

Ecosystem Service Values in Benefit-Cost Analysis of Flood Mitigation Projects

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ECOSYSTEM SERVICE VALUES IN BENEFIT-COST ANALYSIS OF FLOOD MITIGATION PROJECTS

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In this thesis, I have presented ways to expand the stream of benefits and costs towards improving intergenerational equity of projects that impact floodplain ecosystems. I propose the use of ecosystem service values for project analysis. Additionally, I submit two methods of increasing intergenerational equity. I suggest the use of relative pricing and quasi-hyperbolic discount rates. Adjustments to standard benefit cost practices are necessary in ecologically complex transactions in which decisions can irreversibly damage irreplaceable and unique environmental resources. Failing to incorporate these factors into the benefit cost analysis leads to transaction costs. Ultimately, future generations inherit the cost of decisions that neglect ecologically complex systems. Addressing transaction costs requires the planner to mind ecological scenarios and economic values for ecosystem services. Relative pricing and quasi-hyperbolic discounting are tools that can assist the planner in this effort. It is possible that these tools will become more relevant to the planning profession if ecological and intergenerational considerations continue to pervade the analysis of projects.

Contents

Introduction	5
Research Questions	6
Chapter One: Literature Review	7
What is Benefit Cost Analysis?.....	7
Ecosystem Services: Valuing the Ecological Benefits.....	9
Market Failure, Opportunity Cost, and Valuation Methodologies.....	10
Benefit Transfer	13
Other Costs and Benefits: Qualitative Components.....	14
Inter-temporal Distribution of Goods and Transaction Costs in Ecology.....	15
Changing Value of Ecosystem Services over Time.....	18
Discount Rates	19
Chapter Two: Introduction to Benefit Cost Analysis of Floodplain Restoration - Lower Tolt River	31
Rationale for Studying this Site and Site Information	37
Chapter Three: Benefits and Costs of Lower Tolt Project	42
Quantitative Benefits	42
Qualitative Benefits	54
Quantitative Costs.....	54
Qualitative Costs	55
Results of Benefit Cost Analysis	57
Chapter Four: Discussion	65
Increasing Benefits over Time.....	66
Transaction Cost Economics and Hyperbolic Discounting: Alternatives to Relative Pricing.....	69
Implications for the Planner: Ecosystem Services and Hyperbolic Discounting.....	75
Conclusion.....	79
Bibliography	80

Figures

Figure 1: Valuation Methodologies	12
Figure 2: Exponential vs. Quasi-Hyperbolic Discounting	24
Figure 3: Map of the Tolt Site	32
Figure 4: Lower Tolt River Floodplain Reconnection Site - Prior to Restoration	40
Figure 5: Lower Tolt River Floodplain Reconnection Site - After Restoration	41
Figure 6: Exponential vs. Quasi-Hyperbolic Discounting of Tolt Site	58
Figure 7: Sensitivity Test of NPV for Exponential Discounting	59
Figure 8: Impact of Uncertainty in Parameters of Exponential NPV .. Error! Bookmark not defined.	
Figure 9: Sensitivity Test of NPV for Quasi-Hyperbolic Discounting	62
Figure 10: Impact of Uncertainty on Quasi-Hyperbolic Discounting Parameters	63
Figure 11: Sensitivity Analysis of Quasi-Hyperbolic NPV without Riparian Habitat	73

Tables

Table 1: Parameters of the Benefit Cost Analysis	35
Table 2: Parameters of Sensitivity Tests	37
Table 3: Flood Risk Reduction Projects near Carnation	46
Table 4: Cost Estimates of Tolt Project	55

Introduction

I investigate the role of ecosystem services in benefit cost analysis of flood mitigation projects. Including ecosystem service values in benefit cost analysis provides a better understanding of total project impacts both now and in the future. Given the finite quantity of environmental resources, reducing the quantity of them today means that future generations cannot use them tomorrow. Accordingly, I investigate the role of the discount rate in benefit cost analysis of projects that impact ecosystem services.

I illustrate this practice by conducting a benefit cost analysis on a floodplain restoration project in King County, Washington. A project on the Lower Tolt River was initiated in 2004 to maintain flood protection for the neighboring community and restore floodplain habitat. The result of the project was a wider floodplain that serves both flood protection and habitat restoration goals. I use ecosystem service values for estimating the stream of benefits and costs over time. Using ecosystem service values for projects that benefit multiple generations creates an opportunity to discuss the theoretical and ethical implications of benefit cost analysis.

I present results of the benefit cost analysis through standard (exponential) and quasi-hyperbolic discounting practices. The results demonstrate that quasi-hyperbolic discount rates reflect consumer preference when rewards are delayed for many years. This approach becomes relevant in analyzing the economic impact of ecosystem services, which provides streams of benefits to multiple generations. Through broadening the stream of benefits and incorporating the preference of delayed reward, I illustrate a model for inter-generational equity of floodplain management.

Research Questions

I explore the following questions through this thesis:

- How can ecosystem services be incorporated into an *ex post* benefit cost analysis on the Lower Tolt River Floodplain Reconnection Project?

This question prompts an exercise of benefit cost analysis. In practice, this exercise is simple, and is completed to create a context for deeper discussion. I apply ecosystem service values in the economic analysis, which open the door to explore components of benefit cost analysis that improve inter-generational equity.

- How can benefit-cost analysis be changed to enhance intergenerational equity of infrastructure projects?

This second question invites ethical and theoretical discussion regarding the use of benefit cost analysis in projects that bridge multiple generations.

Chapter One: Literature Review

What is Benefit Cost Analysis?

Benefit-cost analysis is a decision-making tool that assists planners in determining potential project impacts. It is a standard practice of government agencies that results in billions of dollars in annual investment across the nation. Historians note the importance of benefit cost analysis in the development of the United States. Examples of projects include flood control, irrigation, reservoir construction, and development regulations. These efforts alter economic, ecological, and social landscapes by imposing costs and creating public benefits.

A guiding principle in benefit-cost analysis and economics is Pareto efficiency - when a change from one position to another improves the situation of stakeholders and no one is harmed. Most policy changes fail in achieving Pareto efficiency because most changes make some people worse off. Despite this fact, welfare could be improved even if Pareto efficiency was not met.¹ This reflects the Kaldor-Hicks rationale for projects, which applies a potential compensation test (PCT). PCT determines a project as efficient when the gains accruing to project winners are enough to potentially compensate project losers. This test does not require that actual compensation take place.² In short, benefit cost analysis provides decision-makers with a rationale for stating that one project is better than an alternative. Benefit cost analysis assists economists and planners in determining a method for investing capital in light of certain parameters.

This approach to economic analysis occurs at small and large scales in the United States. Benefit cost analysis guidelines promote procedural regularity to give public perception

¹ Richard Zerbe and Dwight Dively. *Benefit-Cost Analysis in Theory and Practice* (New York, NY: Harper-Collins, 1994): 12.

² Richard Zerbe, Tyler Scott, "(Almost) Everybody Wins: A true Pareto justification for practical welfare economics and the use of benefit cost analysis," (Draft Paper, last modified March 2012): 2. Microsoft Word File.

of fairness in the selection of projects.³ The U.S. government standardizes benefit cost analysis practice through guidance documents for policy analysts and planners of government-funded programs. Two influential documents are Principles and Guidelines⁴ (P&G) and Circular A-4.⁵ P&G determines economic and physical requirements of projects completed by United States Army Corps of Engineers (USACE), USDA Soil Conservation Service, Bureau of Reclamation, National Resource Conservation Service, and the Tennessee Valley Authority. P&G guides the steps of the benefit-cost analysis as well as other analyses. Circular A-4, authored by the Office of Financial Management, guides analysis of regulatory impacts. The goal of these documents is to present economic, social, and environmental impacts of projects; however, economic theory and analysis suggests that federal benefit cost analysis rules fail to include all potential costs and benefits associated with a project.

Economists, policy analysts, and planners often disagree on the standards that guide benefit-cost analysis of projects. A contentious issue among them is the type of benefits and costs incorporated into benefit cost analysis.⁶ The benefits and costs represented in the analysis suggest the spatial and temporal distribution of impacts that may result from a project or regulation.⁷

Benefits and costs are monetized values created as a result of a change. The economic benefits and costs that result from a project inform decision-makers. Economic benefits can be defined as increases in the net value of the output of goods and services, expressed in monetary units.⁸ Costs can be defined as decreases in net values of goods

³ Theodore, Porter, *Trust in Numbers*, (Princeton, NJ: Princeton University Press, 1995): 149.

⁴ Kyna Powers, *Benefit-Cost Analysis and the Discount Rate for the Corps of Engineers' Water Resource Projects: Theory and Practice*, CRS Report for Congress, June 23, 2003.

⁵ Circular A-4, Office of Management and Budget, (September 17, 2004).

⁶ Eric Hiekkila, *The Economics of Planning*, (New Brunswick, N.J.: Center for Urban Policy Research, 2000): 172.

⁷ Richard Zerbe and Dwight Dively, *Benefit-Cost Analysis in Theory and Practice*, 237.

⁸ *Ibid.*, iv.

and services. When compared together, analysts can determine “net benefit” or “net cost” of a proposed change.

Government agencies admit that economic analysis cannot include all project impacts.⁹ Additionally, agencies must document non-economic impacts of projects, such as environmental and social impacts.¹⁰ Pragmatic or other considerations may cause analysts to limit their inquiry. It can be very difficult to assess how the world will look after a project.¹¹ Although agencies can document non-market costs and benefits through qualitative analysis, there is merit to representing these values in a quantitative way.

Ecosystem Services: Valuing the Ecological Benefits

Ecosystem services consist of flows of materials, energy, and information from natural capital stocks which combine with manufactured and human capital services to produce human welfare.¹² Changing the quantity or quality of various types of natural capital and ecosystem services may impact human welfare.¹³ These changes may dramatically alter ecosystems, having an impact on the benefits and costs of human activities.

Ecosystems provide a range of services and goods. A short list of ecosystem services include the following: gas regulation, climate regulation, water regulation, water supply, erosion control/ sediment retention, soil formation, nutrient cycling, waste treatment, pollination, biological control, habitat, food production, raw materials, genetic resources, recreation, and cultural resources. These services reflect the economic benefits that facilitate welfare.

⁹ Circular A-4, Office of Management and Budget (September 17, 2004).

¹⁰ Committee of Improving Principles and Guidelines for Federal Water Resources Project Planning. *A Review of Proposed Revisions to the Federal Principles and Guidelines Water Resources Planning Document*, (Washington, D.C.: The National Academies Press): 3.

¹¹ Heikkila, *The Economics of Planning*, 171.

¹² Robert Costanza, et al., “The Value of the World’s Ecosystem Services and Natural Capital,” *Nature* 387 (May 15, 1997): 254.

¹³ Costanza, “The Value of the World’s Ecosystem Services and Natural Capital,” 255.

Market Failure, Opportunity Cost, and Valuation Methodologies

Valuation of ecosystem services relies on market and non-market information. One can derive values from market transactions. For example, an apple's value is determined by the amount of money a customer pays. If a market were perfect, then the value of the apple and all other transactions necessary to sell the apple would be included in the price. Perfect markets occur when prices fully reflect marginal costs and benefits, and market failures occur when this condition is not achieved.¹⁴ Market failures result in externalities. In the apple example, externalities arise in the health impacts of applied pesticides or the environmental impacts of carbon emitted in transporting the product to market. These externalities increase the cost of producing the apple; however, the market fails to include these costs in the price of the apple. The consumer does not pay for pesticide remediation or carbon emissions.

Complex markets do not follow the apple example. The consumer who buys one more apple does not witness a shift in economic and environmental equilibria. This model does not hold true for large scale transactions. Constructing dams, highways, or restoration projects are transactions with higher costs. The market is less competitive, so consumers cannot "shop around." Such projects are subject to economies of scale, complex environmental impacts, single-source provisioning, and regulated transactions. Standard competitive market conditions do not apply.¹⁵ Smith's simple transaction example of the "Butcher" exchanging with the "Baker"¹⁶ does not reflect complex infrastructure transactions. As a result, establishing the economic value of an infrastructure project requires methods beyond market-based transactions.

Opportunity costs uncover the values of resources that markets cannot determine. Non-market resource values require an assessment of the resources' highest and best

¹⁴ Heikkila, *The Economics of Planning*, 186.

¹⁵ Ibid.

¹⁶ Adam Smith, *Wealth of Nations* 5th Edition, (London: Methuen and Co. 1904): Book I, Chapter IV.

alternative uses. This approach asks, “What opportunities might be lost elsewhere as a result of this project?”¹⁷ In considering ecosystem services, we ask the same question. If this section of river provides habitat for salmon, what is the opportunity cost of maintaining habitat? Perhaps residential housing or a levee could be constructed in place of the habitat. The highest a best alternative use of the land reveals the opportunity cost of maintaining salmon habitat.

In valuing goods and services, often planners and economists encounter a range of opportunity costs. This reflects the fact that resources matter more to some than others. In the example of salmon habitat, a fly-fisherman may value habitat more than a housing developer. The fly-fisherman values the habitat according to the opportunity cost of not building houses. If the salmon fisherman wishes to improve quality habitat, the fisherman may value houses lower than habitat. Meanwhile, the housing developer values the habitat according to the opportunity cost of not building houses. In this manner, ranges of high values and low values arise in valuing goods and services.

Market goods and services are often valued via market transactions. However, many valuable ecosystem services may not be traded in markets, such as carbon sequestration or water filtration. They have value regardless of their role in standard markets, and methodologies have been developed to measure their value. Eight methodologies are accepted in peer-reviewed academic literature for valuing ecosystem goods and services. These goods and services are tangible contributors to the economy.¹⁸

¹⁷ Heikkila, *The Economics of Planning*, 180.

¹⁸ Jason Twill. “Economics of Change: Catalyzing the Investment Shift Toward a Restorative Built Environment,” (Unpublished manuscript, October 2011): 16, http://www.eartheconomics.org/FileLibrary/file/Green%20Building/The%20Economics%20of%20Change_1.3_web_version.pdf.

Figure 1 provides a list of the eight ecosystem service valuation methodologies currently accepted in peer reviewed academic literature. Many of these methodologies are standard in establishing dollar estimates of value.

Figure 1: Valuation Methodologies

<p>Avoided Cost (AC): services allow society to avoid costs that would have been incurred in the absence of those services; storm protection provided by barrier islands avoids property damages along the coast.</p>
<p>Replacement Cost (RC): services can be replaced with human-made systems; nutrient cycling waste treatment provided by wetlands can be replaced with costly treatment systems.</p>
<p>Factor Income (FI): services provide for the enhancement of incomes; water quality improvements increase commercial fisheries catch and the incomes of commercial fishermen</p>
<p>Travel Cost (TC): service demand may require travel, which have costs that can reflect the implied value of the service; recreation areas can be valued at least by what visitors are willing to pay to travel to it, including the imputed value of their time.</p>
<p>Hedonic Pricing (HP): service demand may be reflected in the prices people will pay for associated goods, for example housing prices along the coastline tend to exceed the prices of inland homes.</p>
<p>Marginal Product Estimation (MP): service demand is generated in a dynamic modeling environment using a production function (Cobb-Douglas) to estimate the change in the value of outputs in response to a change in material inputs.</p>
<p>Contingent Valuation (CV): service demand may be elicited by posing hypothetical scenarios that involve some valuation of alternatives; for instance, people generally state that they are willing to pay for increased preservation of beaches and shoreline.</p>

Source: Adapted from Farber¹⁹

Using valuation methodologies to assess ecosystem services can be a useful practice in making decisions of environmental conservation. However, even these methods are flawed. Methodologies can indicate the value of a good, but not fully reveal the value of a good or service. For example, we pay to use water in our houses, but we may value it more than what we pay for it.²⁰ The market price does not reflect the full range of benefits associated with the good. Additionally, valuation methodologies generate different values for the same ecosystem service. For example, a forest valued with

¹⁹ Stephen Farber, Robert Costanza, and Matthew Wilson, "Economic and ecological concepts for valuing ecosystem services," *Ecological Economics* 41 (2002): 388-389.

²⁰ Heal, Geoffery, "Valuing Ecosystem Services," *Ecosystems* 3 (2000): 28.

contingent valuation and then valued by travel cost methodology may demonstrate conflicting values.

Benefit Transfer

Benefit transfer (BT) provides another means of assigning values to ecosystem services beyond those outlined above. BT is the “...transfer of existing estimates of non-market values to a new study which is different from the study for which the values were originally estimated.”²¹ This practice can be useful for analysts since the cost of conducting non-market valuations can be high. However, there is a risk that the values taken from the original study may not apply to another study because the population, ecosystem, and policies guiding decisions differ greatly.

Boyle and Bergstrom provide several guidelines for determining the best use of BT studies. These include the following:

“(1)The non-market commodity of the site must be identical to the non-market commodity to be valued at the policy site; (2) The populations affected by the non-market commodity at the study site and the policy site must have identical characteristics; (3)The assignment of property rights at both sites must lead to the same theoretically appropriate welfare measure.”²²

The risk to BT validity increases as the importance of its accuracy increases. Benefit cost analysis indicates the stakeholders with standing in decision-making, so those stakeholders have the right to question the values used in benefit cost analysis. If values fail to reflect the reality of stakeholders then they may challenge the integrity of the analysis.

²¹ K.J. Boyle and J.C. Bergstrom, “Benefit transfer studies: myths, pragmatism, and idealism,” *Water Resources Research*, 28, no. 3 (1992): 657.

²² Boyle and Bergstrom, “Benefit transfer studies,” 657.

Other Costs and Benefits: Qualitative Components

The previous sections provide an overview of valuation methodologies that inform economic decision-making. Ecological economist Geoffery Heal notes that valuing ecosystem services is not necessary because people do not always make decisions according to economic value. However, he notes, “The exception to this rule is benefit cost analysis, which requires an enumeration and evaluation of benefits from conserving a natural ecosystem and... placing values on the services provided by the system is a necessary step.”²³ For this reason, additional qualitative analysis creates a space for incorporating intangible values into environmental decisions.

Benefit cost analysis uses a Hicksian approach to interpret economic changes of a project – which states that the marginal value of a dollar is the same across a population.²⁴ This ignores the distribution of benefits and costs. A change to income among rich people is treated the same as a change among poor people. This approach fails to reflect reality. Accordingly, components that address qualitative benefits and costs create an opportunity for a population to express their preference for costs and benefits.

In practice, benefit cost analysis typically incorporates qualitative components. The United States Army Corps of Engineers (USACE) assesses the qualitative benefits and costs of infrastructure changes. In the place of quantitative impacts, an overall description of significant effects is included in the Environmental Quality components of

²³ Geoffery Heal, “Valuing Ecosystem Services.” *Ecosystems* 3, (2009): 28-29.

²⁴ Scott Farrow, “Incorporating Equity in Regulatory and Benefit-Cost Analysis,” (unpublished paper prepared for SRA/RfF Workshop on New Ideas for Risk Regulation, June 22-23, 2009).
http://sra.org/docs_reg_risk_pres/P6.c.i%20-%20Farrow%20Incorporating%20Equity.pdf.

USACE benefit cost analyses.²⁵ Some critics have questioned whether USACE methods of qualitative analysis are adequate.²⁶

Qualitative components do not replace the need to apply numeric values of intangibles in quantitative components. Benefit cost analysis provides the most efficient alternative according to the parameters, “that is, the alternative that generates the largest net benefits to society (ignoring distributional effects).” This is useful information for decision makers and the public to receive, even when economic efficiency is not the overriding public policy objective.²⁷ Subsequently, quantitative analysis of non-market benefits informs decisions about economic efficiency, but this information should not be the sole indicator of benefits. Both quantitative and qualitative information should inform decisions.

Inter-temporal Distribution of Goods and Transaction Costs in Ecology

When considering the rights of future generations, we consider their ability to receive the benefits or incur the costs of current decisions. Benefits and costs that result from irreversible decisions, such as species loss or groundwater pollution, impact the rights of future generations to use those resources. Since undamaged ecosystems provide economic benefits for society in perpetuity, agencies that do not preserve ecosystems will impose costs on society for long periods of time.

The inter-generational nature of ecosystem services becomes especially pertinent in light of increasing ecological scarcity and bounded rationality that surround infrastructure transactions. Typically, multiple parties compete for the use of environmental resources within a limited timeframe, such as a contract negotiation. Transaction cost economics indicates that “imperfect information” clouds the judgment

²⁵ Armah and others, “Principles and Guidelines for Evaluation Federal Water Projects: U.S. Army Corps of Engineers Planning and the Use of Benefit Cost Analysis,” (Unpublished capstone project from the Evans School of Public Affairs, University of Washington, August, 2009): 13.

²⁶ Paul Scodari. “Survey and Analysis of Criticisms of Corps Planning and Links to Planning Guidance,” (Working Paper, February 2005): 21.

²⁷ Circular A-4, Office of Management and Budget, (September 17, 2004).

of transaction participants because they do not have all the facts regarding benefits and costs. As a result, participants face “bounded rationality” regarding components of infrastructure negotiations. Bounded rationality asserts that decision-makers intend to be rational, but they sometimes fail in important decisions.²⁸ Individuals and organizations are ill-equipped to make completely rational decisions in the context of complex transactions. Benefit-cost analyses, when used as the basis for infrastructure projects, become contracts between stakeholders used to govern transactions. As transaction cost economics demonstrates, all complex contracts are inevitably incomplete.²⁹

Ecosystems are consistently undervalued in decision-making, both at present and in the future. Most ecosystem services are not traded in markets, so their value cannot be measured by standard market transactions.³⁰ Ecosystem services are public goods,³¹ unless they have been allocated in a private ecosystem services market. Without institutions or legal definitions demonstrating ownership of ecosystems services, their depletion or degradation will result in diminished flows of ecosystem services due to overuse.³² Hardin outlined in “Tragedy of the Commons” the risk of common resources that lack representation. In the issue of the polluter, Hardin argues that the independent, self-enterprising polluter has no reason to cease polluting if the cost of cleaning pollutants is less than the profit gained from discharging them.³³ If a consumer of ecosystem services represents their right to not suffer pollution of the environmental resource, or to demand pollution clean-up, they are in the position to determine the cost to the polluter. However, if no person exerts their right to ecosystem services, then the pollution will continue. Consequently, the ecosystem service is undervalued because

²⁸ Oliver E. Williamson. “The Theory of the Firm as Governance Structure: From choice to Contract” *The Journal of Economic Perspectives* 16, no. 3 (Summer, 2002): 174.

²⁹ Oliver E. Williamson. “The New Institutional Economics: Taking Stock, Looking Ahead.” *Journal of Economic Literature* 38, no. 3 (September 2000): 599.

³⁰ Costanza et al., “The Value of the Worlds’ Ecosystem Services and Natural Capital,” 259.

³¹ *Ibid.*, 257.

³² J.B. Ruhl. “The Tragedy of Ecosystem Services.” *Bioscience* 58, no. 10 (November 2008): 972.

³³ Garrett Hardin, “Tragedy of the Commons,” *Science* 162, no. 3859 (May 1 1998): 1246.

it lacks representation. At present, undervaluing the ecosystem service and polluting may not be a problem, but in the future it may be.

Economic undervaluation of ecosystem services produces dramatic effects in the natural world. Ecological resources demonstrate nonlinearity in response to change. A simple change could cause large-scale impacts in ecosystems.³⁴ Uncertainty regarding the resilience to change of an ecosystem becomes exacerbated by issues of complexity. Ecosystems are complex, featuring actors and forces that influence each other, but the severity and timing of responses to ecological change become difficult to forecast. Likewise, forecasting economic values of ecosystem services becomes difficult.

Infrastructure decisions can impact ecosystems in unknown and irreversible ways. Due to their complexity, organizations cannot internalize all externalities affecting ecosystems in infrastructure transactions. As a result, externalities fall on current and future generations. Since future generations incur these costs, they should have standing in decisions that impact ecosystem functions. For this reason, including ecosystem service values in economic decisions presents a rational method for analyzing infrastructure decisions. Including all possible ecosystem services broadens the extent of benefits considered in economic analysis, giving the recipients of these benefits standing. This includes future recipients. The inclusion of full costs and benefits in the analysis ensure that the values of future generations are incorporated into the decision.

Intergenerational equity will improve with greater consideration of costs and benefits over time.³⁵ There are several methods to incorporating future generations into present decisions. These include the following: first, adjusting the value of ecosystem services in the stream of costs and benefits; and second, adjusting the discount rate.

³⁴ Simon Levin, "Ecosystems and the Biosphere as Complex Adaptive Systems," *Ecosystems* 1 (1998): 433.

³⁵ David Pearce, "Development, the Environment, and the Social Rate of Discount," *The World Bank Research Observer* 6, no. 2 (July, 1991): 149.

Changing Value of Ecosystem Services over Time

The value of ecosystem services changes over time. When environmental quality is a factor in the production of ecosystem services, then environmental quality leads to changes in production costs which in turn affect the price and quantity of output in an industry. This impacts the returns to other inputs into ecosystem services as well as outputs.³⁶ For this reason, environmentalists and economists forecast that the value of ecological services will change according to their supply, demand, and quality. “If output of some material goods increases, but access to ecosystems services diminishes, then relative price of environmental amenities should rise over time.”³⁷

The change in value over time is contingent on the health of the numerous components of an ecosystem. As ecosystems are restored, their economic value increases. Restoration practices, such as process-based restoration, support this idea. Beechie provides the example of river floodplains, which can be restored to pre-human conditions with minimal corrective action. As long as restoration project sites are provided the structural means to re-establish basic processes, they can improve their ecological services and goods over time.³⁸

Processes are typically measured as rates, such as rate of erosion or sedimentation.³⁹ The change in value to ecosystem services can be factored into benefit cost analysis by applying the anticipated rate of change to ecological processes. This approach improves the integrity of the economic analysis by anticipating changes to the stream of benefits and costs. Additionally it increases the intergenerational equity of the analysis by anticipating the change in demand of future consumers.

³⁶ Myrick Freeman, *Benefits of Environmental Improvement*, (Baltimore: Resources for the Future 1979): 62.

³⁷ Thomas Sterner and U. Martin Persson. “An Even Sterner Review: Introducing Relative Prices into the Discounting Debate,” *Review of Environmental Economics and Policy* 2, no.1 (Winter 2008): 62.

³⁸ Beechie et al., “Process-based Principles for Restoring River Ecosystems,” *BioScience* 60, no. 3 (March 2010): 209.

³⁹ Ibid.

Discount Rates

To this point I have focused on expanding the stream of benefits and costs to improve the integrity of benefit cost analysis as well as the intergenerational equity. In addition to this practice, some economists have argued that intergenerational equity can be improved through the discount rate. In the following section, I provide an overview of discount rates and brief discussion regarding why discount rates are important to intergenerational equity.

In economics, much debate has been directed at the discount rate when accounting for ecological services and future generations. Consumers value benefits more now than they do in the future. This practice factors into benefit cost analysis, which determines whether people receive a benefit now or not.⁴⁰ The practice of discounting future benefits becomes problematic when considering environmental problems that occur in the future. Discounting benefits and costs does not account for long-term environmental issues that change the values of environmental resources for future generations. Environmental problems disappear in benefit cost analysis.⁴¹

Due to this issue, some economists argue against discounting entirely. Heal presents arguments of Ramsey, who states, "Discounting future utilities is ethically indefensible and arises purely from weakness of the imagination."⁴² Pigou notes the issues of discounting, commenting that discrepancies between desire and satisfaction can injure economic welfare "by checking the creation of new capital and encouraging people to use up existing capital to such a degree that larger future advantages are sacrificed for smaller present ones."⁴³

⁴⁰ Giles Atkinson and Susana Mourato, "Environmental Cost-Benefit Analysis," *The Annual Review of Environment and Resources* 33 (2008): 329.

⁴¹ *Ibid.*, 330.

⁴² Geoffery Heal, "Intertemporal Welfare Economics and the Environment" *Handbook of Environmental Economics* 3 (New, York, NY: Elsevier Pub. Co., 2005): 1107.

⁴³ A C. Pigou, "The Economics of Welfare," (London: Macmillan and Co., 1920) Book 1, Chapter 11.5.

Despite these arguments, there is a risk to avoiding discounting. When we choose not to discount, we assume that we act in the future the same way we act today. We have no preference over what happens today or tomorrow. For example, if we wish to go for a hike today or a hike next month, we would value the hike especially high now if we knew that there was a high risk of snow prohibiting a hike next month. Of course, we do not have perfect information over future events, so receiving benefits now becomes more important than in the future. Discounting provides us with a defined order of preferences from which we must choose.⁴⁴

While there is an argument about whether to apply a discount rate, there is more debate over the appropriate rate. In exponential discounting, the hiker assumes that her desire to hike will always be strong. She does not assume that her preference towards hiking changes over time. As a result, her time-preference, i.e. the discount rate, is fixed. This approach reflects the way decision-makers think of the future. A positive discount rate assumes that the economy will always grow, and that future generations will always be wealthier than the previous. However, future generations may not be wealthier than the current generation. There could be zero or negative growth on account of environmental degradation. For example, a time-consistent discount rate may not be possible in a world where global warming causes very high economic damages. As decision-makers look further into the future, incidents such as these could occur and influence the rate of return we receive on capital.

Weitzman illustrates the problem of discounting long-run future events by describing responses to global warming. He provides the example of sea-level rise, which would flood low-lying coastal cities if mitigating infrastructure like dikes and pumps were not constructed. This infrastructure would be expensive, but if we were to save for this protective infrastructure now then a modest savings could accumulate *with a steady*

⁴⁴ Heal, "Intertemporal Welfare Economics and the Environment," 1108.

interest rate and pay for infrastructure in the distant future.⁴⁵ The value of future resources, as well as costs, is perceived as small today.

In the example of the hiker, she may satisfy her desire today, tomorrow, next week or she may hike next year. Unlike a hike, the use of environmental resources is not as elastic. Once depleted, we cannot transfer ecological resources to tomorrow or next year. For example, once an aquifer has been contaminated with radioactive materials or harmful chemicals, that aquifer is no longer available for use tomorrow, next year, or perhaps ever. The generation that pollutes the aquifer may not consume the sum total of aquifers, but it depleted an environmental resource that is likely to become scarce in the future. This resource could have great value for future generations.⁴⁶ As a result, our desire to consume the aquifer in this way is irrational if we consider that future generations value resources in a similar way (or greater) as the current generation.

Discounting for the future using only today's rates to value environmental resources ignores problems that matter in the future. This creates problems of intergenerational inequity since it prioritizes present generations over future ones. Economists continue to discuss this issue, which has not yet been solved. However, economists have posited adjustments to the exponential discount rate that improve intergenerational equity.

Quasi-Hyperbolic Discounting

Economists suggest quasi-hyperbolic discounting as a method to improve intergenerational equity in benefit cost analysis. Exponential discounting is time-consistent, while hyperbolic and quasi-hyperbolic are time-inconsistent. That is, in quasi-hyperbolic discounting, the distance in time from the precipitating event or project matters, and not just the cost of capital in a given year or the given constant for the discount rate. The model for this approach can change under the circumstances of the economic analysis. These vary according to the institution responsible for the

⁴⁵ Martin L. Weitzman, "Just Keep Discounting, But..." *Discounting and Intergenerational Equity*, Edited by Paul Portney and John Weyant, (Washington D.C.: Resources for the Future 1999): 23.

⁴⁶ Pigou, "The Economics of Welfare" I.11.5.

analysis and its intent,⁴⁷ so economists present several rationales and approaches for quasi-hyperbolic discount rates. Explaining the mathematical approach behind each rationale is beyond the goals of this thesis, so I present the conceptual arguments behind them.

The first rationale for considering quasi-hyperbolic discount rates has been presented by Laibson and Cropper.⁴⁸ They argue that a person who discounts the future hyperbolically will not fulfill the future consumption plans that she designs today. Evidence of this has been presented by Thaler, who posits that consumers have “time-inconsistent” preferences. Thaler demonstrates that consumers vary their discount rates with the length of time they wait.⁴⁹ The impact of waiting one more week after waiting 52 weeks is less than waiting one week when she can have the good now. The consumer has a higher discount rate for the near term, and a lower discount rate for the distant future. This presents a problem for near-term decision making. The consumer wishes to maximize present utility, which she estimates with a high, near-term discount rate. She anticipates that she will discount the long-run at a lower rate, but when tomorrow comes she engages in the same behavior that she did before. In this way, she always puts off the decision to conserve until a later date, repeating this decision again and again.⁵⁰ If consumers were to compete against themselves for resources, quasi-hyperbolic consumers would always operate in Pareto-inefficiency since they would consume the future self’s resources. The consumer can intervene on this behavior by committing resources to a different alternative that may not provide the same level of

⁴⁷ Partha Dasgupta, Karl-Goran Maler, and Scott Barrett, “Intergenerational Equity, Social Discount Rates, and Global Warming,” *Discounting and Intergenerational Equity*, Edited by Paul Portney and John Weyant, (Washington D.C.: Resources for the Future 1999): 51.

⁴⁸ Cropper, Maureen, David Laibson, “The Implications of Hyperbolic Discounting in Project Evaluation” *Discounting and Intergenerational Equity*. Edited by Paul Portney and John Weyant, (Washington D.C.: Resources for the Future 1999): 163-171.

⁴⁹ Richard Thaler, “Some Empirical Evidence on Dynamic Inconsistency,” *Economics Letters* 8 (1981) 201.

⁵⁰ Cropper, Laibson, *Discounting and Intergenerational Equity*, 165.

utility in the short-term. She anticipates that committing resources would yield greater utility in the long-term.⁵¹

Exponential discounting anticipates a high rate of return in the near-term, which tempts the consumer to exploit the resource; however, if the consumer anticipates this behavior then she can commit to saving the resource through some mechanism, such as a trust. Quasi-hyperbolic behavior exhibits “a motive for lowering the rate of return on all capital investment projects because of the under-saving that occurs”⁵² on the part of the consumer. If the current generation is willing to conserve resources then they essentially commit to receiving a lower rate of return today. This lowers their welfare. However, the change in the way the consumer uses resources use impacts the resources then available to future generations and thus the way future generations consume, so future generations receive a similar rate of return as well.⁵³ Subsequently, the current generation does not compete with the future generation.

Figure 2 illustrates how year one’s decision-makers who adjust for quasi-hyperbolic choices are willing to sacrifice today for greater returns at a future date. In the first period the discount rate is the same as in exponential discounting, but the rate falls sharply after that, and remains low, a fraction of what it would be with an exponential approach. In this example, eventually the quasi-hyperbolic discount rate yields a higher present value than the exponential rate.

Adjusting for hyperbolic decisions does not make the problem of determining the most appropriate discount rate (or formula) disappear. It just gives decision-makers a model for perceiving present value when they commit to lower levels of consumption today. Laibson developed quasi-hyperbolic discounting to demonstrate the influence on

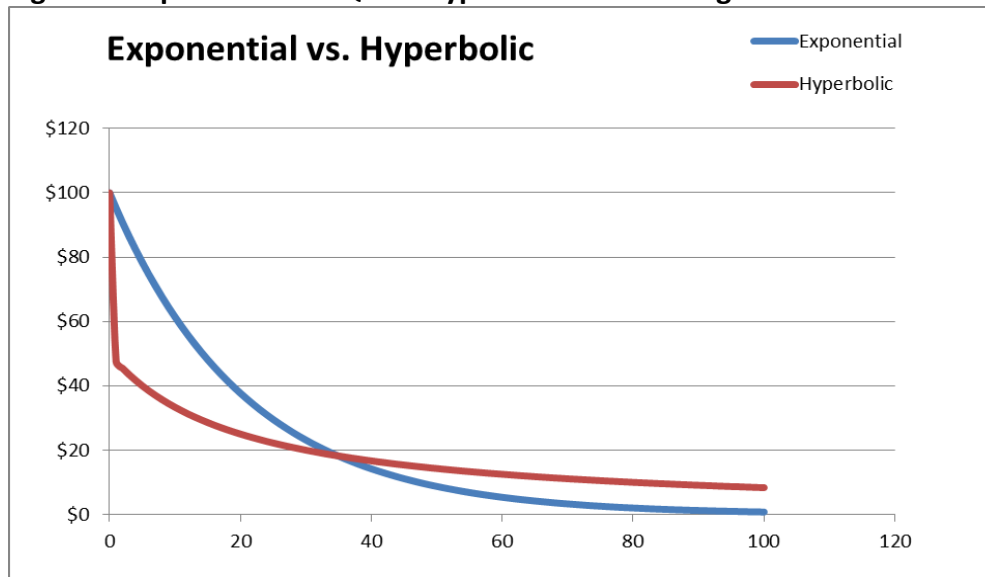
⁵¹ David Laibson, “Golden Eggs and Hyperbolic Discounting,” *The Quarterly Journal of Economics* 112, no. 2 (May 1997): 443-477.

⁵² Cropper, Laibson, “The Implications of Hyperbolic Discounting,” 164.

⁵³ *Ibid.*, 167.

behavior that can occur if consumers have to wait just one year before liquidating an asset. According to the model, just one year of waiting can be enough to inspire savings on the part of the consumer. Laibson was analyzing financial instruments, liquidity, and savings. Savings and liquidity, I argue, are the same concepts at work when analyzing decisions to conserve or deplete natural resources.

Figure 2: Exponential vs. Quasi-Hyperbolic Discounting



Economists, following Laibson,⁵⁴ build on the standard exponential model of discounting.. The discount factor incorporates a time delay in receiving the benefits (again, in a simple model of liquidating an asset). The time delay is multiplied by the original discount rate. This is the expression of hyperbolic discounting; as one looks further into the future from the event, the denominator in this discount factor grows, expressing the idea that the longer one will have to wait, the smaller the effect (utility, present benefit) of waiting a bit longer. (1)

$$1) \text{ Discount Factor} = 1 / (1 + \text{Time Delay in Receiving Reward} \times \text{Discount Rate})$$

⁵⁴ Ibid., 167.

Laibson modeled a special case where, in the first period (first year), assets were not liquid and there for no discounting occurred. In Rasmussen's explanation of quasi-hyperbolic discounting, a beta factor is introduced. The delta (i.e., the discount factor) is multiplied by beta. For this reason the model is called "beta-delta." (2)

2) Delta x Beta

Beta is always between 0 and 1. As Rasmussen explains, "[t]his means there is a lot of discounting from the present to time 1, ... but after that the discount factor between any two adjacent periods falls to a constant delta." As in hyperbolic discounting, the discount factor incorporates time, so the influence of the discount factor on present value over time is a declining discount rate. For this reason, quasi-hyperbolic discount rates are also referred to as "time-declining discount rates."

This is a departure from standard exponential discounting. Rasmussen summarizes these changes. Standard exponential discounting assumes a constant discount factor (1).⁵⁵ This need not be the case – the discount rate could change over time, but the underlying idea is that for personal utility curves, consumption earlier adds more utility than consumption later (a principle easily applied if the discount rate is constant). The change in Delta remains consistent with the year of consumption. The utility function for exponential discounting (U) from consumption (C) across time (subscript number of years) is as follows. (3)

$$3) U_0 = C_0 + (\Delta_{1} \times C_1) + (\Delta_{2} \times C_2) + (\Delta_{3} \times C_3) \dots$$

Quasi-hyperbolic discounting multiplies the Delta by beta. Since the beta is between year 0 (the present) and time period 1 (next year), there is a lot of discounting that takes place in the first period.⁵⁶ This accounts for the drop between time 0 and time 1 that occurs in Figure 2. Every year after time 1 the discount factor falls at a constant delta;

⁵⁵ Eric Rasmussen, "Some Common Confusions about Hyperbolic Discounting," (unpublished white paper, last modified March 25, 2008): 8, <http://www.rasmusen.org/special/hyperbolic-rasmusen.pdf>.

⁵⁶ Ibid.

however, the date of the “present” is always changing.⁵⁷ Rasmussen presents this equation for the utility of consumption with quasi-hyperbolic discounting as follows. (4)

$$4) U_0 = C_0 + (\beta \times \delta_{t_1} \times C_1) + (\beta \times \delta_{t_2} \times C_2) + (\beta \times \delta_{t_3} \times C_3) \dots$$

The quasi-hyperbolic approach creates a relativistic perception of time, meaning that the date of the “the present” is always changing.⁵⁸ This means that the difference between present values in time period 4 and 5 is not simply a discount factor, but a discount factor relative to an earlier time period, such as year 1. The beta allows the consumer to sharply distinguish between “right now” and “all future time-periods.”⁵⁹ Consumers perceive of the future (say year 50) as relative to a previous time period (say year 1). This is different than exponential discounting, which perceives of the difference between years 0 and 1, and years 49 and 50, the same. This helps the consumer understand that preferences can change between year 1 and year 50. As a result, the consumers, if they are willing to wait at all, may actually forego spending and thus be willing to save over a long period of time.

This approach assists economists concerned with the consumption of assets of many kinds. Laibson, applied quasi-hyperbolic discounting to an analysis of liquidity in financial markets. Laibson set out to show that financial market innovation increases the liquidity of assets, which results in less saving on behalf of consumers.⁶⁰ Since liquidating assets becomes a simple transaction for the consumer, they sell off assets and spend rather than conserve them for the future. This approach is helpful in understanding the management of other resources, such as ecological services, as well as a rationale for commitment behavior.

⁵⁷ Ibid.

⁵⁸ Ibid.

⁵⁹ Ibid. 9.

⁶⁰ Laibson, “Golden Eggs and Hyperbolic Discounting,” 446.

Much like financial assets, organizations that manage environmental assets can liquidate them. The cost of liquidating environmental resources falls on future owners, such as the next generation, who no longer have access to those resources. Quasi-hyperbolic discounting allows individuals and managers of ecological assets to perceive of future resources through the lens of commitment. If current managers perceive of their successors as time-inconsistent, the current generation will opt to constrain the options of their successors by committing resources to a certain use.⁶¹ In the analysis presented in Chapter 2, quasi-hyperbolic behavior explains how the current generation could be persuaded to invest in natural capital, and commit ecological resources to future generations.

While the quasi-hyperbolic discount approach has been championed by environmentalists and some economists, other economists disagree with its application. They argue that these rates create a situation in which a person applying an individual declining rate will regret not having consumed more in the past.⁶² This argument states that the consumer is not optimizing her resources, and she could receive a higher rate of return. Laibson responds to this concern by explaining that the government can induce conservative behavior by offsetting utility lost or penalizing consumption. He argues that this could occur through the government augmenting interest or tax rates, thus inducing people to save.⁶³ In environmental transactions the government typically incentivizes or regulates, meaning that it increases the benefits of conserving environmental goods or increases the costs of consuming them.

The second rationale for applying time-declining discount rates has been presented by Weitzman. He argues that time-declining discount rates are a practical measure that incorporates uncertainty into the selection of the discount rate. Current exponential

⁶¹ Rassmussen, "Common Confusions about Hyperbolic Discounting," 14.

⁶² Mark Long, Richard Zerbe, and Tyler Davis, "The Social Discount Rate as a Function of Individuals' Time Preferences," (Working Draft, no date): 5.

⁶³ Cropper, Laibson, *Discounting and Intergenerational Equity*, 170.

discount rates have been extrapolated from past rates of return on capital. These rates have uncertainty in the future since they have been informed by historical growth. Conceptualizing future growth rates can be a difficult task since they depend on environmental circumstances, political relations, degree of diminishing returns, and many other unknowable factors.⁶⁴ This approach suggests that the present value of a project is determined by uncertain scenarios. The probability of a scenario is more certain in the short-run, but less certain in the distant future. Weitzman adjusts the discount rate by multiplying the discount factor by a beta, while beta represents the degree of uncertainty. A beta closer to one reflects greater certainty than a beta closer to zero. The result is similar to Laibson's approach, with the present value declining over time.

The third rationale for time-declining discount rates has been presented by Chichilnisky⁶⁵ and Li and Lofgren,⁶⁶ who argue that declining discount rates influence sustainable development. Chichilnisky argues that the "issue is to describe value so that it does not underestimate the future's interests, so that the future is given an equal treatment (as the present)."⁶⁷ She develops axioms for *sustainable preferences* in decision-making that reflect the needs of the present as well as the future. Her approach features a similar "beta" as Weitzman, but rather than referring to it as uncertainty, it is a weight given to future generations. If there were a finite number of generations, to any generation one could assign weights which decline into the future, and assign extra weight to last generation.⁶⁸ This weight is defined by each generation's instantaneous utility, which is a function of consumption and resource stocks at each time period. This approach "ranks paths of consumption and natural resource use

⁶⁴ Martin Weitzman, "Why the Far Distant Future Should Be Discounted at Its Lowest Possible Rate." *Journal of Environmental Economics and Management*, 36 (1998): 202-203.

⁶⁵ Graciela Chichilnisky. "An Axiomatic Approach to Sustainable Development," *Social Choice and Welfare* 13 (1996): 231-257.

⁶⁶ Ben Groom et al., "Declining discount rates: the long and short of it," *Environmental and Resource Economics* 32 (2005): 471.

⁶⁷ Chichilnisky, "An Axiomatic Approach to Sustainable Development," 233.

⁶⁸ *Ibid.*, 243.

according to their long-run characteristics,”⁶⁹ and assumes that future generations have similar preferences to those we have now. In a world of finite resource stocks, these weights assign greater value to the needs of future generations than standard discounting allows. As a result, they allocate resources for use in the future.

Li and Lofgren present a contrasting approach to the same sustainable development goals as Chichilnisky.⁷⁰ They assume society is made of utilitarians and conservationists, whose utility functions are identical except for the discount rates. The overall goal is to “maximize the weighted sum of wellbeing for both members of society given their different weights for future generations.”⁷¹ Their proof demonstrates that the exponential discount rate declines to zero, with preference towards the present generation. Meanwhile the weighted discount rate will reach zero after the exponential rate, giving preference to the distant future. As a result, neither the present nor future generations is ignored in the economic analysis of a project.

The section above outlines various rationales for time-declining discount rates, each requiring different assumptions. Understanding the rationale behind each approach can be a difficult task; however, the effect of the quasi-hyperbolic discount rate is that the discount factor will decrease as time increases.⁷²

Conclusion of Literature Review

In Chapter 1, I provide a base for perceiving of ecological resources as economic assets. Understanding their economic contributions is critical to fully incorporating all costs and benefits of a project. Accordingly, these assets can be adapted to economic analysis. However, these assets are different from normal economic resources. They do not benefit from market transactions indicating their value. Future returns are subject to unknowable environmental factors. Likewise, decisions about the management of

⁶⁹ Groom, “Declining discount rates,” 470.

⁷⁰ Ibid., 470.

⁷¹ Ibid., 471.

⁷² Atkinson, Mourato, “Environmental Cost-Benefit Analysis,” 329.

ecosystem services require that economic valuations and methodologies be adjusted to reflect the long-term economic returns and finite stocks. Incorporating ecosystem services into benefit cost analysis means that special considerations must be made.

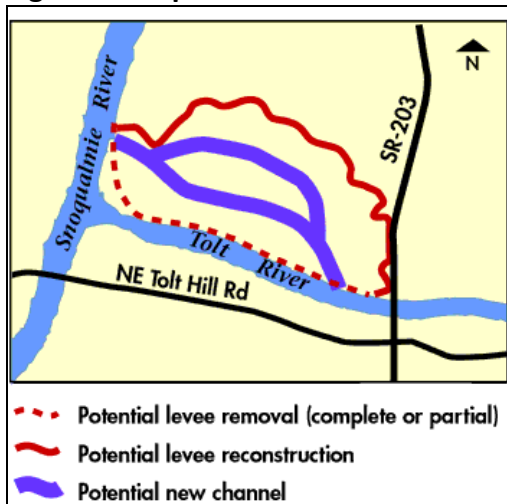
In Chapter 2 and 3 I explore the role of ecosystem services in benefit cost analysis, I conduct an ex post economic analysis of a project that changes ecosystem services King County. This exercise illustrates the issues articulated in Chapter 1.

Chapter Two: Introduction to Benefit Cost Analysis of Floodplain Restoration - Lower Tolt River

The following section presents a project of the King County Water and Land Resources Division (WLRD) to restore Chinook salmon habitat on the Tolt River. The effort is called the “Tolt River Floodplain Reconnection Project” (Tolt site). The analysis that follows reveals that the project is beneficial under both the exponential and quasi-hyperbolic discount rates, with net present values of **\$3,726,990** and **\$3,195,484** (respectively) over 100 years. The purpose of the project was to improve salmon habitat, but it accomplished other environmental and social benefits as well.

Between c. 1940 and 2005 the Tolt site hosted a levee that protected public land, agricultural resources, and private residences. While this levee provides a degree of protection from the Tolt River, the larger Snoqualmie River is responsible for flooding in Carnation. Carnation is the town located one mile northeast of the project. Since the levee provided nominal flood protection, WLRD anticipated an opportunity to improve salmon habitat, which had been cut off from the Tolt by the levee. As illustrated in Figure 3, WLRD planned to remove the levee (dotted red line) and rebuild it 800 feet back (solid red line) and provide new channels (purple line) in the riparian land created.

Figure 3: Map of the Tolt Site



Source: King County Water Land and Resources Division⁷³

The project was initiated by King County in the 2004 to accomplish the following goals:⁷⁴

- Recreate salmon habitat, including floodplain planting and logjams;
- Restore side channel habitat as well as pools and riffles to the main channel;
- Add a levee revetment that improves the strength of the new levee;
- Set the levee back 800 feet. This allows the river to meander through the restored floodplain;
- Maintain level of flood protection by replacing 2,500 feet of levee along the bank of the Tolt River.

In the planning phase of the project, stakeholders determined the economic impact of this project as “non-significant,”⁷⁵ so they did not conduct an *ex ante* benefit cost analysis of the project. A determination of non-significance means that the project does not have probable adverse environmental impact, so an Environmental Impact

⁷³ “Lower Tolt River floodplain restoration project,” King County, Accessed on May 28, 2012, <http://www.kingcounty.gov/environment/animalsAndPlants/restoration-projects/tolt-restoration.aspx>.

⁷⁴ King County, “Snoqualmie 2015,” February 2006, http://www.govlink.org/watersheds/7/pdf/Snoq2015_13-31.pdf, 29.

⁷⁵ King County, “Determination of Non-Significance,” June 22, 2006, <http://your.kingcounty.gov/dnrp/library/archive-documents/wlr/cposa/tolt-restoration/pdf/determination-of-non-significance.pdf>.

Statement (EIS) is not required of King County.⁷⁶ The Washington State Department of Ecology states that a benefit cost analysis is optional if the project's lead agency determines it helpful.⁷⁷ Rather than seeking quantitative economic benefits, King County believed this project would accomplish qualitative goals. Specifically, the county wished to restore Chinook salmon spawning habitat. Chinook are listed on the Endangered Species Act (ESA), and restoring the habitat of this species accomplishes economic, cultural, and environmental goals of the Puget Sound region.⁷⁸

A benefit cost analysis of this project communicates the economic advantages of restoring salmon habitat. This information becomes important to King County, which invests heavily in salmon restoration. For example, the county engaged in 81 restoration projects between 2006 and 2010.⁷⁹ These plans occasionally conflict with the interests of local communities. Conflicts can delay or stop a project. To promote restoration policy and advance plans, the economic benefits of a project are powerful pieces of information that communicate the importance of the salmon restoration to the environment and economy.

I conduct an *ex post* benefit cost analysis of the Lower Tolt River Floodplain Reconnection Project to determine net present value of the project at the time of its construction. Since few market goods result from the project, I incorporate ecosystem services values into the analysis. Chapter 1 explains why the ecosystem service values are important to benefit cost analysis. They ensure that the full value of goods and services lost or gained as a result of the project are accounted for in decision-making. This practice internalizes externalities. For those costs and benefits that cannot be monetized and calculated, I explain their qualitative impacts. Table 1 outlines costs,

⁷⁶ Ibid.

⁷⁷ "Environmental Impact Statement Process," Washington State Department of Ecology, Accessed on June 4, 2012, <http://www.ecy.wa.gov/programs/sea/sepa/handbk/hbch03.html>.

⁷⁸ Puget Sound Partnership, "Article 9: Protect and Recover Salmon," *Action Agenda*, December 11, 2011, 92.

⁷⁹ King County, "Chinook Salmon Recovery Projects," King Stat, Accessed on May 7, 2012, <http://your.kingcounty.gov/dnrp/measures/performance/en-chinook-salmon.aspx>.

benefits, and other parameters of the analysis. To approximate the benefits and costs, I rely on benefit transfer methodology. I explain how I derived each annualized value in their respective sections in Chapter 3.

Each cost and benefit has been adjusted for inflation to 2010 values, which is the year the project was completed, using the Bureau of Labor Statistics Inflation Calculator.⁸⁰ Some values have low-estimates and high-estimates. These values reflect the changing preferences for ecosystem services among consumers. This is true for all values except Riparian Habitat. This value is reported by Earth Economics in a report to SPU on the Lower Tolt Watershed.⁸¹ This is an important report to the Tolt watershed since it has been used by other economic and environmental analysts, including Triangle Associates and Tetra-Tech. These organizations co-authored a report for SPU that addresses management alternatives in the Lower Tolt Watershed.⁸² They elaborate on the Earth Economics value for Riparian Habitat and methodology used in generating it. Triangle Associates and Tetra-Tech indicate that the values provided by Earth Economics were derived with benefit transfer methodology and informed by a range of peer-reviewed sources. This means that the range between high and low values could be larger in the Earth Economics report than if the values were transferred from a single peer-reviewed source.

For other benefit values, I derived values from multiple sources so I could estimate site-specific user data. For example, the Recreational Park Use value relies on data provided by a Trust for Public Land report for the City of Seattle as well as data provided by the City of Carnation. Essentially, I apply a benefit transfer method, using general data and adjusting them for the context of the Tolt site.

⁸⁰ "CPI Inflation Calculator," Bureau of Labor Statistics, Accessed on May 28, 2012, http://www.bls.gov/data/inflation_calculator.htm.

⁸¹ Triangle Associates and Tetra-Tech, "South Fork Tolt Watershed Management Plan," (unpublished report prepared for Seattle Public Utilities, accessed in June 2011): 4-18. http://www.seattle.gov/util/groups/public/@spu/@conservation/documents/webcontent/01_012728.pdf.

⁸² Ibid.

Table 1: Parameters of the Benefit Cost Analysis

Benefits	Value	Source
Recreation: Fishing	\$14.67/user/day	WDFW ⁸³
Recreation: Park Use	\$.89 – \$2.40/user/day	Trust for Public Land ⁸⁴ and Carnation data ⁸⁵
Flood Risk Reduction	\$3,360/household/year	King County ⁸⁶ and FEMA data ⁸⁷
Riparian Habitat	\$11,981 – \$44,554/acre/year	Earth Economics ⁸⁸

Costs	Value	Source
Construction: Materials/Labor	\$6,150,000	King County ⁸⁹
Maintenance	\$90,000	King County ⁹⁰
Project Identification	\$5,000	King County ⁹¹
Feasibility	\$175,000	King County ⁹²
Design	\$212,500	King County ⁹³
Review of Alternatives	\$175,000	King County ⁹⁴
Permitting	\$212,500	King County ⁹⁵
Final Design	\$15,000	King County ⁹⁶

⁸³ TCW Economics, “Economic Analysis of Non-Treaty Fisheries in Washington State,” (unpublished manuscript prepared for Washington Department of Fish and Wildlife, last modified December 2008): 15-20. <http://wdfw.wa.gov/publications/00464/wdfw00464.pdf>.

⁸⁴ Trust for Public Land, “The Economic Benefits of Seattle’s Park and Recreation System,” (unpublished manuscript, last Modified March 2011,): 11. http://www.seattleparksfoundation.org/TPL_EconomicBenefits.pdf.

⁸⁵ “Public Parks and Open Space,” City of Carnation, Accessed on May 27, 2011, http://www.carnationwa.gov/index.asp?Type=B_LOC&SEC=%7BA6EE32AC-4E9C-4237-8D47-37E08B8C88AC%7D.

⁸⁶ King County, “2009 Values for 100-year-flood,” (unpublished data, Accessed on April 7, 2012), Excel data, <http://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=13&ved=0CEYQFjACOAo&url=http%3A%2F%2Fyour.kingcounty.gov%2Fdnrp%2Flibrary%2Fwater-and-land%2Fflooding%2Flocal-hazard-mitigation-plan-update%2Fdata-100-year-flood.xls&ei=j3GET5GLE7LaiQLL6Lj1BA&usq=AFQjCNGchdVO2C3H29L79NhN2BCvaeixKg>.

⁸⁷ King County, “Lower Snoqualmie & Skykomish Rivers Flood Insurance Study,” (unpublished report , accessed on November 7, 2006). <http://green.kingcounty.gov/wlr/science/seminar/pdfs/PDF11.pdf>.

⁸⁸ “Lower Tolt River floodplain restoration project,” King County.

⁸⁹ Jon Hansen, Presentation regarding Tolt Site, King County, “Lower Tolt River Floodplain Reconnection Project,” Accessed on March 1, 2012. http://www.rco.wa.gov/documents/salmon/conference/2011/hansen_j.pdf.

⁹⁰ Salmon Recovery Funding Board (SRFB), “Salmon Recovery Program In-Stream Habitat Application Materials Checklist,” Last modified on February 29, 2004, <http://www.rco.wa.gov/prism/projectsnapshot.aspx?ProjectNumber=08-2056>.

⁹¹ King County, “Snoqualmie 2015: Appendix C,” (unpublished report, February, 2006): 75.

⁹² Ibid.

⁹³ Ibid.

⁹⁴ Ibid.

⁹⁵ Ibid.

Other Parameters

Method	Net Present Value
Discount Rate	4%
Time Frame	100 years
Beta	.5

A 4% discount rate is consistent with the practices of the United States Army Corps of Engineers (USACE) rate for water projects.⁹⁷ A 100-year timeframe reflects the long-term nature of government infrastructure projects (50-100) years.⁹⁸ I use quasi-hyperbolic discounting, but also show results with exponential discounting. A beta of .5 means that decision-makers are willing to reduce their return on welfare in year one by 50%.

Ecosystem service values can vary greatly over time. They depend on environmental quality and the community's willingness to pay for the ecosystem services. This analysis incorporates uncertainty and variance in parameters through the use of sensitivity tests. Specifically, I use Monte Carlo simulation. All variables were given a uniform distribution with a mean, low, and high estimate. A uniform distribution means that each trial run of the simulation features a random combination of values within the low and high estimates. The mean provides a base case scenario, so the simulation can determine whether an input falls below or above the mean. I ran 10,000 trials, which translates to 10,000 input combinations. The variation of parameters will influence net present value. For example, if one trial of the simulation randomly selects all low values for the "benefit parameters" then the project may not generate enough benefits to justify the cost; however, this is one trial among 10,000. 9,999 other scenarios are possible.

⁹⁶ Ibid.

⁹⁷ United States Army Corps of Engineers (USACE), "Memorandum for Planning Community of Practice," (unpublished memorandum, October 21, 2011), <http://planning.usace.army.mil/toolbox/library/EGMs/EGM1201combined.pdf>.

⁹⁸ Association of State Floodplain Managers, "Discount Rate," (unpublished memorandum, May 17, 2008), http://www.floods.org/PDF/WhitePaper/ASFPM_Discount_%20Rate_Whitepaper_0508.pdf.

Table 2 shows the mean, low, and high input parameters. Each benefit value is annualized. Changes that impact users reflect the annual population that experience benefits. Spatial parameters have been applied to the 48.5 acres of the site. An explanation of each parameter is included in Chapter 3.

Table 2: Benefit Parameters for Sensitivity Tests

Parameters	Distribution	Value Used in Sensitivity Test	Mean	Low	High
Discount Rate	Uniform	0.04	0.04	0.03	0.05
Beta	Uniform	0.5	0.5	0.4	0.6
Benefits Categories					
Riparian Habitat	Uniform	\$547,093	\$547,093	\$236,701	\$857,485
Park Use	Uniform	\$4,737	\$4,737	\$3,388	\$6,086
Fishing	Uniform	\$45,518	\$45,518	\$10,710	\$80,325
Flood Risk Reduction	Uniform	\$3,360	\$3,360	\$3,024	\$3,696
Total Annual Benefits		\$600,842	\$600,842		

It is important to remember that construction, maintenance, and other costs only occur at year zero. They are one-time costs, so their annualized values do not occur each year. Subsequently, costs are not discounted over time. The only cost categories with precise estimates are Construction and Maintenance, and all other cost categories were informed by King County’s Snoqualmie 2015.⁹⁹ This is a CIP plan for natural infrastructure developed by for the Snoqualmie watershed. In Chapter 3, I explain each cost category and their general contribution to the project. In Table 3 below,

Table 3: Cost Parameters for Sensitivity Tests

Cost Categories	Distribution	Value Used in Sensitivity Test	Mean	Low	High
Construction	N/A	\$6,150,000	N/A	N/A	N/A
Maintenance	N/A	\$90,000	N/A	N/A	N/A
Review of Alternatives	Uniform	\$175,000	\$175,000	\$50,000	\$300,000
Project Identification	Uniform	\$5,000	\$5,000	N/A	N/A
Feasibility	Uniform	\$212,500	\$212,500	\$25,000	\$400,000
Design	Uniform	\$212,500	\$212,500	\$25,000	\$400,000
Permitting	Uniform	\$15,000	\$15,000	\$5,000	\$25,000
Final Design	Uniform	\$175,000	\$175,000	\$50,000	\$300,000

⁹⁹ King County, “Snoqualmie 2015,” February 2006, http://www.govlink.org/watersheds/7/pdf/Snoq2015_13-31.pdf, 29.

Rationale for Studying this Site and Site Information

In the Puget Sound region, levee setbacks provide valuable flood mitigation for communities. The concept behind setbacks is simple. A constricted river is given greater area by removing the levee that confines it, and setting the levee back at a certain distance. This practice accomplishes a variety of objectives.

First, levee setbacks can improve ecosystem services. River systems nurture plant and animal species that improve the quality of life for people. Vegetation can process pollutants. Salmon habitat provides food and an economic resource. Community members visit rivers for recreation. River systems play an important role in ecology, culture, and the economy.

Second, levee setbacks provide an economic benefit to the community. The risk of flooding is greatest among residential and commercial establishments in the floodplain. Floods have the potential to damage property and place human life at risk. Flooding can significantly damage property, so flood protection measures, such as a levee setback, can lower the risk of flood damage. As a result, a levee setback can provide an economic value to a community in the form of reduced risk to property.

A primary goal of the Lower Tolt River Floodplain Reconnection Project is to restore the Tolt's natural meander at the site, creating space for ecosystem service processes. This is a process-based restoration approach, which contrasts with other restoration efforts that "create specific habitat characteristics to meet perceived 'good' habitat conditions or uniform habitat standards."¹⁰⁰ These attempts at restoration require a higher level of engineering and maintenance. The cost of this approach may be high over time, while the benefits short-lived. In contrast, process-based restoration attempts to restore



¹⁰⁰ Beechie et al, "Process-based Principles for Restoring River Ecosystems," 209.

drivers and functions of habitats.¹⁰¹ The value generated by this approach may be low initially, but conditions improve over time as the habitat matures and natural processes re-establish.

Figures 4 and 5 demonstrate present and past conditions on the Tolt site. The goal of the restoration project is to restore the site to 1937 conditions, which are shown in Figure 5.

¹⁰¹ *ibid.*



Figure 4: Lower Tolt River Floodplain Reconnection Site - Prior to Restoration

<p>Aerial Photo, 2004</p>	 <p>Source: King County, DNRP¹⁰²</p>
<p>Aerial Photo, 2004</p>	 <p>Source: King County, DNRP¹⁰³</p>
	<p>The aerial photo shows the confined channel of the Tolt River emptying into the Snoqualmie River. The area directly north of the channel is unmanaged, vegetative riparian habit. The levee constricts the Tolt’s braids, reducing the area of the floodway and increasing the velocity of the river flow. The higher velocity flood flows sweep valuable gravel for salmon spawning habitat downstream.</p>

¹⁰² “Project pictures, information and schedule: Lower Tolt River Floodplain Restoration Project,” King County, Accessed on May 28, 2012, .<http://www.kingcounty.gov/environment/animalsAndPlants/restoration-projects/tolt-restoration/project-schedule.aspx>.

¹⁰³ Ibid.

Figure 5: Lower Tolt River Floodplain Reconnection Site - After Restoration

<p>Aerial Photo, 1937</p>	 <p>Source: King County, DNRP¹⁰⁴</p>
<p>Aerial Photo, 2004</p>	 <p>Source: King County, DNRP¹⁰⁵</p>
<p>The aerial photo shows the confined channel of the Tolt River emptying into the Snoqualmie River. The restoration and levee setback intend to restore the site to historical conditions. Compared with the 2000 conditions, the confluence with the Snoqualmie is characterized by meandering braids and sediment deposits. The result of these efforts included 35 acres of new salmon spawning habitat, trails for hiking, reduced flood risk, and increased vegetative habitat.¹⁰⁶</p>	

¹⁰⁴ Ibid.

¹⁰⁵ Ibid.

¹⁰⁶ Earth Economics, "Supplemental Ecological Services Study: Tolt River Watershed Asset Management," (unpublished manuscript, December 16, 2005): 33. http://www.eartheconomics.org/FileLibrary/file/Reports/Puget%20Sound%20and%20Watersheds/Tolt_River_Ecological_Service_Study.pdf.

Chapter Three: Benefits and Costs of Lower Tolt Project

Quantitative Benefits

Recreation: Fishing

Benefit of Change	\$14.67 per user per day
Assumption	WTP of anglers to fish the site. 8.5 anglers fished 93% of open fishing days on this site.

The Tolt site serves recreational demands for local residents. King County states that recreational fishing will improve through the restoration process.

“The improvement in fish habitat may attract more people for fishing. Fishing and wildlife viewing appear to be valuable contributors to the tourism economy of the Valley.”¹⁰⁷

Improvements to the Tolt site create a new demand for fishing in the area. Washington Department of Fish and Wildlife commissioned the “Economic Analysis of Non-Treaty Fisheries in Washington State,” which estimated willingness to pay for anglers per day at \$45. Residents fished roughly 93% of all fishing days.¹⁰⁸ Since the Tolt site is not open for the entire year (only 128 days), 93% of open fishing days on this site is equal to 119 days per year.¹⁰⁹ Identifying the exact number of anglers that use the site per day would require more resources than the Department of Fish and Wildlife may be willing to commit. For the purposes of this exercise, I assume that a low estimate of the anglers per day is 2 and a high estimate is 15. Both these estimates are low, but the Tolt site is a new angling destination as well as a small one.

¹⁰⁷ King County, “Response to SEPA Comments from the City of Carnation: Regarding the Lower Tolt River Floodplain Reconnection Project,” (unpublished report, last modified on March 29, 2007): 12. <http://your.kingcounty.gov/dnrp/library/archive-documents/wlr/cposa/tolt-restoration/pdf/sepa-responses-carnation.pdf>.

¹⁰⁸ TCW Economics, “Economic Analysis,” 15-20.

¹⁰⁹ Washington Department of Fish and Wildlife, “Fishing in Washington: 2011-2012 Sportfishing Rules Pamphlet,” 39. <http://wdfw.wa.gov/publications/01185/>.

By multiplying the willingness to pay per day (\$45) by the days per year possible (119) by the average demand per day (8.5), this site has an average value of \$45,517. This is an average value between a low estimate of \$10,404 (2 users per day) and a high estimate of \$80,325 (15 users per day). When divided by 365 days and the number of users, the value per user per day is \$14.67.

Recreation: General Park Use

Benefit of Change	\$.89 (low) and \$2.40 (high) per user per visit
Assumption	Seattle and Carnation residents have a similar demand for park recreation no matter the acreage available.

In a response to SEPA review questions, King County addressed City of Carnation’s concerns about changes to recreational use of the park.

“The project provides access into a previously unused portion of the park (the reconnected floodplain area) and will encourage wildlife viewing and hiking.”¹¹⁰

An estimation of the value for park visits has been adapted from a 2011 survey of Seattle.¹¹¹ The exact value for Carnation residents is unknown, so I use Seattle’s survey of “value of a park visit” and “number of visits” and I adjust for Carnation’s population. Seattle residents visited parks 160 times throughout a year and valued each visit at \$1.95. I assume that Carnation residents visited between 50% and 150% of Seattle’s visits (80 to 240 visits). I assume residents value each visit in a range of 50% and 150% (\$0.89 to \$2.40). From these numbers I generate low and high valuations for an increase in 48.5 acres of new parkland for 1,844 residents of Carnation. This creates a large range (\$10,404 and \$93,642), which will inform sensitivity tests.

Flood Risk Reduction

Benefit of Change	\$ 3,360 per household per year (In Carnation’s 100-year
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¹¹⁰ King County, “Response to SEPA Comments from the City of Carnation,” 12.

¹¹¹ Trust for Public Land, “The Economic Benefits of Seattle’s Park and Recreation System,” 11.

	floodplain)
Assumption	Conservative estimate of Carnation’s willingness to accept flood risk. Construction cost estimates of neighboring flood mitigation projects are accurate.

In Carnation, the flooding is a serious problem; however, project documents state that this project maintains flood protection rather than improves it. Despite the objectives of the project, riparian habitat improvements as well as other improvements to flood prevention along the Tolt River can reduce the cost of flood risk to Carnation residents.

Communities must deal with the financial implications of flood risk due to the requirements of the Federal Emergency Management Agency’s (FEMA) National Floodplain Insurance Program (NFIP).¹¹² Home-owners that wish to insure their residences against flooding must participate in the NFIP program. The value of the annual NFIP payment reveals the cost homeowners incur as a result of living in the floodplain.

Communities can lower their flood insurance payments by participating in FEMA’s Community Rating System (CRS).¹¹³ The CRS collaborates with flood-prone communities to assess and mitigate the flood risk to home-owners through best-management practices. Providing that communities meet certain best-management practices, they can qualify for reductions in flood insurance on a sliding scale. A high-level of compliance with best-management practices could result in a Class One, and a low-level of compliance could result in a Class Five. The list of practices is long, and examples include flood warning systems, stormwater reduction, habitat studies, levee setbacks, home elevations, and many more. Participating in the CRS requires a great deal of time

¹¹² “The National Flood Insurance Program.” Federal Emergency Management Agency (FEMA), Accessed on May 28, 2012, <http://www.fema.gov/business/nfip/>.

¹¹³ “Community Rating System,” FEMA, Accessed on May 28, 2012, <http://www.fema.gov/business/nfip/crs.shtm>.

and money. Small cities are slow in applying to these programs because they are often short-staffed.¹¹⁴

Carnation is a small community, and they have not yet qualified for the CRS. Provided they have the resources to apply for the CRS, staff in the Carnation planning department anticipate qualifying for the CRS at a low classification.¹¹⁵ This lowers the annual flood insurance rate of the Carnation home-owner. Until this occurs, Carnation will continue to pay the flood insurance determined by FEMA.

The average cost of flood insurance to Carnation residents is not available, but the average premium for flood insurance in King County is \$498 per year.¹¹⁶ The number of structures that are flood insured under FEMA in the 100-year floodplain is 85.¹¹⁷

Changes to the values can be estimated through Carnation's potential qualification in the CRS program. While Lower Tolt River Floodplain Reconnection Project does not significantly impact the flood risk to Carnation, this project is one of several projects that will lower flood risk and improve riparian conditions. The net impact of these multiple efforts will qualify Carnation for the CRS and reduce the annual flood insurance rates. Once Carnation participates in the CRS, city staff members anticipate qualifying for a Class 2 discount which is 20%.¹¹⁸

The cost of the Tolt site is a percentage of the total costs of flood risk reduction projects that would qualify Carnation for reduced flood insurance rates. The Tolt site accounted for 39% of the total costs for all projects.¹¹⁹ Table Three lists Tolt River projects and their

¹¹⁴ Linda Scott, City Planner for City of Carnation, telephone interview, April 10, 2012.

¹¹⁵ Ibid.

¹¹⁶ King County, "Lower Snoqualmie & Skykomish Rivers Flood Insurance Study," (unpublished report, accessed on November 7, 2006). <http://green.kingcounty.gov/wlr/science/seminar/pdfs/PDF11.pdf>.

¹¹⁷ King County, "2009 Values for 100-year-flood."

¹¹⁸ Linda Scott, City Planner for City of Carnation, telephone interview, April 10, 2012.

¹¹⁹ King County Flood Control District, "Current Project Allocations – 2012 CIP," (Unpublished report, July 20, 2011), http://your.kingcounty.gov/dnrp/library/water-and-land/flooding/kcfzcd/KCFCD_adv_com_packet_072811_rev.pdf.

estimated costs. Provided Carnation qualifies for Class 2 Discount rates, Carnation residents will reduce their annual flood insurance payments by \$3,360.

Table 4: Flood Risk Reduction Projects near Carnation

Project	Cost
Tolt River Natural Area Floodplain Reconnection/Acquisition	\$6,150,000
Tolt River Flood Repairs	\$163,271
Tolt River Corridor Study	\$51,500
Lower Tolt River Acquisition	\$800,000
San Souci Neighborhood Buyout	\$3,064,848
Tolt River SR 203 to Trail Bridge Floodplain Reconnection	\$1,856,352
Tolt River Repetitive Loss Mitigation	\$180,514
Tolt River Mile 1.1 Levee Setback	\$3,820,352
Total Cost:	\$16,086,837

Source: King County Flood Control District, “Current Project Allocations – 2012 CIP,” July 20, 2011

There are several tradeoffs to using these estimates. The first is that not all home owners participate in the NFIP program. Subsequently, risk to the community is only measured by the amount of people who have purchased floodplain insurance. The community may be willing to accept greater degrees of risk, but this level cannot be demonstrated with the data available. The second tradeoff of this estimate is that it does not include Carnation flood insurance rates. The average flood insurance premiums in FEMA could be lower or higher than the King County average.

Another tradeoff of this approach is that the Tolt site studied in this paper is the only completed project, so the true cost of flood risk reduction projects is not reflected in the estimation above. If costs of other projects exceed estimates, the contribution of Tolt site would be smaller.

Riparian Habitat: Deciduous Forest, Grassland, Open River, Wetland

Benefit of Change	\$5,026 (Low), \$18,564 (High)
Assumption	Earth Economics’ ecosystem service valuation of the site provides an accurate analysis. Quantity and/or quality of ecosystems improve due

to restoration.

Earth Economics, a non-profit organization in Tacoma, conducted an ecosystem service valuation of this project prior to the change. The results of the analysis were published in a 2006 report titled “Supplemental Ecological Services Study: Tolt River Watershed Asset Management Plan.” The report was prepared for Seattle Public Utilities (SPU) by Earth Economics, ecological economists from the Gund Institute for Ecological Economics (GIEE), and SPU staff.¹²⁰ The purpose of the report was to demonstrate the value of ecological services provided by the Tolt watershed. The methodology employed relied on Geographic Information System (GIS) data provided by SPU and benefit transfer of ecological goods and services from peer-reviewed literature. The site provided the following categories of ecosystem types: Deciduous Forest, Grassland, Open River, and Freshwater Wetland. The combined values of these services across the 48.5 acres of the site were determined to be valued at a low of \$236,701.85 and a high of \$857,485.96 (USD 2010).¹²¹ On a per acre basis these values are \$4,880 and \$17,680. I adjust these numbers for the benefit cost analysis. Earth Economics indicated that the size of the project is 50 acres, but the true size of the project is 48.5 acres. Additionally, they have been adjusted for inflation from 2005 to 2010 USD. Later in this section, I further adjust these numbers to accommodate for relative prices.

This study alone has not been influential in the management of natural capital in King County, but it serves as an example of several collaborations between Puget Sound governing bodies and businesses that consult with ecological economic assessors. For example, the King County Conservation District¹²² and Watershed Resource Inventory

¹²⁰ Earth Economics, “Supplemental Ecological Services Study: Tolt River Watershed Asset Management,” (Unpublished report, 2005):1, http://www.eartheconomics.org/FileLibrary/file/Reports/Puget%20Sound%20and%20Watersheds/Tolt_River_Ecological_Service_Study.pdf.

¹²¹ Earth Economics, “Supplemental Ecological Services Study: Tolt River Watershed Asset Management,” 33.

¹²² Earth Economics, “Special Benefit from Ecosystem Services: Economics Assessment of the King Conservation District,” (unpublished report, July 28, 2006), <http://www.kingcd.org/pdf/KCD-Special-Benefit-Analysis.pdf>.

Area (WRIA) 9¹²³ have consulted with Earth Economics for similar assessments as the Tolt site. Other organizations participate in ecological economic assessment, such as ECONorthwest, which has authored numerous case studies and ecosystem service valuations in the Pacific Northwest region.¹²⁴ These efforts and organizations demonstrate that ecological economics is a field of interest for governments and businesses. Moreover, they explain the economic value of ecological resources to the public. For example, Triangle Associates and Tetra-Tech, which are Puget Sound-based consulting firms, used the Earth Economics Tolt study to explain management alternatives in South Fork Tolt Watershed.¹²⁵ Despite this study's limited audience (SPU), the integrity of Earth Economics' Tolt study matters to the public sentiment of ecosystem service valuation.

The \$236,701 to \$857,485 range is critical to understanding the full suite of benefits and services provided by the site; however, the size and range of values is alarming and invites discussion regarding the integrity of the values. The large range signals that the exact values of the Tolt site are uncertain. If uncertainty of values led to the exclusion of ecosystem service values, then the benefits would likely fail to exceed project costs. A serious discussion of Earth Economics' methodology explores whether ecosystem services should be included in this analysis despite uncertainty.

To find these values, Earth Economics used benefit transfer from GIEE.¹²⁶ As noted in Chapter One, benefit transfer policy sites must mirror the demographics and ecosystems of the study site. The original studies that informed this analysis were not available at the time of this writing, so this author cannot confirm that the benefits

¹²³ Earth Economics, *The Puyallup River Watershed: An Ecological Economic Characterization* (Unpublished report, May 2011), http://issuu.com/earth_economics/docs/puyallup_river_watershed.

¹²⁴ ECONorthwest, "Case Studies," (unpublished report, May 27, 2011). <http://www.econw.com/case-studies/>.

¹²⁵ Triangle Associates and Tetra-Tech, prepared for Seattle Public Utilities, "South Fork Tolt Watershed Management Plan," (Unpublished report, June 2011): 4-18. http://www.seattle.gov/util/groups/public/@spu/@conservation/documents/webcontent/01_012728.pdf

¹²⁶ Triangle Associates and Tetra-Tech, "South Fork Tolt Watershed Management Plan," Appendix A-2.

transferred were appropriate for the Tolt site. Despite this issue, I argue that the values should be preserved in this analysis for several reasons.

First, the inclusion of a range of ecosystem service values is standard practice for ecosystem service valuation. Ranges account for varying preferences of consumers, but they can also account for the varying study sites that informed benefit transfer. The use of various study sites by Earth Economics was noted by Triangle Associates and Tetra-Tech in their report to SPU.¹²⁷ Subsequently, Earth Economics does not hide the fact that the Tolt sites' values are uncertain. Of the values Earth Economics applies from the Gund Institute, only low values were chosen for the valuation.¹²⁸ Conservative estimates in ecosystem service valuation are typically employed to stem skepticism of valuation methodologies. Lastly, the values chosen for this site were gathered from a database operated by GIEE. Although no report notes the details of collaboration, I have worked with Earth Economics and I understand the relationship between this organization and GIEE. These organizations collaborate occasionally on specific projects. With regards to the Tolt site, Earth Economics managed the ecosystem service valuation, but it extended its literature review into the GIEE database of ecosystem service valuations. Not long after this study, Earth Economics began assembling a separate database so future projects would not require such collaborations.

Second, Earth Economics conducted on-site analysis of the site prior to the change;¹²⁹ their analysts surveyed the type of land cover and associated services prior to restoration. A review of ecosystem services prior to the change is critical to estimating the marginal increase in services as a result. It allows for a “before and after” perspective.” This improves the integrity of the GIS data provided by SPU. A “ground check” of remote sensing data ensures that GIS data is correct.

¹²⁷ Ibid.

¹²⁸ Earth Economics, “Supplemental Ecological Services Study,” 33.

¹²⁹ Ibid.

Third, Earth Economics examined the range of services provided by various land covers. Deciduous Forest, Grassland, Freshwater Wetland, and Open River provide a host of services, including gas regulation, water regulation, water supply, soil retention, waste treatment, and others.¹³⁰ The value of these services accumulates across the 48.5 acres of the site, thus accounting for their high values. Additionally, these services are expected to increase over time.

Consistent with the principles of process-based restoration, ecosystem services on this site will improve in the future.¹³¹ Economists recommend that benefit cost analysis accommodate increases in value to account for changing values of ecosystem services.¹³² For the purposes of this thesis, I assume that value of Riparian Habitat (Deciduous Forest, Grassland, Freshwater Wetland, and Open River) increases in a linear form through 100 years of the analysis. Ecosystem responses to changes are widely viewed as non-linear,¹³³ so I provide a range of growth possibilities – between 3% and 5% per year. These rates do not reflect real growth rates of ecosystem service values, but rather they illustrate the range of relative price growth over time. These rates are above inflation, which was 2.2% for non-food and energy commodities between November 2010 and November 2011.¹³⁴

I generate low and high annualized growth by multiplying the per acre values by 3% and 5%. This provides an annual growth in value per acre. The 3% growth in value per acre is \$146 per acre. A 5% growth in value per acre is \$884. These values are added to the original per acre annualized values (\$4,880 and \$17,680). As a result, the annual value per acre can range between \$5,026 and \$18,564.

¹³⁰ Ibid.

¹³¹ Beechie et al. "Process-based Principles for Restoring River Ecosystems," 209.

¹³² Sterner, "An Even Sterner Review: Introducing Relative Prices into the Discounting Debate," 62.

¹³³ Martin Scheffer et al., "Catastrophic shifts in ecosystems," *Nature* 413 (October 11, 2001): 591.

¹³⁴ "Consumer Price Index," Bureau of Labor Statistics, Accessed on May 25, 2012. <http://www.bls.gov/cpi/cpit01test1111.htm>.

Salmon Spawning Habitat: Literature Review and Discussion of Uncertainty in Ecosystem Services

Salmon habitat is a notable value missing from this analysis, especially since King County engaged in this project for salmon restoration. Earth Economics included salmon spawning habitat in its “Supplemental Ecological Services Study,”¹³⁵ but I omitted this value from my analysis. I attempted to replace this value with others, but I ultimately chose to exclude salmon habitat as a value. In the following section, I explain how these values were considered and why they have been dismissed. Additionally, I articulate why a separate category for salmon habitat is unnecessary when considering the Riparian Habitat values provided above.

The value of salmon habitat in King County has been determined through a study by Layton, Brown, and Plummer (LBP).¹³⁶ LBP conducted a contingent valuation of fish types according to the willingness to pay (WTP) of households in the Puget Sound region for salmon restoration. Several fish types were considered, and respondents demonstrated different WTP for each. Fish types relevant to the Tolt site fall under the LBP category of “Western Washington and Puget Sound Migratory Fish (PM).” Between 1996 and 2000, the Snoqualmie run averaged a spawner abundance of 1,200 Chinook salmon.¹³⁷ The Tolt receives 17.5% of the Snoqualmie Chinook salmon run.¹³⁸ LBP determined the WTP of households for improvements in PM to be \$322 for a 10% increase in population and \$644 for a 100% increase.¹³⁹

¹³⁵ “Earth Economics, “Supplemental Ecological Services Study,” 37.

¹³⁶ David Layton, Gardner Brown, and Mark Plummer, “Valuing Multiple Programs to Improve Fish Populations,” (unpublished presentation prepared for Washington State Department of Ecology) <http://www.ecy.wa.gov/programs/wr/hq/pdf/1-MarkPlummer.pdf> (1999).

¹³⁷ Snohomish County, “Section 4.0: Status of the Salmon in the Snohomish River Basin” *Snohomish River Basin Conservation Plan*, (unpublished report, June 2005): 4-4, http://www.co.snohomish.wa.us/documents/Departments/Public_Works/surfacewatermanagement/snohomishsalmonplanfinal/section4.pdf.

¹³⁸ Salmon Recovery Funding Board (SRFB), “Salmon Recovery Program In-Stream Habitat Application Materials Checklist.”

¹³⁹ Layton, David, Gardner Brown, Mark Plummer, “Valuing Multiple Programs to Improve Fish Populations.”

It is possible to use the LBP study for the Tolt site if the number of salmon generated on this site were known. Although the Tolt receives 17.5% of the Snoqualmie Chinook run, the number of salmon currently using the Tolt site is unclear. Moreover, it is unclear how many salmon would result from marginal improvements to the site's ecological processes. This is consistent with data gaps between habitat change, local biological responses, and ecosystem service values.¹⁴⁰ Since salmon population increases cannot be attributed to this site, estimating the WTP for salmon improvements by this site is inappropriate for valuing the entire site.

Loomis et al.¹⁴¹ conducted a contingent valuation of river and lake restoration for salmon habitat, which provides an intrinsic value for removing two dams on the Elwha River and restoring ecosystem services. He estimated that the mean annual value per household for this sort of action in Washington State is \$73.¹⁴² While the approach reflects intrinsic values, applying the value to other projects presents problems. First, the value pertains to a very specific type of restorative action. Second, this value is not spatially scalable, and cannot be applied to projects with a range of spatial impacts. As a result, this study cannot value marginal increases in habitat.

Another approach to valuing salmon restoration was provided by Knowler et al. This study resolves the issue of scalability, but fails to acknowledge the intrinsic value of salmon habitat.¹⁴³ Knowler assesses Coho salmon habitat benefits and associated market values in British Columbia, Canada. This study focuses on a region that provides similar habitat characteristics as the Tolt site. Knowler et al. takes into account Coho salmon productivity and the resulting economic impacts on the salmon fisheries in the Strait of Georgia. Neighboring areas with a high quality of habitat land use were

¹⁴⁰ Ibid.

¹⁴¹ John B. Loomis, "Measuring the economic benefits of removing dams and restoring the Elwha River: Results of a contingent valuation survey." *Water Resources Research* 32, no. 2 (February 1996): 441.

¹⁴² Ibid.

¹⁴³ Knowler et al., "Valuing freshwater salmon habitat on the west coast of Canada." *Journal of Environmental Management* 69 (2003): 261.

estimated to provide better habitat conditions for salmon breeding and rearing than areas with other land uses, thus demonstrating higher production values in high quality habitat.

There are several trade-offs to using this study. While the Tolt site provides habitat for Coho, it also provides a habitat for Chinook, an ESA listed species. Subsequently, this study risks undervaluation because it does not account for scarcity of Chinook salmon nor the increase in value of Chinook as a result of regulation. Moreover, this study bases values on market transactions rather than intrinsic values. As noted in Chapter 1, transaction costs result in a failure to reflect the full value of non-market goods. As expected, Knowler et al. provides a low value for acreage of habitat. Converted from Canadian to USD, adjusted for inflation, and converted to acres, the value of habitat is \$2.94 per acre per year (low) and \$7.73 per acre per year (high). Annually, these values generate between \$142.59 and \$374.91 (2010 USD) for the entire 25 acres of salmon habitat generated by the site.¹⁴⁴ When compared with the LBP study, the Knowler values are significantly lower. This is because Knowler's values are generated from market transactions – the price per pound of Coho salmon. This market-based approach to valuation does not reflect the non-market reasoning behind King County's investment in this site. King County restored this site for non-market reasons, including regulatory compliance and intrinsic values for salmon. Using market transactions to value this site would fail to reflect its full value.

The three studies presented above are inappropriate for application to the Tolt site; however, this does not mean that salmon habitat was excluded from the analysis all together. As indicated in the Riparian Habitat section, a host of ecosystem services result from restoration of the entire site. Habitat is created as a result of these ecosystem services functioning together. King County restored habitat on the site, hoping that natural processes would be restored over time. These processes facilitate

¹⁴⁴ Snoqualmie Watershed Forum, "Meeting Summary," (unpublished report, July 20, 2011) <http://www.govlink.org/watersheds/7/pdf/minutes/2011/Minutes7-20-11.pdf>.

the restoration of salmon habitat. Subsequently, inclusion of an independent habitat value on top of Riparian Habitat is considered “double counting.”

Qualitative Benefits

ESA Listed Species

King County values salmon restoration, especially in the habitat of an ESA listed species. In 1999, Chinook salmon were listed as an endangered species. As a result, the National Marine Fisheries Service (NMFS) was required to develop a recovery plan for Puget Sound Chinook. The long-term goal of the plan is to bring Chinook populations to self-sustaining levels.¹⁴⁵ Through enforcing this plan, local jurisdictions must work with NMFS to implement the plan.

Regulatory compliance compels King County to engage in restorative actions, but local values contribute to benefits as well. For example, economic and cultural interests encourage restoration efforts, creating a base of community and political support for the Tolt project.

Finally, other ecosystem services provided by the site are a concern of the local community, but not all these ecosystem services should be incorporated into the benefit cost analysis. Three specific ecosystem services not included in this analysis are aesthetic services, recreational floating (rafting), and recreational camping. While these are real goods and services provided by the site, the restoration project does not change these services.

Quantitative Costs

As noted in Chapter 2, project documents indicate the Construction and Maintenance costs of the project were available for review but not all costs of the Tolt site. The costs of planning, designing, and studying the site need to be estimated. For this, I use King

¹⁴⁵ National Oceanic and Atmospheric Administration (NOAA), “Puget Sound Chinook ESU Recovery Plan Summary,” (unpublished report, May 10, 2012). <http://www.nwr.noaa.gov/Salmon-Recovery-Planning/Recovery-Domains/Puget-Sound/upload/PS-Chnk-summary.pdf>.

County’s report “Snoqualmie 2015,”¹⁴⁶ which is a 10-year capital improvement plan (CIP) for the Snoqualmie watershed. “Snoqualmie 2015” provides a value range for categorical costs of natural capital projects. Additionally, the report provides a range of estimates for each cost category. For the Tolt project, I assume that the actual costs, besides construction and maintenance, fall within the ranges provided by “Snoqualmie 2015.” For this reason I use a range of values for each cost and use those values to inform sensitivity tests on costs.

Table 5: Cost Estimates of Tolt Project

Costs	Value Used in Sensitivity Test	Source
Construction:	\$6,150,000	King County ¹⁴⁷
Materials/Labor		
Maintenance	\$90,000	King County ¹⁴⁸
Project Identification	\$5,000	King County ¹⁴⁹
Feasibility	\$175,000	King County ¹⁵⁰
Design	\$212,500	King County ¹⁵¹
Permitting	\$212,500	King County ¹⁵²
Final Design	\$15,000	King County ¹⁵³
Review of Alternatives	\$175,000	King County ¹⁵⁴
Total	\$7,035,000	

“Snoqualmie 2015” explains the significance of each cost, which I include in the section below. As indicated above, Construction and Maintenance costs were determined from project specific sources.

Project Identification¹⁵⁵

This component sets policy solutions into action, taking policies about restoration into a new level of discussion regarding best locations and best-management practices. These decisions are determined by the amount of benefits that a project generates.

¹⁴⁶ King County. “Snoqualmie 2015,” “Snoqualmie 2015: Appendix C,” 75.

¹⁴⁷ Jon Hansen, “Lower Tolt River Floodplain Reconnection Project.”

¹⁴⁸ SRFB, “Salmon Recovery Program In-Stream Habitat Application Materials Checklist.”

¹⁴⁹ King County, “Snoqualmie 2015: Appendix C,” 75.

¹⁵⁰ Ibid.

¹⁵¹ Ibid.

¹⁵² Ibid.

¹⁵³ Ibid.

¹⁵⁴ Ibid.

¹⁵⁵ Ibid.

Feasibility¹⁵⁶

Feasibility studies are inquiries into the ecological, hydrological, and geological impacts of the project. This phase asks whether a project should be pursued. The study for the Tolt site is available upon request from King County. It is called “Third Party Review, Lower Tolt River Floodplain Reconnection Project.”¹⁵⁷

Review Options and Select Best Alternative¹⁵⁸

Surveys and additional studies of the site take place in this phase. The final alternative is selected.

Design¹⁵⁹

Engineers and decision-makers assemble schematic designs.

Permitting¹⁶⁰

Permits and their costs vary according to the type of action and their impact on species.

Final Design¹⁶¹

The as-built drawings are assembled, including planting plans, engineering schematics, and other inputs.

Construction Costs¹⁶²

King County reported on restoration costs in a funding report to the Salmon Recovery Board, which provided King County with funds to implement the project. Construction costs are best analyzed in ex post reports since ex ante cost estimates may not anticipate the full cost possible. In this sense, including an ex post cost report of the project contributes to the validity of the project.

Maintenance Costs

The only maintenance costs reported on the site are those involving ecological monitoring.¹⁶³ The newly installed levee will not be subject to the same review and

¹⁵⁶ Ibid.

¹⁵⁷ “Lower Tolt River Floodplain Restoration Project,” King County.

¹⁵⁸ King County, “Snoqualmie 2015: Appendix C,” 75.

¹⁵⁹ Ibid.

¹⁶⁰ Ibid.

¹⁶¹ Ibid.

¹⁶² SRFB, “Salmon Recovery Program In-Stream Habitat Application Materials Checklist.”

¹⁶³ Ibid.

repair standards as other levees in King County, so costs associated with maintenance are minimal. The Snoqualmie River impacts flood risk in Carnation more than the Tolt River,¹⁶⁴ so the degree of protection required of this levee is considerably less than levees on the Snoqualmie. Subsequently, no maintenance costs are included in this analysis.

Qualitative Costs

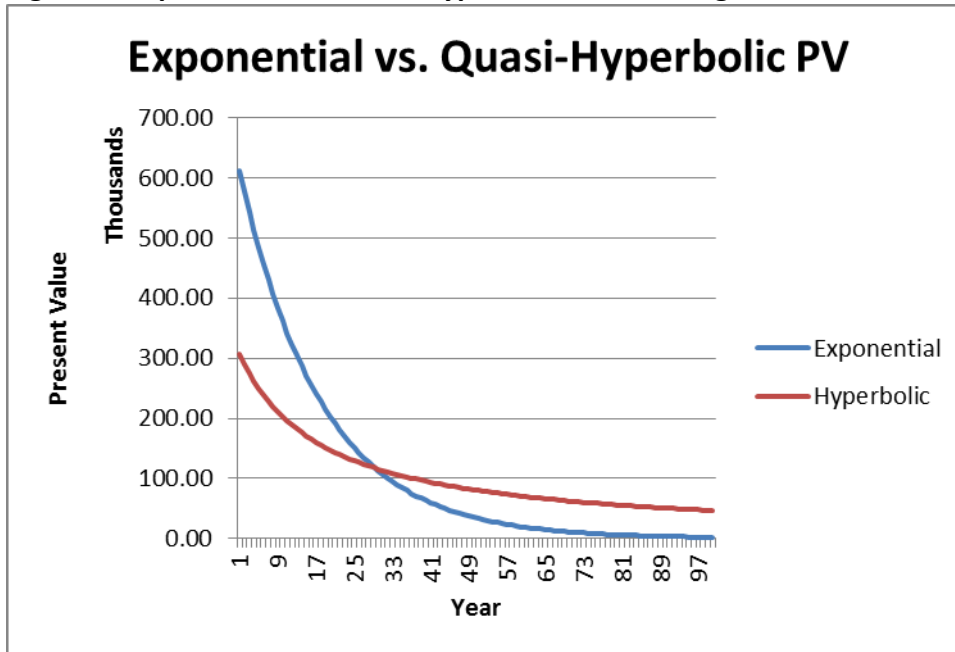
Unforeseen transaction costs should be considered in the analysis. Notably, the community's preference for recreation on the site causes transaction costs for Carnation residents, who had to represent their interests during the SEPA review process. For residents, this process requires time and coordinated effort. Similarly, costs are imposed on Carnation employees. This is particularly true if Carnation wishes to participate in the CRS program, which imposes more responsibilities on a small staff of public employees. If these hours were tracked by Carnation employees, it would be possible to factor quantitative these forms of transaction cost into the analysis.

Results of Benefit Cost Analysis

I apply two discounting methods, so two Present Values (PV) result. For exponential discounting, the NPV is **\$3,726,990**. For quasi-hyperbolic discounting, the NPV is **\$3,195,484**. The project is net beneficial over the life of 100 years. Figure 6 demonstrates that the quasi-hyperbolic discount factor will cause present value (PV) to exceed the PV of exponential discounting in year 28. This is consistent with time-declining discount rates.

¹⁶⁴ King County Water and Land Resources Division. "Response to SEPA Comments from the City of Carnation Regarding the Lower Tolt River Floodplain Reconnection Project," (March 29, 2007) Accessed at <http://your.kingcounty.gov/dnrp/library/archive-documents/wlr/cposa/tolt-restoration/pdf/sepa-responses-carnation.pdf/>

Figure 6: Exponential vs. Quasi-Hyperbolic Discounting of Tolt Site



Exponential Discounting

The project is net beneficial with 100% certainty. Recall in Chapter 2 that I ran the sensitivity test 10,000 times, using the exponential and hyperbolic NPVs as baselines. These baseline NPVs were generated from baseline input parameters, which were the average of high and low benefits and costs. The sensitivity tests took values from the high and low benefits and costs, so many more NPVs other than the baseline are possible. Subsequently, Figure 7 demonstrates a high value of over \$20,000,000. The Probability of NPVs totaling this much (left y-axis) is well below 1%. These scenarios also occurred with a low frequency (right y-axis) over the 10,000 trials of the simulation. They occurred less than 30 times. However, since the low and high values for NPV are so large, the mean NPV is \$9,004,049, and the standard deviation is \$5,080,386. Since these values feature a low probability of occurring, it is best to focus attention on values

that have a higher probability of occurring. However, it is important to remember that all values, both low and high, demonstrated that benefits exceed costs.

Note that values closer to the baseline NPV of \$3,726,990 occurred with higher frequency, thus increasing their probability of occurring. Figure 7 shows that between 2% and 3% of the trials exceeded a net present value of approximately \$2,500,00 and \$13,000,000.

Figure 7: Sensitivity Test of NPV for Exponential Discounting

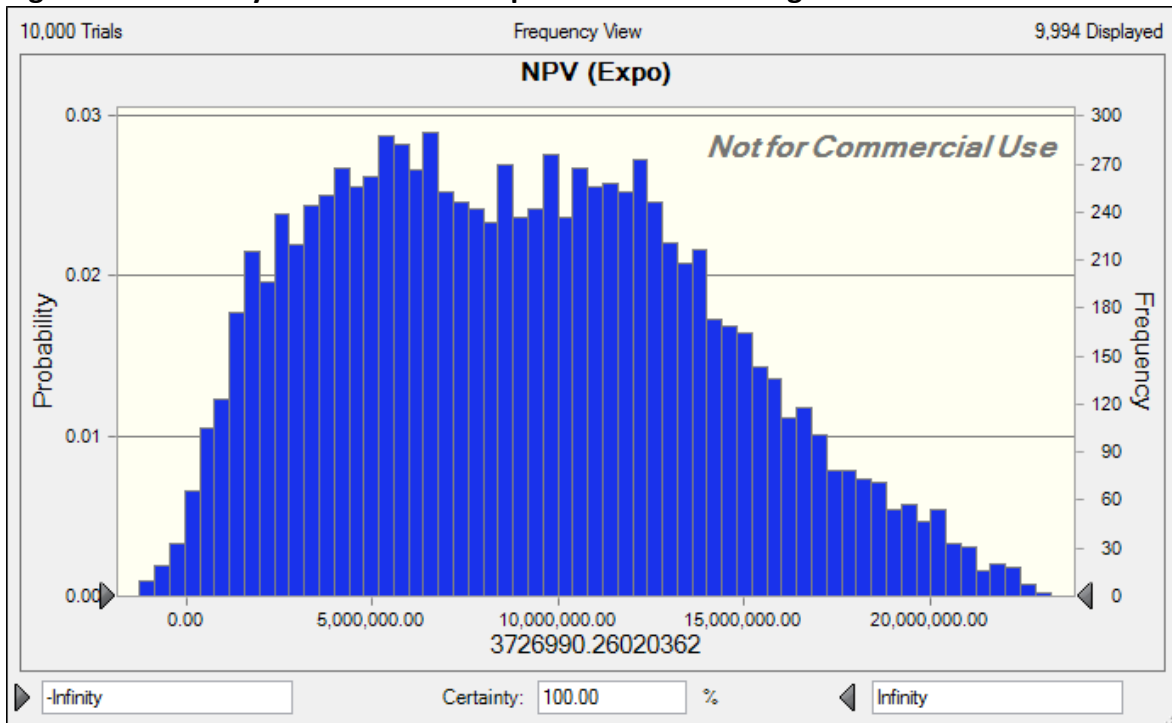
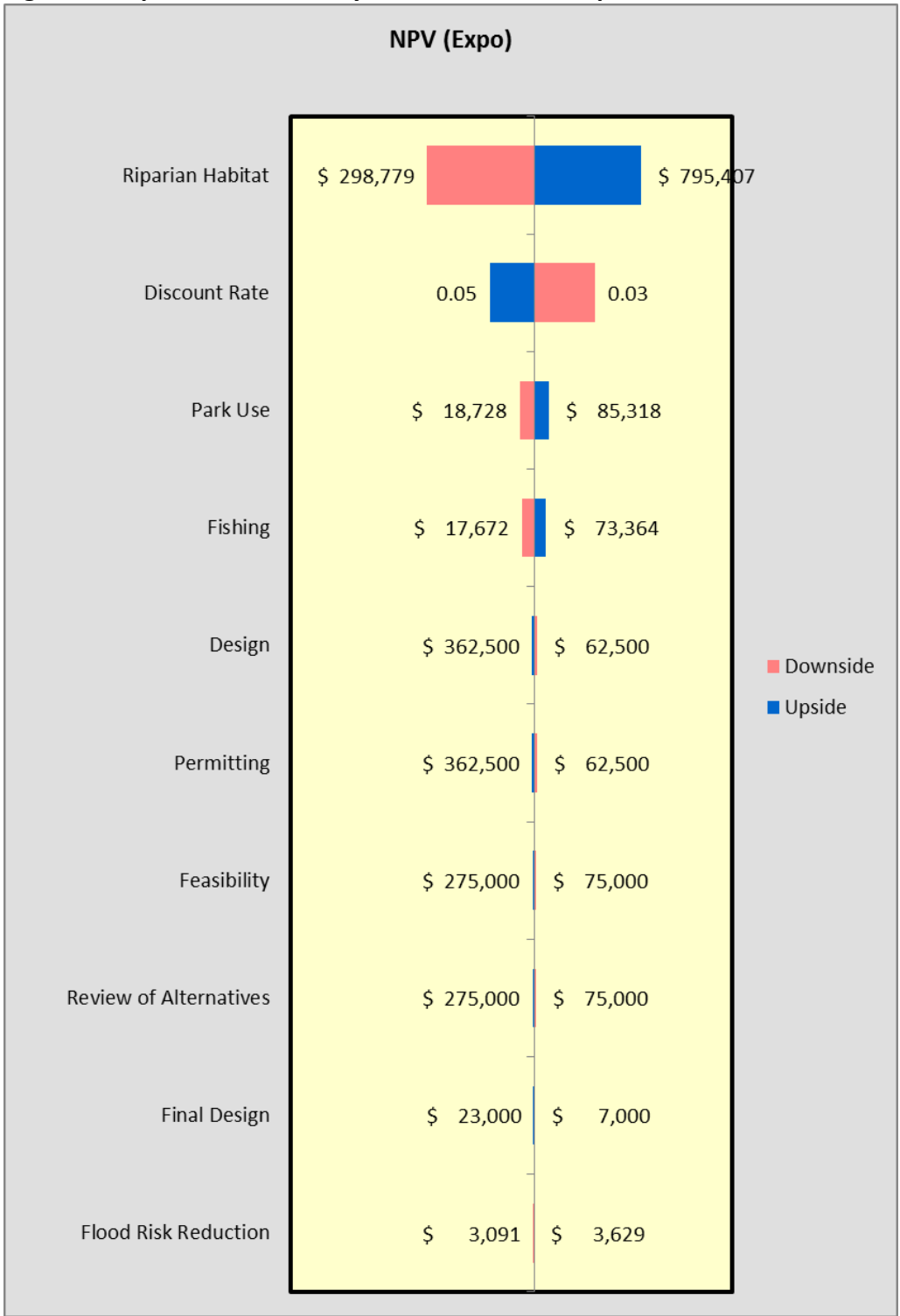


Figure 8 is a tornado chart that ranks the most important and most uncertain parameters from top to bottom. Riparian Habitat ranks first because four ecosystem services are included in its range, the range is large, and this number increases 3-5% annually. The second most impactful variable that is also very uncertain is the discount rate. Notably, the cost parameters are the least important because they only occurred once.

Figure 8: Impact of Uncertainty in Parameters of Exponential NPV



Quasi-Hyperbolic Discounting

With 100% certainty, the net benefits of the project exceed costs. The mean NPV is \$5,667,698 and the standard deviation is \$4,022,553. Figure 9 demonstrates a slightly log-normal distribution, with the expected NPV tending lower than the baseline of \$3,195,484.

Figure 9: Sensitivity Test of NPV for Quasi-Hyperbolic Discounting

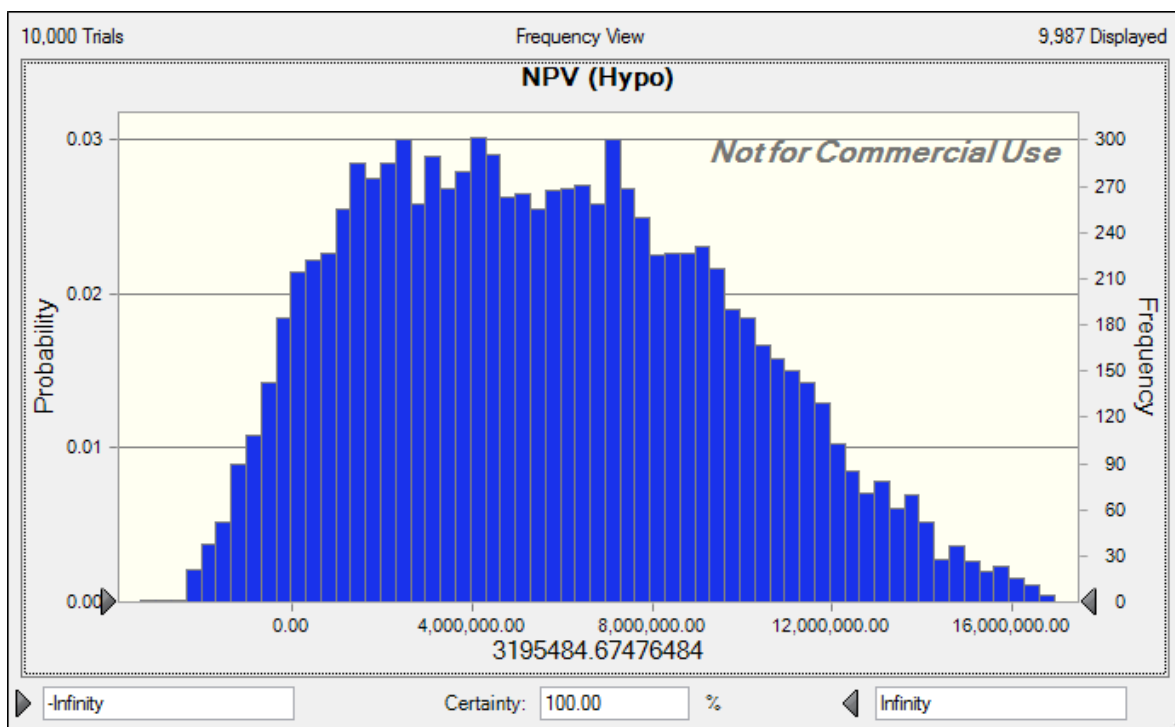
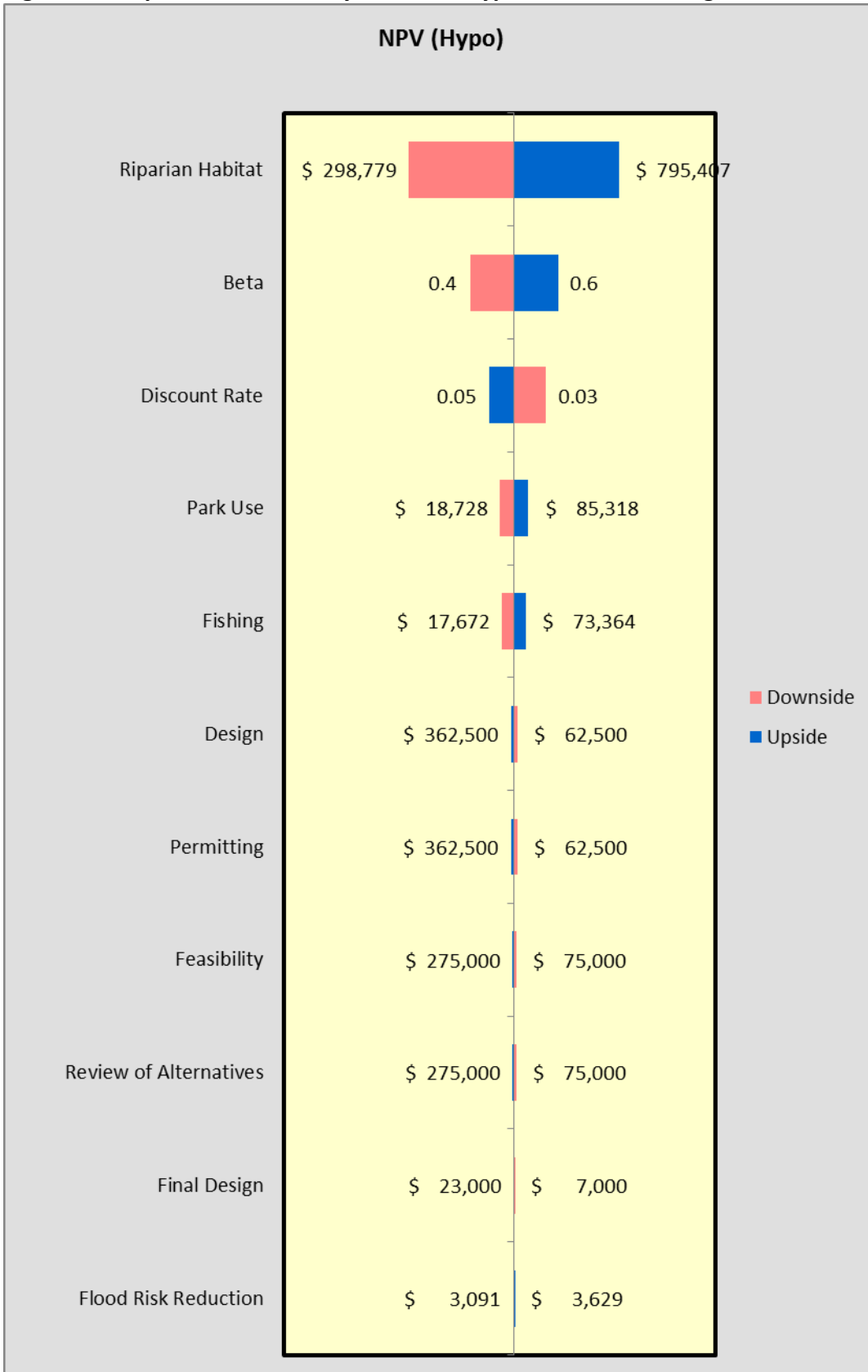


Figure 10 is a tornado chart of the net present value with quasi-hyperbolic discounting adjustment. Riparian Habitat still ranks first, but the beta plays a considerably large role. Finally, the discount rate is the third most impactful and uncertain variable. The influence of the discount rate over 100 years is weakened by the inclusion of the beta. This is consistent with the concept that discount rates decline as consumers look further in the future.

Figure 10: Impact of Uncertainty on Quasi-Hyperbolic Discounting Parameters



Conclusion of Benefit Cost Analysis of the Lower Tolt River Floodplain Reconnection Project

The Lower Tolt River Floodplain Reconnection Project creates economic benefits for the community. An *ex ante* analysis was not conducted so changes to the site were informed by planning documents authored by King County and the City of Carnation, or perhaps other sources. Ecosystem service valuations provided economic values for the goods and services that were created from the site. Many of the projected benefits are subject to uncertainty. Sensitivity testing demonstrates the uncertainty of each variable as well as demonstrates the project's net benefits under a variety of conditions.

This analysis demonstrates that ecosystem service values in benefit cost analyses internalize potential externalities of infrastructure transactions. As the complexity of transactions rise, the potential for transaction costs increases. With regards to ecological services, the future generation will experience transaction costs and thus deserves standing in the decision to preserve the site or maintain its degraded state. The inclusion of ecosystem service values is one approach to reducing the level of externalities.

Beyond ecosystem service values, I have included other methods that improve equity between generations. This includes the annual increase in ecosystem service values and the quasi-hyperbolic discount rate. The annual increase reflects the increase in value that occurs due to increasing scarcity of riparian habitat. The quasi-hyperbolic discount rate demonstrates that the discount rate declines over time if current decision-makers commit to a conservative action plan. Both of these approaches increase the likelihood of the project passing the benefit cost analysis.

Chapter Four: Discussion

Benefit cost analysis of projects that impact ecosystem services determines the way in which future generations access environmental assets. The ex post analysis of the Tolt site illustrates some of the issues that arise in assessing ecosystem services and their role in intergenerational equity. Economic literature posits several methods to account for intergenerational equity, and I have incorporated two into the benefit cost analysis of the Tolt project. The first method anticipates increasing values from restored habitat over time, and incorporates expected price increases into the benefit-cost stream of the project. This is referred to as relative pricing. This generally practiced approach relies on neoclassical economics (prices in existing markets) to explain consumer-supplier transactions, and I argue that relying solely on this method for intergenerational equity is an inappropriate approach to making decisions that impact ecological values and multiple generations.

The second method to incorporating intergenerational equity is the quasi-hyperbolic adjustment to discounting. This method features a limited audience compared with the relative pricing approach. This is because few policies encourage the use of quasi-hyperbolic discounting, as opposed to exponential discounting, which is the adopted approach of the Office Management and Budget. However it fits the framework of planners, who are concerned with multiple dimensions of welfare (environmental, social, and economic) rather than strict reliance on market prices to determine ecosystem value. I present quasi-hyperbolic discounting from the perspective of the planner, who must implement decisions at the institutional level and navigate the traditional costs of complex transactions.

Understanding the institutional level that guides benefit cost analysis, and thus the intergenerational transactions associated with it, I use a transaction cost economics

(TCE) framework. TCE provides an appropriate lens for understanding multi-generational decisions and ecological resources, rather than neoclassical economic frameworks.

Increasing Benefits over Time

Neoclassical economists include multiple generations in benefit cost analysis through expanding the benefit-cost stream. They have argued that expanding the discount rate is an inappropriate method^{165,166}. They argue the following: If environmental economists believe that values for ecological resources will increase over time, then they should reflect that growth in the stream of benefits (and costs) in the parameters of their analysis. This can assist economists in conceptualizing the growth in value for ecological functions, which includes increasing scarcity of ecological resources and the corresponding increases in demand. Arrow et al. comment on this approach, as follows:

“A more widely accepted alternative (to declining discount rates) is to apply the time invariant (social discount rate)... to benefits and costs evaluated in consumption equivalents, which reflects the evolution of WTP through time. This disentangles issues of evolving values for the environment from issues of discounting and does not change the discount rate to apply to the consumption stream.”¹⁶⁷

This approach features strengths but undeniable weaknesses in the environmental context. Increasing values over time is consistent with the goal of including the full stream of costs and benefits. It accounts for obvious externalities of non-market values since the current value of a good is not fully reflected in market transactions. On the other hand, it relies on a neoclassical approach to economic transactions, which

¹⁶⁵ Mark Long, Richard Zerbe, Tyler Davis, “The Social Discount Rate as a Function of Individuals’ Time Preferences,” 15.

¹⁶⁶ David Pearce and Anil Markandya, “Development, the Environmental, and the Social Discount Rate,” *The World Bank Research Observer* 6, no. 2 (July 1991): 139.

¹⁶⁷ Arrow, K., W. et al. “Inter-temporal Equity, Discounting and Economic Efficiency,” *Climate Change: Economic and Social Dimensions of Climate Change*, Edited by J. P. Bruce, H. Lee, and E. Haites. (Cambridge: Cambridge University Press, 1995) 128–144.

assumes that the markets are competitive and thus prices convey important information about willingness to pay. Criteria of perfect competition include the following: consumers and suppliers experience limited barriers to entry; each participant has perfect information; all goods are homogenous; and the decisions of one participant will not impact other participants. Under these conditions, the preferences of consumers appear predictable, and akin to a simple market transaction. A deeper discussion regarding ecological transactions reveals that decisions that impact resources like the habitat of the Tolt are not simple.

When comparing these criteria to the Tolt project, it becomes apparent that the transaction does not benefit from perfect competition. This is demonstrated by the transaction that occurs in restoring the Tolt site. All transactions have sellers and buyers, or suppliers and consumers. In this scenario, King County is the supplier, the present and future generations are the consumers; and Tolt ecosystem functions are the goods and services. Notably, both supplier and consumer lack perfect information. The demand and supply of ecosystem functions in a particular area can change over time with market conditions, including the health of ecosystems as well as demand for them. Projecting the increase in value of ecosystem services in one year requires not only projecting the demand for a good or service, but also the quality of the ecosystem function a later year, over and over, for decades beyond the year of construction. This approach requires that the analyst understand multiple economic, political, and ecological conditions of a particular area. This is no simple task. Moreover, they must take into the account ecological performance, which is subject to stochastic changes.¹⁶⁸ These variables are subject to change over time, and forecasting their extent of change is difficult. Subsequently, relative pricing approaches are subject to uncertainty.

Beyond perfect information, this transaction fails to meet other criteria for perfect competition. King County and residents encounter many barriers to entry since the cost

¹⁶⁸ Scheffer et al., "Catastrophic shifts in ecosystems," *Nature* 413 (October 11, 2001): 591.

of restoring natural capital is high and the willingness of firms or other organizations besides King County to participate in the market is low (perhaps non-existent). All goods and services associated with benefits are not homogenous. For example, native Chinook are a more important asset than hatchery Chinook. Lastly, the decision of one participant, King County, significantly impacts current and future goods and services on the site.

If economists analyze benefits and costs of restoration projects ex ante, and they assume that benefits and costs fall under neoclassical assumptions, then they take a high-risk approach to estimating future benefits and costs. Indeed, many other benefit and cost streams are possible. Traditionally, economists analyze uncertainty with sensitivity tools, such as Monte Carlo simulations, which I employed in my analysis. These tools serve the analysis when the lower and upper bounds of the benefits and costs are known. However, Chapter 1 notes that ecological functions demonstrate non-linear responses to change. No high and low bounds of the cost and benefit parameters may be large enough to fully incorporate the amount of uncertainty inherent to ecological functions. Compounding factors such as pollution, species migration, climate change, and economic health may impact economic returns in unknown ways. Sensitivity analysis cannot account for the severity or timing of catastrophic events that dramatically change the flow of ecological services or the extent of demand by society.

In the context of ecosystem services, such as the Tolt project, economists and planners must consider the irreversibility of the project and unique resources inherent to it. Additionally, they must consider the risk of not restoring the site. Chapter Two explains the context of salmon restoration in King County. The Chinook salmon is an ESA listed species. Subsequently, King County cannot approach this site with a high-degree of risk. A high-risk approach would choose a project which had benefits that exceeded costs and values were based on market transactions or WTP. If King County only chose projects that were net beneficial, then the organization may never invest in salmon

habitat. On the other hand, ESA inspires King County to move beyond market-based pricing and WTP for salmon. In the case of this project, it seems to have catalyzed the investment in habitat restoration that allows ecosystem service values to grow over time. Science for the ESA demands that habitat be restored in order to grow salmon populations.

As suggested in expansions of the benefit stream over time, growing the salmon population does not necessarily allow King County to give future generations a seat at the bargaining table. However, King County and other government planners are inspired by the ESA to hedge against the risk of ecosystem services losing value or quality. King County insulates against risk because the damage of failing to do so would be irreversible.

The existence of this endangered species cannot be mitigated through a similar replacement, such as hatchery Chinook or another salmonid. Once a habitat site has been destroyed, reversing the damage cannot be accomplished without significant cost. This means that a market-priced result is not the goal of County.

If neoclassical economics does not provide a reliable approach, then another framework must be consulted. Ultimately, the TCE perspective suggests that quasi-hyperbolic adjustment must be considered alongside relative pricing. This is a better alternative to accommodate for inter-generational equity in the context of benefit cost analysis of ecological resources.

Transaction Cost Economics and Quasi-Hyperbolic Discounting: Alternatives to Relative Pricing

The unique nature of the Tolt's Chinook habitat, and the irreversibility of species loss means that King County must be willing to conserve environmental resources rather than consume them. Accordingly, they require an economic model that demonstrates preference for conservation rather than preference for strictly market-based pricing of

values. This fact becomes clear in a deeper analysis of public organizations, such as King County.

TCE adheres to a hypothesis of discriminating alignment,¹⁶⁹ such that transactions are more economical (and less costly) when the structures that govern them align and safeguard the interests of the parties to the transaction. Asset specificity in transactions concerns assets that are specific to the given buyer and/or seller. Bounded rationality suggests that the buyer and seller have limited capacity to know, in advance, the effects of their actions over time. These are critical features for understanding why the Tolt project deserves quasi-hyperbolic discounting.

Asset Specificity

In TCE, asset specificity refers to the degree to which a supplier, consumer, and the products they are transacting for, have value only to them – that is, the asset cannot be sold to another party without a considerable loss in value. It is common for transactions involving infrastructure projects, because these are place-based durable and immobile assets, to have high degrees of asset specificity, and thus to be more economical if governed by one firm, or perhaps a regulated firm, or perhaps a government entity on behalf of the public that depends on these essential services. The most extreme form of asset specific to a transaction would be of a specific resource or site that could not be replaced.¹⁷⁰

The riparian habitat along the Tolt is an asset specific to the residents of Carnation and King County, and thus the King County government is expected to act on behalf of these consumers to invest wisely in ecosystem services, just like any other form of infrastructure. This is a fine set of circumstances for applying generalized or benefit-transfer ecosystem service values in a benefit stream. However, the Chinook, as an endangered species, is an asset of value to this site that is very special. We can assume,

¹⁶⁹ Williamson, “The New Institutional Economics: Taking Stock, Looking Ahead,” 597.

¹⁷⁰ Williamson, “The Theory of the Firm as Governance Structure,” 175.

as lawmakers have, that endangered species are valued by everyone – not just the residents of King County, and not just the current generation. In acting to restore Chinook habitat, King County and its residents provide an asset of specific value to them, and an asset of value specific to everyone else in the world, in this and future generations. One may conclude that this is not a good time for taking risks or applying standard approaches that search only for the market price of salmon, or even the market price of the ecosystems services that comprise salmon habitat. Quasi-hyperbolic discounting brings the interests of future generations to the bargaining table.

The asset specific nature of this site means that any transaction associated with it does not fit the context of similar transactions. For example, King County cannot apply a “one-size-fits-all” best-management practice to this site and expect the same results they received on another site. Similarly, the agency cannot use the same economic method to analyze this site as they would for other types of infrastructure. The ecological assets on this site are fundamentally different than other resources and projects (though restoration for Chinook could comprise a category of transactions that have similar attributes). Today, the Tolt project appears unique; King County appears to have adjusted its instruments and approaches for this site-specific resource. They could adjust benefit cost analysis with quasi-hyperbolic discounting to become a useful method of analysis in this category of cases.

Bounded Rationality

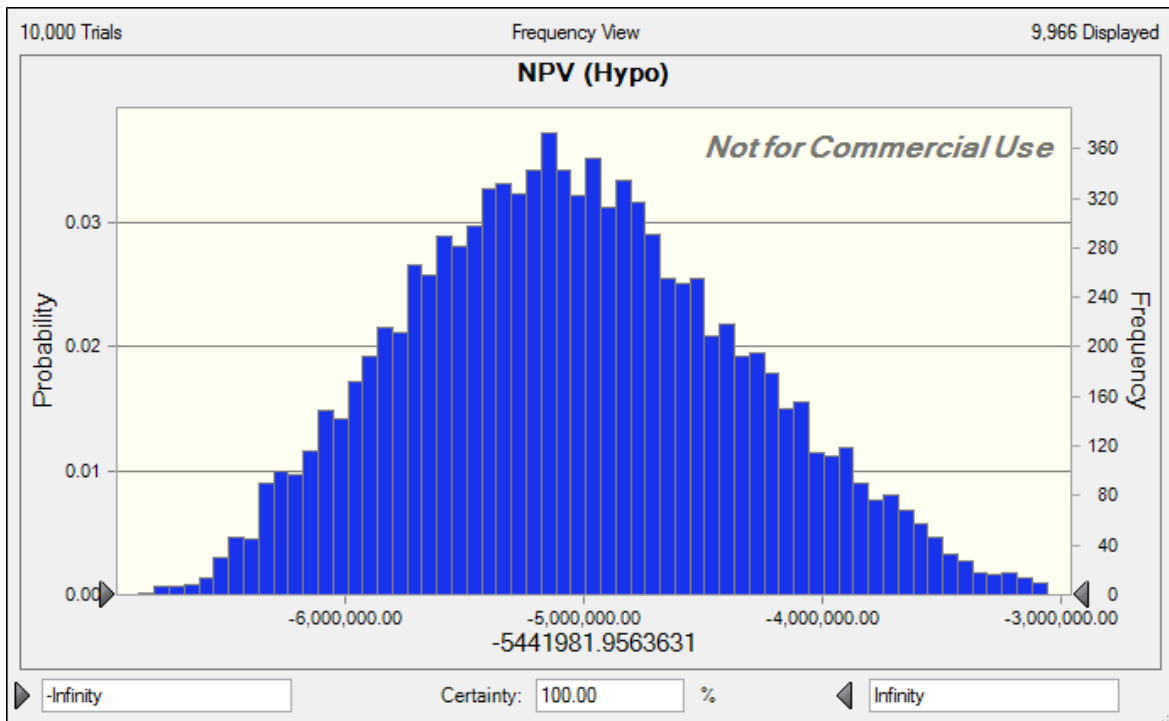
Bounded rationality refers “to behavior that is intendedly rational but only limitedly so.” It results in “satisficing,” which “is the quest for an alternative this is ‘good enough.’”¹⁷¹ While satisficing may achieve short-term goals, it subjects organizations to considerable long-term risk. This is especially true if the public scrutinizes the integrity of the organization’s analysis. A better option would be to acknowledge the firm’s boundedly rational limitations and overcome them, thus reducing transaction costs.

¹⁷¹ Ibid., 174.

King County is rationally bound to economic analysis that uses the “one-size-fits-all” approach. Without the ability to apply discounting methods other than exponential, the project may fail economic analysis. As a result, the agency satisfices economic analysis by avoiding it entirely. Recall that the County did not conduct an ex ante benefit cost analysis of the project. Instead, they received a determination of “non-significance,”¹⁷² (page 31). As a result, the agency did not consider conducting an economic analysis of the project. A likely reason is because a benefit cost analysis of the project using the methods and means typically acceptable for economic analysis would have demonstrated a negative value, thus failing the analysis. Indeed, Figure 11 demonstrates that if Riparian Habitat values were excluded from the analysis, the Tolt project would fail the benefit cost analysis. That is, net present value would be negative – the present value of costs would be greater than the present value of benefits.

¹⁷² King County Water Land and Resources Division, “Determination of Non-Significance.”

Figure 11: Sensitivity Analysis of Quasi-Hyperbolic NPV without Riparian Habitat



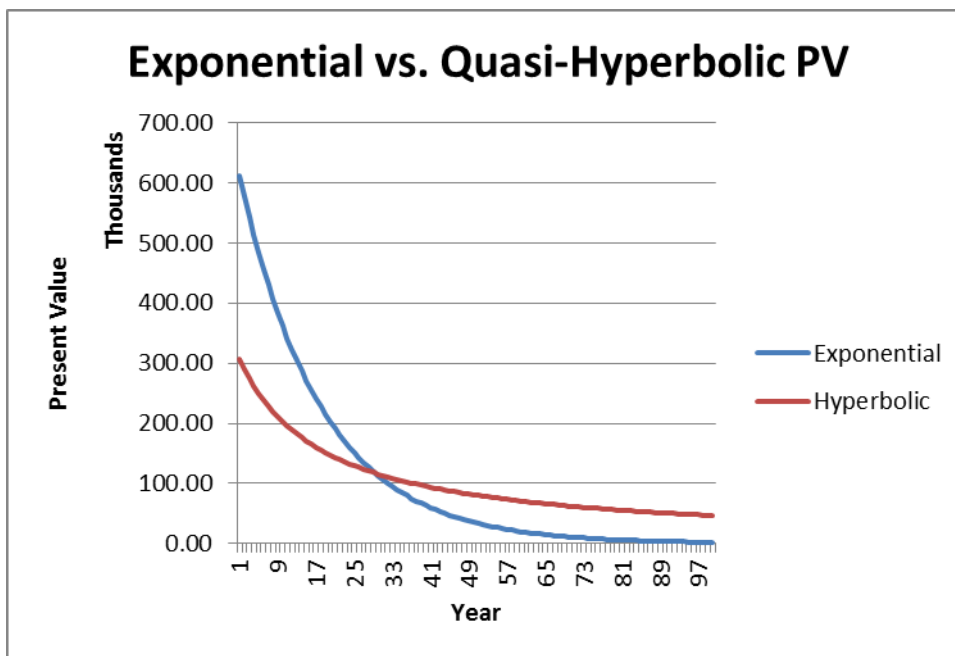
Clearly, ecosystem service values present a means to increase the benefits of a restoration project. As I hope to have shown in this ex post benefit cost analysis, King County could overcome bounded rationality on this and similar projects. Accordingly, the benefits that future generations in King County and Carnation receive from the ecosystem services are given standing in this approach. Quasi-hyperbolic discounting is one step further.

Quasi-Hyperbolic Discount Rates

Addressing the data issues of the county can lower transaction costs with regards to the benefit and cost stream; however, an additional step must accommodate the intergenerational nature of the project. I have already addressed the limitations of relative pricing to accommodate for intergenerational equity, I suggest quasi-hyperbolic discounting as a more appropriate means.

Quasi-hyperbolic discounting addresses the limitations of King County. First, it takes into account the asset specific nature of the Tolt site. As demonstrated in Figure 6 (revisited), next year's utility drops precipitously. This approach acknowledges that the resources provided on this site cannot be replicated, thus the current generation is willing to sacrifice its return on welfare in order to conserve resources. The present value of the site in year one falls as compared with present values derived from exponential discounting. Exponential discounting suggests that the value generated by this site could be generated elsewhere, but this does not fit with the preference of King County for Chinook salmon habitat nor the regulations guiding county actions. For this reason, exponential discounting fails to meet the asset specific nature of this project while quasi-hyperbolic discounting does.

Figure 6 (Revisited): Exponential vs. Quasi-Hyperbolic PV



Moreover, the quasi-hyperbolic discount rate adjustment brings future generations into the project's economic analysis. It acknowledges that the future generations value the ecosystem services of the site. This manifests in the time-declining nature of the quasi-hyperbolic discount rate. Figure 6 demonstrates that present value does not reach zero

within the 100 years of the analysis. Finally, the present values of the current generation and the last generation are similar, while preference is still given for the near-term and the long-term. This is consistent with Chichilnisky's axiom for accommodating both the needs of the present and future generations.¹⁷³

Implications for the Planner: Ecosystem Services and Hyperbolic Discounting

I have noted several approaches to addressing transaction costs inherent to King County adjustments to benefit costs analysis of projects that impact future resources. Reducing transaction costs through including ecosystem service values and hyperbolic discounting improves the tools available to the planning practitioner. Notably, these tools assist the planner in lowering transaction costs by allowing the planner to 1) justify commitment mechanisms, such as irreversible natural capital investment; and 2) honestly estimate construction and planning costs and benefits.

Commitment

The decision-makers who advocated for the Lower Tolt River Floodplain Reconnection Project made a decision to conserve resources. As with other floodplains, this area could have been used for other forms of economic development, such as residential housing. Since the plans and policies of the decision-makers determine a different approach, consumers receive a lower return on welfare in exchange for ecosystem services. Decision-makers demonstrate their commitment to future generations by investing in restoration.

As outlined by Laibson, consumers make decisions hyperbolically, which means that consumers may not follow through with their future plans. This creates a rationale for commitment mechanisms, such as conservation policy or restoration projects. From year to year, the preference or demand for environmental assets may change drastically. In response to this problem, current governments create policies and

¹⁷³ Chichilnisky, "An Axiomatic Approach to Sustainable Development," 233.

mechanisms that enforce conservation activities, committing present assets for the enjoyment of future generations. Wetlands, forests, aquifers, and other environmental resources receive a status that protects them from degradation or overuse. These commitment mechanisms create a situation in which the present generation must value future environmental assets.

Governments cannot force citizens to act as though these objects were of equal importance today as in the future.¹⁷⁴ However, the government must find a way to protect the interests of its future population. Pigou agrees by writing, "There is wide agreement that the State should protect the interests of the future in some degree against the effects of our preference for ourselves."¹⁷⁵ To preserve the rights of future generations to environmental goods and services we would conserve or save a portion of them for future consumption. This argument is the basis of conservation.

Obviously, conservation activities are a political issue, and decision-makers debate whether an environmental resource should be used today or not. The preference to use a resource sooner rather than later depends on the decision-makers responsible, and their preferences may change from year to year. Advocates of traditional exponential discounting essentially state that the rate at which we value something today remains constant from one period to the next. However, Samuelson warns his peers of the dysfunctional nature of time-consistent preferences, stating, "...it is extremely doubtful whether we can learn much from considering such an economic man, whose tastes remain unchanged, who seeks to maximise some functional of consumption alone, in a perfect world, where all things are certain and synchronized. For in any case such a functional would have to be dependent upon certain parameters which are socially determined..."¹⁷⁶ Samuelson's argument suggests that exponential discounting fails to

¹⁷⁴ Pigou, *The Economics of Welfare*, I.11.7.

¹⁷⁵ Ibid.

¹⁷⁶ Paul Samuelson, "A Note on the Measure of Utility," *The Review of Economic Studies*, 4, no. 2 (Feb., 1937): 160.

reflect reality. It infers that agencies that rely on traditional discounting methods fall victim to the same irrational approach. Conversely, hyperbolic discount rates acknowledge that preferences change from year to year,¹⁷⁷ thus it provides a means for firms to commit to a lower return on investment. This is a helpful tool for planners who wish to justify commitment for a certain resource to the future.

Honest Cost Estimations

It is no secret that real infrastructure costs commonly exceed projections. As a result, ex ante costs are underrepresented while the projected benefits exceed them. This means that projects that should not pass benefit cost tests are approved. Flyvbjerg suggests that ex ante cost estimators on infrastructure projects purposefully under-represent costs.¹⁷⁸ He tests whether planners and analysts actively lie in cost analysis because they suspect that projects will not pass an economic analysis of project alternatives. His study shows that the cost estimation of the transportation projects, as well as many other project types, consistently underestimate costs. These mistakes, and often lies, can inflict financial, legal, and political damage on agencies and leadership.

The pressure to demonstrate the economic viability of projects is a transaction cost of organizations. Planners, analysts, and other leadership fall victim to self-interest and public-interest. Flyvbjerg notes there is a culture that wishes to “to keep costs low” and that is more important “than estimating costs correctly.”¹⁷⁹ These fallacies result in inefficient public spending.

The Tolt project is an example of cost escalation. A report regarding the Tolt project’s costs was authored by King County for the Washington State Recreation and Conservation Office, and it indicates that the project saw increases in the Architectural

¹⁷⁷ Laibson, “Golden Eggs and Hyperbolic Discounting,” 445.

¹⁷⁸ Bent Flyvbjerg, Mette Skamris Holm, and Soren Buhl, “Underestimating Costs of Public Works Projects: Error or Lie?” *Journal of the American Planning Association* 68, no. 3 (Summer 2002): 279.

¹⁷⁹ *Ibid.*, 288.

and Engineering component of its budget.¹⁸⁰ Architectural and Engineering costs refer to pre-construction design and planning components of the project, and not actual construction costs. As noted in Chapters 2 and 3, the estimated and actual costs were not available for review, so the scale of underestimation is unclear. It is not noted in project documents whether the King County exceeded construction costs.

In light of this behavior, ecosystem service values provide planners with an opportunity to expand the benefit stream. Subsequently, these projects will more likely pass a benefit cost analysis. Although cost underestimation may still occur as a result of technical problems, ecosystem service values allow those responsible for the cost analysis to create a more accurate and honest projection of net benefits without fear of failing benefit cost analysis.

¹⁸⁰ Washington State Recreation and Conservation Office, "Final Report," (unpublished report, October 3, 2011). <http://www.rco.wa.gov/prism/projectsnapshot.aspx?ProjectNumber=08-2056>.

Conclusion

The economic and ecological impact of changes to the environment, through restoration or degradation, influences human welfare over multiple generations. Benefit cost analysis presents a method for analyzing project impacts; however, the practice presents a number of issues for organizations. First, ecological benefits are difficult to assess in light economic and environmental uncertainty. Second, analysis of impacts on future generations becomes a difficult task since planners are under pressure to meet the preferences of the current generation.

In this thesis, I have presented ways to expand the stream of benefits and costs and improve intergenerational equity of decision-making. I propose the use of ecosystem service values for project analysis. Additionally, I submit two methods of increasing intergenerational equity. Between compensating for relative pricing and quasi-hyperbolic discount rates, I argue that while increasing the stream of benefits is important, adjusting the discount rate is the best alternative to improve intergenerational equity. This is especially true in ecologically complex scenarios. In ecologically complex transactions, decisions can irreversibly damage irreplaceable and unique environmental resources. Failing to incorporate these factors into the benefit cost analysis of projects leads to transaction costs. Ultimately, future generations bear the cost of decisions that neglect ecologically complex systems.

This thesis suggests that transaction costs of organizations that practice benefit cost analysis can be addressed through adjusting certain practices. Addressing transaction costs requires the planner to mind ecological scenarios, economic values for ecosystem services, and changes that could occur in the future. Relative pricing and quasi-hyperbolic discounting are tools that can assist the planner in this effort. It is possible that these tools will become more relevant to the planning profession if ecological and intergenerational considerations continue to pervade the analysis of projects.

Bibliography

- Armah and others, "Principles and Guidelines for Evaluation Federal Water Projects: U.S. Army Corps of Engineers Planning and the Use of Benefit Cost Analysis," Capstone Project from the Evans School of Public Affairs, University of Washington, August, 2009. http://evans.washington.edu/files/Principles_and_Guidelines_for_Federal_Water_Projects.pdf.
- Arrow, K., W. et al. "Inter-temporal Equity, Discounting and Economic Efficiency," *Climate Change: Economic and Social Dimensions of Climate Change*. Edited by J. P. Bruce, H. Lee and E. Haites. Cambridge: Cambridge University Press, 1995: 128–144.
- Association of State Floodplain Managers. "Discount Rate." Unpublished memorandum, May 17, 2008. http://www.floods.org/PDF/WhitePaper/ASFPM_Discount_%20Rate_Whitepaper_0508.pdf.
- Atkinson, Giles and Susana Mourato, "Environmental Cost-Benefit Analysis," *The Annual Review of Environment and Resources* 33 (2008): 317-344.
- Beechie, Timothy et al. "Process-based Principles for Restoring River Ecosystems." *BioScience* 60, no. 3 (March 2010): 209-222.
- Boyle, K.J. and J.C. Bergstrom. "Benefit transfer studies: myths, pragmatism, and idealism." *Water Resources Research* 28, no. 3 (1992): 657-663.
- Bureau of Labor Statistics. "CPI Inflation Calculator." Accessed on May 28, 2012. http://www.bls.gov/data/inflation_calculator.htm.
- Chichilnisky, Graciela. "An Axiomatic Approach to Sustainable Development." *Social Choice and Welfare* 13 (1996): 231-257.
- Circular A-4. Office of Management and Budget. September 17, 2004.
- City of Carnation. "Public Parks and Open Space." Accessed on May 27, 2011. http://www.carnationwa.gov/index.asp?Type=B_LOC&SEC=%7BA6EE32AC-4E9C-4237-8D47-37E08B8C88AC%7D.
- Committee of Improving Principles and Guidelines for Federal Water Resources Project Planning. *A Review of Proposed Revisions to the Federal Principles and Guidelines Water Resources Planning Document*. Washington, D.C.: The National Academies Press, 2010.
- Costanza, Robert. "The Value of the World's Ecosystem Services and Natural Capital." *Nature* 387 (May 15, 1997): 253-260.
- Cropper, Maureen, David Laibson. "The Implications of Hyperbolic Discounting in Project Evaluation." *Discounting and Intergenerational Equity*. Edited by Paul Portney and John Weyant. Washington D.C.: Resources for the Future, 1999: 163-171.
- Dasgupta, Partha, Karl-Goran Maler, and Scott Barrett. "Intergenerational Equity, Social Discount Rates, and Global Warming," *Discounting and Intergenerational Equity*.

- Edited by Paul Portney and John Weyant. Washington D.C.: Resources for the Future, 1999: 51.
- Earth Economics. "Supplemental Ecological Services Study: Tolt River Watershed Asset Management." Unpublished report, December 16, 2005.
http://www.earthconomics.org/FileLibrary/file/Reports/Puget%20Sound%20and%20Watersheds/Tolt_River_Ecological_Service_Study.pdf.
- Earth Economics. "Special Benefit from Ecosystem Services: Economics Assessment of the King Conservation District." Unpublished report, July 28, 2006.
<http://www.kingcd.org/pdf/KCD-Special-Benefit-Analysis.pdf>.
- Earth Economics. "The Puyallup River Watershed: An Ecological Economic Characterization." Unpublished report, May 2011.
http://issuu.com/earth_economics/docs/puyallup_river_watershed.
- ECONorthwest, "Case Studies," Unpublished report, accessed on May 27, 2011.
<http://www.econw.com/case-studies/>.
- Farber, Stephen, Robert Costanza, and Matthew Wilson. "Economic and ecological concepts for valuing ecosystem services." *Ecological Economics* 41 (2002): 388-389.
- Farrow, Scott. "Incorporating Equity in Regulatory and Benefit-Cost Analysis." Unpublished Paper prepared for SRA/RfF Workshop on New Ideas for Risk Regulation, June 22-23, 2009. http://sra.org/docs_reg_risk_pres/P6.c.i%20-%20Farrow%20Incorporating%20Equity.pdf.
- Federal Emergency Management Agency (FEMA). "Community Rating System." Accessed on May 28, 2012. <http://www.fema.gov/business/nfip/crs.shtm>.
- Federal Emergency Management Agency (FEMA). "The National Flood Insurance Program." Accessed on May 28, 2012. <http://www.fema.gov/business/nfip/>.
- Flyvberg, Bent, Mette Skamris Holm, and Soren Buhl. "Underestimating Costs of Public works Projects: Error or Lie?" *Journal of the American Planning Association* 68, no. 3 (Summer 2002): 279-295.
- Freeman, Myrick. *Benefits of Environmental Improvement*, Baltimore: Resources for the Future, 1979.
- Groom, Ben et al. "Declining discount rates: the long and short of it," *Environmental and Resource Economics* 32 (2005): 455-493.
- Hansen, Jon. "Lower Tolt River Floodplain Reconnection Project." King County. Unpublished presentation regarding the Lower Tolt Floodplain Reconnection Project, accessed on March 1, 2012.
http://www.rco.wa.gov/documents/salmon/conference/2011/hansen_j.pdf.
- Hardin, Garrett. "Tragedy of the Commons." *Science* 162, no. 3859 (May 1 1998): 1243-1248.
- Heal, Geoffery, "Valuing Ecosystem Services." *Ecosystems* 3, no. 1 (2000): 24-30.
- Heal, Geoffery. "Intertemporal Welfare Economics and the Environment." *Handbook of Environmental Economics* Volume 3. New York, NY: Elsevier Pub. Co., 2005: 1106-1143.
- Heikkila, Eric. *The Economics of Planning*. New Brunswick, N.J.: Center for Urban Policy Research, 2000.

- King County. "2009 Values for 100-year-flood." Excel Sheet. Accessed on April 7, 2012. <http://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=13&ved=0CEYQFjACOAo&url=http%3A%2F%2Fyour.kingcounty.gov%2Fdnrp%2Flibrary%2Fwater-and-land%2Fflooding%2Flocal-hazard-mitigation-plan-update%2Fdata-100-year-flood.xls&ei=j3GET5GLE7LaiQLL6Lj1BA&usg=AFQjCNGchdVO2C3H29L79NhN2BCvaeixKg>.
- King County. "Chinook Salmon Recovery Projects." King Stat. Accessed on May 7, 2012. <http://your.kingcounty.gov/dnrp/measures/performance/en-chinook-salmon.aspx>.
- King County. "Lower Tolt River floodplain restoration project." Accessed on May 28, 2012, <http://www.kingcounty.gov/environment/animalsAndPlants/restoration-projects/tolt-restoration.aspx>.
- King County Flood Control District. "Current Project Allocations – 2012 CIP." Unpublished report, July 20, 2011. http://your.kingcounty.gov/dnrp/library/water-and-land/flooding/kcfzcd/KCFCD_adv_com_packet_072811_rev.pdf.
- King County. "Lower Tolt River Floodplain Restoration Project." Accessed June, 5, 2012. <http://www.kingcounty.gov/environment/animalsAndPlants/restoration-projects/tolt-restoration.aspx>.
- King County. "Project pictures, information and schedule: Lower Tolt River Floodplain Restoration Project." Accessed on May 28, 2012. <http://www.kingcounty.gov/environment/animalsAndPlants/restoration-projects/tolt-restoration/project-schedule.aspx>.
- King County. "Response to SEPA Comments from the City of Carnation: Regarding the Lower Tolt River Floodplain Reconnection Project." Unpublished report, last modified March 29, 2007. <http://your.kingcounty.gov/dnrp/library/archive-documents/wlr/cposa/tolt-restoration/pdf/sepa-responses-carnation.pdf>.
- King County. "Snoqualmie 2015." Unpublished report, last modified February 2006. http://www.govlink.org/watersheds/7/pdf/Snoq2015_13-31.pdf.
- King County. "Determination of Non-Significance." Unpublished report, last modified June 22, 2006. <http://your.kingcounty.gov/dnrp/library/archive-documents/wlr/cposa/tolt-restoration/pdf/determination-of-non-significance.pdf>.
- King County. "Lower Snoqualmie & Skykomish Rivers Flood Insurance Study." Unpublished presentation, accessed on November 7, 2006. <http://green.kingcounty.gov/wlr/science/seminar/pdfs/PDF11.pdf>.
- Knowler et al. "Valuing freshwater salmon habitat on the west coast of Canada." *Journal of Environmental Management* 69, no. 3 (2003): 261-273.
- Laibson, David. "Golden Eggs and Hyperbolic Discounting," *The Quarterly Journal of Economics* 112, no. 2 (May 1997): 443-477.
- Layton, David, Gardner Brown, Mark Plummer. "Valuing Multiple Programs to Improve Fish Populations." Unpublished presentation prepared for the Washington State Department of Ecology. 1999. <http://www.ecy.wa.gov/programs/wr/hq/pdf/1-MarkPlummer.pdf>.
- Levin, Simon. "Ecosystems and the Biosphere as Complex Adaptive Systems." *Ecosystems* 1 (1998): 431-436.

- Long, Mark, Richard Zerbe, and Tyler Davis. "The Social Discount Rate as a Function of Individuals' Time Preferences." Working Draft, no date. 5.
- Loomis, John B. "Measuring the economic benefits of removing dams and restoring the Elwha River: Results of a contingent valuation survey." *Water Resources Research* 32, no. 2 (February 1996): 441-447.
- National Oceanic and Atmospheric Administration (NOAA). "Puget Sound Chinook ESU Recovery Plan Summary." Unpublished report, May 10, 2012.
<http://www.nwr.noaa.gov/Salmon-Recovery-Planning/Recovery-Domains/Puget-Sound/upload/PS-Chnk-summary.pdf>.
- Pearce, "Development, the Environment, and the Social Rate of Discount," *The World Bank Research Observer* 6, no. 2 (July, 1991): 137-152.
- Pearce David and Anil Markandya. "Development, the Environmental, and the Social Discount Rate." *The World Bank Research Observer* 6, no. 2 (July 1991): 139.
- Pigou, A.C. "The Economics of Welfare." London: Macmillan and Co., 1920.
- Powers, Kyna. *Benefit-Cost Analysis and the Discount Rate for the Corps of Engineers' Water Resource Projects: Theory and Practice*, Congressional Research Service Report for Congress, June 23, 2003.
- Puget Sound Partnership. "Article 9: Protect and Recover Salmon." *Action Agenda*. December 11, 2011.
- Rasmussen, Eric. "Some Common Confusions about Hyperbolic Discounting." Unpublished white paper. Last modified March 25, 2008. <http://www.rasmusen.org/special/hyperbolic-rasmusen.pdf>.
- Ruhl, J.B. "The Tragedy of Ecosystem Services." *Bioscience* 58, no. 10 (November 2008): 969-974.
- Salmon Recovery Funding Board (SRFB). "Salmon Recovery Program In-Stream Habitat Application Materials Checklist." Unpublished report, last modified on February 29, 2004. <http://www.rco.wa.gov/prism/projectsnapshot.aspx?ProjectNumber=08-2056>.
- Samuelson, Paul. "A Note on the Measure of Utility." *The Review of Economic Studies* 4, no. 2 (Feb., 1937): 155-161.
- Scheffer, Martin et al., "Catastrophic shifts in ecosystems," *Nature* 413 (October 11, 2001): 591-596.
- Scodari, Paul. "Survey and Analysis of Criticisms of Corps Planning and Links to Planning Guidance," Working paper, last modified February 2005.
- Scott, Linda. City Planner for City of Carnation. Telephone interview. April 10, 2012.
- Smith, Adam. *Wealth of Nations* 5th Edition. London: Methuen and Co., 1904.
- Snohomish County. "Section 4.0: Status of the Salmon in the Snohomish River Basin." *Snohomish River Basin Conservation Plan*. Unpublished study, June 2005.
http://www.co.snohomish.wa.us/documents/Departments/Public_Works/surfacewatermanagement/snohomishsalmonplanfinal/section4.pdf.
- Snoqualmie Watershed Forum, "Meeting Summary," Unpublished report, July 20, 2011.
<http://www.govlink.org/watersheds/7/pdf/minutes/2011/Minutes7-20-11.pdf>.

- Sterner, Thomas and U. Martin Persson. "An Even Sterner Review: Introducing Relative Prices into the Discounting Debate." *Review of Environmental Economics and Policy* 2, no.1 (Winter 2008): 61-76.
- TCW Economics, "Economic Analysis of Non-Treaty Fisheries in Washington State." Unpublished report prepared for Washington Department of Fish and Wildlife, last modified December 2008. <http://wdfw.wa.gov/publications/00464/wdfw00464.pdf>.
- Thaler, Richard. "Some Empirical Evidence on Dynamic Inconsistency," *Economics Letters* 8 (1981): 201-207.
- Theodore, Porter. *Trust in Numbers*. Princeton, NJ: Princeton University Press, 1995.
- Triangle Associates and Tetra-Tech, "South Fork Tolt Watershed Management Plan." Unpublished report prepared for Seattle Public Utilities, accessed in June 2011. http://www.seattle.gov/util/groups/public/@spu/@conservation/documents/webcontent/01_012728.pdf.
- Trust for Public Land. "The Economic Benefits of Seattle's Park and Recreation System." Last modified March 2011. http://www.seattleparksfoundation.org/TPL_EconomicBenefits.pdf.
- Triangle Associates and Tetra-Tech, South Fork Tolt Watershed Management Plan," Unpublished report prepared for Seattle Public Utilities, June 2011. http://www.seattle.gov/util/groups/public/@spu/@conservation/documents/webcontent/01_012728.pdf.
- Twill, Jason et al. "Economics of Change: Catalyzing the Investment Shift Toward a Restorative Built Environment." Unpublished manuscript, Last modified October 2011. http://www.eartheconomics.org/FileLibrary/file/Green%20Building/The%20Economics%20of%20Change_1.3_web_version.pdf.
- United States Army Corps of Engineers (USACE). "Memorandum for Planning Community of Practice." Unpublished manuscript, October 21, 2011. <http://planning.usace.army.mil/toolbox/library/EGMs/EGM1201combined.pdf>.
- Washington State Recreation and Conservation Office. "Final Report." Unpublished report, October 3, 2011. <http://www.rco.wa.gov/prism/projectsnapshot.aspx?ProjectNumber=08-2056>.
- Washington Department of Fish and Wildlife, "Fishing in Washington: 2011-2012 Sportfishing Rules Pamphlet," <http://wdfw.wa.gov/publications/01185/>.
- Weitzman, Martin L. "Just Keep Discounting, But..." *Discounting and Intergenerational Equity*. Edited by Paul Portney and John Weyant. Washington D.C.: Resources for the Future, 1999.
- Weitzman, Martin L. "Why the Far Distant Future Should Be Discounted at Its Lowest Possible Rate." *Journal of Environmental Economics and Management* 36, no. 3 (1998): 201-208.
- Williamson, Oliver E. "The Theory of the Firm as Governance Structure: From choice to Contract" *The Journal of Economic Perspectives* 16, no. 3 (Summer 2002): 171-195.
- Williamson, Oliver E. "The New Institutional Economics: Taking Stock, Looking Ahead." *Journal of Economic Literature* 38, no. 3 (September 2000): 595-613.
- Zerbe, Richard and Dwight Dively. *Benefit-Cost Analysis in Theory and Practice*. New York, NY: Harper-Collins, 1994.

Zerbe, Richard and Tyler Scott, "(Almost) Everybody Wins: A true Pareto justification for practical welfare economics and the use of benefit cost analysis." Draft Paper, last modified March 2012. Microsoft Word File.