estimate the age of forested areas, and value the younger forest at a lower value.

Similarly, the value for Riparian buffer zones is not included in the NLCD. These areas are critical to habitat and other ecosystem functions, so we applied a standard 50ft buffer to identify riparian buffer zones. We know that the value varies depending on the type of cover – young forest, mature forest, shrub, or wetland. In order to avoid double counting, we subtracted the riparian buffer zone acreage from the total acreage for forest, wetland, and shrub.

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However there is currently a lack of valuation data for these distinctions, so although we note their acreage here, we did not value riparian areas by category. Instead, we applied general values extracted from the literature.

Estimated Value of the Snoqualmie Watershed

A total of 23 ecosystem services were identified in the Snohomish Basin. Valuation proceeded on 13 ecosystem services. Table 6 shows the ecosystem services that were valued for each of the land cover types.

Table 5: Services and Cover Class Valued

	Agricultural lands	Beach	Eel grass beds	Estuary	Forest - Mid	Forest - Late	Grasslands/Rangelands	Lakes/Rivers	Pasture	Riparian buffer	Shrub	Urban green space	Wetland	Barren/Developed	Perennial Ice/Snow
Water Supply					x	x		x		x			x		
Food															
Raw Materials															
Medicinal Resources															
Gas and Climate Regulation							x			x	x	x	x		
Disturbance Regulation										x			x		
Soil Erosion Control							x								
Water Regulation							x			x		x	x		
Biological Control					x	x	x								
Water Quality & Waste Processing							x						x		
Soil Formation									x						
Nutrient Cycling				x											
Biodiversity & Habitat					x	x		x		x	x		x		
Primary Productivity															
Pollination	x						x								
Aesthetic & Recreation	x				x	x		x		x			x		
Scientific & Educational															
Spiritual & Religious										x			x		

Earth Economics maintains, and is continually expanding, a database of ecosystem service valuation studies. The following tables show the dollar values for the low and high boundaries for ecosystem service values after an extensive literature review. The following tables shows estimates, based on peer-reviewed academic journal articles using the benefit transfer methodology, of the value of each cover type valued in the Snohomish Basin.

		Aggregate Dollar Value per Acre		**Total Dollar Value**	
Cover Type	***Acres***	***Low***	***High***	***Low***	***High***
Early Forest	44,158	$7.00	$950.23	$309,103.09	$41,959,860.94
Pole Forest	37,520	$7.00	$950.23	$262,640.81	$35,652,739.01
Mid Forest	74,004	$73.42	$1,093.26	$5,433,039.26	$80,905,773.11
Late/Old Forest	102,097	$395.77	$2,420.48	$40,407,012.41	$247,124,252.44
Riparian forest pole	15,352	$35.49	$12,567.43	$544,758.57	$192,932,652.43
Riparian Forest mid to late	35,977	$3,258.01	$25,134.86	$117,212,802.37	$904,272,048.79
Riparian Shrub	7,577	$35.49	$12,567.43	$268,877.51	$95,226,130.71
Fresh Wetland	11,462	$6,676.61	$59,914.27	$76,527,303.82	$686,737,362.74
River/Lakes	4,484	$77.71	$22,013.28	$348,451.64	$98,707,547.52
Shrub/Scrub	43,937	$7.00	$950.23	$307,557.49	$41,750,050.33
Grassland/herb	16,528	$96.35	$96.35	$1,592,472.80	$1,592,472.80
Agriculture	992	$29.90	$39.60	$29,660.80	$39,283.20
Pasture	9,560	$6.25	$6.25	$59,750.00	$59,750.00
Urban green space	17,309	$1,293.04	$4,743.10	$22,381,229.36	$82,098,317.90
Snow and Ice	370	$0.00	$0.00	$0.00	$0.00
Barren and developed land	22,580	$0.00	$0.00	$0.00	$0.00
Totals	**443,907**			**$265,684,659.90**	**$2,509,058,241.91**

The following tables provide more specific information on how the valuation was conducted. Appendix A has references for each of the values used here.

Table 6: Values used for Agricultural Lands, Forest – Late, and Forest – Mid

	Agricultural lands		Forest - Late		Forest - Mid	
Ecosystem Service	Min.	Max.	Min.	Max.	Min.	Max.
Gas and climate regulation			$27.43	$623.33	$43.56	$990.00
Disturbance regulation						
Water flow regulation			$9.61	$9.61	$9.61	$9.61
Water quality						
Water supply						
Biodiversity and habitat					$269.85	$500.24
Pollination	$2.40	$12.10	$31.49	$141.41	$62.97	$282.82
Soil erosion control						
Soil formation						
Biological control						
Nutrient cycling						
Aesthetic and recreational	$27.50	$27.50	$4.89	$318.91	$9.78	$637.81
TOTALS	**$29.90**	**$39.60**	**$73.42**	**$1,093.26**	**$395.77**	**$2,420.48**

Table 7: Values for Grasslands/Rangelands, Marine, and Lakes/Rivers

	Grasslands/Rangelands		Marine		Lakes/Rivers	
Ecosystem Service	Min.	Max.	Min.	Max.	Min.	Max.
Gas and climate regulation	$3.85	$3.85				
Disturbance regulation						
Water flow regulation	$1.65	$1.65				
Water quality	$47.91	$47.91				
Water supply			$259.34	$772.68	$58.89	$834.44
Biodiversity and habitat					$17.13	$1,479.84
Pollination	$13.77	$13.77				
Soil erosion control	$15.97	$15.97				
Soil formation	$0.54	$0.54				
Biological control	$12.66	$12.66				
Nutrient cycling						
Aesthetic and recreational					$1.69	$19,699.00
TOTALS	**$96.35**	**$96.35**	**$259.34**	**$772.68**	**$77.71**	**$22,013.28**

Table 8: Values for Pasture, Riparian Buffer, and Shrub

	Pasture		Riparian Buffer		Shrub	
Ecosystem Service	Min.	Max.	Min.	Max.	Min.	Max.
Gas and climate regulation			$43.56	$990.00	$$6.20	$62.30
Disturbance regulation			$7.56	$235.73		
Water flow regulation						
Water quality						
Water supply			$2,105.00	$13,015.08		
Biodiversity and habitat			$58.89	$269.91	$0.62	$250.12
Pollination						
Soil erosion control						
Soil formation	$6.22	$6.22				
Biological control						
Nutrient cycling						
Aesthetic and recreational	$0.03	$0.03	$1,043.00	$10,624.14	$0.18	$637.81
TOTALS	**$6.25**	**$6.25**	**$3,258.01**	**$25,134.86**	**$7.00**	**$950.23**

Table 9: Values for Urban Green Space and Wetland

	Urban green space		Wetland	
Ecosystem Service	Min.	Max.	Min.	Max.
Gas and climate regulation	26.81	$874.79	$29.43	$267.53
Disturbance regulation				
Water flow regulation	$5.72	$170.89	$6,357.71	$6,357.71
Water quality				
Water supply			$199.11	$31,404.56
Biodiversity and habitat			$58.89	$12,537.14
Pollination				
Soil erosion control				
Soil formation				
Biological control				
Nutrient cycling				
Aesthetic and recreational	$1,261.31	$3,697.42	$31.47	$9,347.33
TOTALS	**$1,293.04**	**$4,743.10**	**$6,676.61**	**$59,914.27**

Economic Asset Value

Discounting is a technique used to calculate a present value for a future benefit. If offered the choice between a dollar today and a dollar next year, the dollar today is worth more because you could put it in the bank and earn interest. So the dollar in the future is worth less than a dollar today by the amount of interest you could earn. If the interest rate is five percent, then you could have $1.05 in a year, so receiving a dollar in one year is worth five percent less than a dollar today. The discount rate in this case would be five percent. Note that this is true only when there is no risk of bank failure or losing your investment.

The use of a discount rate for other types of assets assumes that the benefits we harvest in the present are worth more than the benefits provided for future generations. This favors the selection of projects with the most benefits into the present and the costs further into the future.

The Federal Office of Management and Budget sets annual discount rates based on economic predictions for the coming year. The latest set of recommendations was released in December 2009, and is used by agencies such as the Army Corps. The current nominal discount rate is 4.5% for projects lasting 30 or more years. This rate is most commonly used for lease-purchase analysis. The real discount rate, adjusted to exclude the inflation premium, is 2.7% for projects of 30 or more years, and is used for constant-dollar flows. We use the 2.7% discount rate in this report.

However, unlike most built assets, the value of ecosystems remains constant over the long term, or even appreciates. A patch of new forest gradually captures more carbon, provides more water purification, and provides better soil stability over time, for example. Therefore it does not make sense to apply a discount rate to many ecosystems, so we have also included an asset value using a zero discount rate.

The estimated asset value using a 3% discount rate and a 0% discount rate over 100 years is shown below. These are low estimates. Additional data and a more refined analysis will result in the increase in values; the range in value will get narrower and the lower value will rise. These values, even on the low side, clearly justify significantly higher investment in restoration and conservation than is currently available.

Table 10: Present Value Calculations

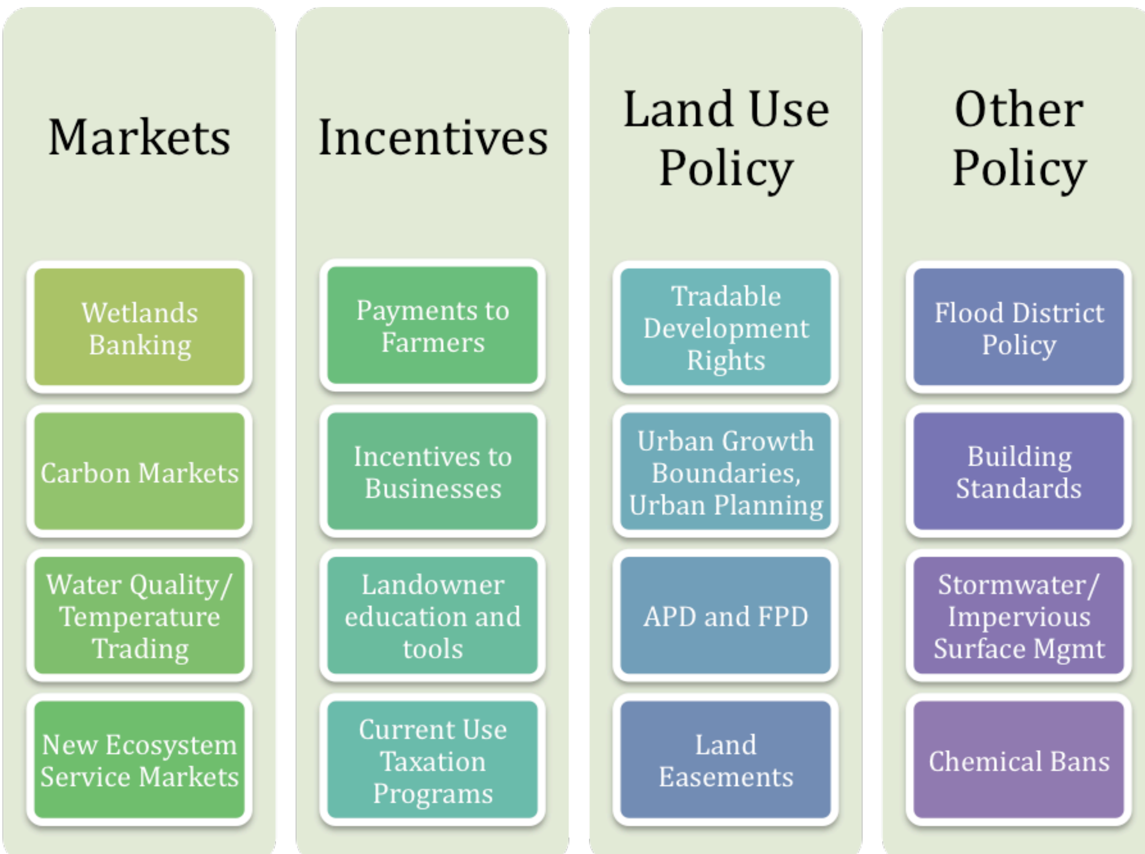
Discount Rate	NPV Low	NPV High
0%	$26,568,465,990	$250,905,824,191
2.7%	$9,154,750,090	$86,455,127,574

Part 4: Management Implications: Vision for Snoqualmie

Tools for Restoration

King County, Snohomish County, local jurisdictions, non-profits, citizens, and businesses have already started developing tools for restoring and protecting the Snoqualmie Basin's valuable natural resources. This report provides sound economic analysis to justify continued development of these tools, along with several suggestions for new approaches to funding, which capitalize on ecosystem service benefits. Figure 11 shows some of the current and potential tools in the "toolkit" for the Snoqualmie Basin.

Figure 11: Snoqualmie Basin Toolkit



Ecosystem Markets

One group of tools that has garnered particular attention recently is ecosystem service markets. This approach has been developed within the Puget Sound Partnership Funding Strategy and a number of other groups nationally and internationally, including the Willamette Partnership in Oregon and the Katoomba Group.

Typically an ecosystem market includes payments from beneficiaries of an ecosystem service to provisionary of the service. For example, in Costa Rica, many local public utilities rely on the water purification and provisioning services provided by forested areas. However, by the 1980's, landowners had cleared 79% of original forest cover for farming and cattle ranching - greatly decreasing the ability of forestland to provide ecosystem services (Tidwell 2006). Now, these water utilities pay landowners to keep trees on their land, thereby protecting the natural hydrological services forests provide.

Wetlands mitigation banks, a type of ecosystem service market, are already developing in the Snoqualmie Basin.

Wetland Mitigation Banks are a market-based strategy for preserving wetlands. When a proposed development action would harm a local wetland, and it is not possible to alter the development plan to avoid wetland impacts, the developer may mitigate the destruction of the wetland by buying a credit from a mitigation bank. The money goes to restoration or preservation of a sensitive wetland or stream elsewhere. Birds and other mobile wildlife can travel to the new site, while protection and management activities preserve local plant diversity. One bank, the Snohomish Basin Mitigation Bank consists of 225 acres; 155 have been restored, 94 acres have been re-established, and 23 acres enhanced. The site's unique topology allows it to function without negatively affecting neighboring farmers. The bank offers aquatic resource impact credits to private developers, cities, counties, the state, and federal agencies. Most impact credits are calculated on a case-by-case basis, but depending on the type of wetland a credit can range from .85 to 1.2 – that is, for every one acre of wetland impacted, a credit in the bank will offset the impact from 85% to 120%.

A number of other markets may be suitable for the Snoqualmie Basin. Water quality or temperature markets have been developed in several areas in the United States. In the Willamette River Valley, individuals who undertake riparian planting efforts that reduce water temperature may sell a credit to an entity that is emitting warm water into the River. This program is designed to help ensure that water temperature remains stable enough to suit salmon populations. Farmers and rural landowners could receive payment for this type of riparian planting. Three quarters of American voters appreciate farmland for the scenic beauty it provides (AFT, 2001), which could potentially be included within a payment system.

Agricultural and forestry lands may also be eligible for carbon credits by changing practices such as using no- or low-till planting; planting cover crops; changing forestry practices and capturing methane from dairy manure. A good number of programs in the Pacific Northwest are taking steps in this direction, a few of which are described below (Stuart 2008):

- Pacific Northwest Direct Seed – Farmers received payments for using direct seed practices
- Northwest Neutral Carbon Offsets – Developing protocols for small forest landowners to earn carbon sequestration credits
- VanderHaak Dairy, George DeRuyter & Sons Dairy, and others – Commercial anaerobic digester
- National Farmers Union – Carbon credits certified by Chicago Climate Exchange for no-till crop production, conversion of cropland to grass, sustainable rangeland management

Markets are not the only solution to ecosystem restoration and protection. Some ecosystem services cannot or should not be sold in markets – breathable air, for example, is non-excludable, and considered a basic right. Therefore policy solutions are better suited to protecting clean air – such as the Clean Air Act in the United States. Existing programs and new programs to support sustainable agriculture and forestry in the Snoqualmie Basin must be included in the future vision of the watershed.

Conclusion

This study was conducted to examine the value of ecosystem service production in support of a visioning process and future restoration and conservation in the Snoqualmie Basin. Earth Economics conducted this ecosystem service valuation by estimating the range of economic values for ecological goods and services produced annually by the Snoqualmie Basin's 443,000 acres.

Using USGS National Land Classification Data on vegetation types, Earth Economics estimated the range of annual value provided by Snoqualmie Basin ecosystem services at $265 million - $2.5 billion. A 2.7% discount rate provides a range of $9 billion - $86 billion. These numbers are likely underestimates for both the low and high ends of the ranges.

If protected, much of the value provided by restoring healthy ecological processes in the Snoqualmie Basin will be garnered by future generations. The annual values calculated for the Snoqualmie Basin correspond to thin slices of the benefits that future generations will gain if the Basin is maintained in an ecologically healthy condition. Unlike human-built capital, like cars and buildings, ecological capital appreciates and can be self-maintaining.

The total estimated annual value generated by ecosystem services in the Snoqualmie Basin is estimated to be in the range of $265 million to $2.5 billion.

Estimated ecosystem service benefits provided by the Snoqualmie Basin total **$26 billion to $250 billion over 100 years at a zero percent discount rate.** This represents the summation of the flow of annual benefits to recipients across a century, treating all recipients equally and assuming there is no appreciation in value or inflation.

This analysis does not include the benefits of successful early actions, and avoidance of further listings of endangered species within the Basin, under the Endangered Species Act. Clearly, if the threatened Chinook salmon continue to decline in Washington rivers, and if at a later date local jurisdictions are forced to take action under an endangered listing of Chinook salmon, the costs of Chinook restoration are likely to be far higher.

Both the high and low estimates of ecosystem services are likely underestimates of their true value. Some identified services could not be valued. Other services that were valued are likely higher in the Snoqualmie Basin than in studied watersheds, for example, water purification and non-market valuations only captured partial values. The values of ecosystem services are rising rapidly due to increasing scarcity. In the case of recreation, the upper watershed is overvalued and lower watershed likely undervalued, with an ambiguous net result. The large ranges of value reflect the fact that benefit transfer methodology is an inexact science with significant uncertainty and variability. The ranges for these estimates will close with ongoing research. Nevertheless using inexact science for asset management is better than no science at all.

A better understanding of the relationships between watershed ecosystem health and the provision and value of these goods and services is critical information for asset management decisions. A scenario where further degradation of Northwest watersheds continues might result in numerous other species declining into threatened and potentially endangered species status. Under another scenario, where the full suite of benefits provided by healthy watershed ecosystems and floodplain processes are examined and accounted for in asset management, currently threatened populations might recover. This would prevent an ecological slide that would have resulted in a significantly larger number of threatened and endangered species.

Watershed Utilities and Efficiency

In ecological systems where a large number of highly valuable public goods are produced, private owners will manage land based on very few private excludable products that benefit a few (e.g., timber) at the expense of more valuable public goods and services that benefit all.

Many public goods are non-excludable and non-rival; people receiving flood protection benefits from a healthy watershed, for example, cannot crowd each other out (we are not rivals for flood protection as we are for freeway space, which is non-excludable but rival). Many watershed services fall into this category of non-excludable and non-rival goods and services, including water filtration, flood protection, biodiversity, habitat, nursery value, and aesthetic value.

A public utility is the most efficient institution for managing the full suite of ecosystem goods and services that are public, non-excludable and non-rival. Unlike a private firm that aims to maximize profits, a public utility provides service at least cost while efficiently managing a watershed for the full suite of public goods and services at the required watershed scale.

Ideally, an "environmental" or "watershed" utility would bill for services and reinvest in both built and natural capital to efficiently produce the suite of these services at least cost. Such a utility could bill for the provision and filtration of water, which would include both the human-built capital of a delivery system and the natural capital system that produces and contributes filtration. Water users would be billed accordingly. The same watershed also provides flood protection benefits. The floodplain beneficiaries could be billed for the benefits they receive, and the funds could be reinvested in the health of the watershed, a scenario that reduces flooding and human-built flood protection capital, such as levees.

We currently have several entities and jurisdictions providing flood protection including private owners, SPU, King County, and the Army Corps of Engineers. SPU provides substantial flood protection value to the Cedar River watershed through good management of the upper watershed, but receives no services fees for it. King County receives flood district funds for flood mitigation. King County has also shown that it is more economically viable to purchase some properties and widen the floodplain (increasing floodplain health) rather than to continually contribute to funds for flood damage on properties that are clearly within the active area of the floodplain. It would be more efficient if the beneficiaries were charged a fee for the provision of flood protection at least cost under a utility model. This would entail reinvestment in natural capital, such as the upper watershed, and select purchases in the floodplain, and appropriate engineering and construction.

Managing storm water, drinking water, flood protection, biodiversity and other watershed products through separate or combined institutions is likely less efficient than setting up a public utility to manage the suite of services with the necessary natural and human-built capital.

Recommendations

1. The natural assets of the Snoqualmie Basin are significant and highly valuable. A visioning process should consider a more detailed analysis of the ecosystem goods and services that the Basin provides, as well as the distribution of these services to beneficiaries.

2. The Snoqualmie Basin supplies sufficient ecosystem service benefits to justify significant investment. Because most of the benefits are held in the future, the estimate of value depends on how future value is weighted; including what discount rate is used.

3. Groups in the Snoqualmie Basin should partner with other organizations and agencies to increase the knowledge base on Northwest ecosystem services

provided by watersheds, specifically the watersheds neighboring the Snoqualmie Basin.

4. The public should be informed of ecosystem services and their value, which the Snoqualmie Basin provides.

5. Decision makers within the Basin should consider the potential design of an “environmental utility” or “watershed utility” to better manage these natural assets and the goods and services they provide to the public.

This analysis supports a triple bottom line approach. The range of 23 identified categories of ecological goods and services provided by the Snoqualmie Basin should be more closely examined. This can be done in a collaborative arrangement with other agencies and organizations to conduct a set of ecosystem service studies. For example, if each of the 30 agencies from British Colombia to Portland conducted one ecosystem service study with a full research agenda in their jurisdiction, the compilation of these studies would contribute greatly to better defining and narrowing the range of value produced by Northwest ecosystems. This approach would reduce the cost of the studies and all jurisdictions would benefit.

Overall the Snoqualmie Basin has begun a groundbreaking step of valuing the full range of ecosystem services provided by the Basin, and by including this analysis in future decision making.

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Table 11: Table of Valuation Studies Used

Land Cover	Ecosystem Service General	Author(s)	Minimum	Maximum
Agricultural lands	Aesthetic & Recreational	Bergstrom, J., Dillman, B. L. and Stoll, J. R. 1985	$27.50	$27.50
	Pollination	Robinson, W.S., Nowogrodzki, R. and Morse, R. A. 1989	$12.10	$12.10
		Southwick, E. E. and Southwick, L. 1992	$2.40	$2.40
Forest	Aesthetic & Recreational	Bennett, R., et. al.	$169.13	$169.13
		Bishop, K.	$569.01	$637.81
		Maxwell, S.	$11.78	$11.78
		Shafer, E. L., et. al.	$538.99	$538.99
		Willis, K. G.	$9.78	$17.84
	Habitat Refugium & Nursery	Garber et al. 1992	$269.85	$452.57
		Kenyon, W. and Nevin, C.	$500.24	$500.24
	Gas & Climate Regulation	Bagstad, K. (unpublished)	$43.56	$990.00
	Pollination	Hougner, C. 2006	$62.97	$282.82
	Water Regulation	Loomis, J.B. 1988	$9.61	$9.61
Grasslands	Biological Control	Pimentel et al. 1997	$12.66	$12.66
	Gas & Climate Regulation	Costanza et al. 1997	$3.85	$3.85
	Pollination	Pimentel et al. 1997	$13.77	$13.77
	Soil Erosion Control	Costanza et al. 1997	$15.97	$15.97
	Soil Formation	Costanza et al. 1997	$0.54	$0.54
	Waste treatment	Pimentel et al. 1997	$47.91	$47.91
	Water Regulation	Costanza et al. 1997	$1.65	$1.65
Lakes/Rivers	Aesthetic & Recreational	Burt, O. R. and Brewer, D.	$461.82	$461.82
		Cordell, H. K. and Bergstrom, J. C.	$135.37	$1,419.65
		Kealy, M. J. and Bishop, R. C.	$12.93	$12.93
		Kreutzwiser, R.	$181.25	$181.25
		Patrick, R.,et. al.	$1.69	$25.56
		Piper, S.	$240.20	$240.20

		Shafer, E. L. et. al.	$551.74	$1,101.41
		Loomis J.B. 2002	$11,131.00	$19,699.00
	Habitat Refugium & Nursery	Loomis 1996	$17.13	$17.13
		Streiner and Loomis 1996	$1,479.84	$1,479.84
	Water Supply	Bouwes, N. W. and Scheider, R.	$617.46	$617.46
		Croke, K., Fabian, R. and Brenniman, G.	$565.91	$565.91
		Henry, R., Ley, R. and Welle, P.	$429.30	$429.30
		Knowler, D. J. et. al.	$58.89	$269.91
		Ribaudo, M. and Epp, D. J.	$834.44	$834.44
Marine	Water Supply	Soderqvist, T. and Scharin, H.	$259.34	$431.16
		Hanley, N., Bell, D. and Alvarez-Farizo, B. 2003	$772.68	$772.68
		Nunes, P and Van den Bergh, J. 2004	$551.76	$551.76
Pasture	Aesthetic & Recreational	Boxall, P. C.	$0.03	$0.03
	Soil Formation	Pimentel, D. 1998	$6.22	$6.22
Riparian buffer	Aesthetic & Recreational	Duffield, J. W., Neher, C. J. and Brown, T. C.	$1,043.47	$1,474.20
		Sanders, L. D., Walsh, R. G. and Loomis, J. B.	$2,297.39	$2,297.39
		Bowker, J. M., English, D.B. and Donovan, J.A. 1996	$4,420.54	$10,624.14
	Disturbance Regulation	Rein, F. A. 1999	$7.56	$235.73
	Gas & Climate Regulation	Bagstad, K. (unpublished)	43.56	$990.00
	Habitat Refugium & Nursery	Knowler, D. J. et. al.	$58.89	$269.91
	Water Supply	Berrens, R. P., Ganderton, P. and Silva, C. L.	$2,105.00	$2,105.11
		Danielson, L., et. al.	$4,806.25	$4,806.25
		Mathews, L. G., Homans, F. R. and Easter, K. W.	$13,015.08	$13,015.08
Shrub	Aesthetic & Recreational	Bennett, R., et. al.	$169.13	$169.13
		Bishop, K.	$569.01	$637.81
		Boxall, P. C., McFarlane, B. L. and Gartrell, M.	$0.18	$0.18
		Haener, M. K. and Adamowicz, W. L.	$0.20	$0.20
		Maxwell, S.	$11.78	$11.78
		Prince, R. and Ahmed, E.	$1.49	$1.90
		Shafer, E. L., et. al.	$538.99	$538.99

	Gas & Climate Regulation	In house calculation	$6.20	$62.30
	Habitat Refugium & Nursery	Kenyon, W. and Nevin, C.	$250.12	$250.12
		Shafer, E. L. et. al.	$2.98	$2.98
		Haener, M. K. and Adamowicz, W. L. 2000	$0.62	$0.62
Urban green space	Gas & Climate Regulation	McPherson, E. G. 1992	$175.37	$874.79
		McPherson, E. G., Scott, K. I. and Simpson, J. R. 1998	$26.81	$26.81
		Birdsey, R.A.	$203.44	$203.44
	Water Regulation	McPherson, E. G. 1992	$5.72	$5.72
		Birdsey, R.A.	$170.89	$170.89
Wetland	Aesthetic & Recreational	Doss, C. R. and Taff, S. J.	$4,187.89	$4,626.73
		Mahan, B. L., Polasky, S. and Adams, R. M.	$34.47	$34.47
		Allen, J. 1992	$103.35	$9,347.33
		Hayes, K. M., Tyrrell, T. J. and Anderson, G. 1992	$1,212.84	$2,318.09
	Gas & Climate Regulation	Roel calculation for LA	$26.81	$267.53
	Habitat Refugium & Nursery	Knowler, D. J. et. al.	$58.89	$269.91
		Streiner and Loomis 1996	$1,479.84	$1,479.84
		Allen, J. et. al. 1992	$5,147.20	$12,537.14
	Water Supply	Creel, M. and Loomis, J.	$542.65	$542.65
		Lant, C. L. and Tobin, G.	$199.11	$2,192.67
		Pate, J. and Loomis, J.	$3,598.28	$3,598.28
		Hayes, K. M., Tyrrell, T. J. and Anderson, G. 1992	$1,287.83	$2,001.85
		Allen, J. et. al. 1992	$10,488.00	$31,404.56

APPENDIX B: References for Report

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APPENDIX C: Glossary

Adapted in part from MA (2005) and Daly and Farley (2004)

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

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

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

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

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

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

Ecosystem: A dynamic complex of plant, animal, and microorganism communities and their nonliving environment interacting as a functional unit.

Ecological Economics: The union of economics and ecology, with the economy conceived of as a subsystem of the earth ecosystem. There is a constant flow of “goods” and “services” between the economy and the earth ecosystem.

Ecosystem Functions: Ecosystem functions result from the interaction of an ecosystem’s structural components (e.g. trees, forests, slopes, streams) and its dynamic processes (e.g. hydrological cycle, Earth’s rotation). Ecosystem functions are processes or attributes that maintain ecosystems, and many are also “ecosystem services” because they benefit humans; these include soil accumulation, habitat formation and water filtration.

Ecosystem functions that provide benefits to humans are counted as “ecosystem services”.

Ecosystem Goods: These are tangible items or flows produced by nature that benefit humans. Ecosystem goods are produced by “provisioning” services, one of the four categories of ecosystem services.

Ecosystem health: A measure of the stability and sustainability of ecosystem functioning or ecosystem services that depends on an ecosystem being active and maintaining its organization, autonomy, and resilience over time. Ecosystem health contributes to human wellbeing through sustainable ecosystem services and conditions for human health.

Ecosystem Services: The benefits people obtain from ecosystems. These include provisioning services such as food and water; regulating services such as flood and disease control; cultural services such as spiritual, recreational, and cultural benefits; and supporting services such as nutrient cycling that maintain the conditions for life on Earth. The concept “ecosystem goods and services” is synonymous with ecosystem services.

Ecosystem Service Valuation (ESV): 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 the full diversity of valuable ecosystem goods and services. Commonly employed valuation methods include: “Avoided Cost”, “Replacement Cost”, “Hedonic Pricing”, “Contingent Valuation”, “Group Valuation”, “Marginal Product Estimation”, “Travel Cost” and “Factor Income.”

Equity: Fairness of rights, distribution, and access. Depending on context, this can refer to resources, services, or power.

Externality: A consequence of an action that affects someone other than the agent undertaking that action and for which the agent is neither (sufficiently) compensated nor penalized. Externalities can be positive or negative.

Financial Capital: Shares, bonds, banknotes, and other financial assets. Financial capital plays an important role in our economy, enabling the other types of “capital” to be owned and traded. However, it has no real value in itself. Financial capital represents a promise in the place of one of the other types of “real” capital.

Geographic Information System (GIS): A computerized system organizing data sets through a geographical referencing of all data included in its collections. Earth Economics uses GIS data to calculate the total acreage of each land cover type- forest, grass and shrub, urban, rivers and streams etc- within a given study area. GIS is an important tool in Ecosystem Service Valuation.

Habitat: Area occupied by and supporting living organisms. Also used to mean the environmental attributes required by a particular species or its ecological niche.

Health: Strength, feeling well, and having a good functional capacity. Health, in popular idiom, also connotes an absence of disease. The health of a whole community or population is reflected in measurements of disease incidence and prevalence, age-specific death rates, and life expectancy.

Human Capital: Includes acquired knowledge through education, self-esteem, and interpersonal skills such as communication, listening, and cooperation as well as creating individual motivation to be productive and socially responsible. It is well recognized that education and training are essential to economic growth, innovation and a high quality of life.

Institutions: The rules that guide how people within societies live, work, and interact with each other. Formal institutions are written or codified rules. Examples of formal institutions would be the constitution, the judiciary laws, the organized market, and property rights. Informal institutions are rules governed by social and behavioral norms of the society, family, or community.

Landscape: An area of land that contains a mosaic of ecosystems, including human-dominated ecosystems. The term cultural landscape is often used when referring to landscapes containing significant human populations.

Markets: The organized exchange of commodities (goods, services, or resources) between buyers and sellers within a specific geographic area and during a given period of time. Markets are the exchange between buyers who want a good--the demand-side of the market--and the sellers who have it--the supply--side of the market.

Market failure: The inability of a market to bring about the allocation of resources that best satisfies the wants of society. In particular, the overallocation or underallocation of resources to the production of a particular good or service caused by spillovers or informational problems or because markets do not provide desired public goods.

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

Policy-maker: A person with power to influence or determine policies and practices at an international, national, regional, or local level.

Provisioning Services: Ecosystem services that benefit humans by providing basic materials such as water, timber and food.

Regulating Services: Ecosystem services that benefit humans through the natural control of ecosystem processes. Intact ecosystems provide regulation of climate, water, soil, and keep disease organisms in check. Degraded systems propagate these organisms to the detriment of human health.

Social Capital: Is 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. Without a functioning society in which people respect each other and have some concern for the well-being of others, most economic activity would be impossible.

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

Supporting Services: Ecosystem services that are the basis of the vast majority of food webs and life on the planet. These include primary productivity, nutrient cycling and the fixing of CO_2 by plants to produce food.

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

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

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

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

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