Benefit-Cost Analysis of Nature-Based Sediment Retention Strategies on the South Fork Toutle

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This report is prepared for the Lower Columbia Fish Enhancement Group and their partners.

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1 Executive Summary

The 1980 Mount St. Helens eruption fundamentally altered the Toutle and Cowlitz River systems, triggering decades of high sediment loads that continue to exacerbate flood risk, diminish fish habitat, and burden downstream communities with ongoing dredging and infrastructure costs.

As part of a system-wide sediment management approach that includes structural solutions on the North Fork Toutle, the Lower Columbia Fish Enhancement Group (LCFEG) is implementing nature-based restoration on the South Fork Toutle (SFT). These projects employ large wood and habitat-forming processes to slow water, store sediment, rebuild wetland and floodplain function, and restore ecological connectivity primarily for the purpose of improving salmon habitat. These nature-based solutions demonstrate a watershed-scale approach to sediment management that improves ecological resilience, even as it reduces downstream risk.

This report quantifies the environmental, social, and economic benefits of the SFT restoration project through an ecosystem services valuation, economic impact assessment, and benefit-cost analysis. Using Benefit Transfer Methods (BTM), Earth Economics estimates the value of 13 ecosystem services—including flood risk reduction, carbon sequestration, habitat improvement, water quality, and recreation.

Restoring the South Fork Toutle floodplain provides, on average, $78 million in ecosystem service benefits over 30 years ($54 million, discounted at 2 percent). Compared to the cost of restoring the entire SFT floodplain ($30 million), this results in a benefit-cost ratio of 2.59 (1.81 discounted at 2 percent), meaning that project benefits outweigh costs. Carbon sequestration, recreation, flood control, and water quality benefits are the largest contributors to total value.

In addition to nonmarket ecosystem service benefits, project investments generate substantial economic activity across Washington state. Construction-related expenditures are estimated to support $21 million in wages and nearly 400 regional jobs (full-time equivalents), reflecting both direct, indirect and induced spending and employment. Full-time equivalent (FTE) employment represents the total hours of work generated by the project expressed as full-time jobs over the total project timeline and does not imply that 400 distinct individuals are each employed full-time.

These results demonstrate that nature-based sediment management on the SFT is a cost-effective strategy that delivers significant co-benefits to communities, ecosystems, and the regional economy while also supporting long-term watershed resilience. This analysis provides an evidence base to inform future investments, including potential scaling of nature-based sediment retention strategies across the greater Toutle-Cowlitz watershed.

2 Introduction

2.1 Background on the South Fork Toutle

The 1980 Mount St. Helens eruption caused environmental, social, and economic impacts that are still felt today. This is particularly true of sediment transported by the eruption, which are still eroding and causing unprecedented sedimentation in the Cowlitz River. This degrades ecosystems and threatens fish populations, fills shipping lanes in the Lower Cowlitz and Columbia Rivers, worsens flood risk for downstream communities, and harms the local recreational economy which had largely been dependent on fish and wildlife populations (Committee on Long-Term Management of the Spirit Lake/Toutle River System in Southwest Washington et al., 2018). Elevated sedimentation continues, with no anticipated decline. As such, the watershed requires a long-term management plan using a variety of structural and nature-based strategies to effectively retain sediment in the headwaters, while improving other ecosystem conditions.

Following the eruption of Mount St. Helens, emergency response actions were rapidly implemented to protect downstream communities, including construction of the Sediment Retention Structure (SRS) on the North Fork Toutle River (NFT), the construction of the Spirit Lake tunnel, levee improvements to protect downstream communities, and ongoing dredging of the Lower Cowlitz and Columbia rivers. While these measures have been effective in reducing immediate risk, they were authorized and designed as emergency solutions. The SRS, built by the USACE in 1989, reached capacity in 1998. Since being raised in 2012, it filled again, leading the USACE to obtain approval for continued capacity expansions until 2035. In the interim, they continue to dredge the Lower Cowlitz and Columbia rivers to maintain current levels of flood protection for downstream communities. After more than 40 years of reliance on emergency authorities, management options have remained limited in scope and flexibility. LCFEG's nature-based sediment retention strategies build on this legacy of risk reduction by providing additional, long-term tools that work with natural river processes to improve system resilience and reduce downstream sediment impacts.

The Spirit Lake/Toutle-Cowlitz River Collaborative was established to develop and coordinate management solutions. The Lower Columbia Fish Enhancement Group (LCFEG) has begun collaborating with the Collaborative to implement nature-based sediment retention strategies on the NFT and South Fork Toutle (SFT) Rivers. These include one worksite on each river, as part of an ongoing 17-mile and 600-acre restoration initiative. Using large timber, they construct natural sediment retention structures that sequester sediment over time, slowly converting the barren floodplains into woody wetlands. By establishing new wetlands, these projects not only store sediment in the headwaters (thus complementing other structural control measures), but also provide multiple ecosystem services to benefit nearby and downstream communities.

As these projects mature, they will restore ecological functionality of the watershed, improving recreational experiences, providing additional salmon habitat, protecting communities, and more. This report supports continued implementation of nature-based strategies throughout the watershed by quantifying the environmental, social, and economic impacts (ecosystem services) provided by LCFEG's efforts on the SFT River. The analysis includes a holistic Benefit-Cost Analysis (BCA) that shows the broader return on investment for nature-based strategies. It provides a starting point to incentivize research on how scaling nature-based strategies within the watershed could address the lasting impacts of the Mount St. Helens eruption.

2.2 Purpose of This Report

This report offers a preliminary analysis of the economic value of co-benefits provided by nature-based solutions across the entire SFT watershed, evaluating the full 17 miles of restoration potential along the South Fork, where LCFEG is actively implementing projects. LCFEG has completed 3.5 miles as of 2025 and funded to complete an additional 2.5 miles by 2027. As restoration plans have not been fully finalized for some portions of the SFT, these results should be considered high-level estimates, demonstrating the magnitude of benefits provided by restoration.

This introduction includes a primer on ecosystem services and valuation techniques to familiarize readers with ecological economics concepts. The methods used to estimate the value of the ecosystem services provided by LCFEG's SFT project have also been described. The results have been reported by each type of ecosystem service to show how the project can address multiple issues experienced within the watershed. Finally, based on the results, next steps are recommended to guide future research.

2.3 An Ecosystem Services Primer

2.3.1 Why value ecosystem services

Including the non-market values of ecosystem services in decision-making leads to stronger, more informed decisions. Traditionally, these benefits have been excluded from accounting frameworks—effectively valued at $0—resulting in incomplete assessments of program or project worth. Ignoring this value can lead to inefficient investments and higher long-term costs. As natural systems are degraded, communities become more vulnerable and taxpayers pay to replace lost services (e.g., water filtration) with built infrastructure—and in many cases, lost ecosystem goods and services are irreplaceable. Recognizing and quantifying ecosystem services benefits is now a common approach to evaluating restoration projects like LCFEG's work on the South Fork Toutle, ensuring that decision-makers account for the full range of values that river restoration provides.

2.3.2 Natural capital, ecosystem function, and ecosystem services

Natural capital consists of any "minerals, energy, plants, animals, ecosystems, climatic processes, nutrient cycles, and other natural structures and systems found on Earth that provide a flow of natural goods and services" (Daly and Farley, 2004). As forests, wetlands, and rivers intercept rainfall and filter water, those natural storage and filtration processes support clean water supplies. Together, these provide the foundation for all human societies, yet such value is frequently overlooked. The flows of ecosystem goods and services produced by ecosystem functions are illustrated in Figure 1.

Figure 1. Natural Capital, Ecosystem Function, and Ecosystem Goods and Services.

Healthy landscapes support thriving communities and economies, with ecosystem services providing resources and critical processes to support industry and improve quality of life. There are many frameworks for categorizing ecosystem services. The commonly cited include the Millennium Ecosystem

Assessment framework (MEA) (Alcamo et al., 2003), The Economics of Ecosystems and Biodiversity framework [TEEB] (De Groot et al., 2010), the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services framework (IPBES, 2017), and the Common International Classification of Ecosystem Services [CICES] (Haines-Young & Potschin, 2018). The number of distinct services recognized varies widely; for instance, CICES includes over 100 services, while the MEA and TEEB frameworks name just 21. Generally, ecosystem services are organized into four broad categories:

- ***Provisioning services*** are tangible resources for human use, such as foods, water storage, energy, fuel, forage, fiber, and minerals.
- ***Regulating services*** maintain and provide buffers for natural processes, including: the long-term terrestrial storage of carbon; local and regional climate regulation; water capture, conveyance and supply; water quality; soil creation and retention; disaster risk reduction (e.g., flood control); pollination; and regulation of pest species and disease.
- ***Supporting services*** provide critical habitat and refugia for plants, animals, and other species throughout their lifecycles.
- ***Informational services*** support social, cultural, or spiritual needs, such as education; aesthetic beauty; spiritual and cultural heritage; and recreational and touristic experiences.

2.3.3 Estimating the Value of Ecosystem Services

Ecosystem service valuation is the process of quantifying the monetary value of these benefits. Some ecosystem goods and services are traded in markets (e.g., food, natural fibers, wetland credits), and for these, there are mechanisms to assign or impute monetary values using market prices. However, many other valuable ecosystem benefits are not traded in markets ("non-market" goods and services). To understand the economic value of these, economists use other means by which to estimate their value. Most non-market valuation methods are derived from either *stated preferences* or *revealed preferences*. Stated preference methods estimate value by directly asking people what they would be willing-to-pay for a particular resource (or accept for its loss). Revealed preference methods infer values by observing spending behavior in related markets, such as travel costs or variations in property values associated with specific amenities.

Secondary methods may also be used to estimate the value of ecosystem services. In such instances, researchers generalized published estimates to "transfer" sites sharing ecological and social characteristics. This is known as Benefit Transfer Method (BTM), broadly defined as "…the use of existing data or information in settings other than for what it was originally collected" (Richardson et al., 2015). BTM is frequently used to estimate the value of nonmarket goods or services, as it is often the most pragmatic option available for quickly generating reasonable estimates at-scale and at a fraction of the cost of conducting multiple primary studies. A common application of BTM are property appraisals, in which the value and features of comparable nearby properties that have recently sold (e.g., two bedrooms, garage, one acre, recently remodeled) are used to estimate the value of off-market property. Again, such results can be somewhat imprecise; their value comes from the ability to generate reasonable results (appropriate to support initial decision making) in a timely and cost-effective manner.

2.4 Economic Impact Primer

To understand how spending on the SFT restoration projects affects Washington's economy, Earth Economics conducted an economic impact analysis using secondary literature. An economic impact analysis estimates how spending in one sector (such as ecological restoration) circulates to other sectors through interconnected supply chains and household spending. For example, when money is invested in restoration projects, such spending ripples through the economy: construction firms buy materials, suppliers hire workers, and employees spend their wages in local communities.

These "ripple effects" are captured through three types of effects:

- **direct** effects (the immediate project spending),
- **indirect** effects (business-to-business purchases as industries resupply), and
- **induced** effects (household spending by workers whose income depends on those industries).

Together, these effects show the total economic impact of that initial spending.

These types of effects are shown across several economic indicators:

- **Output** is known as the overall value of goods and services generated.
- **Value added to GDP** represents the net contribution to local economies, after subtracting intermediate inputs from total economic output.
- **Employment** counts the number of full-, part-time, and seasonal jobs supported by spending. Such jobs are in full-time equivalents which aggregate total labor hours and may reflect a mix of part-time, seasonal, or short-term positions rather than total full-time jobs supported by project spending.
- **Labor income** is defined as wages earned by workers in affected industries.
- **Tax revenues** at local, state, and federal levels generated by direct, indirect, and induced spending.

Together, these provide a broad picture of the impact restoration investments can have on state and local economies. As the literature supporting this analysis reported only employment and wage effects, this report is limited to these indicators. Future research could incorporate more complex models that include all indicators described above.

2.5 Benefit-Cost Analysis and Asset Value Primer

Benefit-Cost Analysis (BCA) is a decision-making tool used to determine whether investments yield net gains. Benefit-cost ratios (BCRs) greater than 1.0 indicate that benefits exceed costs and are cost-effective. Benefits and costs are often projected over a project's full timeline and discounted to present-day dollars to facilitate comparison of projects of varying durations.

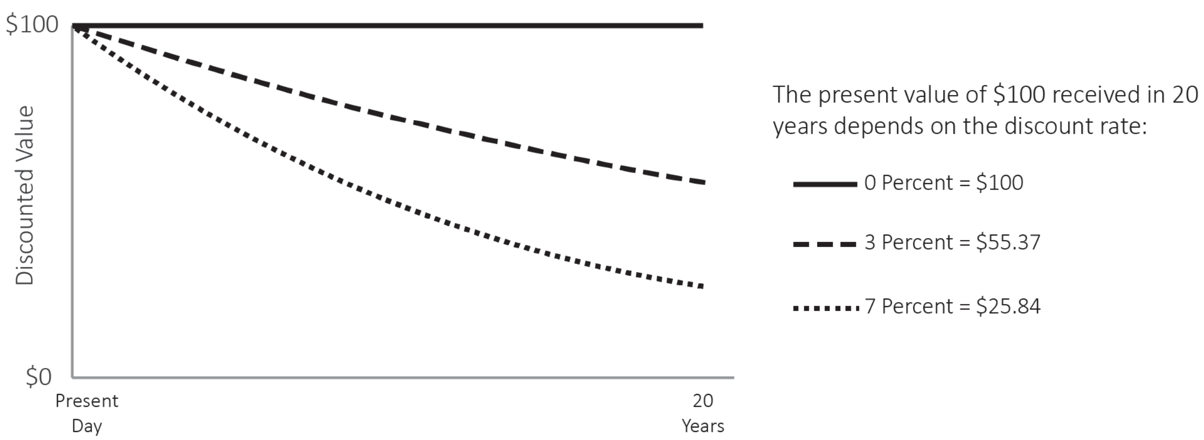
Asset values provide a measure of total expected benefits over time, providing policy makers with a sense of the full value over time, supporting planning of investment and stewardship activities at-scale. Just as with built capital, the asset value of natural capital in the SFT restoration project can be estimated. Annual flows of ecosystem services from these sites continue into the future, provided they are not degraded or depleted.

Asset values are often expressed as Net Present Value (NPV), allowing comparison of benefits that are produced at various points in time. To allow benefits and costs from different time periods to be compared in the present-day, future values are *discounted*. Discounting adjusts for two major factors that influence the value of money over time:

- ***Time preference***: We tend to prefer consumption now over consumption in the future, meaning a dollar today is worth more than a dollar received in the future.
- ***Opportunity cost of investment***: Present-day investments provide returns in the future.

While discount rates are often based on market interest rates, economists disagree on the appropriate discount rate for natural capital benefits (Arrow et al., 2004; Sterner & Peterson, 2008). The choice of discount rate is critical as it heavily influences how we value benefits and costs over long periods. High discount rates mean that future value has less worth; this can have affect the cost-effectiveness of projects which produce benefits and costs over longer time periods. Because natural capital can produce benefits in perpetuity, many economists advocate for (lower) discount rates that do not favor short-term benefits. Federal agencies, such as the National Oceanic and Atmospheric Administration (NOAA) and the United States Army Corps of Engineers (USACE) use discount rates around three percent (U.S. Department of Treasury, 2020; Dunford, 2018), especially for water-related projects. The 2023 Circular A-4 (updated by OMB every three years) recommends a discount rate of 2 percent. Other economists argue for even lower discount rates (Weitzman, 2001). Again, the choice of discount rate significantly affects NPV calculations. For example, $100 received in 20 years under a 0 percent discount rate is still $100, but at 3 percent, is valued at $55.37 by year 20; at a 7 percent rate, that value is just $25.84 (Figure 2). Ultimately, selecting which discount rate is considered appropriate is a policy choice.

Figure 2. A stylized comparison of discount rates' effect on present values



3 Methods

3.1 Benefits Transfer Methods

Two common categories of BTM are ***point-value* transfers** and ***value function* transfers**. Point-value transfers convert estimates reported in primary research into unit values (e.g., $/acre/year), which are then scaled by the number of equivalent units at the transfer site. Value function transfers build from statistical models reported in the valuation literature, substituting transfer site attributes for the value of explanatory variables (e.g., median income, distance to surface waters) to produce new, semi-tailored estimates. Later chapters use both BTM approaches to estimate the value of ecosystem service benefits.

Several methods were applied to estimate the range of non-market values of ecosystem services in this report. Acre-based point transfer estimates were derived from the Earth Economics database. A model developed by Ghermandi et al. (2010) was for function transfer to estimate site-specific estimates of some ecosystem services. Last, dollar-per-ton estimates were developed from the downstream benefits provided by erosion prevention. Where the value of an ecosystem service was estimated using multiple methods, the range and average across all estimates has been reported.

Table 1. Ecosystem Services Included in this Report and Methodologies Used

Ecosystem Service	Point Transfer	Function Transfer	Erosion Reduction
Air Quality	•		
Agricultural Productivity			•
Biological Control	•		
Commercial Fisheries			•
Cultural Value	•		
Flood Risk Reduction	•	•	•
Habitat	•	•	
Navigation			•
Recreation and Tourism	•	•	•
Water Capture, Conveyance and Supply	•	•	
Water Quality	•	•	•
Water Storage	•		

3.1.1 Point Value Transfer Estimates

For more than two decades, Earth Economics has curated a database of published valuation estimates to support the rapid valuation of ecosystem services. The database currently includes over 10,000 estimates, each tagged with up to 200 attributes, including study site location and characteristics (e.g., proximity to urban areas, climate), methodology and sampling approach, valuation type (e.g., revealed or stated preferences). Where feasible, each estimate has been “regularized” into a unit value (e.g., $/acre/year, $/household/year). This facilitates selection of datasets that closely match “transfer” sites. All transcriptions undergo internal peer review to ensure that estimates have been properly transcribed and that the underlying methodology conforms with contemporary best practices.

For the SFT site, valuation studies of both forests and wetlands were selected, as the objective of the SFT project is to promote forested wetlands. The following sections describe the studies selected from the Earth Economics database for each ecosystem service.

3.1.1.1 Air Quality

Vegetation can capture air pollutants, such as particulate matter and ozone, reducing adverse health effects from respiratory illness.

Nowak, D. J., Hirabayashi, S., Bodine, A., & Greenfield, E. (2014). Tree and forest effects on air quality and human health in the United States. *Environmental Pollution, 193*, 119-129.

This study models improvements in air quality for forests at state and county levels in the lower-48 (Washington state values were used for this report). The capacity of forests to remove air pollutants was estimated for NO_2, O_3, $PM_{2.5}$, and SO_2. Monetary air quality benefits are derived from the US EPA's BenMAP platform, which calculates avoided costs of adverse health effects such as emergency room visits, and hospital admissions from respiratory illness. The values for pollutant removal were originally published as 2010 USD/hectare/year, for both urban and rural areas for each state.

3.1.1.2 Biological Control

Healthy ecosystems limit invasive species, pests, and diseases, protecting human health, crops and livestock. A number of natural predators can help to control pest species, limiting potential damage. For example, birds consume insects that may infest trees and damage forests at higher populations.

Anielski, M., Wilson, S. J. 2005. Counting Canada's Natural Capital: Assessing the Real Value of Canada's Boreal Ecosystems.

This study identified, inventoried, and measured the economic value of ecosystem services produced in Canada's boreal region. The authors estimated both market and non-market benefits provided by natural capital. The biodiversity value estimated for forests was used here ($5.4 billion in 2002 dollars).

Pimentel, D., Wilson, C., McCullum, C., Huang, R., Dwen, P., Flack, J., ... & Cliff, B. (1997). Economic and environmental benefits of biodiversity. *BioScience*, *47*(11), 747-757.

This review estimated annual economic and environmental benefits from biodiversity in the U.S. valued at approximately $300 billion. Other ecosystem functions are supported by biodiversity, including: biomass and organic waste recycling, soil formation, nitrogen fixation, bioremediation of chemical pollution, genetic resources and crop and livestock yields, biotechnology, biological pest control, perennial grains, pollination, habitat and ecotourism, pharmaceuticals, and carbon sequestration.

3.1.1.3 Cultural Value

Natural areas often hold special importance to people. One way to partially capture this value is to estimate "existence" value, based on what people would be willing-to-pay to protect a given area.

Cedar River Group, Mundy Associates LLC, Beyers, W.B. 2002. Evaluation of Blanchard Mountain Social, Ecological & Financial Values. Washington State Department of Natural Resources.

Prepared for Washington's Department of Natural Resources, this report evaluated the social, ecological, and financial values of 4,827 acres of forest managed by the Skagit County Forest Board. A contingent valuation survey of 200 local residents determined their willingness-to-pay to preserve the forest was almost $600,000.

van Kooten, G.C., Bulte, E.H. 1999. How much primary coastal temperate rain forest should society retain? Carbon uptake, recreation, and other values. Canadian Journal of Soil Science 29(1): 1879-1890.

This study estimated the willingness-to-pay to preserve old growth forests in British Columbia, Canada. Inferring values from published studies and government reports, the authors estimated that the preservation of coastal forest was valued at about $100 per hectare.

Watson, V. G. (1994). *Wilderness preservation and protection of old-growth forests* [Master's Thesis, University of British Columbia]. https://doi.org/10.14288/1.0087549.

This Master's thesis deployed a dichotomous choice Willingness-to-Pay survey to assess support for the BC government's *Protected Areas Strategy*, which proposed protection of an additional 6 percent of the Province. Three surveys were distributed: province-wide general public, and upper division college students, in both land use economics and forestry economics programs. The author identified an average WTP of $371.34 per household per year, or $484M per year across the Province as a whole.

3.1.1.4 Flood Risk Reduction

Floodplains act like natural sponges, soaking up extra water flowing through the landscape and reducing the impact of excess water on infrastructure downstream.

EES Consulting, Inc. (2016). Chehalis Basin Strategy: Draft Economics Study Update.

The Chehalis Basin Strategy sought to reduce flood damage and restoring aquatic species habitat. Using a 100-year study period, the analysis compares net impacts, quantifying capital and O&M expenses, and modeling reductions in structural damage, agricultural losses, transportation delays, and improvements to the local fishery. This report used Restorative Flood Protection cost information as it most closely aligned with SFT restoration. Activities included adding large wood to river channels, restoring channel and floodplain processes, reconnecting floodplain storage, and relocating certain land uses. Costs were reported as $/river mile.

3.1.1.5 Habitat

Forests and wetlands are home to a wide variety of plants and animals. Even people who never visit wetlands value knowing that these ecosystems and species have their homes protected for the future.

Cedar River Group, Mundy Associates LLC, Beyers, W.B. 2002. Evaluation of Blanchard Mountain Social, Ecological & Financial Values. Washington State Department of Natural Resources.

Prepared for Washington's Department of Natural Resources, this report evaluated the social, ecological, and financial values of 4,827 acres of forest managed by the Skagit County Forest Board. A contingent valuation survey of 200 local residents determined their willingness-to-pay to protect forest habitat was valued at $1.1 million.

Wu, J., Skelton-Groth, K. 2002. Targeting conservation efforts in the presence of threshold effects and ecosystem linkages. Ecological Economics 42, 313-331.

This study of Pacific Northwest riparian habitat investments for salmon restoration showed that conservation benefits are lost when associated environmental benefits are ignored in federal conservation policies. The marginal social benefit of non-use values for fish were found to be $499–$10,862 per kilometer of stream.

3.1.1.6 Water Capture, Conveyance and Supply

Water flowing from nature is used in many ways—for irrigating crops, industrial use, or drinking water.

Hill, B. H., Kolka, R. K., McCormick, F. H., & Starry, M. A. (2014). A synoptic survey of ecosystem services from headwater catchments in the United States. *Ecosystem Services*, *7*, 106-115.

Water supplies were estimated for over 500 headwater stream catchments and production functions were developed for nine ecoregions. Water supply was valued using market rates for household water consumption.

3.1.1.7 Water Quality (Nutrient and Contaminant Removal, Nitrogen and Phosphorus)

Wetlands and forests improve water quality by trapping dirt and filtering or metabolizing pollutants such as excess fertilizer, making water healthier for people and wildlife.

Hill, B. H., Kolka, R. K., McCormick, F. H., & Starry, M. A. (2014). A synoptic survey of ecosystem services from headwater catchments in the United States. *Ecosystem Services*, *7*, 106-115.

Water purification benefits were estimated for over 500 headwater stream catchments and production functions were developed for nine ecoregions. Water quality improvements (nitrogen and phosphorus reductions) were valued as avoided and replacement costs, as well as value in water quality trading markets.

3.1.1.8 Water Storage (Groundwater)

Natural lands help water seep into shallow aquifers, refilling wells and groundwater.

Anielski, M., Wilson, S. J. 2005. Counting Canada's Natural Capital: Assessing the Real Value of Canada's Boreal Ecosystems.

This study identified, inventoried, and measured the economic value of ecosystem services produced in Canada's boreal region. The authors used a global meta-analysis of wetland valuation studies to estimate a value for groundwater storage of $45/hectare/year.

3.1.2 Function Transfer Estimates

Function transfer is a more-sophisticated BTM approach, in which statistical models reported in the literature are used to estimate per-unit values for new sites, after substituting transfer site attributes for the original explanatory variables. Value functions are selected based on similarities of primary and transfer sites, including beneficiary populations. Function transfer models can be based on single-site primary studies or meta-analyses (see below) of multiple primary studies.

Meta-analyses are studies of studies, designed to assess the effect of ecological, climatological, or socioeconomic contexts, as well as site attributes. There are several advantages to using meta-analyses for function transfers:

- Because meta-analytic value functions are estimated from multiple primary studies, they control for greater variation in ecosystem, beneficiary, and methodological characteristics.
- This produces more generalizable models than can be obtained from individual studies, partly because information from multiple contexts is used.
- More-general models can help to address literature gaps, inferring value at new transfer sites based on trends reported across multiple studies and study sites.
- Studies have found that meta-analytical function transfer produces smaller errors than point value transfer approaches (Kaul et al., 2013).
- The use of function transfer to estimate ecosystem service values is recommended by federal agencies, particularly where functions are developed from meta-analyses (OMB, 2023).

This analysis applies the statistical function reported in a global study by Ghermandi et al. (2010), which reviewed 170 valuation studies reporting 418 valuation estimates across 186 wetland sites. The authors developed a meta-analysis to estimate the value of thirteen ecosystem services across six wetland types, producing multiple models. Of these, the reduced model demonstrated a higher goodness-of-fit (R^2 = 0.49; adjusted R^2 = 0.45). It was selected because it provided the most reliable estimates and excluded many extraneous, non-significant methodological variables.

Six explanatory variables make these models especially useful and present an opportunity to produce high-resolution estimates that vary by context: *wetland type*, *wetland size*, *wetland abundance* (the spatial extent of wetlands within 50 km of each patch), *population density* (population within 50 km of each wetland patch), the magnitude of *human presence* for each patch, and *Gross Domestic Product*

(GDP) per capita. Because such factors are known to influence the value of ecosystem services (e.g., economies of scale, relative scarcity, likelihood of human impacts and human influence) and also vary across landscapes, the models can estimate locationally specific values.

After discussion with LCFEG staff, wetland type was determined to be riverine. Project boundaries were provided by LCFEG and totaled 1,100 acres of wetland restoration. Washington state wetlands were identified using the US Fish and Wildlife Service's National Wetland Inventory; within 50 km of the project site's centroid there are 63,786 hectares of wetlands. The 2020 US EPA dasymetric population dataset was adjusted using the American Community Survey to calculate population density. Human presence in the headwaters was classified as medium-low. Finally, GDP per capita was estimated by dividing Cowlitz County's total GDP by its population.

Of the 11 ecosystem services estimated by Ghermandi et al. (2010), five are relevant to the LCFEG wetland context: *flood control and storm buffering*, *water supply*, *water quality improvement*, low-impact *recreation*, and *habitat*. Services uncommon on SFT project site were not valued.

3.1.3 Erosion Reduction Co-Benefit Estimates

Hansen and Ribaudo (2008) estimate the ecosystem service values that benefit from upstream soil erosion reduction. Values were characterized on a per-ton dollar basis for 14 benefits, capturing relationships between reduced soil erosion and environmental and economic outcomes. Table 2 reports these categories and those included in this report. The authors use multiple methods to estimate public and private willingness-to-pay for such benefits. Their models link physical processes of erosion and sedimentation to economic effects on industries, households, and municipalities.

Table 2. Categories of benefits affected by water erosion (Hansen & Ribaudo 2008)

Service	Benefit	Description	Used
Navigation	Reservoir services	Less sediment in reservoirs	
	Navigation	Shipping industry avoidance of damages from groundings	•
Recreation	Water-based recreation	Cleaner fresh water for recreation	•
	Marine recreational fishing	Increased catch rates for marine recreational fishing	•
Agricultural Productivity	Irrigation ditches and canals	Reduced cost of removing sediment and aquatic plants from irrigation channels	•
	Soil productivity	Reduced losses in soil productivity	•
Flood Control	Flood damages	Reduced flooding and damage from flooding	•
	Road drainage ditches	Less damage to and flooding of roads	•
Commercial Fisheries	Marine fisheries	Improved catch rates for marine commercial fisheries	•
	Freshwater fisheries	Improved catch rates for freshwater commercial fisheries	
Water Quality	Municipal and industrial water use	Reduced damages from salt and mineral dissolved in sediment	•
	Municipal water treatment	Lower sediment removal costs for water-treatment plants	•
	Steam power plants	Reduced plant growth on heat exchangers	

This report used the county-level values for Cowlitz County, WA. Values are estimated as dollar (2000 USD) per metric ton of avoided sedimentation. These were inflated to 2024 USD and applied to the annual metric tons of sediment stored by the proposed project.

3.1.4 Benefits and Costs Over Time

For this analysis, Earth Economics forecasted annualized benefits over 30 years, discounted at both 0 and 2 percent (following OMB's Circular A-4). Project costs were assumed to have already occurred and were thus not annualized or discounted. A total project cost estimate of $30 million was derived from LCFEG spending reports and direct communications. These represent the full lifecycle of the restoration effort—including administrative expenses, construction, worksite scoping, maintenance, and other project activities—rather than only completed or pending phases. Because these costs are treated as a single total value rather than distributed over time, they remain undiscounted. This approach provides a conservative comparison, as discounted benefits are evaluated against full, undiscounted project costs. Total lifecycle project benefits were then divided by total lifecycle costs to generate each project's Benefit-Cost Ratio (BCR).

3.2 Economic Impacts

To conduct an economic impact analysis of the SFT restoration project, this analysis relied on secondary literature. A study by RTI International (with oversight from Washington DNR) examined how riparian and other environmental restoration activities in the Snohomish Watershed generate employment and labor income in Washington State (RTI International et al., 2022). They used IMPLAN, an industry-standard input-output model (IMPLAN Group LLC, 2025), to analyze how spending flows through state and local economies, supporting construction, environmental consulting, engineering, forestry and related sectors.

RTI International evaluated the direct, indirect, and total economic impacts of restoration spending. While economic impact studies typically report value-added to GDP, total output, and tax impacts, RTI reported only employment and wages. Though they modeled multiple restoration activities, this report used only 'Riparian Habitat' data, as this most closely matched work planned for the SFT. Total wages and employment were reported for per million dollars of spending. These were transformed to per dollar multipliers and combined with total SFT project spending ($30 million) to estimate total wages and jobs.

4 Results

LCFEG has reported that full restoration of the SFT floodplain is estimated at about $30 million. A portion of the total plan has been constructed, and an additional portion has been funded and is planned for construction within the next few years. The estimated budget for the unfunded restoration remaining on the mainstem SFT floodplain is $25M. Earth Economics found the restoration of the SFT floodplain could provide an average of $78 million in benefits over 30 years (see Table 4). At a 2 percent discount rate, this is $54 million. Compared to the estimated cost of $30 million to restore the entire South Fork floodplain, the benefit-cost ratio ranges from 1.45 to 4.27 (1.02 to 2.98 discounting at 2 percent, see Table 3). Most of this benefit stems from *carbon sequestration* by the planted trees, followed by *recreational* benefits, *flood control* benefits, and *water quality improvements*. Project spending during construction supports $21 million in total wages and nearly 400 jobs (Table 5)

Table 3. Benefit-cost ratios

Discount Rate	Low	Mean	High
0%	1.45	2.59	4.27
2%	1.02	1.81	2.98

Table 4. Ecosystem service values over 30 years, 2024 USD

	0% Discount Rate			2% Discount Rate		
Ecosystem Service	Low	Mean	High	Low	Mean	High
Agricultural Productivity	$3,038,000	$3,618,000	$4,197,000	$2,314,000	$2,755,000	$3,196,000
Air Quality	$13,000	$13,000	$13,000	$9,000	$9,000	$9,000
Biological Control	$12,000	$41,000	$70,000	$8,000	$29,000	$49,000
Carbon Sequestration	$25,544,000	$25,544,000	$25,544,000	$17,158,000	$17,158,000	$17,158,000
Commercial Fisheries	$907,000	$1,080,000	$1,253,000	$691,000	$822,000	$954,000
Cultural Value	$172,000	$332,000	$480,000	$120,000	$231,000	$334,000
Flood Control	$1,127,000	$10,610,000	$22,703,000	$858,000	$7,415,000	$15,803,000
Habitat	$69,000	$9,947,000	$26,622,000	$48,000	$6,924,000	$18,531,000
Navigation	$64,000	$76,000	$89,000	$49,000	$58,000	$68,000
Recreation	$9,963,000	$13,197,000	$14,532,000	$7,587,000	$9,574,000	$10,479,000
Water Quality	$1,368,000	$10,392,000	$27,855,000	$1,042,000	$7,287,000	$19,389,000
Water Storage	$172,000	$172,000	$172,000	$120,000	$120,000	$120,000
Water Supply	$1,026,000	$2,802,000	$4,577,000	$714,000	$1,950,000	$3,186,000
Total	**$43,476,000**	**$77,824,000**	**$128,107,000**	**$30,717,000**	**$54,332,000**	**$89,276,000**

Table 5. Economic impacts supported by total restoration spending

Metric	Direct + Indirect Effects	Induced Effects*	Total Effects
Wages ($)	$11,155,620	$9,935,580	$21,091,200
Jobs (Number)	234	165	399

*Calculated for this report by subtracting the summed direct and indirect effects from the total effects, not included in the reported economic impacts by RTI International.

5 Conclusion and Discussion

LCFEG's implementation of nature-based restoration and sediment retention strategies on the South Fork Toutle River demonstrates how ecological design can help address long-standing sediment challenges while generating substantial co-benefits for communities and ecosystems throughout the watershed. By integrating large woody material into natural sediment retention structures, the project initiates the gradual conversion of barren floodplain into functioning wetland systems capable of storing sediment, supporting habitat, and moderating downstream risks.

These results show that interventions can generate meaningful environmental, social, and economic value, and that incorporating ecosystem service benefits into project evaluation reveals a strong return on investment for nature-based approaches. Over 30 years, restored floodplains are projected to generate $78 million in ecosystem service benefits ($54 million discounted at 2 percent) against an estimated $30 million project cost, resulting in a benefit-cost ratio of 2.59 (1.81 discounted). *Carbon sequestration*, *recreation*, *flood control*, and *water quality* benefits account for the largest share of value. Project spending also supports $21 million in wages and nearly 400 FTE jobs statewide. These findings reinforce the potential for expanding similar strategies across the watershed and highlight opportunities to further advance research and monitoring.

Beyond these benefits, preliminary sediment analysis conducted by the Lichen Land and Water, Inc. has shown that NBS for sediment retention are cost effective ($2.56 per cubic yard) compared to dredging, raising and other alternatives to sediment retention ($12.40, $3.50 and $3 per cubic yard, respectively) (Lichen Land and Water, Inc., personal communications, 2025). This demonstrates that NBS are cheaper than or on par with conventional sediment retention structures in terms of costs per sediment stored.

Although LCFEG has only implemented restoration actions along 3.5 of the 17 miles of the South Fork Mainstem, the report demonstrates that even preliminary analysis indicates that nature-based solutions can deliver strong returns on investment by providing ecosystem services, including reduced sediment loads.

5.1 Directions for future investigation and planning

Future restoration along the NFT present an opportunity to deepen and refine the analysis conducted for this study. Several areas of inquiry would allow researchers to build a more comprehensive understanding of the ecological and economic benefits of nature-based sediment retention strategies. A key area for advancement involves economic impact modeling. While this study relied on a secondary IMPLAN analysis, future work could incorporate a full input-analysis, including IMPLAN state and county multipliers. Developing project-specific spending profiles for the NFT would further strengthen this effort by identifying which industries are most engaged in the work, and how project dollars invested locally circulate regionally or move out-of-state.

Additional research on sediment dynamics would also benefit future evaluations. This study assumed a linear rate of sediment fill, yet the natural system is more variable. A more refined approach could model dynamic accumulation patterns. Paired with a detailed assessment of dredging costs would improve estimates of the number of dredging cycles deferred or eliminated as sediment is retained upstream.

Improvements to ecological data inputs would allow for more precise benefit estimates. Comprehensive GIS-based landcover data for the full NFT project area would refine landcover estimates. Similarly, site-specific growth curves for newly planted vegetation (particularly trees) would enhance long-term projections for carbon sequestration, storage, and related ecological functions.

Primary research on the ability of these projects to mitigate flood risk are also a significant opportunity. Whereas the current study relied on BTM, future analyses could incorporate hydrologic modeling, flood hazard mapping, or other site-specific approaches to better capture how restoration reduces flood exposure and related damages.

Recreation benefits could be improved through more detailed beneficiary mapping, including identifying those who recreate in restored and downstream areas, their activities, and any spending that accompanies such visits. Finally, future research could examine how restoration affects fish populations (both ecologically and economically) by evaluating changes in habitat availability, recreational fishing opportunities, nonuse values, and the role of salmon in nutrient cycling.

Together, these research opportunities offer a roadmap for enhancing future analyses and for building a more complete understanding of how nature-based sediment retention strategies can strengthen the resilience and ecological health of the Toutle River watershed.

The quantification of these co-benefits leads to stronger, more informed decision-making. Traditionally, these benefits have been excluded from accounting frameworks—effectively valued at $0—resulting in incomplete assessments of a project's true worth. Including these values in decision-making provides a full accounting of *all* the benefits nature provides, and can lead to more efficient investments, help meet resiliency goals, and maximize public wellbeing.

5.2 Additional Limitations

There are several challenges inherent in accurately estimating the full economic value of anything. Despite such uncertainties, it is clear that ecosystems produce significant economic value for society. There are known gaps in the primary literature on the economic value of ecosystem services, and this report does not include all ecosystem services known to be provided. For this reason, the values reported here likely understate the value provided by these projects. Caution should also be exercised when comparing total ecosystem services values across landcover types, as differences may reflect information gaps, rather than real differences in the level of benefits produced by specific landcovers, or the value of such services.

As with any form of analysis, BTM has strengths and weaknesses. One critique argues that every ecosystem is unique and produces unique ecosystem benefits. While this is true to some degree, it suggests that the only means to understand the true value of a given ecosystem is through resource-intensive primary studies. In general terms, BTM is a systematic approach to generalizing knowledge from one place to predict characteristics of another, controlling for key contextual attributes, and is a widely accepted practice in a broad range of fields. Its value comes from its efficiency and pragmatic ability to quickly generate defensible estimates of a broad range of nonmarket benefits.

Many of the selected studies report a range of values, rather than single-point estimates. This variance has been preserved; no studies are removed from the dataset because their estimates were deemed too high or too low. Instead results have been reported in a way that allows the reader to appreciate the range and distribution of values. While the final estimates reported here may be imprecise, such uncertainty is preferable to assuming that ecosystem services have zero (or infinite) value. For decision makers, it is better to be approximately right than precisely wrong.

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