SUPPLEMENTAL ECOLOGICAL SERVICES STUDY

Tolt River Watershed Asset Management Plan

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Prepared for:

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***For ease of data presentation, and by nature of ecosystem service valuations, annual value estimates have been rounded to the nearest thousand dollars. Note that all present value estimates in this report have been calculated based on exact values before rounding.**

Abbreviations

APEX	Asia Pacific Environmental Exchange (Now known as Earth Economics)
GIEE	Gund Institute for Ecological Economics
GIS	Geographic Information System
PSRC	Puget Sound Regional Council
PV	Present Value
SPU	Seattle Public Utilities
USFS	United States Forest Service
WRIA	Water Resource Inventory Area

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Executive Summary

The Seattle Public Utilities (SPU) is developing an asset management plan for the Tolt River Levee Restoration and Habitat Preservation Project. At the same time, a project team of ecological economists from the Earth Economics (formerly APEX) and the Gund Institute for Ecological Economics (GIEE) worked with the SPU staff to estimate the economic value of the ecological goods and services provided annually by:

1) the entire 63,800 acre Tolt River watershed;
2) the portion of the south fork of the Tolt River (lower basin) owned by SPU;
3) the portion of the south fork of the Tolt River (upper basin) owned by the US Forest Service, as well as a combined value of SPU and USFS lands;
4) the proposed Tolt River Levee Restoration and Habitat Preservation Project including the value of ecological goods and services provided by the site before and after restoration as well as the net benefits of the project;
5) the San Souci Reach area upriver from Carnation, as delineated by SPU; and
6) the Hancock Easement, a six mile strip of land between 150-300 feet from the Tolt River, as identified by SPU, which would double the riparian buffer from the current 150 foot riparian buffer.

SPU manages substantial land holdings in the Tolt River watershed with natural assets providing a suite of 23 highly valuable ecosystem goods and services. Except for water supply and water filtration, SPU does not charge for most of the public goods and services it provides. Although rendered for free, these ecological goods and services are valuable. The Tolt River watershed provides flood protection, natural drought mitigation, nutrient flows, biodiversity, salmon habitat, aesthetic value, and other public goods and services. Most of these highly valuable services are public services which are non-excludable, benefiting everyone.

A public utility is the most efficient institution for managing the full suite of public ecosystem goods and services within a watershed. A private firm will maximize returns from privatized ecological goods, such as timber, and degrade public goods such as flood protection, recreation, and biodiversity. A watershed, or environmental, public utility could manage a watershed to maximize the pubic benefits from the full suite of public goods and services at least cost. The utility could provide efficient management of public and privatizable goods and services at the required watershed scale.

Asset management decisions which involve water or other ecosystem goods and services should be informed by the best available understanding and analysis of the relationships between watershed ecosystem health and the provision and value of watershed goods (like water) and services (including salmon habitat, refugium and nursery services). This is what SPU commissioned Earth Economics to do in this report.

Methods

Partnering with GIEE, Earth Economics utilized the best economic methods currently available for estimating the value of ecological goods and services. Acreages of vegetation types in Geographic Information System (GIS) data, provided by SPU staff, were used with a benefit transfer methodology. This methodology is based on peer reviewed academic journal articles in order to estimate the high and low dollar value range of a list of 23 ecosystem services produced within the acreage of each vegetation type. These values were then summed for an initial rough-cut total valuation of ecosystem goods and services provided annually by each area. These values were then modified according to the particular area of the Tolt River watershed being examined. The present value (PV) was then calculated from the estimates of the annual flow of ecosystem benefits using several discount rates for comparison.

Results

1. The Entire Tolt River Watershed: Earth Economics estimated the range of annual value for ecosystem services provided across 63,800 acres of the Tolt River watershed at $368-1,364 million. This yields a present value (PV) of $5.6-20.9 billion at a 7% discount rate. Using a 3.5% discount rate, more commonly used for renewable and self-sustaining ecosystem services, yields a range of $10.9-40.3 billion. Benefits with a 5% and zero discount rate were also calculated. With any discount rate, these numbers are large. The methods for estimating the ecosystem service values were inherently conservative.

2. SPU lands in the South Tolt (Lower Basin): The 8,373 acres of the SPU lands in the lower basin of the Tolt River watershed provide an estimated range of annual ecosystem benefits of $40.8-148.1 million. The range of present values at a 7% discount rate is $0.6-2.3 billion, $0.9-3.1 billion at a 5% discount rate, or $1.2-4.4 billion at a 3.5% discount rate.

3. Forest Service Lands in the South Tolt (Upper Basin): The 3,689 acres owned by the US Forest Service were estimated to produce an annual range of benefits of $22.3-80.4 million with present values of $0.3-1.2 billion (7% discount rate), $0.5-1.7 billion (5% discount rate), and $0.7-2.4 billion (3.5% discount rate). The combined valuation of SPU and US Forest Services lands ranges from $63.2-228.5 million annually. The estimated combined present value of ecosystem goods and services produced by the SPU and US Forest Service lands is $1.0-3.5 billion (7% discount rate), $1.3-4.8 billion (5% discount rate) and $1.9-6.8 billion (3.5% discount rate).

4. Proposed Tolt River Levee Restoration and Habitat Preservation Project: Earth Economics examined and valued the Tolt River Levee Restoration and Habitat Preservation Project ecosystem services provided by the site in current conditions (levied off from the Tolt River), followed by valuations of the projected future conditions after project completion. The net benefits of the project in terms of annual ecosystem services provided are estimated to range from $134,000-484,000. This provides a present value of $2.1-7.4 million at a 7% discount rate, $2.8-10.2 million at 5%, or $4.0 -14.3 million at a 3.5% discount rate. This analysis does not include the benefits of successful early actions and avoidance of a Chinook salmon endangered species listing, which would be substantial and additional to the benefits demonstrated in this study.

Both the high and low estimates of ecosystem services are likely underestimates of the true value. Some identified services could not be valued. The others that were valued are likely higher, for example water purification, in the Tolt River than watersheds in which the studies originate. Some non-market valuations captured only partial values. Further, the values of ecosystem services are generally rising rapidly due to increasing scarcity. In the case of recreation service, the upper watershed is likely 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. With ongoing research, the ranges for these estimates will close.

The levee restoration and habitat preservation project appears to be justified based on the public benefits and value provided by ecosystem services alone. The investment in the restoration of natural riparian processes in the lower Tolt River is more than an investment in Chinook salmon restoration. It is an investment in natural capital and the full suite of public benefits, from flood protection to aesthetic value, which a healthy Tolt River watershed provides.

5. San Souci Reach Area, As Delineated by SPU: San Souci Reach on the Tolt River comprises 57 properties, totaling 77 acres upstream from the town of Carnation. This land was estimated to produce a total range of annual ecosystem benefits of $221,000-828,000. The ranges of present value for this annual stream of benefits are estimated at a 7% discount rate to be $3.4-12.7 million, or $4.6-17.4 million at a 5% discount rate, and $6.5-24.5 million at a 3.5% discount rate.

6. Hancock Easement, As Identified by SPU: Earth Economics valued 186 acres along a six mile length of the Tolt River San Souci Reach (just upriver of the town of Carnation) currently owned by the Hancock Timber Resource Group. This 186 acre strip of timberlands extends beyond the current 150-foot buffer from the river's edge to 150-300 feet from the Tolt River, for a six mile reach. Acquisition of an easement on these lands would increase protection for the San Souci Reach. The range of value for ecosystem services provided by this additional buffer was calculated to be $1,207,000-4,453,000 annually with a present value of $18.5-68.1 million at 7% discount rate, $25.4-93.5 million at 5% discount rate, and $35.7-131.7 million at 3.5% discount rate.

Introduction

This ecological economics analysis aims to complement the Seattle Public Utilities (SPU) Asset Management Project Development Plan with a valuation of the ecological goods and services generated within the Tolt River watershed. It examines the enhanced value of ecosystem services that are expected upon completion of the Tolt River Levee Restoration and Habitat Preservation Project. The restoration project is a voluntary effort to preserve and restore Chinook salmon spawning habitat at the confluence of the Tolt and Snoqualmie Rivers. In addition, Earth Economics examines ecosystem services provided by the San Souci Reach and Hancock buffer easement along the Tolt River upriver from the community of Carnation, Washington.

This study supports a triple bottom line approach, identifying natural capital assets, goods and services produced by this capital, as well as the value of these goods and services. These ecosystem service valuations for SPU build off recent work completed by Batker, et al. (2005) in support of salmon habitat restoration for the Water Resource Inventory Area 9 (WRIA 9) Steering Committee and the King County Dept. of Natural Resources.

Asset management has typically focused on "built capital" and financial assets. However, water and electric utilities, and flood and storm-water districts, are critically dependent not only on built facilities but also on "natural capital" for provision of water, drainage, electricity, flood protection and other goods and services. Watersheds under SPU management provide a range of 23 identified categories of ecological goods and services. A better understanding of the relationships between watershed ecosystem health and the provision and value of these goods and services can inform asset management decisions.

The sections that follow describe the key concepts for including natural capital in asset management decisions (Section 1), study approach (Section 2), findings (Sections 3-6) and conclusions and recommendations (Section 7).

1. <u>Key Concepts</u>

The field of economics has advanced greatly in recent years. The methods, tools and techniques for measuring the value produced by natural systems have improved greatly since 1985. As the field has developed, new concepts like "natural capital" and techniques such as ecosystem service valuation have advanced. Many of these concepts are evolving rapidly.

Below is a basic discussion of the key concepts that were used in preparation for the methodology and results of the study.

1.1 The Inclusion of Natural Capital in Asset Management

Ecosystems and natural resources, or natural capital, were deemed in the past as virtually limitless compared to human-built capital. They were then considered as "free" and therefore of no value. Natural capital is now scarce and getting even scarcer. Valuing 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 overall inefficiency. Consideration of the full suite of ecological goods and services produced by watersheds and lands under SPU management as part of asset management would place SPU at the global forefront of natural capital asset management and increase the quality and productivity of service provided.

1.1.1 Natural Capital

Natural capital comprises native plants and animals, topography, geology, nutrient and water flows, and natural processes (stocks or funds) that nature provides, yielding a valuable and regular return of benefits (Daly and Farley 2004). It contributes to our economy and quality of life. It provides benefits such as provision of water, natural water filtration, energy production, flood control, recreation, natural storm water management, biodiversity, and education. The Tolt River watershed is natural capital. This includes the topography, soils, timber, plants and wildlife, riparian and other processes by which water, nutrients and wildlife move through the watershed producing a variety of benefits to people. The Tolt River watershed should be considered as a natural capital asset from a management perspective.

1.1.2 The Economic Nature of Natural Capital

Healthy ecosystems are self-maintaining and have the potential to provide valuable goods and services in perpetuity. Incorporating ecological capital into asset management and utility planning is of enormous importance. By including natural capital within asset management planning, SPU is on the forefront of economic analysis. This is natural for a utility that has provided clean drinking water filtered by ecosystems in the Cedar River watershed for over a century. SPU is one of a few utilities that do not require filtration of water. SPU is the only utility to own an entire upper watershed, the Cedar River watershed. This natural ecosystem service of water filtration has saved rate-payers tremendous amounts of money and has provided tremendous service. SPU has set a global standard for water utility stewardship and good management.

Other utilities have only recently understood the full importance of ecosystems in the provision and filtration of water. New York City uses over one billion gallons of water each day. Facing degraded drinking water quality New York City weighed the options of building a water filtration plant costing over $7 billion, or instead, of investing $1.5 billion to restore the health of the watershed and allow natural processes to filter the water and meet drinking water standards. The City decided to invest in watershed restoration which had a far higher rate of return and a less costly and less risky method for meeting standards.

Seattle has long benefited from the "free" water filtration services that the Tolt and Cedar River watersheds have provided. The following analysis examines the value of ecosystem services produced in 63,800 acres of the Tolt River watershed and the net ecosystem service benefits of the proposed Tolt River Levee Restoration and Habitat Preservation Project, as well as values produced by the San Souci Reach and possible Hancock easement that would further buffer the San Souci Reach as identified by SPU.

1.2 Ecological Productivity

1.2.1 Ecosystems and Value Production

Ecosystems have components and structure (trees, forests, soil, hill slopes, etc.) and processes (water flows, nutrient cycling, animal life cycles, etc.) that create functions (water catchments, soil accumulation, salmon runs) generating ecological goods and services (salmon, timber, flood protection, recreation, etc.). Figure 1 shows this basic relationship. Ecosystem infrastructure is defined as the physical components within the 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). Beneficiaries may be global (carbon sequestration), or local (drinking water production). These structures, processes, and functions produce economically valuable and essential goods and services.

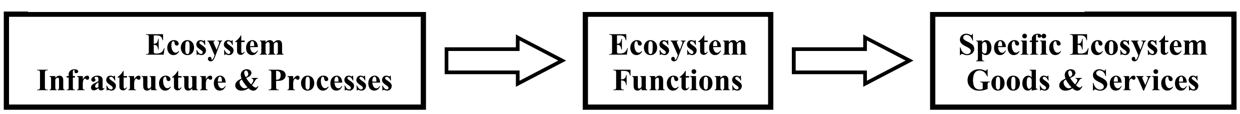

Figure 1. Relationship of Ecosystems to Ecosystem Services

The proposed Tolt River Levee Restoration and Habitat Preservation Project reestablishes the basic ecological processes necessary not only for Chinook salmon spawning but also for the production of a larger basket of valuable ecosystem goods and services. Restoring these ecological processes within a natural range of variability maintains structure and the ecological goods and services that follow.

1.2.2 Ecosystem Goods

Ecosystems provide goods. Water, timber, fish, and wildlife are examples of these. Most goods are exclusive, which means that if one individual owns or uses a particular good, that individual can exclude others from owning or using the same good. For example, if one person eats an apple, another person cannot eat that same apple. Excludable goods can be traded and valued in markets. The 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, 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. The stream of goods provided by an ecosystem is a "flow of goods."

1.2.3 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 et al. 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. The productivity of ecosystems in producing goods and services is a result of ecosystem process, function, and structure.

These services include flood protection, recreation (hiking, biking, boating, swimming, hunting, fishing, birding), nutrient recycling, biodiversity, aesthetic value, refugia, storm protection and water control. Table 1 lists some ecosystem services and Appendix A provides brief descriptions of specific ecological services.

Ecological services are oftentimes non-excludable. A healthy watershed provides aesthetic value to anyone who looks at it. All people downstream benefit from the flood protection afforded by a forested watershed as opposed to a scoured watershed. Many ecosystem services, such as biodiversity, refugia, natural water filtration and storm protection, are not sold in markets. The stream of services provided by an ecosystem is referred to as a "service flux." A flow of goods can be measured as quantitative productivity over time while a service flux generally cannot. As a result, ecological services are more difficult to measure and value than goods.

Table 1. Examples of Ecological Services ***(from Daily et al. 1997)***
Purification of the air and water
Mitigation of floods and droughts
Recreation
Detoxification and decomposition of wastes
Generation and renewal of soil and soil fertility
Pollination of crops and natural vegetation
Control of the vast majority of potential agricultural pests
Dispersal of seeds and translocation of nutrients
Maintenance of biodiversity
Protection from the sun's harmful ultraviolet rays
Partial stabilization of climate
Moderation of temperature extremes and the force of wind and waves
Support of diverse human cultures
Provision of aesthetic beauty

1.2.4 The Value of Ecosystem Services Relative to Ecosystem Goods

While the value of a service flux may be more difficult to measure, in many cases its value may significantly exceed the value of the flow of goods. For example, a study of Philippine mangroves showed that the services of storm protection and nursery functions (85% of commercial fish species are dependent on the mangroves for a period of time within their lifecycle) produced several times the value of shrimp aquaculture operations which displaced the mangrove ecosystems (Boumans et al. 2004).

1.2.5 Process, Function, Structure and Value Production

The quality, quantity, reliability, and combination of goods and services provided by the ecosystems within a watershed depend highly on the structure and health of the ecosystems within the watershed. Structure refers to a specific arrangement of ecosystem components. The importance of ecosystem structure can be understood through the metaphor of a car. The steel, glass, plastic and gasoline that comprise a car must retain a very particular structure to provide transportation service. Absent a car's structure (a pile of the same constituent materials), a "car" cannot provide a transportation service. Salmon, for example, require certain processes, structures and conditions. Ecological service production is more dependent on structure than the flows of goods. A single species timber plantation may yield a flow of goods, such as timber, but it cannot provide the same service fluxes, such as biodiversity, recreation and flood protection, as an intact natural forest.

1.2.6 Integrated Ecosystems

A heart or lungs cannot function outside the body. The human body cannot function without a heart and lungs. Good health requires organs to work as part of a coordinated 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). In addition, ecosystem services are systems of enormous complexity. Individual services influence and interact with each other, often in nonlinear ways (Limburg et al. 2002).

1.2.7 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.) which require maintenance expenditures, dissipate, may depreciate, and usually end up discarded, requiring further energy inputs for disposal or recycling. Destruction of ecosystem functions thus 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. 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.

2. Ecosystem Services Approach

The Earth Economics team used a benefit transfer methodology with the GIS data provided by SPU staff in order to estimate the value of ecosystem goods and services produced in the Tolt River watershed. The Earth Economics team also examined the Tolt River Levee Restoration and Habitat Preservation Project as a supplement to the Asset Management Project Development Plan. This study helps identify further benefits and costs associated with the protection and enhancement of Chinook salmon habitat. This approach would also assist other SPU operations.

Valuation figures from the Gund Institute for Ecological Economics (GIEE) database establishing per acre values for different categories of ecosystem services were used with the SPU GIS data for each land cover type within the watershed, which were then adjusted with ecosystem health coefficients. This provided estimates of the value of the ecological services produced by the total of each land cover type within the watershed and, in sum, the watershed as a whole.

Global figures are used where no local studies exist. The lowest global value in the literature for an appropriate ecosystem service is used to estimate the low boundary, while the highest global value determines the high boundary. As more data about the values is placed in the model, the range narrows and more accurate figures emerge for each locality.

2.1 Study Location

This study was conducted on the Tolt River watershed (approximately 63,800 acres) which is in the foothills of the Cascade Range near Carnation, Washington and is managed by SPU, the US Forest Service (USFS) and private timber companies. It supplies approximately 30% of the drinking water of the population in the Seattle vicinity (SPU 2004).

The water production originates out of the south fork of the Tolt River, which has about 12,000 acres. SPU owns about 8,373 acres of this area, or about 70% of the south fork watershed. The USFS owns the remainder.

The Tolt River Levee Restoration and Habitat Preservation Project is a voluntary proposed project for the restoration of the threatened Chinook salmon. The project area, approximately 50 acres, is located at the confluence of the Tolt and Snoqualmie Rivers.

The San Souci Reach area, as delineated by SPU, includes 57 properties totaling 77 acres just upriver from the town of Carnation. It does not include the Hancock Easement discussed below.

The Hancock Easement as identified by SPU includes Hancock Timber Resource Group timberlands in the Tolt River watershed along a six mile length of the Tolt River San Souci Reach, just upriver of the town of Carnation. The area examined was a strip of 186 acres of timberlands extending an additional 150 feet beyond the current 150 foot buffer from the river's edge.

2.2 Brief Description of Approach

Earth Economics staff reviewed current literature on ecosystem services and goods enhanced by salmon protection and restoration in the Tolt River watershed. The GIS land cover data provided by SPU was examined in the context of the full suite of 23 ecosystem services. A benefit transfer methodology, a database of ecological service studies housed at the GIEE, was used for high and low dollar valuation ranges for as many services as possible in the Tolt River watershed area covered by the GIS data. This GIS analysis is a snapshot of the Tolt River watershed's ecosystem services. It is a static, not dynamic, valuation. Changes in land cover as a result of natural and human-induced processes may not be fully valued.

The team conducted analyses of the entire watershed, the SPU owned lands and USFS lands in the upper basin of the south fork of the Tolt River, as well as a combined analysis.

The Earth Economics team examined the Tolt River Levee Restoration and Habitat Preservation Project from the general identification of ecosystem services with subsequent identification of the areas where values associated with the project are likely to be the largest and most important. A survey of the restoration site provided greater detail for valuation including estimates of ecosystem health. Finally, a benefit transfer method was used to derive the range of values for expansion and contraction of the value of ecological services associated with the Tolt River Levee Restoration and Habitat Preservation Project.

As potential alternatives to the Tolt River Levee Restoration and Habitat Preservation Project, the Earth Economics team also conducted valuations of the the San Souci Reach area, as delineated by SPU, and the Hancock Easement, as identified by SPU.

2.3 Methodology for Valuing Ecological Goods and Services within the Tolt River Watershed

The methodology for valuing ecosystem services involves the identification and categorization of ecological services, GIS data and peer-reviewed studies of market and non-market values using direct use and indirect use valuation methods. These aspects are discussed in the next sections.

2.3.1 Categorizing Ecological Services

Based on a review and synthesis of the valuation literature on ecological services, De Groot et al. (2002) categorized 23 ecosystem processes and functions of ecosystem services (see Table 2). These are grouped into four function categories: 1) regulation, 2) habitat, 3) production, and 4) information functions. Regulation and habitat functions are considered essential functions that are necessary before production and information functions can be active (De Groot et al. 2002).

Table 2. Ecosystem Functions and Services (from De Groot et al. 2002)

Functions		Ecosystem Infrastructure and Processes	Goods and Services (Examples)
Regulation Functions		*Maintenance of essential ecological processes and life support systems*	
1	Gas regulation	Role of ecosystems in bio-geochemical cycles	Provides clean, breathable air, disease prevention, and a habitable planet
2	Climate regulation	Influence of land cover and biological mediated processes on climate	Maintenance of a favorable climate promotes human health, crop productivity, recreation, and other services
3	Disturbance prevention	Influence of ecosystem structure on dampening environmental disturbances	Prevents and mitigates natural hazards and natural events generally associated with storms and other severe weather
4	Water regulation	Role of landcover in regulating runoff and river discharge	Provides natural irrigation, drainage, channel flow regulation, and navigable transportation
5	Water supply	Filtering, retention and storage of fresh water (e.g. in aquifers and snowpack)	Provision of water for consumptive use; includes both quality and quantity
6	Soil retention	Role of vegetation root matrix and soil biota in soil retention	Maintains arable land and prevents damage from erosion, and promotes agricultural productivity
7	Soil formation	Weathering of rock, accumulation of organic matter	Promotes agricultural productivity, and the integrity of natural ecosystems
8	Nutrient regulation	Role of biota in storage and re-cycling of nutrients	Promotes health and productive soils, and gas, climate, and water regulations

9	Waste treatment	Role of vegetation and biota in the removal or breakdown of xenic nutrients and compounds	Pollution control/detoxification, Filtering of dust particles through canopy services
10	Pollination	Role of biota in the movement of floral gametes	Pollination of wild plant species and harvested crops
11	Biological control	Population control through trophic-dynamic relations	Provides pest and disease control, reduces crop damage
Habitat Functions		*Providing habitat (suitable living space) for wild plant and animal species*	
12	Refugium function	Suitable living space for wild plants and animals	Maintenance of biological and genetic diversity (thus the basis for most other functions)
13	Nursery function	Suitable reproduction habitat	Maintenance of commercially harvested species
Production Functions		*Provision of natural resources*	
14	Food	Conversion of solar energy into edible plants and animals	Hunting, gathering of fish, game, fruits, etc.; small scale subsistence farming and aquaculture
15	Raw materials	Conversion of solar energy into biomass for human construction and other uses	Building and manufacturing; fuel and energy; fodder and fertilizer
16	Genetic resources	Genetic material and evolution in wild plants and animals	Improve crop resistance to pathogens and pests
17	Medicinal resources	Variety in (bio)chemical substances in, and other medicinal uses of, natural biota	Drugs, pharmaceuticals, chemical models, tools, test and essay organisms
18	Ornamental resources	Variety of biota in natural ecosystems with (potential) ornamental use	Resources for fashion, handicraft, jewelry, pets, worship, decoration and souvenirs
Information Functions		*Providing opportunities for cognitive development*	
19	Aesthetic information	Attractive landscape features	Enjoyment of scenery
20	Recreation	Variety in landscapes with (potential) recreational uses	Travel to natural ecosystems for eco-tourism, outdoor sports, etc.
21	Cultural and artistic information	Variety in natural features with cultural and artistic value	Use of nature as motive in books, film, painting, folklore, national symbols, architecture, advertising, etc.
22	Spiritual and historic information	Variety in natural features with spiritual and historic value	Use of nature for religious or historic purposes (i.e., heritage value of natural ecosystems and features)
23	Science and education	Variety in nature with scientific and educational value	Use of natural systems for school excursions, etc., use of nature for scientific research

The project team utilized this classification of ecological services as the framework for analyzing the ecological services produced within the Tolt River watershed.

2.3.2 Valuation Methodology

The project team used the methodology of value transfer to conduct the valuation. Because the cost of conducting original studies for every ecological service on every site for every vegetation type is prohibitive, researchers have developed a technique called benefit, or value, transfer. Value transfer is a widely accepted economic methodology in which the estimated economic value of an ecological good or service is determined by examining previous valuation studies of similar goods or services in other comparable locations.

This valuation is akin to a house appraisal where an appraiser considers the valuations (sales) of other houses in different locations, similar attributes and differences, and specific aspects of the house and property being appraised. The number of bedrooms, condition of the roof, unfinished basement and mountain view comprise additive values for estimating the full value of the house. These values are additive, just as an extra bedroom, a better view or an excellent location provide different services and each add to the total value of a house.

The Gund Institute for Ecological Economics, the leading national ecological economics institution, has compiled a database of published, peer-reviewed ecological service valuation studies. The database provides value transfer estimates based on landcover types and is updated as new literature becomes available.

The value of the ecosystem services described above is additive. An acre of forestland provides a water regulation and filtration service. It also provides aesthetic, flood protection and refugium benefits. One study may establish the value per acre of a watershed in water filtration for a drinking water supply. Another study may examine the value per acre of refugium for wildlife. To determine the full per acre value provided by a vegetation type, ecosystem service values are summed up and multiplied by the acreage.

The valuation techniques utilized to derive the values in the database were primarily developed 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 which entails asking individuals or groups what they are willing to pay for a good or service.

Table 3. Valuation Methods

Direct Use Values	
Market Price	Prices set in the marketplace appropriately reflect the value to the "marginal buyer." The price of a good tells us how much society would gain (or lose) if a little more (or less) of the good were made available.
Indirect Use Values	
Avoided Cost	Value of costs avoided by ecosystem services that would have been incurred in the absence of those services. For example, flood control provided by barrier islands avoids property damages along the coast.
Replacement Cost	Cost of replacing ecosystem services with man-made systems, as when nutrient cycling waste treatment are replaced with costly treatment systems.
Factor Income	The enhancement of income by ecosystem service provision. For example, water quality improvements increase commercial fisheries catch and incomes of fishermen.
Travel Cost	Cost of travel required to consume or enjoy ecosystem services. Travel costs can reflect the implied value of the service. For example, recreation areas attract tourists whose value placed on that area must be at least what they were willing to pay to travel to it.
Hedonic Pricing	The reflection of service demand in the prices people will pay for associated goods. For example, housing prices along the coastline tend to exceed the prices of inland homes.
Contingent Valuation	Value for service demand elicited by posing hypothetical scenarios that involve some valuation of land use alternatives. For example, people would be willing to pay for increased preservation of beaches and shoreline.
Group Valuation	Discourse-based contingent valuation, arrived at by bringing together a group of stakeholders to discuss values to depict society's willingness to pay.

2.3.3 Methodology for Evaluation of the Impacts of the Proposed Project

The second phase of this study involved a more detailed examination of several areas of the watershed. An onsite survey was conducted to estimate the impact on ecological service values with the implementation of the Tolt River Levee Restoration and Habitat Preservation Project. The project team developed a value transfer methodology utilizing the field survey data as well as other consultant reports on the project site already completed for SPU in order to estimate the future impacts of the project in terms of key ecosystem services affected.

The methodology of benefit transfer is still new; significant questions remain. Many valuation studies are available for forest ecosystem service values while very few studies have been conducted on the valuation of marine and riparian area services. The applicability of studies must also be examined. For example, wetlands in Renton were shown to have $51,000 per acre in flood protection value. These wetlands buffer expensive residential properties and provide a far greater value in flood protection than wetlands in the lower Tolt River watershed where there are few high value properties. This is why we excluded the Renton study or others like it in our analysis. Decisions on what studies to include are not so simple. This is one reason for choosing a range of values as a better expression of the inherent uncertainty over quoting a single figure.

In addition, not all ecosystem functions and services apply to some areas of the Tolt River watershed. Recreation value will be produced in the Tolt River Levee Restoration and Habitat area and will likely be higher than estimated values due to the associated park owned by King County. Additional refinement to the current benefit transfer methodology to pick up specific site changes, such as increased recreational beach use and reduced recreational use of inner-tubes for floating down that reach, would require further study.

SPU restricts access on the south fork of the Tolt River so no recreational value was counted because the area is off-limits for recreational use. In addition, other categories of ecosystem functions were not included for the analysis of the Tolt River Levee Restoration and Habitat area and the south fork of the Tolt River. Soil formation, waste treatment, pollination, biological control, food production, genetic resources, medicinal resources, ornamental resources and recreational resources were not included in the analysis either because they were not appropriate in this case (no recreation allowed) or we had no appropriate studies available (medicinal and spiritual resources). Some in the Earth Economics/GIEE team felt strongly that some of these values should have been included. This is another reason why the actual estimates are highly conservative with the true values perhaps significantly higher.

Estimating ecosystem health is another critical issue. Existing wetlands in the project site are heavily impacted by invasive species, reducing some of the refugia functions. In the Tolt River Levee Restoration and Habitat project area we assumed that the restoration of scouring processes would give native species a greater advantage. Thus, the productivity of existing wetlands composed largely of reed canary grass, Himalayan blackberries (*rubus discolor*) and other invasive species, was deemed to be less than the ecosystem service productivity of wetlands with reestablished riparian habitat and processes under the future conditions.

An ecosystem service valuation of current and future conditions for the site was conducted and a present value of ecosystem services provided by the project was calculated. The accuracy of this analysis depends on the accuracy of the estimated future ecological conditions.

These figures should be considered a starting point for ecosystem service valuation and should be updated with specific valuation studies within the watershed.

2.3.4 Present Value Calculation and Discounting

How to treat a stream of renewable benefits earned across time (and generations) is a difficult issue. On one hand, it may reflect the current cost of capital or other financial opportunity costs, or it may be justified by a social discount rate (people naturally discount the future). On the other hand, the use of the discount rate in the context of ecosystem services implies an ethical decision on what state we will leave natural capital for future generations. The discount rate assumes that the benefits we harvest in the present are worth more than the benefits provided for future generations, a view that those from the future may not share.

There is a great deal of literature examining the basis for using different discount rates such as the prime rate of interest, the market rate of interest, inferred social discount rate. We provide three calculations of the PV with three discount rates. The Army Corps of Engineers uses a 3.5% discount rate for renewable natural resources, and 5% and 7% discount rates are normally used by SPU. These were the three discount rates used in this study.

Present value maximization biases favor the selection of projects that pull benefits into the present and push costs into the discounted future. This bias toward present value and discounting of future value can result in market failures or perverse “unsustainable” decisions where renewable resources are liquidated for short term gain at much greater long term costs.

Had Seattle residents in 1900 discounted the value of the Cedar River watershed to future generations, such as our generation, they may not have acquired it. Had they maximized their present value, SPU might not own the watershed today. However, they placed significant weight to future value, and the Cedar River watershed is of substantial value to us today. **The ability of a public utility to manage vast amounts of value across generations is one reason why public utilities are more economically efficient than privately owned companies in managing natural capital assets.**

Calculation of the PV and discounting is known to be inter-generationally inconsistent. A person living in the future and applying the same methodology would maximize their future “present” value, not ours. A future decision-maker would select different resource allocation decisions. The use of a zero discount rate sets the value of ecosystem services provided for free and in perpetuity as infinite without an arbitrary time limitation. In this case, a square foot of sod producing any positive ecosystem service value would be of infinite value. Thus, a zero discount rate is also flawed.

Ecological economists solve this dilemma by defining a sustainable scale, one where basic ecosystem services within a watershed are kept intact. This ensures ecological sustainability and that 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 a form of wealth. Many ecosystem services are necessary for our survival: oxygen production, waste decomposition, and storm protection. This wealth 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, which burns up, is used up, or depreciates to eventually become waste and require 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 Tolt River watershed using a zero discount rate was used to provide a glimpse of how the people of Seattle would see the stream of future ecosystem service benefits. In fact, ecosystem services have increased in value at an accelerating rate as these services become increasingly scarce. With current development projections in the area, this could be expected to continue. Thus, the true value of these services may be much larger.

2.4 Study Limitations

This study provides a first-cut estimate of the economic value of the ecological goods and services generated within the Tolt River watershed. The study, based primarily on value transfer and not on original research of each ecosystem service within the Tolt River watershed, should be regarded as preliminary.

Apart from the limitations listed below, the primary study limitation for the Tolt River Levee Restoration and Habitat Preservation Project is in accurately establishing the future conditions. As this study proceeded, the engineering specifications for the proposed Tolt River Levee Restoration and Habitat Preservation Project changed from emphasizing a larger levee structure to a greater use of log-jams within the expanded riparian zone. This analysis is based on the original project proposal. The acreages of forest, grasslands, wetlands and riparian zone could be different under the more recent proposal. This would alter the magnitude but not the direction of the values.

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. Watershed management is better informed with fact-based estimates rather than an implicit assumption of zero value for the following reasons:

1) ***Limited ecosystem service studies.*** Although the field of ecosystem service valuation has expanded rapidly, regionally relevant studies are still extremely limited. The value of some ecosystem services has not been estimated. For example, the value to people of ecosystem processes that produce gravel for salmon spawning has, to our knowledge, never been estimated. Where ecosystem services of value are identified and valuations have not been conducted, zero value is the default estimate. This contributes to values for both the low and high valuations that are underestimates.

2) ***Uncertainty and service identification.*** Some ecological services may not yet be identified. The dollar estimates of the value produced by natural systems are inherently underestimates. For example, while we may be able to place a dollar value on the water filtration services provided by a forest, we cannot fully capture the aesthetic pleasure that people gain from looking at the forest, nor every aspect of the forest's role in supporting the intricate web of life. Thus, most ecological service valuations serve as base markers somewhere below the minimum value of the true social, ecological, and economic value of an ecological service.

3) ***Lack of appropriate valuation studies.*** Medicinal, historic and spiritual values were identified but eliminated from the study because existing studies were inappropriate for this area. However, assuming that the Tolt River watershed produces no value in these categories is incorrect and reduces its true value. Taxol, a breast cancer drug was discovered from the Northwest yew tree which occurs in the watershed. No methodology on how to distribute this value to the ecosystem that produced it on a per acre basis has yet been developed. Historical values are site specific and resources were insufficient for a specific study of the Tolt River watershed. Similarly, there is no accepted method for monetizing spiritual value.

4) ***Static analysis.*** The values of goods and services, natural capital or otherwise, are dynamic. The current analysis provides a "snapshot" of value in the Tolt River watershed and for the project site. The values of many ecological services rapidly increase as they get increasingly scarce (Boumans et al. 2002). This could give rise to a general tendency for value transfer based on studies performed over the past ten years to underestimate the value of ecological services produced by ecosystems today.

5) ***GIS information*** The GIS vegetation cover data used is fairly coarse. For instance, it does not differentiate the quality of different wetlands. We used the age of forest stands to provide an estimate of ecosystem health and services provided. A recently-clear cut area will not yield the same flood protection, soil stabilization, or other services as an old growth forest.

6) ***Process.*** Since this methodology is based on ecosystem services provided per acre of vegetation type, it does not pick up the full value of process changes. For example, the establishment of log jams and barriers or restoring the natural processes of the lower Tolt River watershed will have impacts beyond the project site because they are process changes. These are not captured in the geographical analysis of the site.

7) ***Irreversibility.*** Most economic modeling and analysis is a marginal analysis. Marginal analysis assumes a degree of reversibility. Value changes on the margins are smooth, consistent, and continuous.

8) ***Endangered species status.*** This report does not incorporate the "no action option" and the risk of further decline of Chinook salmon which could require more costly actions in the future.

3. <u>Outcomes: The Current Tolt River Watershed</u>

3.1 Tolt River Watershed Ecosystem Service Valuation

The ecological goods and services produced by each land cover type in the Tolt River watershed were estimated utilizing the methodological approach outlined in the previous section. The results are presented in Tables 4a through 5 below.

Tables 4a-4d show the estimates of ecological services produced by each GIS vegetation type within the Tolt River watershed. Forestlands make up the vast majority of the study area. Most of the value is generated by forested land cover and reflects a typical upper watershed valuation. Forests are primary generators of ecological service value along with wetlands and coastal marine ecosystems (Costanza, et al.1997). Nutrient regulation, flood protection (disturbance prevention), water regulation, water supply, information, and refugium functions provide the largest contributions of benefits to people.

The value generated on the 63,800 acres of the Tolt River watershed in ecosystem services is estimated to be in the range of $368 to $1,364 million, annually (shown in Table 5).

These estimates are based on the range of values for these land covers conducted outside the Tolt River watershed. As cursory estimates based on benefit transfer methodology they provide a ball-park range. A specific study or set of studies should be conducted to narrow the range in values.

3.1.2 Value by Landcover Type

Table 4a. Tolt River Watershed Forest and Grassland Ecosystem Service Value Estimates *(in $US)*

Ecological Service	Forest		Grassland and Shrub-land	
	Low	***High***	***Low***	***High***
Gas regulation	2,196,358	5,820,349	16,326	43,264
Climate regulation	1,932,795	4,897,878	11,494	29,126
Disturbance prevention	21,963,580	159,016,316	195,914	1,418,418
Water regulation	21,963,580	119,591,691	185,030	1,007,488
Water supply	21,963,580	166,923,205	174,146	1,323,508
Soil retention	636,944	5,381,077	5,682	47,999
Soil formation	21,964	219,636	218	2,177
Nutrient regulation	219,635,796	463,431,529	1,632,617	3,444,823
Waste treatment	21,963,580	147,068,129	195,914	1,311,841
Pollination	307,490	549,089	2,286	4,082
Biological control	43,927	1,713,159	261	10,188
Refugium function	10,981,790	33,450,532	70,747	215,495
Nursery function	3,118,828	4,282,898	17,001	23,346
Food	6,589,074	18,192,433	76,189	210,357
Raw materials	2,196,358	22,271,070	5,442	55,182
Genetic resources	131,781	439,272	327	1,088
Medical resources	0	0	0	0
Ornamental resources	65,891	439,272	0	0
Aesthetic information	153,745	3,184,719	1,524	31,564
Recreation	2,196,358	38,655,900	21,768	383,121
Cultural & artistic information	21,963,580	131,781,478	217,682	1,306,094
Spiritual & historic information	0	0	0	0
Science & education	21,964	43,927	141	283
Navigational services	219,636	439,272	0	0
Total	**$ 360,268,596**	**$ 1,327,792,830**	**$ 2,830,708**	**$ 10,869,444**

Table 4b. Tolt River Watershed Agriculture and Pasture, and Urban Ecosystem Service Value Estimates *(in $US)*

Ecological Service	**Agriculture and Pasture**		**Urban**	
	Low	***High***	***Low***	***High***
Gas regulation	82	217	0	0
Climate regulation	72	183	4,081	10,341
Disturbance prevention	821	5,941	0	0
Water regulation	1,524	8,298	46,371	252,489
Water supply	821	6,237	324,596	2,466,930
Soil retention	34	287	10,758	90,887
Soil formation	1	14	46	464
Nutrient regulation	8,206	17,315	927,417	1,956,851
Waste treatment	821	5,495	417,338	2,794,494
Pollination	8	15	9,738	17,389
Biological control	2	64	835	32,552
Refugium function	352	1,071	185,483	564,983
Nursery function	100	137	59,262	81,381
Food	1,524	4,208	46,371	128,030
Raw materials	176	1,783	0	0
Genetic resources	0	0	0	0
Medical resources	0	0	0	0
Ornamental resources	0	0	0	0
Aesthetic information	8	170	5,843	121,028
Recreation	0	0	102,016	1,795,480
Cultural & artistic information	469	2,813	1,391,126	8,346,757
Spiritual & historic information	0	0	0	0
Science & education	2	4	1,391	2,782
Navigational services	0	0	0	0
Total	**$ 15,021**	**$ 54,251**	**$ 3,532,672**	**$ 18,662,839**

Table 4c. Tolt River Watershed Lakes, Rivers, Ponds and Reservoirs and Wetland Ecosystem Service Value Estimates *(in $US)*

Ecological Service	Lakes, Rivers, Ponds and Reservoirs		Wetlands	
	Low	*High*	*Low*	*High*
Gas regulation	0	0	4,476	11,861
Climate regulation	0	0	3,939	9,981
Disturbance prevention	0	0	44,760	324,060
Water regulation	0	0	44,760	243,717
Water supply	0	0	44,760	340,174
Soil retention	0	0	1,298	10,966
Soil formation	0	0	45	448
Nutrient regulation	0	0	447,597	944,430
Waste treatment	0	0	44,760	299,711
Pollination	0	0	627	1,119
Biological control	0	0	90	3,491
Refugium function	65,344	199,038	22,380	68,169
Nursery function	3,712	5,097	6,356	8,728
Food	0	0	22,380	61,791
Raw materials	39,206	397,553	2,238	22,693
Genetic resources	0	0	0	0
Medical resources	0	0	0	0
Ornamental resources	1,568	10,455	13	90
Aesthetic information	1,830	37,900	313	6,490
Recreation	5,228	92,004	1,343	23,633
Cultural & artistic information	52,275	313,652	26,856	161,135
Spiritual & historic information	0	0	0	0
Science & education	523	1,046	45	90
Navigational services	0	0	45	90
Total	**$ 169,685**	**$ 1,056,744**	**$ 719,078**	**$ 2,542,866**

Table 4d. Tolt River Watershed Rock Ecosystem Service Value Estimates *(in $US)*

Ecological Service	Rock Ecosystem	
	Low	***High***
Gas regulation	0	0
Climate regulation	1,558	3,949
Disturbance prevention	0	0
Water regulation	0	0
Water supply	0	0
Soil retention	0	0
Soil formation	0	0
Nutrient regulation	531,278	1,120,997
Waste treatment	0	0
Pollination	0	0
Biological control	177	6,907
Refugium function	88,546	269,712
Nursery function	0	0
Food	0	0
Raw materials	0	0
Genetic resources	0	0
Medical resources	0	0
Ornamental resources	0	0
Aesthetic information	1,240	25,678
Recreation	17,709	311,683
Cultural & artistic information	177,093	1,062,557
Spiritual & historic information	0	0
Science & education	177	354
Navigational services	0	0
Total	**817,779**	**2,801,838**

Table 5. Total Ecosystem Service Value Estimates Provided Annually by the Tolt River Watershed *(in $US)*

Ecosystem Category	Low Value	High Value
Forest	360,269,000	1,327,793,000
Grasslands & Shrub-lands	2,831,000	10,869,000
Agriculture & Pasture	15,000	54,000
Urban	3,533,000	18,663,000
Lakes, Rivers, Ponds & Reservoirs	170,000	1,057,000
Wetland	719,000	2,543,000
Rock	818,000	2,802,000
Total Value	**$ 368,355,000**	**$ 1,363,781,000**

3.1.3 Discussion of Tolt River Watershed Ecosystem Service Values

There are good reasons to believe that some of the benefit transfer values are underestimates when considering the unique features of the Tolt River watershed.

1. Seattle receives a significant amount of water from the Tolt River watershed. This value is far higher than a typical watershed. This contribution to Seattle's water quality and supply is likely higher on a per acre basis than the highest current valuation of watersheds for water production which is somewhat out of date.
2. The relatively high gradient of the Tolt/Snoqualmie, and high value of urbanized areas in the lower watershed implies that the disturbance protection value of the forested Tolt River watershed may be higher than the disturbance protection studies which are based on areas outside the Northwest which have a milder gradient and less residential and commercial value downstream.
3. The refugium and nursery functions are likely many factors larger than the estimated values. This study does not account for the threatened status of Chinook salmon. It assumes that there are only marginal changes and marginal or non-critical values. When a service or good approaches a critical point, a non-linear shift in quantity such as extinction or other crises, values tend to rise dramatically. This study does not incorporate the valuation of restoring salmon habitat to avoid endangered status because such studies have not been conducted. Examining ecosystem services when they hit a critical point is an urgent need in ecosystem service valuation.
4. Food and materials production is certainly higher than the lower value. Northwest ecosystems are far more productive than the estimates of lower boundary studies.
5. Recreation is an area that deserves more study. A large part of the watershed is under restricted access, thus recreation values on these areas are likely overestimated. However, some areas, such as the lower Tolt River watershed, exhibit substantial recreation values. The net affect of these changes is uncertain.

3.1.4 Present Value of Tolt River Watershed Ecosystem Services

The present values of Tolt River watershed ecosystem services are presented in Table 6. The stream of benefits over a 100-year time period, discounted at 7%, 5% and 3.5%, are shown in Appendices B-D.

Under any calculation of PV, the ecosystem services provided by the Tolt River watershed are enormous and highly significant, ranging from a low of $5.6 billion for the lower value estimate at a 7% discount rate to $40.3 billion for the higher value estimate at a 3.5% discount rate, the rate used by the Army Corps of Engineers for renewable resources.

Table 6. Present Value of Ecosystem Services Provided by the Tolt River Watershed *(in Billions US$)*

Discount Rate	Low Estimate	High Estimate
7 %	5.6	20.9
5 %	7.7	28.6
3.5%	10.9	40.3

For information purposes, the value of the stream of benefits produced using a zero discount rate was also calculated. Table 7 shows the value of ecosystem service benefits using a zero discount rate over time intervals of 100, 250 and 500 years. The values range from a low of $36.8 billion to a high of $681.9 billion

Table 7. Present Value of Ecosystem Services Provided by the Tolt River Watershed Using a Zero Discount Rate *(in Billions US$)*

Time Horizon	Low Estimate	High Estimate
100 years	36.8	136.4
250 years	92.1	340.9
500 years	184.2	681.9

3.2 Ecosystem Service Valuation of SPU lands in the South Tolt (Lower Basin)

SPU owns 8,373 acres in the lower South Tolt River Basin. This includes primarily forested lands (evergreen, deciduous and transition), roads, bare rock, shrub lands, grassy areas, and just over an acre of woody wetlands.

SPU asset management in the Tolt River watershed includes human-built assets, such as the water filtration plant, dam, roads, water delivery systems and other structures. In addition, the natural assets of plant vegetation, snow pack, topography, habitat and other geophysical assets are also highly valuable assets owned by SPU which should be included in asset management planning. In some cases, natural assets and human-built assets are substitutes. For example, filtration services can be provided naturally, as they are within the watershed or with capital investments, such as the existing filtration plant. Were turbidity in the reservoir not a problem, SPU would not need the existing plant. Were no natural filtration services provided by the watershed, SPU would have to greatly expand the filtration plant.

In other cases, human-built capital complements natural assets and increases management efficiency. For example, the reservoir captures melting water resources in the spring enabling water production into the summer.

Some natural assets cannot be replaced by human-built assets. The quantity of water falling within the watershed is entirely determined by climate, localized weather, topography, vegetation cover, and other geo-biophysical factors outside the human-built capital (cloud seeding can divert some rainfall). This natural capital can be supplemented with water diversion from other natural capital sources (potentially the north fork of the Tolt), however, rainwater is ultimately a natural asset and most dependent on other natural asset factors such as habitat and vegetation coverage, climate, etc.

Snow pack is a tremendously valuable natural asset storage system for vast quantities of water. To replace this storage mechanism with water retention dams and facilities would be enormously expensive. Since we know of no valuation studies of snow pack, this should be an area of interest for SPU considering the implications of global warming.

The production of ecosystem value from the south fork of the Tolt River is split between SPU and USFS lands. This first analysis examines the value produced on SPU property.

The value of some ecological goods and services produced within the 8,373 acres of the SPU lands in the lower basin of the Tolt River watershed were estimated using the benefit transfer methodology previously described. Table 8 shows the acreages of GIS classification types, including the open water of the SPU lands in the lower basin of the Tolt River south fork.

Table 8. Vegetation Acreages in SPU Owned Land in the Tolt River South Fork (Lower Basin)

GIS Classification	Acres
Open Water	1,007.7
Commercial / Industrial / Transportation	6.4
Bare Rock / Sand / Clay	12.2
Transitional	1,347.6
Deciduous Forest	286.0
Evergreen Forest	5,271.3
Mixed Forest	264.2
Shrub-land	105.0
Grasslands / Herbaceous	71.4
Woody Wetlands	1.3
Total SPU Acreage	**8,373.1**

Table 9 shows the ecosystem service value estimates by generalized GIS classification for the 23 ecosystem services provided by the SPU lands in the south fork of the Tolt River watershed.

Table 9. Value of Ecosystem Services Provided Annually by SPU Lands in the Tolt River Watershed South Fork *(in $US)*

Ecosystem Category	Low Estimate	High Estimate
Forest	39,504,000	142,228,000
Grasslands & Shrub-lands	564,000	2,106,000
Urban	580,000	2,857,000
Lakes, Rivers, Ponds & Reservoirs	131,000	767,000
Wetland	9,000	31,000
Rock	23,000	72,000
Total Values (Lower Basin)	**$ 40,811,000**	**$ 148,060,000**

This is a first cut analysis using benefit transfer methodology. It can be further sharpened with specific studies in the areas of highest ecosystem service production, such as the value of water produced and filtered from the SPU land.

This analysis represents an underestimate of the range value generated by 8,373 acres of SPU property in the lower basin of the Tolt River south fork (some values

could not be estimated). The SPU natural assets (topography, habitat and ecosystems) produce ecosystem services with an estimated range of annual benefits of $40.8-148.1 million.

The present value of this flow of benefits was calculated based on discount rates of 7%, 5%, 3.5% and 0% (across 100, 250 and 500 year horizons). The range of net present value at a 7% discount rate is $0.6-2.3 billion. For a discount rate of 5% the present value is $0.9-3.1 billion. At a 3.5% discount rate the range in present value is: $1.2-4.4 billion.

The Earth Economics team also examined the value of this flow of services to future generations using a zero (generation neutral) discount rate. The net value of ecosystem services produced by the SPU lands in the lower basin was calculated with the assumption that current ecosystem health and GIS classification types do not change. The total production of value at a zero discount rate across three time periods (100, 250 and 500 years) is shown in Table 10.

Table 10. Present Value of Ecosystem Services Provided by SPU Lower Basin South Fork Land Using a Zero Discount Rate *(in Billions $US)*

Time Horizon	Low Estimate	High Estimate
100 years	4.1	14.8
250 years	10.2	37.0
500 years	20.4	74.0

These figures are below the true high and low values. A recent SPU analysis of the value of water produced within this watershed suggests that the actual water production value is higher than the high value estimated under this.

3.3 US Forest Service Lands in the South Tolt (Upper Basin)

The 3,689 acres owned by the US Forest Service in the upper basin of the south fork of the Tolt River provide significant ecological services. Management of these lands has been modified to protect SPU water resources within the watershed. The values calculated are again quite likely underestimates because the value of these lands for water production are higher than the high estimate provided in this benefit transfer methodology.

The value of some ecological goods and services produced within the 3,689 acres of the USFS lands within the upper basin of the Tolt River watershed were estimated using the benefit transfer methodology. Table 11 shows the acreages of GIS classification types which comprise the USFS land within the upper basin of the Tolt River south fork.

Table 11. Vegetation Acreages of US Forest Service Land in the Tolt River South Fork (Upper Basin)

GIS Classification	Acres
Open Water	18.2
Commercial / Industrial / Transportation	0.7
Bare Rock / Sand / Clay	200.8
Transitional	156.8
Deciduous Forest	170.5
Evergreen Forest	2,925.3
Mixed Forest	87.2
Shrub-land	54.0
Grasslands / Herbaceous	75.2
Woody Wetlands	0.0
Total USFS Acreage	**3,688.9**

Table 12 shows the ecosystem service value estimates by generalized GIS classification for the 23 ecosystem services provided by the US Forest Service lands in the south fork of the Tolt River watershed.

Table 12. Value of Ecosystem Services Provided Annually by USFS Lands in the Tolt River Watershed South Fork *(in $US)*

Ecosystem Category	Low Estimate	High Estimate
Forest	21,600,000	77,786,000
Grasslands & Shrublands	290,000	1,084,000
Urban	68,000	332,000
Lakes, Rivers, Ponds & Reservoirs	2,000	14,000
Rock	378,000	1,177,000
Total Values (Upper Basin)	**$ 22,338,000**	**$ 80,393,000**

This analysis is a first cut using benefit transfer methodology. It can be further sharpened with specific studies in the areas of highest ecosystem service production, such as the value of water produced and filtered from the upper basin.

This analysis represents an underestimate of the range value generated by the US Forest Service land in the upper basin of the south fork of the Tolt River (some values could not be estimated). The values of ecological services are estimated to be greater than the range of $22.3-80.4 million in benefits annually.

This flow of renewable ecological goods and services were estimated to have a present value of $0.3-1.2 billion (7% discount rate), $0.5-1.7 billion (5% discount rate), and $0.7-2.4 billion (3.5% discount rate).

The Earth Economics team also examined the value of this flow of services to future generations using a zero (generation neutral) discount rate. The net value of ecosystem services produced by the US Forest Service lands in the upper basin of the Tolt River south fork was calculated with the assumption that current ecosystem health and GIS classification types do not change. The total production of value at a zero discount rate across three time periods (100, 250 and 500 years) is shown in Table 13.

Table 13: Present Value of Ecosystem Services on USFS Land Using a Zero Discount Rate *(in Billions $US)*

Time Horizon	Low Estimate	High Estimate
100 years	2.2	8.0
250 years	5.6	20.1
500 years	11.2	40.2

3.4 Tolt River South Fork Combined Basin Results

Combining the lower and upper basins of the south fork of the Tolt River gives a full picture of the ecosystem services provided above the SPU drinking water intake. The summation of the acreages and values for the south fork of the Tolt River above the SPU intake are shown in tables 14 and 15.

Table 14. Combined Acreages of Lower and Upper Basins, Tolt River South Fork

GIS Classification	Acres
Open Water	1,025.9
Commercial / Industrial / Transportation	7.1
Bare Rock / Sand / Clay	213.0
Transitional	1,504.4
Deciduous Forest	456.6
Evergreen Forest	8,196.6
Mixed Forest	351.4
Shrub-land	159.0
Grasslands / Herbaceous	146.6
Woody Wetlands	1.3
Total Combined Acreage	**12,062.0**

Table 15. Combined Value of Ecosystem Services Provided Annually by Upper and Lower Basins, Tolt River South Fork *(in $US)*

Ecosystem Category	Low Estimate	High Estimate
Forest	61,104,000	220,015,000
Grasslands & Shrublands	854,000	3,191,000
Urban	647,000	3,189,000
Lakes, Rivers, Ponds & Reservoirs	133,000	780,000
Wetland	9,000	31,000
Rock	401,000	1,248,000
Total Values (Combined)	**$ 63,148,000**	**$ 228,454,000**

The estimated combined value of ecosystem goods and services produced by the SPU and USFS lands is $63.2-228.5 million. The present value ranges for the combined lands are $1.0-3.5 billion (7% discount rate), $1.3-4.8 billion (5% discount rate), $1.9-6.8 billion (3.5% discount rate).

Combined value estimates for this flow of services to future generations using a zero (generation neutral) discount rate were calculated with the assumption that current ecosystem health and GIS classification types do not change. The zero discount rate is applied across three time periods, 100, 250, and 500 years, and are shown in Table 16.

Table 16. Present Value of Ecosystem Services Provided by Combined Upper and Lower Basins Using Zero Discount Rate *(in Billions $US)*

Time Horizon	Low Estimate	High Estimate
100 years	6.3	34.9
250 years	15.8	57.1
500 years	31.6	114.2

4. <u>Tolt River Levee Restoration and Habitat Preservation Project</u>

4.1 Brief Project Review

Restoring salmon habitat not only recovers endangered salmon species, it also contributes to a full basket of ecosystem services and goods associated with restored natural processes and a healthy riparian habitat. These ecosystem benefits are large and have often been overlooked, resulting in an underestimation of the benefits of salmon restoration. The purpose of the second phase of this study is to evaluate the likely effect of the Tolt River Levee Restoration and Habitat Preservation Project to increase or decrease the ecological service value generated within the immediate 50 acres that it impacts. Although the full effects of the project are cumulative and have impacts outside this area, examining these off-site effects were beyond the scope and budget of this study. The overall direction of the effect would be positive, adding value to the overall restoration project.

The restoration project would be a voluntary and precautionary action benefiting threatened Chinook salmon, restoring native fish habitat, and maintaining current flood protection (Lackey 2004). The structure would maintain flood protection, recreation and public safety in the park, and recreate natural conditions of pools, side channels, and spawning quality gravel beds. This also benefits other ecosystem service production.

A survey of the existing area was completed, providing an overview of the existing landscape, vegetation types, topography and vegetation cover. The prevalence of invasive species and likely scouring with the levee setback were noted.

4.2 Valuation of the Tolt River Levee Restoration and Habitat Preservation Project

4.2.1 Ecosystem Service Valuation of Existing Site

King County maps of the Lower Tolt River Floodplain Reconnection project were reviewed and considered with the on-site survey and other project information. Evaluation of ecosystem services on the existing site was conducted with this data and the same benefit transfer methodology and studies used in the overall Tolt River watershed ecosystem service valuation. The overall values for the existing site are higher than the average ecosystem services across the Tolt River watershed due to the prevalence of wetlands. Existing ecosystem services for the project area range between $99,000 and $360,000 annually.

Table 17 shows the distribution of dollar values provided per year across the vegetation types found in the project area.

Table 17. Value of Ecosystem Services Provided Annually Before Project Implementation *(in $US)*

Ecosystem Category	Low Estimate	High Estimate
Deciduous Forest	21,000	78,000
Grassland	2,000	9,000
Freshwater Wetland	76,000	273,000
Total Values	**$ 99,000**	**$ 360,000**

Wetlands are by far the most valuable contributing areas to the production of ecosystem services on the site. This value will be enhanced with the reconnection to the Tolt River floodplain and restoration of natural riparian processes.

These riparian processes will destroy and recreate wetland and riparian forest areas over time. The existing levee and higher grassy and forested areas will be transformed as the river migrates. A dynamic model would be more accurate in examining these changes, though predicting the rate and extent of these changes is extremely difficult under any condition.

4.2.2 Estimating Ecosystem Services Under Future Conditions

Ecosystem service valuation estimates for existing vegetation covers are reasonably well established. On the other hand, estimating future values under altered conditions is difficult and depends on the accuracy of predicting future ecological conditions. For these reasons, we took a conservative approach to valuation. We assumed that only ten acres would be converted to salmon spawning habitat, though a much larger area is likely to be created within the project area.

More rapid conversion to riparian habitat would increase the net ecosystem service values. Project documents indicate that 35 acres of salmon habitat would be created. Thus the actual net difference in ecosystem service values between the existing and future conditions could be larger than what was estimated in the present analysis. Because the timeframe for establishing 35 acres of salmon habitat was not identified in the project documents, we adopted a more conservative approach. This timing is important in calculating the stream of benefits and PV for the project.

No studies examining the actual value of salmon spawning riparian habitat, which comes under the heading of nursery functions, exist. Because Chinook salmon are threatened, these values are likely very large. After a great deal of discussion, the project team decided to assign highly conservative values of $500-2000 per acre per year for newly created salmon spawning habitat. These estimates are based on assumptions of marginal and non-threatened conditions and the likely value of salmon production. It is a very small step of faith, where likely a larger leap would be justified.

The conversion to riparian wetland habitat produces greater values than those of the existing wetlands. The habitat and refugia values of the existing wetlands onsite and within a 20-mile radius are lower due to the prevalence of invasive species such as reed canary grass, Himalayan blackberries (*rubus discolor*), Canada thistles (*cirsium arvense*), and other invasive species, which occupy more than half of the wetland area. This factor is important in the determination of the project's value. Other ecosystem services such as nutrient cycling are unaffected or could be higher due to invasive species.

4.2.3 Identifying Ecosystem Processes Changed and Service Values Enhanced

Ecological changes under future conditions must be identified to determine the value of ecosystem services under expected future conditions, process, and function. Estimating the expected change in ecosystem services requires examining the likely habitat protection and restoration effects of the Tolt River Levee Restoration and Habitat Preservation Project. In this case, most of the ecosystem services identified as affected by the project were positively affected, with the exception of a reduction in the primary production of the area. This was estimated to have little ecosystem service value because the high primary production is caused by the prevalence of reed canary grass, an invasive plant with reduced refugia and nursery ecosystem service values.

Site visits and a review of the salmon restoration project documents allowed the team to determine the ecosystem services enhanced by the project. The project's restoration measures, as described in the first column of Table 18, influence biological processes, functions, and structure. These determine the level of impact on ecosystem services enhanced or degraded, which is noted in the second column.

Table 18. Initial List of Ecosystem Services Enhanced by Tolt River Levee Restoration and Habitat Preservation Project

Habitat Protection Measure Associated with Tolt Levee Restoration and Habitat Preservation Project	**Ecological Services Expected to be Enhanced**
Stream edges: protect, restore and improve riparian corridor.	*1 Gas regulation:* role of ecosystems in bio-geochemical cycles *2 Climate regulation:* influence of land cover and biologically mediated processes on climate *3 Disturbance prevention:* influence of ecosystem structure on dampening environmental disturbances, flood prevention *4 Water regulation:* role of land cover in regulating runoff and river flow, drainage and natural irrigation. *5 Water supply:* filtering, retention, and storage of fresh water *6 Soil retention:* role of vegetation root matrix and soil biota in soil retention *7 Soil formation:* weathering of rock, accumulation of organic matter *8 Nutrient regulation:* role of biota in storage and re-cycling of nutrients, maintenance of healthy soils and productive ecosystems *9 Waste treatment:* role of vegetation and biota in removal or breakdown of xenic nutrients and compounds, pollution control/detoxification *10 Pollination:* role of biota in the movement of floral gametes *12 Refugium function:* suitable living space for wild plants and animals, maintenance of commercially harvested species

	13 Nursery function: suitable reproduction habitat *14 Food:* conversion of solar energy into edible plants and animals *15 Raw materials:* conversion of solar energy into biomass for human construction and other uses *19 Aesthetic information:* attractive landscape features *20 Recreation:* Variety in landscapes with (potential) recreational uses *23 Science and education:* variety in nature with scientific and educational value
Stream edges: increase the availability of vegetated shallow marsh and riparian habitats.	*1 Gas regulation:* role of ecosystems in bio-geochemical cycles *2 Climate regulation:* influence of land cover and biologically.mediated processes on climate, maintenance of a favorable climate *3 Disturbance prevention:* influence of ecosystem structure on dampening environmental disturbances, storm protection, flood prevention *4 Water regulation:* role of land cover in regulating runoff and river flow *5 Water supply:* filtering, retention and storage of fresh water *6 Soil retention:* role of vegetation root matrix and soil biota in soil retention *7 Soil formation:* weathering of rock, accumulation of organic matter *8 Nutrient regulation:* role of biota in storage and re-cycling of nutrients *9 Waste treatment:* role of vegetation and biota in removal or breakdown of xenic nutrients and compounds, Pollution control/detoxification. *10 Pollination:* role of biota in movement of floral gametes, pollination of wild plant species, pollination of crops *12 Refugium function:* suitable living space for wild plants and animals, maintenance of commercially-harvested species *13 Nursery function:* suitable reproduction habitat, production functions, provision of natural resources *14 Food:* conversion of solar energy into edible plants and animals *15 Raw materials:* conversion of solar energy into biomass for human construction and other use *16 Genetic resources:* genetic material and evolution in wild plants and animals *18 Ornamental:* variety of biota in natural ecosystems with (potential) ornamental use *19 Aesthetic information:* attractive landscape features *20 Recreation:* variety in landscapes with (potential) recreational *21 Cultural and artistic information:* variety in natural features with cultural and artistic value *22 Spiritual and historic information:* variety in natural features with spiritual and historic value *23 Science and education:* variety in nature with scientific and educational value
Protect and improve access to Tolt River watershed, restore Tolt River confluence with Snoqualmie River	*3 Disturbance prevention:* influence of ecosystem structure on dampening environmental disturbances *4 Water regulation:* role of land cover in regulating runoff and river flow *12 Refugium function:* suitable living space for wild plants and animals, maintenance of commercially harvested species *13 Nursery function:* suitable reproduction habitat *16 Genetic resources:* genetic material and evolution in wild plants and animals *19 Aesthetic information:* attractive landscape features
Increase floodplain	*1 Gas regulation:* role of ecosystems in bio-geochemical cycles *2 Climate regulation:* influence of land cover and biologically mediated processes on climate *3 Disturbance prevention:* influence of ecosystem structure on dampening environmental disturbances, storm protection, flood prevention *4 Water regulation:* role of land cover in regulating runoff and river discharge *5 Water supply:* filtering, retention and storage of fresh water

	8 Nutrient regulation: role of biota in storage and re-cycling of nutrients, maintenance of healthy soils and productive ecosystems *9 Waste treatment:* role of vegetation and biota in removal or breakdown of xenic nutrients and compounds *12 Refugium function:* suitable living space for wild plants and animals, maintenance of commercially harvested species *13 Nursery function:* suitable reproduction habitat, hunting, gathering of fish, game, fruits, etc., small-scale subsistence farming and aquaculture *19 Aesthetic information:* attractive landscape features, enjoyment of scenery (scenic roads, housing, etc.) *20 Recreation:* variety in landscapes with (potential) recreational uses
Flow conditions: allow natural disturbance-type flows in a relatively unconstrained river channel	*3 Disturbance prevention:* influence of ecosystem structure on dampening environmental disturbances, storm protection, flood prevention *4 Water regulation:* role of land cover in regulating runoff and river flow *5 Water supply:* filtering, retention and storage of fresh water *12 Refugium function:* suitable living space for wild plants and animals, maintenance of commercially harvested species *13 Nursery function:* suitable reproduction habitat *19 Aesthetic information:* attractive landscape features *20 Recreation:* variety in landscapes with (potential) recreational value
Flow conditions: maintain adequate flows during low flow periods	*4 Water regulation:* role of land cover in regulating runoff and river flow, drainage and natural irrigation, medium for transport discharge *12 Refugium function:* suitable living space for wild plants and animals, maintenance of commercially harvested species *13 Nursery function:* suitable reproduction habitat, hunting, gathering of fish, game, fruits, etc., small-scale subsistence farming, and aquaculture *19 Aesthetic information:* attractive landscape features, enjoyment of scenery (scenic roads, housing, etc.)
Flow conditions: create and restore side flow conditions to provide a range of flow conditions at the Tolt River tributary mouth	*4 Water regulation:* role of land cover in regulating runoff and river flow *12 Refugium function:* suitable living space for wild plants and animals *13 Nursery function:* suitable reproduction habitat
Sediment issues: increase sediment delivery and transport suitable substrate sizes by reconnecting sediment sources to the river	*4 Water regulation:* role of land cover in regulating runoff and river flow *5 Water supply:* filtering, retention and storage of fresh water *7 Soil formation:* weathering of rock, accumulation of organic matter *12 Refugium function:* suitable living space for wild plants and animals *13 Nursery function:* suitable reproduction habitat

Restoring the riparian corridor and increasing the area and diversity of riparian habitats likely has greater benefits than those captured in this analysis. Ecosystem service valuation is not yet sufficiently fine-tuned to capture the full variety of benefits produced by this project. However, the analysis provides better information than the assumption that there is no enhancement of associated ecosystem services.

Increasing stream edges, the diversity of habitats, flow conditions, and sediment delivery and transport, all produce greater ecosystem services. Not all of these benefits could be captured in the valuation portion of the analysis because peer reviewed ecosystem service valuation studies for all of the identified ecosystem changes in riparian habitats have not been conducted. This has the effect of underestimating the net benefits of the project.

4.2.4 Valuation of Ecosystem Services under Expected Future Conditions

Future condition ecosystem services were calculated based on available information after estimating the future ecological conditions in the project site. Table 19 shows the distribution of dollar values provided per acre per year across the vegetation types under the expected future conditions. It shows the breakdown of dollar values within each vegetation type in the project area under projected future conditions. The total estimated range of ecosystem services provided in the project area under restored future conditions is between $233,000 – 844,000.

Table 19. Value of Ecosystem Services Provided Annually Under Expected Future Conditions *(in $US)*

Ecosystem Category	Low Estimate	High Estimate
Deciduous Forest	14,000	52,000
Grassland	4,000	17,000
Open River	2,000	9,000
Salmon Spawning	21,000	76,000
Wetland	192,000	233,000
Total Values	**$ 233,000**	**$ 844,000**

Though open water river benefits are substantially less than wetlands or broadleaf forests, the benefits of restoring greater riparian habitat and riparian wetlands provide net benefit gains in the long run by restoring natural processes. As the stream channel migrates, it provides new broadleaf forest habitat and wetland habitat while washing out other habitat areas. This migration creates the conditions necessary for Chinook salmon spawning.

Restoration of natural processes should also result in a more stable system and overall improvement. These figures must be considered in light of the general uncertainty of estimating the exact future conditions and the future ecosystem service benefits provided. Another uncertainty is the value attached to salmon-spawning riparian habitat. If this project contributes significantly to Chinook salmon restoration as anticipated, then the benefits of avoiding an endangered listing for Chinook salmon may imply a value for Chinook salmon-spawning riparian habitat several factors larger than the figures assumed in this analysis. Additionally, the value of ecosystem services has been appreciating rapidly and the rate of return on the project when including ecosystem services may be higher than expected.

4.2.5 Net Enhancement of Ecosystem Service Values with the Project

The value of the net annual increase in ecological services with the project under future conditions ranges between $134,000-484,000. These figures represent a renewable annual flow of additional benefits from the Tolt River Levee Restoration and Habitat Preservation Project. For several reasons, they are likely underestimates of the full benefits of the project. This model assumes that only 10 acres of habitat will be created and that this area will not grow as the river meanders. If 30 acres of salmon habitat area were created in the first year, then the ecosystem service benefits expected would be larger. The literature on ecosystem service valuation is still not well developed. As a result, the low figures for estimating ecosystem services are generally from older and outdated studies. As methods and measures have improved, ecosystem service valuations have demonstrated rapidly accelerating values for ecosystem services.

The high values may also be underestimates. Ecosystem service studies for riparian areas, for salmon restoration in particular, are incomplete. Many valuable services identified with this project, such as the value of biodiversity, have not been the subject of valuation studies and thus cannot be included in these estimates. It is almost certain that the primary value for this project is derived from the benefits of increased Chinook salmon viability. Yet there are no ecosystem service valuation studies which specifically address this service and benefit. Thus the figures above refer to other ecosystem services, such as improved water quality.

The study is based on a marginal analysis that value changes with vegetation and that floodplain changes result in smooth and predictable changes in ecosystem service values. However, this project is being considered because this area represents critical habitat for Chinook salmon. Examining value when scarcity has discontinuous changes could yield quite different results. Restoration of critical habitat can be assumed to provide increased net values.

4.2.6 Present Value of Ecosystem Services Provided by the Project

Calculation of the present value of the project is sensitive to the discount rate. Table 20 shows the PV for high and low values for the three different discount rates. The adoption of a particular discount rate has a significant impact on PV.

Table 20. Present Value of Ecosystem Services Provided Under Expected Future Conditions *(in $US Million)*

Discount Rate	Low Estimate	High Estimate
7%	2.1	7.4
5%	2.8	10.2
3.5%	4.0	14.3

The Army Corps of Engineers uses a 3.5% discount rate when treating renewable natural resources, making some adjustment for the sustainability of production. A lower discount rate is often justified for projects that enhance ecosystem services.

Once restored, ecosystems are generally self-maintaining and require very low or no maintenance costs as opposed to physical human-built capital construction. A water filtration plant requires staffing and regular maintenance costs. It will eventually depreciate and require further capital investments. A forested watershed providing water filtration services, once restored to a healthy and sustaining condition, requires little maintenance costs (protection from illegal logging and other detrimental activities). It does not depreciate nor require significant further capital investments. A healthy forest can continue to provide high quality water filtration and, in fact, appreciates in value over time. It does not require future capital investments in the way a filtration plant would. It is necessary to include ecosystems in asset management planning.

Unlike human-built capital, ecosystem restoration has the possibility of providing valuable services sustainably with minimal maintenance. Our grandchildren will still benefit from the services provided by the Tolt River Levee Restoration and Habitat Preservation Project. Table 21 presents the flow of value into the future under a generation-neutral discount rate.

Table 21. Present Value of Ecosystem Services Provided by the Project Using a Zero Discount Rate *(in Millions US$)*

Time Horizon	Low Estimate	High Estimate
100	13.4	48.4
250	33.5	121.0
500	67.0	242.0

5. <u>The San Souci Reach Ecosystem Service Valuation</u>

5.1 San Souci Reach Area Description

The San Souci Reach of the Tolt River comprises 57 properties totaling 77 acres upstream from the town of Carnation. The Earth Economics team conducted a survey of the area to ground-truth the GIS vegetative data and to build a strong understanding of the natural processes within the Reach. The area is composed of natural riparian floodplain with strong native vegetation and some invasive species including butterfly bush (*buddleia davidii*) and Himalayan blackberry (*rubus discolor*).

The San Souci Reach of the Tolt River is dynamic. During the previous winter, a three-acre area noted in the GIS data as having forest cover had been washed out and replaced with a large gravel bar. Colonizing species, both native and invasive, are becoming established. The increase in urban land area due to new housing developments was also notable.

Despite the high quality of the natural riparian habitat, new housing developments are encroaching closer to the river. These housing areas are not yet significantly affecting the riparian buffer of the river. Without outright SPU ownership or the purchase of easements, the current ecological quality of the reach is not ensured.

5.2 Valuation of the San Souci Reach

5.2.1 Ecosystem Service Valuation of Existing Site

The San Souci Reach provides the full range of ecological services identified earlier (section 2.3.1). To better understand the services provided by the San Souci Reach and their value to society, Earth Economics conducted an ecosystem service valuation of its properties based on current GIS data provided by SPU with minor corrections determined by the ground survey. The valuation was carried out using the same benefit transfer ecosystem service valuations methods described in section 2.3. Table 22 summarizes the valuation results.

Table 22. Value of Ecosystem Services Provided Annually by San Souci Reach Properties *(in $US)*

Ecosystem Category	Low Estimate	Low Estimate
Forest	213,000	797,000
Urban	1,000	4,000
Open River	1,000	4,000
Wetlands	6,000	23,000
Total Values	**$ 221,000**	**$ 828,000**

The San Souci Reach is estimated to have 53 acres of forest, 10.7 acres of housing developments, 8.1 acres of river, and 5.7 acres of riparian wetlands. **The total range of annual ecosystem benefits provided by the ecosystems (77 acres in total) of the San Souci Reach is estimated to be $221,000-828,000.** The present value of these ecosystem services is $3.4-12.7 million (7% discount rate), or $4.6-17.4 million (5% discount rate) and $6.5-24.5 million (3.5% discount rate). For reasons listed in previous analyses, the lower and upper ranges are both very likely underestimates of the true lower and upper boundaries.

5.2.2 Net Enhancement of Ecosystem Service Values with the Project

Acquisition of properties in the San Souci Reach would preserve critical ecosystem processes and ecological services while preventing future land conversion and the loss of these valuable processes and services.

While purchase of the land or acquisition of conservation easements redounds to the long-term interest of the public and SPU, and may well prevent the necessity for further restoration, this shift in land ownership per se does not confer any increased "net" value to the ecosystem services provided without a projected land use change. Self-interested actions of local land owners could result in vegetative destruction or ecological process changes that would degrade the ecological services provided. This would likely result in a substantial loss of benefits and potentially substantial costs incurred by the public.

SPU ownership would secure these lands and their provision of current and future ecosystem services. In comparison, the Tolt River Levee Restoration and Habitat Preservation Project transforms ecosystem processes, habitat and vegetative cover on 50 acres providing enhanced ecosystem services, this study calculates an expected present value from the project.

5.2.3 Present Value of Ecosystem Services in the San Souci Reach

Since the purchase of San Souci Reach properties will not necessarily result in a net change in ecological processes, vegetative cover, or restoration of habitat in the short run, there is no calculation of a present value on account of the purchase's net enhancement of ecosystem service values. However, the present value of the annual flow of ecosystem services is important, can be calculated and was included in the scope for this study.

Calculation of the present value of San Souci Reach ecosystem services is also sensitive to the discount rate. Table 23 shows the PV for high and low values for the three different discount rates.

Table 23: Present Value of Ecosystem Services Provided by San Souci Reach *(in Millions $US)*

Discount Rate	Low Estimate	High Estimate
7%	3.4	12.7
5%	4.6	17.4
3.5%	6.5	24.5

Most of the beneficiaries of these ecosystem services will live in the (discounted) future. We calculated present values with a zero discount rate for three time horizons to illustrate the magnitude of value provided by San Souci Reach ecosystem services across generations. This assumes that the value of ecosystem services provided to beneficiaries is equal across time. Each generation throughout the time period is treated equally. The calcutions are presented in Table 24.

Table 24. Present Value of Ecosystem Services Provided by San Souci Reach Using a Zero Discount Rate *(in Millions US$)*

Time Horizon	Low Estimate	High Estimate
100	22.1	82.8
250	55.1	206.9
500	110.3	413.8

6. Hancock Ecosystem Service Valuation

6.1 Hancock Area Description

Hancock Timber Resource Group owns significant timberlands in the Tolt River watershed. Earth Economics examined a six mile stretch along the San Souci Reach of the Tolt just upriver of the town of Carnation. The 186 acre strip of timberlands that were valued extends 150 feet beyond the current 150 foot buffer from the Tolt River's edge for a length of six miles. An SPU purchase of a conservation easement would extend the current buffer to 300 feet from the Tolt River along this reach. This will protect the additional 186 acres and help secure the ecosystem services provided by those lands. The GIS data provided by SPU was used by Earth Economics and slightly modified after a ground survey through about one third of the property and an ocular survey of the remaining lands.

This six mile length of the Tolt River is primarily forest habitat within the Tolt floodplain. The 150 foot band of land between 150 feet and 300 feet off the Tolt River comprises 9.1 acres of transitional forest, 41.1 acres deciduous forest, 104.8 acres of evergreen forest, 26.5 acres of mixed forest, and 5.3 acres of shrub lands. Some of the deciduous forestlands, primarily cottonwood stands, may be mature while most of the evergreen forests are not.

Hancock could log areas within this 150 foot strip of buffer land, reducing ecosystem services and potentially impacting salmon habitat.

6.2 Valuation of the Hancock Easement

6.2.1 Ecosystem Service Valuation of Existing Site

The Hancock land provides forest ecological services identified earlier (section 2.3.1). Earth Economics conducted an ecosystem service valuation of the Hancock buffer area based on current GIS data provided by SPU. The valuation was carried out using the same benefit transfer ecosystem service valuation methods described in section 2.3. Table 25 summarizes the valuation results.

Table 25. Value of Ecosystem Services Provided Annually by SPU Identified Hancock Easement Area *(in $US)*

Ecosystem Category	Low Estimate	High Estimate
Forest	1,178,000	4,342,000
Grassland and shrublands	29,000	111,000
Total Values	**$ 1,207,000**	**$ 4,453,000**

The range of value for ecosystem services provided by this additional buffer were calculated to be $1,207,000–4,453,000 annually with present value of $18.5-68.1 million (7% discount rate), $25.4-93.5 million (5% discount rate), and $35.7-131.7 million (3.5% discount rate). This is significant in value. For the reasons listed in previous analyses, the lower and upper ranges are very likely both underestimates of the true lower and upper boundaries.

6.2.2 Net Enhancement of Ecosystem Service Values with the Project

The purchase of a conservation easement from Hancock Timber Group is in the public interest due to the large number of ecological services provided and their high value. Otherwise, logging by Hancock would result in vegetative destruction, and possibly ecological process changes degrading the ecological services provided. The degraded buffer could also threaten Chinook salmon habitat in this section of the Tolt River. The potential loss of public benefits could be avoided by the purchase of a conservation easement.

As long as Hancock Timber Group does not log these timberlands, these ecosystem services will be produced whether or not SPU purchases a conservation easement. If Hancock cut the timber tomorrow, there would be a significant impact on ecosystem services. Should Hancock cut it in 20 years, the impact would not be as great as measured in present value and SPU will gain time to acquire an easement on these lands prior to a timber harvest.

The acquisition of the conservation easement on the proposed Hancock buffer as an alternative to the Tolt River Levee Restoration and Habitat Preservation Project presents the same difficulty discussed in the San Souci case. It represents comparing a protection measure, the purchase of certain property rights with a conservation easement, to a restoration project that changes ecosystems and habitat. The buffer expansion would prevent conversion or potentially damaging logging practices and avoid future costs for an unknown gain in ecosystem services in the future. The Tolt River Levee Restoration and Habitat Preservation Project recreates natural processes on 50 acres of habitat for a net gain in ecosystem services which can be estimated.

While purchase of a conservation easement is in the long-term interest of the public and SPU, a shift in land ownership does not automatically confer any increased value to the ecosystem services. Changes in land use, ecological process, and overall supply or demand will change ecosystem service values. Should there be a dramatic change in land use, such as a zoning change and residential construction or logging, the impact on ecosystem service values would be large. SPU ownership would secure these lands and their provision of current and future ecosystem services.

Calculating a gain from a conservation easement on the buffer was not part of the scope of this study. It would depend on the harvest and land management strategy of Hancock Timber. However, the Hancock buffer area does provide a flow of annual benefits and this was within the scope of this study.

6.2.3 Present Value of Ecosystem Services in the Hancock Easement

The scope of this study did not include a present value calculation of the purchase of land or conservation easements on the Hancock buffer. Without a change in ecological processes, vegetative cover, or restoration of habitat, there is no calculation of a present value due to the net enhancement of ecosystem service values with the purchase as conducted for the habitat changes in the Tolt River Levee Restoration and Habitat Project.

The present value of the annual flow of ecosystem services derived from these lands in their current condition is important and can be calculated. Calculation of the present value of Hancock Easement's ecosystem services is also sensitive to the discount rate. Table 26 presents the high and low present values for the three discount rates.

Table 26: Present Value of Ecosystem Services Provided on Hancock Easement *(in Millions $US)*

Discount Rate	Low Estimate	High Estimate
7%	18.5	68.1
5%	25.4	93.5
3.5%	35.7	131.7

Most of the beneficiaries of these ecosystem services will live in the (discounted) future. To illustrate the magnitude of value provided by the Hancock buffer area ecosystem services across generations, present values calculated with a zero discount rate for three time horizons were prepared. This assumes that the value of ecosystem services provided to beneficiaries is equal across time. Each generation throughout each time period was treated equally. The results are presented in Table 27.

Table 27. Present Value of Ecosystem Services Provided by the Hancock Easement Using a Zero Discount Rate *(Millions of US$)*

Time Horizon	Low Estimate	High Estimate
100	120.7	445.3
250	301.8	1,113.2
500	603.5	2,226.5

7. <u>Conclusions</u>

This study was conducted in support of the ongoing process at SPU to develop an asset management plan for the Tolt River Levee Restoration and Habitat Preservation Project and examine the value of ecosystem services for a variety of properties in the Tolt River watershed. Earth Economics conducted several economic valuation analyses which included the entire 63,800 acre Tolt River watershed: the portion of the south fork of the Tolt River (lower basin lands) owned by SPU; the portion of the south fork of the Tolt River (upper basin lands) owned by the US Forest Service, as well as a combined value of SPU and USFS lands; the proposed Tolt River Levee Restoration and Habitat Preservation Project on including the value of ecological goods and services provided by the site before and after restoration, as well as the net benefits of the project; the San Souci Reach area, upriver from Carnation, as delineated by SPU; and the Hancock Easement, a six mile strip of land between 150-300 feet from the Tolt River, as identified by SPU, which would double the riparian buffer from the current 150 foot riparian buffer.

The Earth Economics team first estimated the range of economic values for ecological goods and services produced annually by 63,800 acres of the Tolt River watershed. It then estimated the potential net value of ecosystem services produced by the proposed Tolt River levee Restoration and Habitat Preservation Project.

Using GIS data provided by SPU staff on vegetation types across 63,800 acres of the Tolt River watershed, Earth Economics estimated the range of annual value provided by Tolt River watershed ecosystem services at $368-1,364 million. This gave a PV of $5.6-20.9 billion at a 7% discount rate. A 3.5% discount rate, more commonly used for renewable, self-sustaining ecosystem services provides a range of $10.9-40.3 billion annually. These numbers are likely underestimates for both the low and high ends of the ranges.

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

Calculation of the present value does not capture a full picture of the benefits for people in the future. For informational purposes, calculations of values generated by the watershed and by the project were calculated with a zero discount rate. Estimated ecosystem service benefits provided by the Tolt River watershed total $36.8-136.4 billion over 100 years at a zero 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.

Earth Economics analyzed the 8,373 acres of the SPU lands in the lower basin of the Tolt River watershed which provide an estimated range of annual ecosystem benefits of $40.8-148.1 million. The range of present value at a 7% discount rate is $0.6-2.3 billion, or $0.9-3.1 billion at a 5% discount rate, and $1.2-4.4 billion at a 3.5% discount rate.

The 3,689 acres owned by the US Forest Service were estimated to produce an annual range of benefits of $22.3-80.4 million with present values of $0.3-1.2 billion (7% discount rate), $0.5-1.7 billion (5% discount rate), and $0.7-2.4 billion (3.5% discount rate). The estimated combined value of ecosystem goods and services produced by the SPU and USFS lands is $63.2-228.5 million annually with present values of $1.0-3.5 billion (7% discount rate), $1.3-4.8 billion (5% discount rate), $1.9-6.8 billion (3.5% discount rate).

An ecological economics analysis of the Tolt River Levee Restoration and Habitat Preservation Project was also examined. Two valuations were conducted, including valuations of the ecosystem services provided by the site in current conditions (levied off from the Tolt River watershed) and of the projected future conditions resulting from project completion. The net benefits of the project in terms of ecosystem services provided are estimated to range annually between $134,000-484,000. This provides a PV of $2.1-7.4 million at a 7% discount rate, or $4.0-14.3 million at a 3.5% discount rate.

This project appears to be justified based on the public benefits and value provided by ecosystem services alone. The investment in the restoration of natural riparian processes in the lower Tolt River is more than an investment in Chinook salmon restoration. It is an investment in natural capital and the full suite of public benefits which a healthy ecosystem provides.

For informational purposes, the flow/flux of benefits from these net benefits was also calculated using a zero discount rate. The Tolt River Levee Restoration and Habitat Preservation Project will provide an estimated $13.4-48.4 million in ecosystem service benefits across 100 years at a zero discount rate.

The San Souci Reach on the Tolt River comprises 57 properties totaling 77 acres upstream from the town of Carnation. This land was estimated to produce a total range of annual ecosystem benefits of $221,000-828,000. The range of present value for this annual stream of benefits is estimated at a 7% discount rate to be $3.4-12.7 million, or $4.6-17.4 million at a 5% discount rate, and $6.5-24.5 million at a 3.5% discount rate.

Earth Economics also valued 186 acres along a six mile length of the Tolt River San Souci Reach (just upriver of the town of Carnation) currently owned by Hancock Timber Resource Group. This 186 acre strip of timberlands extends beyond the current 150-foot buffer from the river's edge to 150-300 feet from the Tolt River for six miles. Acquisition of an easement on these lands would increase protection for the San Souci Reach. The range of value for ecosystem services provided by this additional buffer was calculated to be $1,207,000-4,453,000 annually with a present value of $18.5-68.1 million at 7% discount rate, $25.4-93.5 million at 5% discount rate, and $35.7-131.7 million at 3.5% discount rate.

SPU is managing a very large natural asset ($5.6-40.3 billion, low value at 7% discount rate to high value at 3.5% discount rate) in the Tolt River watershed. SPU should consider the natural assets in any Tolt River asset management plan, in the Cedar River watershed, and in other areas where it has substantial natural asset holdings.

This analysis does not include the benefits of successful early actions and avoidance of a Chinook salmon endangered species listing. Clearly, if the threatened Chinook salmon continue to decline in the Snoqualmie and Tolt Rivers, and if at a later date SPU is forced to take action under an endangered listing of Chinook salmon, the costs of Chinook restoration are likely to be far higher, less certain, of greater risk for water removal, and will have a greater overall financial uncertainty.

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 Tolt River watershed 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, then currently threatened populations might recover, preventing an ecological slide resulting in a significantly larger number of threatened and endangered species.

SPU, a watershed utility, manages substantial land holdings in the Tolt River with natural assets providing a suite of 23 highly valuable ecosystem goods and services. SPU charges for very few of these public goods and services—only water supply and water filtration. The Tolt River watershed also provides flood protection, natural drought mitigation, nutrient flows, biodiversity, salmon habitat, aesthetic value, and other public goods and services. Most of these highly valuable services are public services which are non-excludable or benefit everyone. A public utility is well suited to manage these public services efficiently on a watershed scale.

In ecological systems where a large number of highly valuable public goods are produced, private owners will manage based on very few private excludable products that benefit a few (e.g., timber) at the expense of more valuable public goods and services which benefit all. This scenario is different from the tragedy of the commons where privatization is a viable solution.

Consider public goods that are non-excludable and non-rival, i.e. those receiving flood protection benefits from a healthy watershed 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, refugia, nursery value, aesthetic value, etc.

A public utility is the most efficient institution for managing the full suite of ecosystem goods and services which 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 managing a watershed for the full suite of public goods and services efficiently 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. A watershed utility could bill for the provision and filtration of water, which would include the human-built capital of a delivery system and the natural capital system producing and contributing to filtration. Water users would be billed accordingly. The same watershed also provides flood protection benefits. The floodplain beneficiaries could also be billed for these benefits and the funds used to reinvest in the health of the watershed, which 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. The County has also shown that it is more economically viable to purchase some properties and widen the floodplain (increasing floodplain health) rather than continually pay for flood damage to property owners who 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 SPU holdings in the Tolt River watershed are large and highly valuable. SPU should consider a more detailed analysis of the ecosystem goods and services that the Tolt River watershed provides, as well as the distribution of these services to beneficiaries.
2. The Tolt River Levee Restoration and Habitat Preservation Project supplies sufficient ecosystem service benefits to justify several million dollars of 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. SPU should consider natural assets more fully in asset management planning, particularly in areas like the Cedar River watershed.
4. SPU should partner with other organizations and agencies to increase the knowledge base on Northwest ecosystem services provided by watersheds, specifically the watersheds where SPU has holdings and interests.
5. Because of extensive watershed land holdings, SPU is a watershed utility even though it does not manage watershed assets with full information on the value of goods and services that these assets provide. SPU should conduct a full survey of ecosystem services provided by the utility.
6. The public should be informed of ecosystem services and their value, which SPU provides. SPU should include ecosystem services and values in communications with customers and owners.
7. SPU 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 SPU watersheds 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 SPU has initiated a path breaking step of valuing the full range of ecosystem services provided on SPU lands and other lands in the Tolt River watershed, and further, by including this analysis in asset management. The valuation of the proposed Tolt River Levee Restoration and Habitat Preservation Project is also on the forefront of the of ecosystem service analysis and is critical to understanding the full suite of ecosystem service benefits. SPU should continue with the inclusion of ecosystem services in asset management planning and project analysis, and proceed with informing the pubic of the full range and value of benefits that SPU provides.

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Appendices

Appendix A. Brief Descriptions of Some Ecosystem Services

A great number of studies examine the economic value of ecological services. These studies can be land use, vegetation type, or service based. A few services and valuation studies are discussed below.

Storm Protection and Flood Protection

Storm water management and flood protection provided by wetlands and other ecosystems are of vast value (Farber and Costanza 1987; Kenyon and Nevin 2001; Thibodeau and Ostro 1981). Wetlands between the Gulf States and the Gulf of Mexico, for example, provide buffer functions against hurricanes and tidal surges. As wetland buffers between the Gulf of Mexico and New Orleans have been lost, storm damage has increased dramatically. Existing wetlands prevent billions of dollars in storm damage from a single storm.

A Washington State wetlands study within WRIA 9 assessed the value of flood protection provided by wetlands in Renton, finding that Renton wetlands yielded flood protection benefits worth $41,300/acre to $48,200/acre (Leschine et al. 1997). Similarly, a draft study conducted in Portland, Oregon indicates that creation of a wetland to prevent flooding in a frequently flooded area of southeast Portland would prevent damage amounting to more than $500,000 per flood. This figure is based on actual damages to local homeowners in previous floods in the area (Rojas-Burke 2004).

Water Quality and Supply

Regulation of the quality and supply of water is perhaps the most recognized and studied ecosystem service. Studies have shown that the value of marginal improvements in water quality for specific areas range from $100 to over $1,000 per hectare (Bocksteal et al. 1988; Bouwes and Scheider 1979; Ribaudo and Epp 1984; d'Arge 1989; Desvousages et al. 1987; Cho 1990). Riparian forest buffers are estimated to reduce runoff nitrate levels by 84% and reduce sediment by more than 80% (Northeast Midwest Institute 2004).

Water purification services provided by natural ecosystems are far less expensive than water filtration and treatment facilities. New York City provided over $1.5 billion in watershed conservation measures to restore natural ecosystem filtration to meet water quality standards, rather than spend $8 billion (plus annual maintenance costs) to build a filtration plant (Krieger, 2001). Other jurisdictions have followed a similar pattern. To avoid the need to build a $200 million water filtration plant with additional maintenance and operating expenses, Portland, Oregon spends $920,000 annually to protect and restore the Bull Run watershed, maintaining the natural filtration of its drinking water supply (Krieger 2001). Annual operating costs of artificial water filtration vary. The estimated annual operating costs alone of water filtration facilities in Portland, Maine were $750,000, $3.2 million in Salem, Oregon, and $300 million in New York City (Krieger 2001). Healthy watershed ecosystems permanently provide filtration services, largely for free without capital, maintenance or operating costs.

Trees: Storm Water, Climate Regulation, and Atmospheric Pollutant Removal
Healthy ecosystems provide many bundles of services. Within these systems, trees provide a number of critical ecosystem services, and climate and air regulation have also been valued. One acre of forest can remove 40 tons of carbon from the air and produce 108 tons of oxygen annually (Northeast Midwest Institute 2004). Market values of carbon sequestration range from $10 – 100 per ton (Antle et al. 1999; McCarl et al. 2000; Haener and Adamowicz 2000) and $650 to $3,500 per hectare (Bishop and Landell-Mills 2002).

The level of service will differ based on the ecosystem structure (Bishop and Landell-Mills 2002). For example, a Douglas Fir forest plantation, planted ten years ago will not produce the same services as a natural old growth forest with a variety of tree sizes and species. Carbon sequestration in King County was estimated at about 56 million metric tons in 2000, and is predicted to average about 68 tons per acre in 2005, but the service varies significantly between types of growth (Turnblom et al. 2002).

The environmental purification and recovery of mobile nutrients – waste treatment services – provided by forests have been valued at $35 per acre (Loomis and Richardson 2000). Using land cover analysis, a 1998 report by American Forests related changes in the amount of vegetation and tree cover in the Puget Sound region to storm water management and air quality. The report placed an economic value on the ecology of the most urbanized parts of the Puget Sound watershed. The analysis valued the air quality by pollutants removed by the canopy cover at $166.5 million annually, and estimated storm water benefits amounting to $5.9 billion annually. Forestland is estimated to save about $21,000 per acre in storm water retention costs by capturing up to 50% of rainfall in the region (American Forests 1998).

Waste Treatment
Wetlands provide another important function for purifying water. A 1990 study found that the 11,000-acre Congaree Bottomland Hardwood Swamp in South Carolina removed the same amount of pollutants as the equivalent of a $5 million wastewater treatment plant (EPA 2003). A study in Georgia revealed that a 2,500-acre wetland saves taxpayers $1 million in water pollution abatement costs (EPA 2003).

Agricultural lands
One land use and policy based study (Ribaudo et al., 1989) estimated the following average benefit per acre of agricultural land under the US Conservation Reserve Program: soil productivity: $36; water quality: $79; air quality: $12; and wildlife: $86.

Pollination
Honeybees have been valued as natural pollinators for American cropland at $9 - $20 per hectare, and pollination services provided to US agriculture by all other pollinators are estimated at over $4 billion annually (Southwick and Southwick 1992).

Pest Control

Natural systems also provide pest control services. Estimates indicate that it would cost more than $7 per acre to replace the pest control services provided by birds in forests with chemical pesticides (Krieger 2001).

Recreational Value

Another valuable service that ecosystems provide is recreation. Uses such as fishing and hunting have been valued between $3 and $54 per trip (Adamowicz 1991). The fish and wildlife sector is a major economic force in Washington. Over $854 million was spent in 2002 on recreational fishing alone, while an additional $980 million was spent on wildlife viewing and $408 million on hunting (WDFW 2002). Commercial fishing added $140 million to the Washington economy in 2002 (WDFW 2002). Wildlife watching alone generates significantly more revenue for Washington's economy than the apple industry. It supports over 21,000 jobs in the state, more than any other Washington employer besides Boeing (WDFW 1997). Studies have found water quality for recreational purposes to be valued at $10 and $80 per year (Adamowicz 1991).

Aesthetic Value

Wetlands and other healthy ecosystems also provide aesthetic value, and the higher property prices around wetlands and forests reflect this phenomenon. A study in the Portland, Oregon area found that residential property values increased $436 for every 1,000 feet closer that a property was to a wetland (Mahan et al. 2000). Additional research has also assessed how other environmental amenities enhance property values (Crompton 2001; Anderson and Cordell 1988; Laverne and Winson-Geideman 2003; Dorfman et al. 1996).

Contingency Valuation, Restoration and Species Preservation

Contingency valuation establishes values for non-market goods by interviewing human stakeholders. Habitat valuations depend on the species that the habitat is for, and the use of those species for human demand. Many habitats are valued based on species used for consumption, such as oyster and other seafood production (Batie and Wilson 1978). Many other habitats are protected for valued megafauna (bear, elk, wolves) and protected endangered species. Studies of household values in the Pacific Northwest reflect strong preferences for protection of forests, fish and wildlife. In a study of estuarine function, residents of the Tillamook, Oregon area estimated the value of each additional acre of salmon habitat at approximately $5,000 (Gregory and Wellman 2001). Olsen and others (1991) found that households in the Pacific Northwest were willing to pay between $26-74 per year to double the size of the salmon and steelhead runs in the Columbia River (Quigley 1997). Another study found that Oregon households were willing to pay $2.50 to $7.00 per month to protect or restore salmon, a cumulative total of $2 million to $8.75 million dollars per month (ECONorthwest 1999). The mean annual value per household of river and fishery restoration on the Olympic Peninsula was $59 in Clallam County and $73 for the rest of Washington (Loomis 1996). Another study found Oregon households willing to pay $380 annually to increase preservation of old growth forests, $250 per year to increase endangered species protections, and $144 to increase protection for salmon habitat (Garber-Yonts et al. 2004).

Appendix B. Present Value of Ecosystem Services in the Tolt River Watershed Accrued Over 100 Years, Discount Rate = 7%

Year	Minimum	Maximum	Year	Minimum	Maximum
0	$368,354,000	$1,363,781,000	51	$11,686,722	$43,268,513
1	$344,256,075	$1,274,561,682	52	$10,922,170	$40,437,863
2	$321,734,649	$1,191,179,142	53	$10,207,636	$37,792,395
3	$300,686,588	$1,113,251,535	54	$9,539,847	$35,319,996
4	$281,015,503	$1,040,421,995	55	$8,915,745	$33,009,342
5	$262,631,311	$972,357,005	56	$8,332,472	$30,849,852
6	$245,449,824	$908,744,864	57	$7,787,357	$28,831,637
7	$229,392,358	$849,294,266	58	$7,277,903	$26,945,456
8	$214,385,382	$793,732,959	59	$6,801,779	$25,182,669
9	$200,360,170	$741,806,503	60	$6,356,803	$23,535,204
10	$187,252,495	$693,277,106	61	$5,940,937	$21,995,518
11	$175,002,332	$647,922,529	62	$5,552,278	$20,556,559
12	$163,553,581	$605,535,074	63	$5,189,045	$19,211,737
13	$152,853,814	$565,920,630	64	$4,849,574	$17,954,895
14	$142,854,032	$528,897,785	65	$4,532,312	$16,780,275
15	$133,508,441	$494,296,995	66	$4,235,806	$15,682,500
16	$124,774,244	$461,959,809	67	$3,958,697	$14,656,542
17	$116,611,443	$431,738,139	68	$3,699,717	$13,697,703
18	$108,982,657	$403,493,588	69	$3,457,679	$12,801,592
19	$101,852,950	$377,096,811	70	$3,231,476	$11,964,104
20	$95,189,673	$352,426,926	71	$3,020,071	$11,181,406
21	$88,962,312	$329,370,959	72	$2,822,496	$10,449,912
22	$83,142,347	$307,823,326	73	$2,637,847	$9,766,273
23	$77,703,128	$287,685,352	74	$2,465,278	$9,127,358
24	$72,619,746	$268,864,815	75	$2,303,998	$8,530,241
25	$67,868,922	$251,275,528	76	$2,153,269	$7,972,188
26	$63,428,899	$234,836,942	77	$2,012,401	$7,450,643
27	$59,279,345	$219,473,777	78	$1,880,749	$6,963,218
28	$55,401,257	$205,115,680	79	$1,757,709	$6,507,680
29	$51,776,875	$191,696,897	80	$1,642,719	$6,081,944
30	$48,389,603	$179,155,978	81	$1,535,251	$5,684,060
31	$45,223,928	$167,435,494	82	$1,434,814	$5,312,205
32	$42,265,353	$156,481,770	83	$1,340,948	$4,964,678
33	$39,500,330	$146,244,645	84	$1,253,222	$4,639,886
34	$36,916,196	$136,677,238	85	$1,171,236	$4,336,342
35	$34,501,118	$127,735,737	86	$1,094,613	$4,052,656
36	$32,244,036	$119,379,193	87	$1,023,003	$3,787,529
37	$30,134,613	$111,569,339	88	$956,077	$3,539,747
38	$28,163,190	$104,270,411	89	$893,530	$3,308,175
39	$26,320,738	$97,448,982	90	$835,075	$3,091,752
40	$24,598,820	$91,073,815	91	$780,444	$2,889,488
41	$22,989,552	$85,115,715	92	$729,387	$2,700,456
42	$21,485,562	$79,547,397	93	$681,670	$2,523,791
43	$20,079,965	$74,343,362	94	$637,075	$2,358,683
44	$18,766,322	$69,479,777	95	$595,397	$2,204,376
45	$17,538,619	$64,934,371	96	$556,446	$2,060,165

46	$16,391,233	$60,686,328	97	$520,043	$1,925,388
47	$15,318,909	$56,716,195	98	$486,021	$1,799,428
48	$14,316,737	$53,005,789	99	$454,225	$1,681,708
49	$13,380,128	$49,538,121	100	$424,510	$1,571,690
50	$12,504,793	$46,297,309	**Present Value: $5,624,489,576—$20,823,914,001** **PV (500 years): $5,630,554,000—$20,846,366,714**		

Appendix C. Present Value of Ecosystem Services in the Tolt River Watershed Accrued Over 100 Years, Discount Rate = 5%

Year	Minimum	Maximum	Year	Minimum	Maximum
0	$368,354,000	$1,363,781,000	51	$30,592,230	$113,263,606
1	$350,813,333	$1,298,839,048	52	$29,135,457	$107,870,101
2	$334,107,937	$1,236,989,569	53	$27,748,055	$102,733,429
3	$318,198,035	$1,178,085,304	54	$26,426,719	$97,841,361
4	$303,045,747	$1,121,986,004	55	$25,168,303	$93,182,249
5	$288,614,998	$1,068,558,099	56	$23,969,813	$88,744,999
6	$274,871,426	$1,017,674,380	57	$22,828,393	$84,519,046
7	$261,782,311	$969,213,695	58	$21,741,327	$80,494,330
8	$249,316,486	$923,060,662	59	$20,706,026	$76,661,267
9	$237,444,273	$879,105,392	60	$19,720,024	$73,010,730
10	$226,137,403	$837,243,231	61	$18,780,976	$69,534,029
11	$215,368,955	$797,374,506	62	$17,886,643	$66,222,884
12	$205,113,290	$759,404,291	63	$17,034,898	$63,069,414
13	$195,345,991	$723,242,182	64	$16,223,713	$60,066,108
14	$186,043,801	$688,802,078	65	$15,451,155	$57,205,817
15	$177,184,572	$656,001,979	66	$14,715,386	$54,481,731
16	$168,747,212	$624,763,790	67	$14,014,653	$51,887,363
17	$160,711,630	$595,013,133	68	$13,347,289	$49,416,536
18	$153,058,695	$566,679,174	69	$12,711,704	$47,063,368
19	$145,770,186	$539,694,452	70	$12,106,384	$44,822,255
20	$138,828,749	$513,994,716	71	$11,529,890	$42,687,862
21	$132,217,856	$489,518,777	72	$10,980,847	$40,655,106
22	$125,921,767	$466,208,359	73	$10,457,950	$38,719,149
23	$119,925,493	$444,007,961	74	$9,959,952	$36,875,380
24	$114,214,755	$422,864,725	75	$9,485,669	$35,119,410
25	$108,775,957	$402,728,309	76	$9,033,970	$33,447,057
26	$103,596,150	$383,550,771	77	$8,603,781	$31,854,340
27	$98,663,000	$365,286,448	78	$8,194,077	$30,337,466
28	$93,964,762	$347,891,856	79	$7,803,883	$28,892,825
29	$89,490,249	$331,325,577	80	$7,432,270	$27,516,976
30	$85,228,809	$315,548,168	81	$7,078,352	$26,206,644
31	$81,170,294	$300,522,065	82	$6,741,288	$24,958,709
32	$77,305,042	$286,211,491	83	$6,420,274	$23,770,199
33	$73,623,849	$272,582,372	84	$6,114,547	$22,638,285
34	$70,117,952	$259,602,259	85	$5,823,378	$21,560,271
35	$66,779,002	$247,240,247	86	$5,546,074	$20,533,591
36	$63,599,049	$235,466,902	87	$5,281,975	$19,555,801
37	$60,570,523	$224,254,192	88	$5,030,453	$18,624,573
38	$57,686,213	$213,575,421	89	$4,790,907	$17,737,688
39	$54,939,250	$203,405,163	90	$4,562,769	$16,893,036

40	$52,323,095	$193,719,203	91	$4,345,494	$16,088,606
41	$49,831,519	$184,494,479	92	$4,138,566	$15,322,482
42	$47,458,590	$175,709,027	93	$3,941,491	$14,592,840
43	$45,198,657	$167,341,931	94	$3,753,801	$13,897,943
44	$43,046,340	$159,373,267	95	$3,575,049	$13,236,136
45	$40,996,514	$151,784,064	96	$3,404,808	$12,605,844
46	$39,044,299	$144,556,252	97	$3,242,675	$12,005,566
47	$37,185,047	$137,672,621	98	$3,088,262	$11,433,872
48	$35,414,330	$131,116,782	99	$2,941,202	$10,889,402
49	$33,727,934	$124,873,125	100	$2,801,144	$10,370,859
50	$32,121,842	$118,926,786	**Present Value: $7,679,411,114—$28,431,983,821** **PV (500 Years): $7,735,434,000—$28,639,400,999**		

Appendix D. Present Value of Ecosystem Services in the Tolt River Watershed Accrued Over 100 Years, Discount Rate = 3.5%

Year	Minimum	Maximum	Year	Minimum	Maximum
0	$368,354,000	$1,363,781,000	51	$63,724,663	$235,931,971
1	$355,897,585	$1,317,662,802	52	$61,569,723	$227,953,595
2	$343,862,401	$1,273,104,156	53	$59,487,655	$220,245,020
3	$332,234,203	$1,230,052,325	54	$57,475,995	$212,797,120
4	$320,999,230	$1,188,456,353	55	$55,532,363	$205,601,083
5	$310,144,184	$1,148,267,007	56	$53,654,457	$198,648,389
6	$299,656,216	$1,109,436,722	57	$51,840,055	$191,930,811
7	$289,522,914	$1,071,919,538	58	$50,087,009	$185,440,397
8	$279,732,284	$1,035,671,052	59	$48,393,246	$179,169,465
9	$270,272,739	$1,000,648,359	60	$46,756,759	$173,110,595
10	$261,133,081	$966,810,009	61	$45,175,613	$167,256,613
11	$252,302,493	$934,115,950	62	$43,647,935	$161,600,592
12	$243,770,525	$902,527,488	63	$42,171,918	$156,135,838
13	$235,527,077	$872,007,235	64	$40,745,814	$150,855,882
14	$227,562,394	$842,519,068	65	$39,367,937	$145,754,476
15	$219,867,047	$814,028,085	66	$38,036,654	$140,825,580
16	$212,431,929	$786,500,565	67	$36,750,390	$136,063,363
17	$205,248,241	$759,903,928	68	$35,507,623	$131,462,186
18	$198,307,479	$734,206,693	69	$34,306,882	$127,016,605
19	$191,601,429	$709,378,448	70	$33,146,746	$122,721,357
20	$185,122,154	$685,389,804	71	$32,025,842	$118,571,360
21	$178,861,984	$662,212,371	72	$30,942,842	$114,561,700
22	$172,813,511	$639,818,716	73	$29,896,466	$110,687,633
23	$166,969,576	$618,182,335	74	$28,885,474	$106,944,573
24	$161,323,262	$597,277,618	75	$27,908,671	$103,328,090
25	$155,867,886	$577,079,824	76	$26,964,900	$99,833,903
26	$150,596,991	$557,565,048	77	$26,053,043	$96,457,878
27	$145,504,340	$538,710,191	78	$25,172,022	$93,196,017
28	$140,583,903	$520,492,938	79	$24,320,794	$90,044,461
29	$135,829,858	$502,891,728	80	$23,498,352	$86,999,479
30	$131,236,578	$485,885,727	81	$22,703,722	$84,057,468
31	$126,798,626	$469,454,809	82	$21,935,963	$81,214,945
32	$122,510,750	$453,579,525	83	$21,194,167	$78,468,546
33	$118,367,874	$438,241,087	84	$20,477,456	$75,815,020

34	$114,365,096	$423,421,340	85	$19,784,982	$73,251,227
35	$110,497,677	$409,102,744	86	$19,115,925	$70,774,132
36	$106,761,040	$395,268,352	87	$18,469,492	$68,380,804
37	$103,150,764	$381,901,789	88	$17,844,920	$66,068,410
38	$99,662,574	$368,987,236	89	$17,241,469	$63,834,212
39	$96,292,342	$356,509,407	90	$16,658,424	$61,675,567
40	$93,036,079	$344,453,533	91	$16,095,096	$59,589,920
41	$89,889,931	$332,805,346	92	$15,550,817	$57,574,802
42	$86,850,175	$321,551,059	93	$15,024,944	$55,627,828
43	$83,913,213	$310,677,352	94	$14,516,854	$53,746,694
44	$81,075,568	$300,171,354	95	$14,025,946	$51,929,173
45	$78,333,882	$290,020,632	96	$13,551,639	$50,173,114
46	$75,684,910	$280,213,171	97	$13,093,371	$48,476,439
47	$73,125,517	$270,737,364	98	$12,650,600	$46,837,139
48	$70,652,673	$261,581,994	99	$12,222,802	$45,253,274
49	$68,263,453	$252,736,226	100	$11,809,470	$43,722,970
50	$65,955,027	$244,189,590	**Present Value: $10,555,340,569—$39,079,724,710** **PV (500 years): $10,892,753,644—$40,328,951,109**		