The Economic Value of Wetlands

Wetlands' Role in Flood Protection in Western Washington

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Abstract

Episodic flooding along rivers and streams in the lowlands of Western Washington has become a recurrent theme of recent years. Development practices that eliminate or compromise natural systems capable of controlling runoff appear to be exacerbating flooding problems in many areas. This highlights the importance of the remaining natural systems capable of attenuating flood flows, particularly wetlands, in the region's defenses against increasingly destructive floods.

To economists the problem of protecting wetlands for the flood protection services they provide is complicated by the "public goods" character of wetlands. Although wetlands provide diverse valued services to humans, the incentives that private property owners have to protect wetlands may nevertheless remain low. Wetlands owners can neither easily capture the social benefits that accrue when wetlands are protected nor produce those benefits independent of the cooperation of many others in pursuit of the same goals. Traditionally government is looked to for wetlands protection as a result.

In this report we argue that economic valuation of wetlands' flood protection services can provide a strong rationale for Western Washington communities to protect their remaining wetlands. After describing the general economic rationale for pricing non-marketed natural resource services like flood protection and outlining the approaches economists use to establish such values, we show how the "alternative/substitute cost" method can be used to produce a proxy for the value of the flood protection services that many wetlands currently provide for "free."

We illustrate our argument by estimating the dollar-per-acre values of wetlands systems for flood protection in two Western Washington communities currently experiencing frequent flooding, Lynnwood and Renton. We do this via a variant of the alternative/substitute cost method. Cost estimates for engineered hydrologic enhancements to wetlands currently providing flood protection are used to establish proxies for the value of the flood protection these same wetlands currently provide. A simple "ratio analysis" scheme is employed, making the method easily transferable to other communities which, like Lynnwood and Renton, are seeking ways to enhance the flood protection their remaining wetlands provide. The proxy values we estimate are in the range of tens of thousands per acre in current dollars. The analysis suggests that communities are likely to pay an increasingly high price for flood protection if they allow their remaining natural systems capable of attenuating flood flows to become further compromised in their ability to do so.

Executive Summary

Attitudes toward wetlands have changed enormously over the past several decades. Formerly regarded as nuisances, wetlands are increasingly valued today for the wildlife they support and the numerous other amenities they provide. Nevertheless, wholesale conversion of wetlands to other uses occurred as settlement expanded across the nation, and wetlands continue to be under development pressure in many areas.

Economic valuation, focused on services like flood control that wetlands provide for "free" and which therefore are easily taken for granted, can strengthen the argument for wetlands protection. It can illuminate the values that wetlands services have for society in the present and help policy makers understand the consequences of present policies on the values wetlands services are likely to have in the future. Providing such understanding is the ultimate goal of this report. After reviewing approaches that resource economists use to measure economic values for wetlands services which, like flood protection are not exchanged in markets, we develop case studies built around the current flood-protection enhancement efforts of two western Washington communities undergoing rapid growth (Lynnwood and Renton).

More than half of the wetlands that once existed in western Washington have been lost. Often the cause has been agricultural conversion, but today wetlands are increasingly at risk due to urban and suburban development. Western Washington is now one of the fastest growing regions of the country, and the remaining wetlands in rapidly developing areas are increasingly valuable for the flood protection they can provide. At the same time, the increasing pace and density of development is resulting in the natural wetlands systems that are capable of absorbing urban runoff becoming ever more fragmented, even as the need for flood protection grows ever more critical.

Recent episodes of serious flooding in the Puget Sound region raise the question of whether wetlands are properly valued for the flood protection they can provide. Resource economists

marketplace where goods that are more easily bought and sold are exchanged. Lacking appropriate price signals, private owners may not find it economically rational for them to protect wetlands whose benefits pass freely beyond their boundaries and whose value to society-as-a-whole will only be realized if a great many individuals are equally committed to the cause of wetlands protection.

Wetlands perform a number of functions of value to society, and focusing on any one, like wetlands' ability to attenuate storm flows, necessarily undercounts the total value that wetlands have for the numerous other "services" they also provide. Wetland values flow from services as diverse as support for commercial fishing to support for recreational birdwatching and the provision of open space. Simple cost-benefit comparisons of development vs.

preservation projects must be done with caution, and research points increasingly to the conclusion that, properly enumerated, the values associated with wetlands preservation do not necessarily lose out to development values, even when both are reduced to dollars and cents.

Economic valuation is the process of establishing a price for a good or service. Economists use market and non-market techniques to establish economic values, as well as proxy methods which take the value of one good or service as an indirect measure of another less easily quantified. The values economists try to capture with various measurement techniques include "non-use" values, where the person experiencing the value doesn't actually come in contact with the resource. For example, people attach value to the existence of wilderness areas that they may well never visit.

Studies to date of the value of flood protection provided by wetlands have relied on proxy techniques. The dominant approaches are the "alternative/substitute cost" method and the "damage costs avoided" approach. The Army Corps of Engineers used the damage costs avoided approach in a much-cited study conducted in the 1970s in which flood profiles in two Massachusetts rivers, one with extensive wetlands in its headwaters and the other with few remaining wetlands, were compared. The study concluded that the loss of the wetlands in the headwaters of the Charles River could lead to annual flood damages of over $17 million. The result led the Corps to acquire and protect some 8,500 acres of wetlands in the Charles River drainage. Unfortunately estimates made of the value of wetlands and other environmental services vary widely and there is often no clear consensus among economists on the best way to value a particular service.

In the cities of Lynnwood and Renton, extensive hydrologic studies have been done as part of efforts to enhance the flood control services provided by existing wetlands within their boundaries. In Lynnwood, the focus has been on Scriber Creek, which roughly bisects the city as it wends its way southeasterly to flow into the city of Brier. The Scriber Creek watershed is just 6.8 square miles in extent, but with extensive land clearing the creek has become subject to flooding that periodically overtops local roadways, including the busy and highly developed Highway 99. Just 2% of the land area within Lynnwood remains in wetlands, just over 100 acres in total.

Our economic analysis of the value of flood protection provided by wetlands associated with Scriber Creek utilized data on projected changes in water flows that would result if specific proposed engineered enhancements of the remaining wetlands, designed to further reduce flood flows during storms, were put into place. We assumed that the willingness of the city to pay the estimated costs of the proposed enhancements is an accurate reflection of the value to Lynnwood's residents of the current ability of the unaltered wetlands to perform the flood flow reduction that is currently provided. This approach thus represents a variant of the alternative/substitute cost method of natural resource valuation.

Ratios of the costs of the proposed hydrologic enhancements to the flood flow reduction effect they would achieve, and of the existing wetlands acreage to the flood flow reduction it presently achieves, were formed. These ratios were then combined mathematically to produce a dollars-per-acre estimate of the value of flood protection currently provided by the wetlands. We were able to develop two such estimates, one for the "whole system" hydrologic enhancement proposal developed by consultants for the city, and one for hydrologic enhancement only of the North Scriber wetland, a unique and highly efficient attenuator of storm flows located high in the Scriber Creek watershed.

A similar approach was developed to estimate the value of existing wetlands in the East Side Green River Watershed of Renton. The situation in the rapidly developing Renton Valley is similar to Lynnwood's though the approach the city is using to enhance the flood protection capability of its wetlands is somewhat different. Because the Green River Interlocal Agreement prevents the city from releasing flood flows to the Green River during the most severe storm events, the city needs extensive flood storage if widespread flooding of the Valley is to be prevented. Although numerous wetlands still exist in the Renton Valley, they have become highly fragmented with many pieces effectively cut off from Springbrook Creek, the Valley's main flow conduit. The proposed enhancements to flood flow storage thus involve conveyance of flood flows among wetlands in the Valley and mitigation projects to enhance flood storage.

We used a proposal for hydrologic enhancement identified in a recent environmental impact statement on the East Side Green River Watershed Project as the basis for estimating the value of the existing wetlands in the Valley for flood storage. The proposal consists of a package of flow conveyance improvements involving two existing Valley wetlands and a large wetlands mitigation project involving a third which has been filled. Ratios of the total cost of the package proposal to the total acre-feet of storage it would add, and of the existing flood storage to the number of wetlands acres that support it, were developed. These were combined to develop an estimate of proxy value per acre of the existing wetlands in the Valley for flood storage.

The results of the analysis we did of the Lynnwood and Renton systems gave similar values which, when annualized to $/acre/year, are comparable to values found in the few other economic studies that have been done of the value of wetlands for flood protection. We produced three estimates of "whole system" wetlands value for flood protection, which range from about $36,000/acre to about $51,000/acre. These values reflect both the current efficiencies of wetlands in their unaltered state to attenuate flood flows and the relatively high cost of adding to this capacity, a result of the degraded state of many remaining wetlands. The analysis of the North Scriber Creek wetland's value for flood flow attenuation revealed somewhat lower values, ranging from $8,000 to $12,000 per acre. This lower value is consistent with expectations, based as it is on benefits that are more local in character and on the relative cost efficiency with which additional storage capacity can be added to this particular wetland.

Interpretation and comparison of these results must be done with caution due to a number of differences in the way calculations for the different systems were done and the assumptions we've made that permit us to infer the value of existing wetlands for flood control from the projected costs of enhancements to these same systems. The broader lesson of this analysis is that the per-acre value estimates appear to increase rapidly as the cost inefficiency of enhancing the wetlands that remain also increases. This happens as wetlands systems become increasingly fragmented and degraded. This suggests that policies which permit wetlands to disappear that are presently contributing little to mainstem flood protection, but which have the potential to do so in the future, could lead to rapidly rising values for the remaining wetlands for flood protection, as increasingly marginal wetlands are called into service. At some point the "next best" alternatives to enhanced flood protection will not involve wetlands at all, and the purely engineered systems that might have to be built could prove very expensive indeed. These results suggest that price-sensitive market signals do exist that provide a strong economic rationale for communities in Western Washington to protect wetlands today in order to avoid what are likely to be much higher costs of flood protection in the future.

Inevitably, the actual implementation of the flood storage enhancement projects upon which these cost estimates are based runs the risk of altering other wetlands values. Maximizing the capacity of wetlands to store floodwaters may mean for example that the shrub-forest habitat typical of many Western Washington wetlands gives way to a more open water environment. Wildlife species that depend on the former will then be replaced to some degree by species that benefit from the latter. Wetlands perform diverse services that benefit humans, and the total economic value of wetlands depends on the full suite of valued services that wetlands provide. Thus the values derived in this study are necessarily underestimates of total wetlands value, as they focus on only a single wetlands function, flood and storm water control. The proxy method for estimating wetland's value for flood protection depends upon the costs of projects that, if implemented, would likely diminish at least some other wetlands values. Attempting to enhance the ability of any natural resource system to provide services of value to humans inevitably creates such tradeoffs. Economic analysis can help decision-makers understand these tradeoffs and their implications for human values.

Introduction

Changing Attitudes Towards Wetlands and Their Protection

The attitudes people have about wetlands have shifted enormously over the past several decades. At the time of the European migration, wetlands were regarded as nuisances -- barriers to travel and the expansion of settlement, and havens for dangerous predators and dread diseases. In the mid-1800s these attitudes were enshrined in the Swamp Lands Acts, which promoted the "reclamation" of wetlands via their conversion to agricultural and other lands, through diking, filling and draining.

The effects of these policies on the Nation's wetlands resources have been enormous. Recent estimates are that 53% of all wetlands were lost between the 1780s and 1980s, with agricultural conversion the chief reason (Meyer 1995). The pace of conversion accelerated into the mid-20th Century, with about 11 million acres of wetlands eliminated during the 20-year period ending in 1970.

The laws that promoted this conversion, largely through private action, stayed on the books for generations, yielding only gradually in the second half of the century to new laws that promoted a different set of values with respect to wetlands. Laws such as the Fish and Wildlife Coordination Act of 1958 and the Coastal Zone Management and Federal Water Pollution Control Acts, both passed in 1972, were designed to protect wetlands and the benefits they provide to society, rather than promote their conversion to other uses. A key concept in these laws is that of "mitigation" — if wetlands are to be altered for other uses, then compensation must be provided, often in the form of physical improvements, for those benefits that would be diminished as a result of alteration of system function. With the removal of incentives for drainage, coupled with mitigation requirements, the rate of wetlands loss has now been cut significantly (Meyer 1995).

In effect, the permit systems for wetlands alteration that exist today under both state and federal law recognize the values that formerly were those only of a minority of Americans — native Americans who, in the case of tribes like the Seminoles, had long lived in intimate association with the vast marshes and swamps of what was to become Florida, hunters and trappers among whites like the "swamp Yankees" of the southern New England coast who likewise learned to live by the providence that wetlands could provide, and early naturalists and conservationists like William Bartram, John James Audubon and John Muir.

These latter individuals were in retrospect the vanguard of a new social movement. This movement came to revere the richness of life in wetlands systems on aesthetic and scientific grounds. In the broader society, natural resource values were largely defined by the use made of resources in consumption. A pivotal moment came at the turn of the century when protest against the use of feather plumes taken from egrets for use in the manufacture of ladies' hats led to the creation of the National Audubon Society. Thus was born a movement to protect the wildlife of wetlands and other natural environments not for their commercial value but in the name of values that do not easily translate into the currency of the market place.

Wetlands Loss and Its Impacts in Western Washington

Washington is a rapidly growing state. In the state's most populous county, King, population increased by eight percent between 1990 and 1996, adding some 120,000 new residents. Statewide, population is expected to increase by another 400,000 residents by the year 2000 (Washington OFM 1997). Consequent human alteration of developable land, wetlands included, can thus be expected to continue to be significant. [1] Western Washington has been particularly prone to losses of wetlands over time. Seventy percent of the tidally influenced emergent wetlands in Puget Sound have been lost due to diking, dredging and filling, and more than 50 percent have been lost if one includes the freshwater wetlands along major river courses.

An analysis conducted by the U.S. Geological Survey of historical wetland acreage of 11 estuaries in Puget Sound estimates that 100 percent of the Puyallup River, 99 percent of the Duwamish River, and 96 percent of the Samish River wetlands have been lost (Bortleson et al, 1980). Agricultural conversion was the primary reason for the loss of more than 90 percent of the wetlands originally found in the Skagit Valley, while commercial and residential development was the primary cause of a similar loss for wetlands in the Green/Duwamish and Puyallup River basins (Washington DOE 1996). Estimates made by Canning and Stevens (1989) suggest that current wetlands losses in Snohomish County are about 15 wetland acres per month, or 180 acres per year. If this figure is projected to the rest of the state, statewide losses for the eight counties with similar growth projections, including projected losses for King and Pierce counties, would be 1,800 acres per year for these urbanized counties (Canning and Stevens 1989).

Continued threats to wetlands in Western Washington come from filling for dredged spoil and other solid waste disposal, road and highway construction, and commercial, residential and industrial development (Canning and Stevens 1989). Urban development is rapidly extending into areas containing much of the remaining wetlands resource base. One study found that at a threshold value as low as 5 to 8 percent total impervious surface in a watershed, significant changes in wetlands and stream hydrology begin to occur (Horner et al. 1996). These changes affect both physical habitat and biological characteristics of stream and wetland systems, and the effects become more pronounced with increasing urbanization of the watershed. Horner and his colleagues concluded that altered watershed hydrology was the primary source of the changes in habitat and biological characteristics which they observed.

One of the primary impacts of wetland loss in the urbanized environments of Western Washington relates to flood control. Wetlands play an important role in slowing and storing

[1] In the City of Lynnwood's Comprehensive Plan for example, under future "full buildout" conditions forested land is assumed to shrink to zero, pasture and developable open space to less than 100 acres, and wetlands holdings, now just over 100 acres, are assumed to shrink an additional 14 percent (R.W. Beck 1989).

floodwaters. Riverine wetlands and floodplains provide flat expanses where floodwaters are able to spread out, thereby reducing both the height and velocity of flooding downstream. Once the velocity of floodwaters is reduced, the water stored in these wetland areas will drain more slowly back into the system. If the soil in a wetland area is not fully saturated, the soil itself will provide storage capacity during periods of flooding. Shallow depressions where wetlands often form can hold standing water for weeks or months, contributing to the recharge of groundwater as well. Building structures or filling within floodways confines flood flows to narrower channels and causes increased flood heights and rates. Studies have shown that flood peaks may be as much as 80 percent higher in watersheds without wetlands than in similar basins with large wetland areas (U.S. ACOE 1976).

In numerous places in Western Washington local flooding as a result of stream flashing during heavy rain events has been on the increase in recent years. Such is the case with the Scriber Creek watershed in Lynnwood, and the Springbrook Creek watershed in Renton, both of which serve as case examples in this study. But the same statement can be made about many other river and stream systems in the developed lowlands west of the Cascades, some of which, like Issaquah Creek, now experience very frequent flooding. Wetlands are increasingly valuable for the flood protection they provide. Translating this value into dollars and cents can help non-specialists appreciate better the value to communities of the flood protection services that wetlands provide for "free." One goal of this report is to illustrate how this and other wetlands values can be estimated. We also develop the economic rationale for putting dollar values on "non-market" services like flood protection that wetlands and other environmental resources provide. This gives a context for using a proxy approach in which prices set in markets where ordinary goods and services are exchanged are used to estimate the economic value of the flood protection services currently being provided by Western Washington's wetlands. This method is used to develop estimates of per-acre values of existing wetlands in the Scriber Creek and Springbrook Creek watersheds for the flood control services they currently provide. These estimates are developed in the latter sections of this report.

Economic Choices and Their Effect on Wetlands Resources: A Brief Primer

To resource economists, wetlands loss is due in part to the fact that the value of the "services" wetlands provide in their unmodified state is not properly accounted for in the marketplace. Too many private individuals and firms make economic choices that affect the status of wetlands on the basis of private calculations of costs and benefits that neglect or undercount broader social values. This happens quite naturally, as wetlands are "public goods" and public goods are not priced in the same way that ordinary goods and services are.

As with other environmental public goods like clean air and clean water, wetlands degradation is "jointly produced" by the actions of a great many individuals. Individual contributions to degradation of the ability of wetlands systems to produce services of value to the broader society (but for which nobody pays) are relatively small. This means the costs of wetlands degradation to the individual will be small in comparison to what they represent to society as a whole. On the other side of the equation, the fact that, generally speaking, nobody pays for wetland services, valuable though they may be, looms equally large. The act of protecting wetlands or reversing their degradation, when undertaken by private individuals, results in the normal course of events in few or no monetary benefits to those individuals. The nature of wetlands benefits is such that they readily flow to all members of society, making their "capture" for the purpose of marketing impractical. Because private property owners can't exclude others from enjoying many of the benefits they create, the benefits to the individual who would undertake to protect wetlands are small in comparison to the benefits to society as a whole. In sum, both the ability and the incentive for private individuals to protect or enhance those wetlands values that accrue to society as a whole is low.

Traditionally, government regulation has been relied upon to provide the degree of wetlands protection that is believed necessary. Otherwise, as a result of the public goods character of wetlands, the resources devoted to their protection will be less than they should be. Where markets provide inaccurate price signals, economic science can still be used to establish values for unpriced wetlands services. These values then provide indicators of appropriate levels of social (i.e., governmental) investment in wetlands protection.

In freely functioning economic systems, it's the relative scarcity of the resources that go into the production of tangible (and marketable) goods and services that largely determines what producers produce, how much they produce, and what they can afford to sell it for. The public and private resources that might be invested in wetlands protection and enhancement are also scarce, and protecting wetlands through public investment might mean that some development opportunities are foregone or other, equally worthy, environmental conservation projects are not undertaken. Where wetlands are being enhanced to increase the level of services they provide (for example, for flood protection, the primary focus of this study), a variety of enhancement alternatives may exist. Trade-offs will exist for each wetlands protection decision, just as they do for private investment decisions. The critical questions include how much to invest in wetlands protection and enhancement and which projects to implement. All wetlands are not created equal, particularly when their ability to provide the specific services most desired by local communities are considered. So which wetlands to protect or enhance, and how much to invest in the whole system of wetlands protection, are questions economic analysis can help answer, just as it can inform private-sector investment decisions.

Wetlands Services and Economic Valuation

Approaching resource management questions from an economic perspective leads to a view that environmental policies should be designed with an understanding of the benefits and costs of proposed actions and their alternatives (involving trade-off decisions at the site, watershed and/or regional scale). Many believe however that economic analysis will serve only to illustrate the extent to which wetlands protection impairs economic activity. We believe that, by providing a more complete picture of short- and long-term costs and benefits, information concerning the economic value of wetlands strengthens the argument in favor of wetlands protection. Estimating the monetary value of wetland services provides a means for understanding how investments in the protection or enhancement of wetlands resources can improve the welfare of society. Knowledge of wetlands resource values allows us to recognize the costs (i.e., lost resource values) associated with wetlands development and the long term benefits of wetlands protection.

Natural resource economists work to understand and organize information about the ways that people value environmental resources like wetlands. Wetlands perform a number of functions that provide services that people value. Some of these values are directly measurable through market transactions, such as when commercial fishermen catch and sell fish whose life cycles depend on wetlands, while others, like the value of wild birds in wetlands, may be only crudely captured through market exchanges (e.g., collective expenditures by individuals in support of their birdwatching hobbies). The underlying wetlands functional support in each case is about the same — the provision of areas suitable for spawning or nesting, food supply, or refuge from predators, but the ways in which people derive satisfaction from the resulting wetlands services are quite different. Research conducted by natural and social scientists has helped explicate the connections between wetlands functions and services that people value. These connections are summarized in Table 1.

Table 1. Wetlands functions, related effects of functions, and corresponding societal values (adapted from NRC 1995).

Function	Effects	Societal Value
Hydrologic		
• Short-term surface water storage	• Reduced downstream flood peaks	• Reduced damage from floodwaters
• Long-term surface water storage	• Maintenance of base flows, seasonal flow distribution	• Maintenance of fish habitat during dry periods
• Maintenance of high water table	• Maintenance of hydrophytic community	• Maintenance of biodiversity
Biogeochemical		
• Transformation, cycling of elements	• Maintenance of nutrient stocks within wetlands	• Wood production
• Retention, removal of dissolved substances	• Reduced transport of nutrients downstream	• Maintenance of water quality
• Accumulation of peat	• Retention of nutrients, metals, other substances	• Maintenance of water quality
• Accumulation of inorganic sediments	some nutrients	• Maintenance of water quality
Habitat and Food Web Support		
• Maintenance of characteristic plant communities	• Food, nesting, cover for animals	• Support for furbearers, waterfowl
• Maintenance of characteristic energy flow	• Support for populations of vertebrates	• Maintenance of biodiversity

The economic framework for valuation of wetlands builds on the recognition that wetlands are like other natural assets that yield a flow of goods and services considered valuable by society. Table 2 reorganizes the information in Table 1 on the major goods and services provided by wetlands into a format compatible with the way economists think about natural resource services (i.e., as stocks and flows). Wetlands services are now divided into three major classes based on the ways that they ultimately benefit society. Although some services fall into more than one class, the division remains useful, because the different classes generally require different valuation approaches (Scodari 1994).

Table 2. Wetland services viewed as economic goods and services. (adapted from Scodari 1994)

Intermediate Goods and Services (serve as factors of production for other goods)		Final Goods and Services (produce consumer satisfaction directly)		Future Goods and Services (may fall into any of the other categories)
• Support of commercial fisheries (e.g., fish habitat, aquatic food chain support) • Provision of commercially harvested natural resources (e.g., timber, peat, small fur-bearing mammals) • Water supply and storage • Assimilation of wastes (e.g., for tertiary treatment of human wastes)	• Pollution assimilation/ water purification • Flood Control • Erosion prevention	• Consumptive uses (e.g., fishing and hunting • Non-consumptive uses (e.g., camping, hiking, boating, birdwatching	• Scenic value • Existence value • Educational value	• Bequest value • Option value • Undiscovered goods • Future development value (i.e., conversion to other use)

In this framework "intermediate" goods and services are analogous to factors of production in conventional production systems. They contribute to the production of final goods in the sense that, when combined with other factors of production (like labor and capital), they result in other goods and services that create value through direct consumption. Fishery products, where the fish depend on wetlands for all or part of their life cycles, are examples. The pollution assimilation, flood control and erosion prevention services that wetlands provide are other important examples of intermediate goods and services. They allow other activities (like development in areas prone to flooding) to go forward that would otherwise be impeded or require costly engineering to provide the same level of protection that wetlands provide for "free."

"Final" goods are those that are directly consumed to satisfy human wants. They include recreational values (like fishing) and the enjoyment of other amenities that wetlands can provide (e.g., the viewing value of open space and the flora and fauna found in wetlands). Some final services are less tangible and spill over into the category of "future" goods and services. These include "option" and "bequest" values, which relate to how individuals in society experience satisfaction from just knowing that wetlands continue to exist. Option value relates to benefits that we ourselves might elect to enjoy in the future but choose to forego today. For example, we may purchase wetlands property with the intention of future retirement and the prospect of leisurely enjoyment of wetlands amenity values.[2] Bequest value relates to values future generations will derive from wetlands. Nevertheless, we derive value in the present if we experience satisfaction from the idea that our heirs or future generations will also have wetlands to enjoy.

The inclusion of "future development value" in the last column of Table 2 confronts directly the most difficult question of all for those who would make the case for wetlands protection on the basis of their real, but for the most part unpriced, economic value in their unaltered state. Should development or "natural system" values prevail when the two are placed into direct competition, as they inevitably are when proposed development threatens wetlands resources? Economists have several answers to this question, none of them wholly satisfactory.

The problem is given an interesting conceptual treatment in a recent article by Clyde Kiker and Gary Lynne (1997). Imagine an unaltered wetland as producing the stream of valued services shown in Table 2 as the end products of an assembly line process. This assembly line is driven at its front end by the wetlands functions shown in Table 1. Now imagine that a parcel within the wetland is developed. The development on that parcel gives rise to a second, parallel assembly process that has as its end products a much different set of goods and services whose values are readily measured in the market place. For example, the development could be a shopping mall whose annual sales, employment, or profit from leases provide the basis for measuring its economic value. Unfortunately however, the rise of this second, market-driven assembly process involves human activity that disrupts the functions upon which the wetland's "natural" assembly process has been depending, diminishing or even eliminating completely the services (and hence the values) that the wetland had formerly produced. What decision rule should we therefore adopt in deciding whether (or how) to let the shopping mall development take place?

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[2] The State Wetlands Integration Strategy's (SWIS; Washington DOE 1994) "Economics of Wetlands Work Group Report" (December 1994) references correspondence between the Island County Assessor's Office and County Commission noting an increasingly wide disparity between assessed and market value for property in the county encumbered by wetlands. The fact that such properties were regularly being sold at prices in the tens of thousands of dollars per acre led the County Commission to reconsider the Assessor's practice of placing a nominal $400/acre assessed value on wetlands acreage, based on its "unbuildability".

One answer of course is to deal with the "how" question and try to prevent the detrimental cross-linking of the two assembly processes from occurring. This is precisely what strict siting regulations and mitigation requirements for development affecting wetlands aim to do. In the ideal, we can have both development and "no net loss" of wetlands functional support at the same time and the two streams of services to society can co-occur. In practice however, this has proved very difficult to achieve.

A second, much different, answer to the question is simply to compare and weigh the value of the two streams of benefits, one from nature, the other from private development. For example resource economists Leonard Shabman and Sandra Batie declare, "In most general terms, denial of a wetlands alteration permit requires an analysis documenting that the benefits to human users of maintaining natural wetlands exceed the costs, measured as foregone development values" (Shabman and Batie 1988, quoted in Kiker and Lynne (1997)).

This position is not so radical as it first appears if it is viewed in the context of the actual work that led these economists to endorse this benefit-cost approach (Shabman et al. 1979). In considering the value of Virginia's coastal wetlands for storm buffering versus their development value for residential housing, these investigators found that development value could not be shown to outweigh unequivocally the preservation value. Site development costs were found to be considerably higher than they would be for land-fast sites, and as the experience of recent years has shown, the damage to private property from coastal storms can be considerable.

How to count damage-avoided as a benefit to wetlands preservation raises the larger question of how precisely any of the non-market values associated with wetlands can be measured (discussed in the next section). The cost of mitigation is included in development costs and society increasingly demands wetlands mitigation. Most economists concede that for a variety of reasons simple cost-benefit comparisons do not give a clear signal on what to do in the preservation versus development debate (Kiker and Lynne 1997, Pearce and Turner 1990). Shabman and Batie conclude, "a policy based on a benefit-cost balancing test for wetlands permitting is technically impractical" (quoted in Kiker and Lynne 1997, p. 266).

As Kiker and Lynne point out, a third view is also possible, in which we simply accept what the broad public support for social regulation of wetlands alteration seems to be signaling—that the social value of the services wetlands provide in their unaltered state indeed outweighs the value that accrues to society when wetlands are developed. In effect, the social value of preservation has been determined to outweigh the value associated with development by the political dialogue in which we have been engaged over the past several decades. These social judgments are revealed by the degree of support that laws and regulations protecting wetlands currently enjoy.

The case studies that accompany this report support a middle view. They suggest that under at least some conditions of wetlands scarcity and corresponding societal need for services that wetlands formerly provided "for free," price signals do exist that suggest relatively high and increasing societal willingness to pay for those services. Communities in Western Washington that have experienced repeated flooding from surface runoff reveal high willingness to invest in the preservation and enhancement of their remaining wetlands' capacity to provide storm water control.

This community willingness to pay provides a tangible, but we believe generally unrecognized, price signal regarding the value of those wetlands services which, in their absence, impose direct and highly visible costs in the form of flood damage. Driven by the increasing scarcity in the Puget Sound region of wetlands capable of providing natural flood control, the economic value of wetlands flood control services appears to be on the rise.

This argument is developed through case examples which utilize an indirect (proxy) measure of wetlands flood control value — community willingness to invest in engineered solutions to enhance wetlands flood control ability. Many techniques are available for measuring the economic value of wetlands services, as the next section illustrates.

Economic Value Measurement Techniques

Economic "valuation" is the process of establishing a price for a good or service. Marketable goods have the great advantage that markets establish prices through the process of buying and selling.[3] For environmental goods and services that are not exchanged in ordinary markets, a variety of different valuation approaches may be required. A review of the literature on wetlands valuation methodologies suggests that three major categories of methods are relevant: market and non-market methods, and various proxy methods that utilize cost information.

Non-market measurement techniques can be further divided according to whether they measure use values (either for goods and services that are consumed or for goods and services like birdwatching whose enjoyment does not involve "consumption" in the usual sense of the term) or non-use values (where there is no actual contact or encounter with the resource). The values associated with use are, generally speaking, revealed through the behavior of individuals, while non-use values are such that economists tend to rely more on the stated preferences of individuals, such as can be established through surveys. The use of proxy methods to estimate the values of goods and services that do not easily lend themselves to estimation via other techniques requires justification of why the values so obtained represent reasonable estimates of the value of the original services.

Economists may also use the results of previously completed resource valuation studies, conducted via any of the methods above, provided there are enough similarities between cases to justify the inference that values obtained in one case also apply in another. This process is known as benefits transfer. The variety of measurement techniques available to estimate resource values is illustrated below.

Market Techniques: Measuring Use Values

Market Prices. Some wetlands services can be valued directly by using quantities and prices identified in a competitive market. Market analysis, in conjunction with factor input or productivity analysis, is useful in providing values in cases where wetlands services are priced by the market. An example is the production of salt hay in Spartina meadows, a practice once prevalent in New England. However, the absence of direct markets for most wetlands services hinders valuation based on market transactions.

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[3] The presence of market imperfections can mean however, that even market prices don't reflect the true costs of production or actual benefits to consumers. For example, farm subsidies may encourage conversion of wetlands to crop production, and, because of the subsidy, the price of the crops produced will not reflect what would otherwise be higher costs of production, the result of the marginal quality of the lands being used to grow a portion of the crop.

Non-Market Techniques: Measuring Use Values

<u>Factor Income</u>. Some studies have linked wetland habitat provision to the production of commercial or recreational fisheries and used estimates of the value of these fisheries to infer the value of the supporting wetlands habitat (Lynne, Conroy & Prochaska 1981). Other marketable goods, such as fresh water supply and waste treatment provided by wetlands, can be analyzed similarly.

<u>Travel Cost</u>. Consumer expenditures can provide price signals regarding the value of wetland services, even though what is "bought" is not itself a product of the wetland. The travel cost method is used to value such amenities as recreational opportunities through expenditures incurred on visits to recreational areas. "Participation valuation" is a related technique based on unit-day or recreational day values. Fishing or hunting in wetlands are amenable to value estimation via travel cost studies.

<u>Hedonic Pricing</u>. The "hedonic" price of a good is, as the name suggests, a premium that consumers are willing to pay as a result of location-related, pleasure-enhancing attributes associated with that good or service. The implication is that a similar commodity in a different location wouldn't provide the same total value. The method is based on the observation that real estate, when located on the waterfront, tends to command higher prices than does its inland counterpart. A recognized difficulty in applying this method is the extraction of the amenity-related component from the total price of the good (property). Statistical analysis of housing prices in neighborhoods that are similar but for their proximity to the resources being valued (e.g., wetlands) is used.

Non-Market Techniques: Measuring Use and/or Non-Use Values

<u>Contingent Valuation</u>. [4] The contingent valuation method relies on individuals' stated preferences, most often elicited in response to questions based on hypothetical situations. Respondents may be asked to state their willingness to pay for natural resource protection or for related goods and services such as a recreational experience. The validity of such surveys depends on numerous factors related to survey design and execution, as well as on success in avoiding strategic response and other biases. The validity of estimates of passive (or non-) use values is very difficult to test, as there is no observable behavior upon which to base estimates by alternative methods that utilize revealed preference information.

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[4] The contingent valuation method (CVM) is used most frequently to measure a good or service's total value, which includes both use and non-use value.

Proxy Techniques: Measuring Values

Alternative/Substitute Cost. The alternative/substitute cost method (which we apply in our case studies) can be used to estimate the value of particular wetlands services by calculating the lowest cost provision of the same service by a "next best" alternative. Its validity depends on several assumptions:

- The substitute can provide a similar function as the natural wetland;
- The alternative costed out is truly the least cost alternative; and
- There is "willingness to pay" evidence that per capita demand for the service would be the same at the two different levels of cost (Pearce & Turner 1990).

Several steps are involved in estimating value using this approach. First, the level of environmental service initially provided must be estimated or measured. Second, the least cost alternate supply mechanism must then be identified that provides the same or similar level of service. Finally, in order to avoid overestimation of the social willingness to pay, evidence must be gathered to indicate the public's demand for the alternate provision of service (Scodari 1994). The first two steps consider the supply of the wetland services; the third step is needed to reflect the demand for that service, and its least-cost alternative. This appears to be necessary to fully indicate the value of the service to society. The alternative/ substitute cost method is analogous to the replacement cost method. The cost of a substitute for a given service is determined through replacement of the service that occurs either on-site or off-site.

Damage Costs Avoided. The damage costs-avoided method assesses the value of wetlands services in terms of the cost of the property damage that would occur if the services were lost or absent (Pearce & Turner 1990, Scodari 1994). By their nature, some wetlands service flows protect the value of property, for example by the prevention of erosion or flooding. As with the previous method, an assessment of the service level is necessary to estimate the impact of its absence or loss. Additionally, the level of resulting damage due to a loss of the service must be estimated, and measured in financial terms.

Both these proxy methods are "project cost" related and thus do not directly measure willingness to pay. As such they do not necessarily represent measures of societal welfare (Anderson & Rockel 1991). In addition, these methods do not take into account individual or social preferences for wetland services, or individual behavior in the absence of those services (Scodari 1994). For example, in the absence of flood protection provided by wetlands, individuals downstream might well take individual action to prevent flood damage.

Thus, when the flood does occur, the actual damage might well be less than the estimate made on the basis of the vulnerability of development downstream when upstream wetlands are still functioning to lessen flooding.[5]

Embodied Energy Analysis. This technique was developed by ecologists specifically to "price" ecosystems on the basis of the potential contribution they make to the maintenance of living systems, through the ecological support they provide for such economically useful products as fish and wildlife (Gosselink, et al. 1974). Although the technique now has many variants, basically the annual gross primary production per acre of an ecosystem, expressed in equivalent units of energy, is the "currency" in this approach. Units of energy production are converted to dollars by using energy prices in the U.S. or global economy. Economists have many reservations with this approach, as it fails to satisfy important assumptions of the theory of values (i.e., utility theory) upon which traditional economics is based (Shabman and Batie 1978a,b, Odum 1978).

These economic measurement techniques vary considerably in the reliability of the value estimates they generate for the different goods and services that wetlands provide (Table 3). Each method has a number of practical and theoretical limitations that are not addressed in this report. Additional questions, beyond the scope of this report, concern the specific data needs and data handling techniques appropriate to each method. It is not uncommon for estimates derived by different methods to differ considerably. Table 4 illustrates the range of values obtained in several different studies that used different measurement techniques. Values are expressed in the same units ($/acre/year) and adjusted to the same base year.

[5] The SWIS study (Washington DOE 1994) describes a case along North Creek in Bothell where, in response to recalculated maximum flood heights, the owners of two large office parks found it necessary to raise existing dikes that protect the parks from flooding. Had wetlands and other natural landscapes upstream that formerly reduced flood flows not been removed, the expenditures for raising these dikes presumably would not have been necessary. The costs to the developers of raising the dikes could therefore be counted as "saved defensive expenditures" in counting the value for flood control of the now vanished upstream wetlands.

Table 3. Valuation methodologies by classification of wetland goods and services addressed.

Type of Service	Intermediate Goods and Services		Final Goods and Services		Future Goods and Services
Method	Commercial Factors	Damage-prevention factors	Recreational opportunities	Amenities	
Market Analysis	X		X		
Factor Income	X	X			
Travel Cost			X	X	
Hedonic Pricing	X			X	
Contingent Valuation			X	X	X
Damage Costs Avoided		X			
Alternative or Substitute Cost	X	X			
Embodied Energy	X				X

Table 4. Estimates of wetland function values from various published studies.

Wetland Function	Value (1996$) $/acre/year
Commercial Factors Fish and Shellfish Habitat Waterfowl Habitat Mammal and Reptile Habitat Water Supply	 48[a] 253[b] 18[c] 8,184[d] ; 24,504[e]
Damage Prevention Factors Erosion, Wind, and Wave Barriers Storm or Flood Control	 .67[f] 289[g]; 8,566[h]
Recreational Opportunities Consumptive and Non-consumptive Uses	 9[i]; 38[j]; 115[a]; 114[k]; 12[l]

[a] Bell, 1989 - Factor Income
[b] Gupta and Foster, 1975 - Revealed Preference of Resource Managers (land acquisition decisions)
[c] Farber and Costanza, 1987 - Factor Income
[d] Gupta and Foster, 1975 - Replacement Cost
[e] Thibodeau and Ostro, 1981 - Replacement Cost
[f] Farber, 1987 - Damage Cost Avoided
[g] Gupta and Foster, 1975 - Damage Cost Avoided
[h] Thibodeau and Ostro, 1981 - Damage Cost Avoided
[i] Farber and Costanza, 1987 -Travel Cost
[j] Thibodeau and Ostro, 1981 - User Day Values
[k] Farber and Costanza, 1987 - Contingent Valuation
[l] Bergstrom, Stoll, Titre and Wright, 1990 - Contingent Valuation

Estimating the Economic Value of Wetlands for Flood Protection

Generally speaking, economic valuation has played a limited role in wetlands policy and planning decisions. In the case of flood protection, a study conducted by the Army Corps of Engineers in the 1970s is one outstanding exception to the rule. That study compared flood volumes from a single flooding event (in 1955) that passed a comparable point on each of two rivers in eastern Massachusetts. The first, the Charles, had extensive wetlands in its headwaters, while the second, the Blackstone, was characterized by rapid run-off. Modeling studies showed a significant lowering and desynchronization of the peak flood in the system that had its wetlands intact. These differences in flood volume were then used to estimate the increase in property losses that would likely be associated with various percentage losses of the Charles River wetlands.

The damages-avoided approach was then used to estimate the economic costs and benefits of wetlands preservation in the Charles River basin (Thibodeau and Ostro 1981). It was estimated that the loss of 8,442 acres of wetlands within the Charles River system would result in annual flood damages of over $17 million. For this reason, the Corps elected to preserve the wetlands rather than to construct extensive flood control structures. The Corps set out to acquire some 8,500 acres of wetlands in the Charles River drainage, completing this ambitious acquisition program in 1984.

A review of the literature suggests that proxy methods, specifically the damages-avoided and alternative/substitute cost methods, are most readily applicable to estimating the economic value of the flood protection service that wetlands provide. They appear to provide more reliable estimates than other methods which do not rely on proxies. Projected changes in hydrologic profiles downstream as a result of wetlands loss upstream form the basis for estimating values by either of these proxy approaches.

Because some Western Washington communities have recently undertaken efforts to identify ways to enhance the flood protection that their remaining wetlands provide, hydrologic studies that provide the necessary information on downstream flood flows are now becoming available. This makes it possible to illustrate the application of the alternative-substitute cost method to the estimation of values related to flood protection. Our case analyses are based on the recent experiences of the cities of Lynnwood and Renton. We believe that, numerous estimation problems not withstanding, these results underscore the economies that are inherent in having wetlands available to lessen storm flows in the urbanized areas of Western Washington.

Case Example:
North Scriber Creek Wetlands
Lynnwood, Washington

The City of Lynnwood is a highly urbanized community located along the I-5 corridor in the southwestern portion of Snohomish County (Fig. 1). The city contains 18 major drainage areas covering an area of approximately 7 square miles (R.W. Beck 1991). These drainage basins feed several small creeks and ponds that exist within or pass through the city. Scriber Creek, together with its two primary tributaries, Poplar Creek and Golde Creek, forms the backbone of this drainage system, roughly bisecting the city in a north-south direction (Fig. 2).

An estimate of current and projected future land use within the Scriber Creek watershed was developed as part of the 1989 Scriber Creek Watershed Management Plan (R.W. Beck 1989). Based on interpretation of 1985 aerial photos, the study found the dominant land use to be medium density residential development (more than 40% of total acreage) followed by commercial-industrial development (about 23%). The study also found a total of nearly 1000 acres in a combination of forest, pasture/open space, and wetlands, an area roughly comparable to the area in commercial-industrial use. The 1996 holdings in the open-space category are likely smaller, as extensive additional development has occurred in Lynnwood over the past decade.

On the basis of then current comprehensive planning documents, the study also developed an estimate of future land use. A combination of medium density and multi-family residential development would occupy two-thirds of the watershed, and commercial-industrial development another quarter, in the scenario developed in the plan. To accommodate this additional development, forested land would shrink to zero, and remaining pasture and open space in the non-wetlands category would shrink to less than 100 acres. Wetlands acreage would shrink more modestly, about 14% from its current size. Total open space including wetlands would comprise just 6% of total area within the Scriber Creek watershed. As will be seen below, these land-use changes have significant implications for future flooding potential in the area.

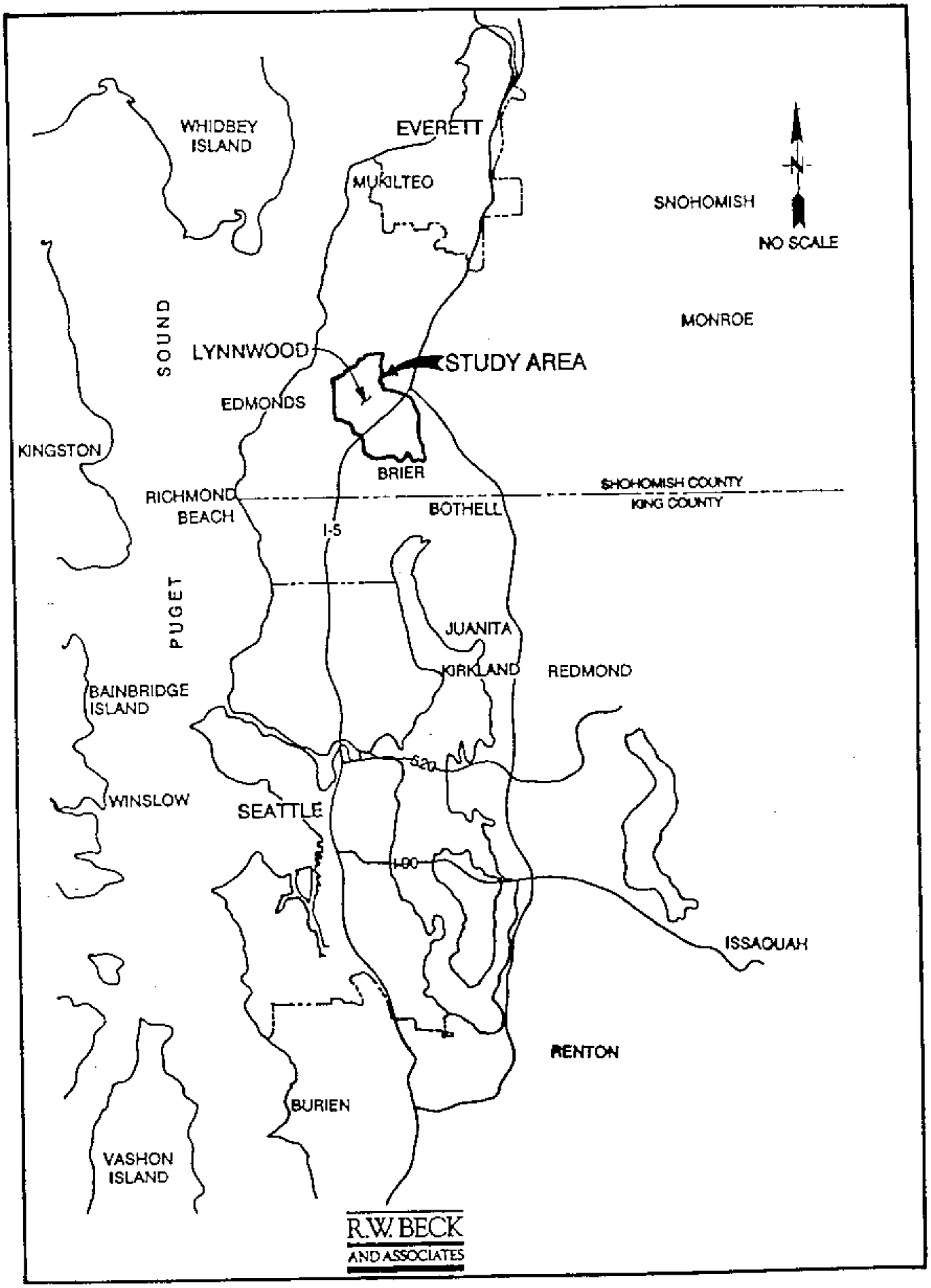

Figure 1. Scriber Creek Watershed (Source: R.W. Beck 1989.)

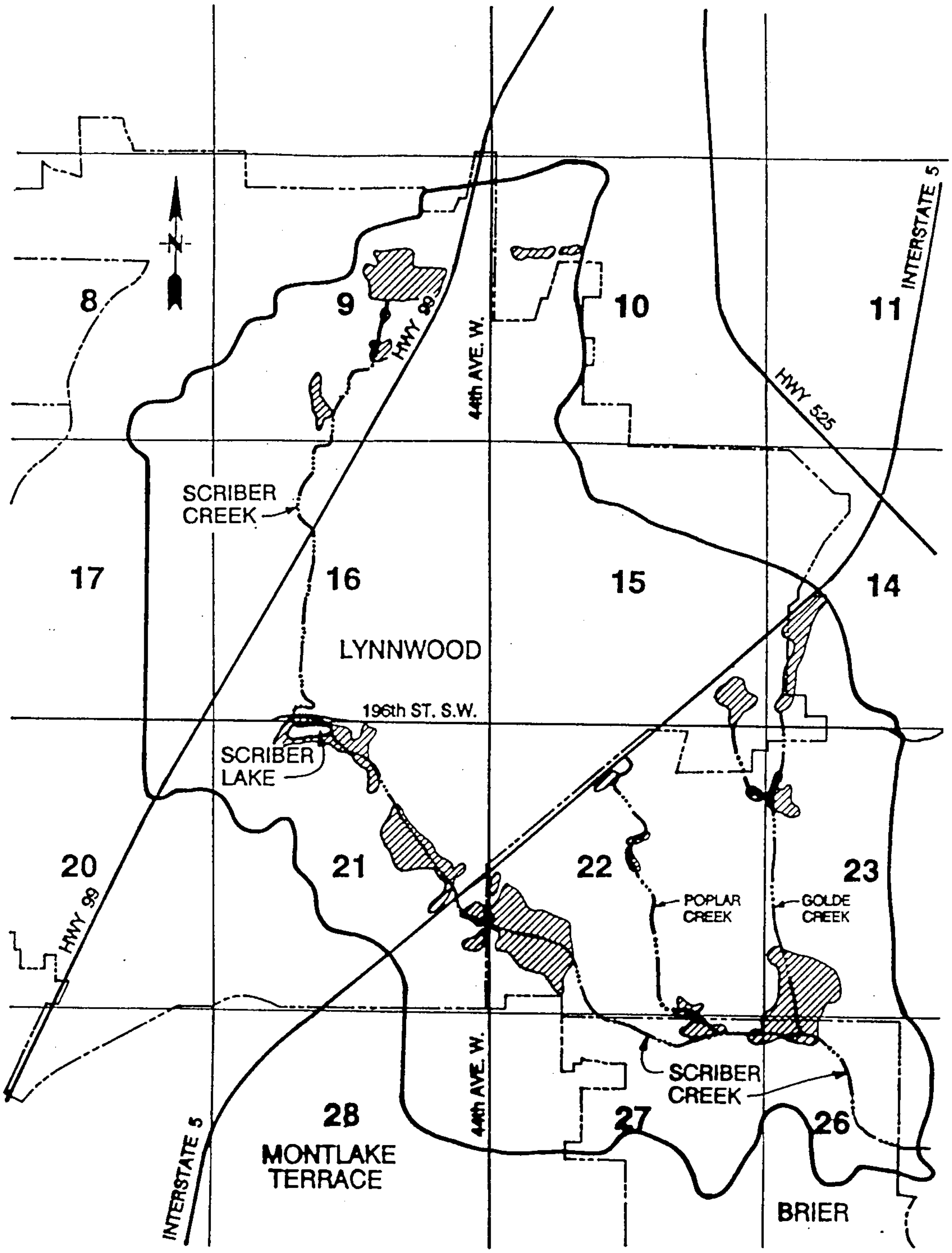

Figure 2. Wetlands in the Scriber Creek Watershed (Source: R.W. Beck 1989.)

Scriber Creek

Scriber Creek originates from drainage and groundwater just beyond the northeast corner of the Lynnwood city limits, feeding the 23.7-acre North Scriber Creek wetland that is the focus of this case study (adjacent to "9" in top left of Fig. 2) shortly after it crosses the city limits. The creek then flows south, initially in close proximity to the heavily developed Highway 99 corridor, then, upon exiting Scriber Lake, in a southeasterly direction until it passes under I-5 and into the city of Brier. The 20-acre Scriber Lake Park is a central amenity of the city, and includes about 17 acres of mostly wooded wetlands.

The creek itself is just 5.1 miles long, emptying into Swamp Creek which in turn empties into the lower Sammamish River drainage of Lake Washington. Much of the creek is culverted, though surface manifestations exist throughout its length. The Scriber Creek watershed is approximately 6.8 square miles in extent, 4.2 square miles of which lie within the City of Lynnwood. The creek's normal flow rate is about 7 cfs (measured at the mouth). It currently suffers both water quantity and water quality problems as a result of locally generated stormwater runoff, particularly from the Highway 99 corridor (City of Lynnwood 1995, Wetland Environmental Permit Application).

Wetlands and Riparian Zones

The 1989 Scriber Creek Watershed Management Plan (R.W. Beck 1989) identifies approximately 189 acres of wetlands within the Scriber Creek watershed, approximately 4% of the watershed area. Within Lynnwood itself are about 107 acres of wetlands, representing about 2% of the total land area within the city limits. Most of the wetland acreage within Lynnwood is associated with Scriber Creek, and about 55% of the total is found in just three individual wetlands. The largest of these is the approximately 24-acre North Scriber Creek wetland.

As noted in Lynnwood's Comprehensive Plan, "most of the wetlands provide high hydrologic values in terms of flood storage, low flow augmentation, and water quality improvement. In addition, the wetlands provide valuable wildlife habitat in an increasingly urban environment." (R.W. Beck 1991, Appendix D, p. 9).

These wetlands are undergoing degradation due to adjacent development or direct physical intrusion. Considerable commercial and residential development has occurred adjacent to the North Scriber Creek wetland in particular, there is extensive residential development at the confluence of Golde and Scriber Creek where there are about 44 acres of wetlands, and a 20-acre wetland near the creek's junction with I-5 is being degraded by a large dumping operation nearby. Degradation is both affecting water quality and eroding the storm water detention capability of the wetlands in the system. This contributes to a pattern of small-scale intermittent flooding throughout the system, mostly involving the overtopping of roadways where they cross Scriber Creek (R.W. Beck 1989).

Proposed Stormwater Detention Enhancements in the Watershed

The 24-acre North Scriber Creek wetland is interconnected, via underground culvert, to a small downstream detention pond built in conjunction with what is now a “Home Base” store. The detention pond predates the Home Base, and functions primarily as a filter for parking lot runoff. Multiple exit pipes at the south end of the pond route the combined flow to Scriber Creek. The North Scriber Creek wetland is privately owned, though the City of Lynnwood is proposing its purchase to facilitate an upgrade of its stormwater detention capability.

The proposal for enhanced stormwater detention is to reconfigure, via insertion of a “stepped” V channel, the interconnection between the wetland and the detention pond. This would permit the combined system to take more runoff during storm events by raising the average level of the wetland. The V-channel would allow progressively more outflow as runoff increases, resulting in both higher high water than now occurs during storms and lower lows during dry periods. Estimates of the effectiveness of the V-channel in reducing peak flows, calculated via simulation modeling for a particular 1984 storm event and under the assumption of the future development scenario described above, appear in the top left-hand column of Table 5. Flows estimated to be 16 cfs without the V-channel would be reduced to 7 cfs with the channel in place (measured at the same point just below the wetland in each case).

The other wetlands shown in Figure 2 were also identified in Lynnwood’s 1989 watershed management study as candidates for enhancements to increase flood storage and reduce peak flood flows. Although the plan to implement engineered enhancement measures at each of these remnant wetlands in addition to the hydrologic enhancements planned for the North Scriber wetland has since been abandoned, estimates of the reduction of flows that could be achieved, together with the associated costs (as estimated in the plan), were developed. The combined flow reduction effects of the full package of hydrologic enhancements originally proposed are also indicated in Table 5 (right-hand side, top), under the same development and storm event conditions as for the North Scriber Creek wetland. This time the flow reduction effect is from 290 cfs without the system modifications, to 255 cfs with them all in place, as measured at the mouth of Scriber Creek.

Table 5. Estimated flow reduction effects of wetlands in Scriber Creek watershed, with and without wetlands modifications, for November 1984 storm. (1)

SCRIBER CREEK WATERSHED				
With Water Detention Facilities	**North Scriber Wetland Only**		**All Wetlands in Watershed**	
	Flow reduction effect of proposed water detention facilities (2)			
	Flow (cfs) (3)	Costs	Flow (cfs) (4)	Costs
Under existing wetland conditions	16		290	
With additional detention facilities	7		255	
Net "effect" of facilities	9		35	
% reduction	56%		12%	
Cost of water detention facilities (5)		$195,000		$1,516,137

With Wetland Systems Unmodified	Flow reduction effect of unmodified wetland system (2)			
	Flow (cfs) (3)	Acres	Flow (cfs) (4)	Acres
With wetlands filled (6)	81		536	
Under existing wetland conditions	16		290	
Net effect of existing wetlands	65		246	
% reduction ("effect ratio")	80%		46%	
Residual reduction potential	20%		54%	
# of acres		23.7		163.2

Notes:
(1) R.W. Beck, 1989, Scriber Creek Watershed Management Plan, Table 3.2, 11/84 storm
(2) HSPF simulation model; future land use conditions, full buildout
(3) Peak discharge measured below N. Scriber Creek Wetland
(4) Peak discharge measured at mouth of Scriber Creek
(5) Construction cost only, land acquisition cost not included
(6) All wetlands filled except area around Scriber Lake

Applying the Alternative/Substitute Cost Approach to Estimate the Economic Value of Flood Storage Provided by the North Scriber Wetland (Ratio Analysis)

The alternative or substitute cost method evaluates wetland flood control services by pricing the cost of providing similar flood control levels via a "next best" alternative, usually the engineering and construction of an artificial flood control device. The following section discusses an application of this method using the information in Table 5 regarding the flood control efforts in Lynnwood.

On-site alternative/substitute cost model[6]: This "ratio analysis" employs data from the Scriber Creek watershed in Lynnwood, Washington. The city is proposing to enhance flood flow reduction through projects that would enhance the ability of the existing wetlands system to lower flood flows during storms. The costs of the proposed enhancement projects can be used to estimate the value of the existing ability of the wetlands to provide similar effects as the proposed projects would provide. In other words, we are assuming that the city is willing to invest the estimated cost of the projects to enhance existing flood protection, and we are treating the city's willingness to pay this amount as a proxy for the value to its residents of the flood protection that already exits.[7]

The Scriber Creek Watershed Management Plan (R.W. Beck 1989) provides an indication of the willingness of the City of Lynnwood to pay for a reduction in flood flows emanating from several wetlands, through the construction of water detention facilities. The computer-simulated water flows in Table 5 are expressed in cubic feet per second (cfs) for an actual storm event affecting the Scriber Creek watershed. The simulation shows that, under future full buildout land use conditions, storm flows exiting the wetland would be reduced from 16 cfs to 7 cfs if a detention facility were to be constructed at the mouth of the North Scriber Creek wetland. This amounts to a 56% reduction in flow over what would occur without the v-channel in place. The Management Plan also provides capital improvement cost estimates for the detention facility to be constructed on this site (R.W. Beck 1989, Table 6.1). These are also shown in the table. Excavation, embankment fill, control structure and landscaping costs, plus mark-up, total $195,000 for this project. Using this indication of the city's

[6] This analysis is based on information and data provided in the Scriber Creek Watershed Management Plan (R.W. Beck, 1989). The flood reduction effect of existing wetlands is expressed in terms of water flow (cubic feet of water per second, or cfs) passing by particular points in the system. The effect of new proposed detention facilities on flows was modeled using the Hydrologic Simulation Program-FORTRAN (HSPF), and construction costs have been identified. The hydrology has been modeled, assuming future full build-out conditions. The estimates of economic values in this section were developed by Tom Green as part of his masters thesis research.

[7] Normally willingness-to-pay estimates are based on costs for replacing lost functions and services rather than on augmenting existing ones. The cost of outright replacement of the flood protection service provided by the wetland would presumably differ on a per unit basis. It would be lower if economies of scale proved significant, but higher if the complexity of the larger project entailed were to be significantly greater (requiring elaborate design, permitting land acquisition, etc.). The North Scriber wetland is so efficient in reducing flood flows in comparison to what the v-channel does that it is more likely our estimates are in fact underestimates.

preference for purchasing additional flood control services, we estimate a value for the existing level of flood control service provided by the North Scriber Creek wetland.

If the North Scriber Creek wetland were to be filled, or otherwise converted to an alternate use that precluded its hydrologic functioning, the corresponding flow rates would be considerably higher. In the lower part of Table 5, computer-simulated flow rates under conditions of full buildout with the wetlands in place are compared to the flows projected if the wetland were to be filled, or otherwise converted to another use. This comparison with and without the wetland shows the current effectiveness of the wetland in moderating flood flows. By its presence in the creek system, the wetland reduces the flood flows for this particular storm event from 81cfs to 16cfs, a reduction of 80%. The North Scriber wetland plays a highly effective role in buffering storm flows in its current condition.

If the city is willing to purchase the added flood control service of the detention facility for a one-time cost of $195,000, at what level do we infer it prices the existing level of flood control service provided by the wetland? Setting up ratios is instrumental to calculating this price. The cost of the proposed detention facility's enhancement per its "percent reduction effect" is in essence equilibrated with the value of the existing wetland acreage per the "percent reduction effect" it achieves in its unmodified state. If we assume that the incremental reductions in cubic feet per second flows for the two different scenarios are comparable (and that each acre of the wetlands has an equal effect in reducing flood water flows) the "percent reduction effect" terms cancel to reveal the cost (or proxy value) per wetland acre, of the flood control service provided as follows:

Cost of enhancement / percent reduction effect X existing percent reduction effect / acres of existing wetland = Cost (or proxy value) of existing wetland acres, for flood control service

$$\frac{\$195{,}000}{56\%\ \text{effect}} \times \frac{80\%\ \text{effect}}{23.7\ \text{acres}} = \$11{,}754/\text{acre}$$

The same approach can be used to calculate a per acre value of the flood reduction effect of the entire Scriber Creek Watershed wetland system under the Watershed Management Plan's future land use conditions (R.W. Beck 1989). Table 5 also shows in the right-hand column the simulation of the combined effect of all wetlands in the Scriber Creek Watershed in reducing flows (as measured at the Creek's mouth) for the same storm event. If water detention facilities were to be constructed as outlined in the Management Plan at each of the locations[8] (Fig. 2), these flow rates would be reduced from 290 cfs to 255 cfs. This amounts to a reduction in flow of 35cfs, or 12%, over existing conditions (upper right portion of Table 5). Although the city will not, in fact, be permitted to construct these facilities, this analysis assumes the city would have been willing to construct the eight projects at the

[8] There are a total of 8 proposed detention facilities in the Management Plan. These include:
North Scriber Creek Wetland Detention Facility; I-5 & 44th Ave. W. Detention Facility;
180th St. Detention Facility; 188th St. Detention Facility;
194th St. Detention Facility; "Park & Ride" Water Quality Pond
Poplar Creek Detention Facility; Birch Way Sediment Pond

estimated cost had it been permitted to do so. The total estimated construction costs of all eight projects amounts to $1,516,137 (R.W. Beck 1989, Table 6.1).

The Watershed Management Plan's assumption of full buildout conditions projects that a total of 163.2 acres of wetland area will exist throughout the Scriber Creek system (R.W. Beck 1989, Table 2.2). As in the above North Scriber Creek wetland case, a comparison of the simulated flows with and without the existing wetland areas (with the exception of the wetlands adjacent to the Scriber Lake city park which would not be affected) leads to an estimate of total the effect on flood flows of these remaining wetlands within the system. By their presence in the watershed, the combined wetlands are estimated to reduce flood water flow from 536 cfs to 290 cfs, a reduction of 46% (lower right portion of Table 5).

Lynnwood was willing to buy additional flood protection, via the proposed hydrologic enhancements, for a total of $1,516,137, so a similar ratio as before may be set up:

Cost of enhancement / percent reduction effect X percent reduction effect / acres of wetland = Cost (or proxy value) of existing wetland acres, for flood control service

$$\frac{\$1{,}516{,}137}{12\%\ \cancel{\text{effect}}} \times \frac{46\%\ \cancel{\text{effect}}}{163.2\ \text{acres}} = \$35{,}612/\text{acre}$$

In either of the cases outlined above, the calculated value per acre of the effect of these wetland areas in reducing flood flows is a proxy for the value of their inherent flood control effect, measured in terms of the cost to improve the flood control function through the installation of on-site water detention facilities. The North Scriber Creek wetland receives a considerably lower value per acre when considered in isolation ($11,754 per acre vs. $35, 612 per acre) because additional flood control via detention facilities can be achieved at this site much more efficiently, or at a lower cost per cfs reduced, than at other wetlands in the system.

Discussion of January 1986 Storm Event

The simulated output data for a second storm event is also detailed in the Management Plan (R.W. Beck 1989, Table 3.3), presented in the same format as the data discussed above. These data are used to repeat the calculations discussed above, as a test of the sensitivity of the method we are using to the individual characteristics of storm events (Table 6). The valuation approach is same. Under future full buildout conditions water flow from the North Scriber Creek wetland would be reduced from 29 cfs to 11 cfs if a detention facility were to be constructed at the mouth of the wetland, for a flow reduction effect of 62%. If this same wetland were to be filled, under conditions of the January 1986 storm water would flow at a rate of 70 cfs from the former wetland area. Thus it can be seen that the presence of the wetland reduces water flow from 70 to 29 cfs, for a reduction of 59%, for this storm simulation. The other components of the analysis are the same as above: the wetland occupies 23.7 acres and the detention facility would cost $195,000 to design and construct.

Table 6. Estimated flow reduction effects in Scriber Creek watershed with and without wetlands modifications, for January 1986 storm (1)

SCRIBER CREEK WATERSHED				
With Water Detention Facilities	**North Scriber Wetland Only**		**All Wetlands in Watershed**	
	Flow reduction effect of proposed water detention facilities (2)			
	Flow (cfs) (3)	Costs	Flow (cfs) (4)	Costs
Under existing wetland conditions	29		400	
With additional detention facilities	11		377	
Net "effect" of facilities	18		23	
% reduction	62%		6%	
Cost of water detention facilities (5)		$195,000		$1,516,137

With Wetland Systems Unmodified	Flow reduction effect of unmodified wetland system (2)			
	Flow (cfs) (3)	Acres	Flow (cfs) (4)	Acres
With wetlands filled (6)	70		601	
Under existing wetland conditions	29		400	
Net effect of existing wetlands	41		201	
% reduction ("effect ratio")	59%		33%	
Residual reduction potential	41%		67%	
# of acres		23.7		163.2

Notes:
(1) R.W. Beck, 1989, Scriber Creek Watershed Management Plan, Table 3.3, 1/86 storm
(2) HSP simulation model; future land use conditions, full buildout
(3) Peak discharge measured below N. Scriber Creek Wetland
(4) Peak discharge measured at mouth of Scriber Creek
(5) Construction cost only, land acquisition cost not included
(6) All wetlands filled except area around Scriber Lake

The ratio is set up as before:

Cost of enhancement / percent reduction effect X percent reduction effect / acres of wetland = Cost (or proxy value) of existing wetland acres, for flood control service

$$\frac{\$195{,}000}{62\%\ \cancel{\text{effect}}} \times \frac{59\%\ \cancel{\text{effect}}}{23.7\ \text{acres}} = \$7{,}830/\text{acre}$$

This calculation produces a lower proxy value for the flood control ability of the North Scriber Creek wetland, as compared to the previous calculation based on the 1984 event because of the different nature of the two storms, and their resulting runoff patterns. In the 1984 event, the unmodified wetland proved more effective at reducing the water flow (80% reduction effect vs. 59% reduction effect), possibly due to the intensity and duration of the rainfall, as well as the saturation level of the wetland soil prior to the storm (R. Swenson, personal communication, 1/8/97). Moreover, the simulation model predicts that the detention facility would have a greater flood control effect under the conditions of the 1986 storm as compared to the 1984 event (62% reduction effect vs. 56% reduction effect). These two factors result in the wetland, valued in terms of the cost to enhance the flood control function through the construction of detention facility projects, receiving a lower value in the second calculation. These ratio calculations thus produce values that are sensitive to the specifics of individual storm events.

The data from Table 6 can also be used to calculate a value per acre of all of the wetlands in the Scriber Creek Watershed, in the same manner for the 1984 event. If water detention facilities were to be constructed at each of the previously indicated locations (see footnote 8), water flow would be reduced from 400 cfs to 377 cfs, measured at the mouth of Scriber Creek. This amounts to a reduction of 23 cfs, or 6% over existing conditions. As noted before, the total estimated construction costs of all eight projects amounts to $1,516,137. By their presence in the existing watershed, under full build out conditions and considering the 1986 storm event, the 163.2 acres of wetlands reduce flood water flows from 601 cfs to 400 cfs, a reduction of 33% (see the lower right section of Table 6).

The costs and acreages remain the same from the 1984 calculations, and a similar ratio is developed.

Cost of enhancement / percent reduction effect X percent reduction effect / acres of wetland = Cost (or proxy value) of existing wetland acres, for flood control service

$$\frac{\$1{,}516{,}137}{6\%\ \cancel{\text{effect}}} \quad X \quad \frac{33\%\ \cancel{\text{effect}}}{163.2\ \text{acres}} \quad = \quad \$51{,}095/\ \text{acre}$$

The two simulated "design storm events" represent conditions of intense rainfall and water runoff. According to the Management Plan, the November 1984 event had a higher rainfall intensity, but a smaller runoff volume, than the January 1986 event. The smaller runoff volume may account for the whole system being "less valuable" with respect to its handling of the 1984 event ($36,000/acre vs. $51,000/acre). The ability of the high-storage volume North Scriber Creek wetland to attenuate the higher intensity flows of the 1984 storm may account for its somewhat higher value for the 1984 event ($12,000/acre vs. $8,000/acre).

Data on additional storm events, or simulation estimates of system response with and without enhancements to typical "period" storms (2-year, 10-year, 25-year, etc.) would help clarify the behavior of these proxy values over a range of different system performance assumptions. Although the point is somewhat speculative, on the basis of these two events, the estimates appear much more sensitive to the efficiencies of engineered structures in reducing flows on a per unit basis than they are to the specifics of individual storms.

Case Example:
East Side Green River Watershed, Renton, Washington

This second case study analysis examines the efforts of another community in Western Washington, the City of Renton, to control local flooding problems through expenditures to modify and remediate local watershed conditions. The city seeks to reduce flooding by reconnecting isolated wetlands to the Springbrook Creek main stem channel, and by excavating a wetland area that was previously filled. The result will be an addition to the city's floodwater storage capacity. The willingness of the City of Renton to pay for additional flood storage capacity indicates that there is value attached to this service, a service that is provided by existing local wetlands, but not to a sufficient degree to prevent frequent flooding in the case study area, known locally simply as the Valley Area (Fig. 3). We will use the cost of increasing the flood storage potential, which would be borne by the city through engineering and construction, as a proxy for the value Renton implicitly places on its natural wetland inventory.

The East Valley Green River Watershed is unique in that, due to the lowering of Lake Washington after construction of the ship canal and Ballard Locks, flows from Springbrook Creek must be mechanically pumped into the Green River. During high flows on the Green River pumping limitations exist, at a time when the need to pump out the lower Springbrook may be most necessary (R.W. Beck 1996). Sufficient flood storage capacity to temporarily hold water onsite, without causing flood damage, needs to be preserved therefore during the most intense, albeit infrequent, storm events. Unlike the situation in Lynnwood, improvement of Renton Valley flood control cannot rely on creek and tributary conveyance improvements, but must use storage as a fundamental component. Predicting the storage requirements of a 100-year storm event is subject to considerable uncertainty, which must be taken into account in planning (R.W. Beck 1996).

The Renton Valley Drainage System

Springbrook Creek is the Renton Valley's main water flow channel, with tributaries Mill and Garrison Creeks (in Kent), and Panther and Rolling Hills Creeks originating on plateaus east of the Valley. Downstream of SW 16th and I-405, Springbrook Creek enters the P-1 Channel which flows to the Black River Pump Station (Figs. 3, 4). In the forebay of the pump station, a storage pond and retaining walls control water flow, and the lower reaches of Springbrook Creek have been deepened and widened by farmers, local jurisdictions, and King County Drainage District #1. The existing Valley wetlands provide several hundred acre-feet of flood storage during the most extreme storm events (R.W. Beck 1996, table 11).

Flooding currently plagues several areas of the valley, due primarily to undersized pipe systems reaching capacity during seasonal large storm events. Land conversion and construction have resulted in an increase in the area prone to flooding. Construction of the East Valley Freeway, which effectively created the Panther Creek Wetland, and the dense development in the Renton Shopping Center area are major contributors. Another result of the land use change that has occurred is the fragmentation and isolation of wetlands that historically comprised an interconnected wetlands system.

The total East Side Green River Watershed (ESGRW) area is approximately 24 square miles, and includes the cities of Renton, Kent and Tukwila. The Renton Valley area encompasses approximately 1,400 acres of the downstream portion of the ESGRW, drained primarily by Springbrook Creek. This area is situated between I-405 to the north, Talbot Road S to the east, SW 43rd Street to the south, and the West Valley Highway to the west. Fifty-four inventoried wetlands comprise approximately 292 acres, or nearly 21% of the total valley land area. These wetlands provide significant flood flow attenuation and reduce stormwater runoff rates by temporarily storing and then slowly releasing floodwater, lowering and desynchronizing peak runoff flows. Many of these wetlands are presently owned by the City of Renton, which is seeking to obtain ownership or easement to additional wetland area. The Full Equations computer model (FEQ) simulations that were run for the ESGRW study show that under future land use conditions the Renton valley wetlands will provide 772 acre-feet of floodwater storage during a 100-year flood, under "conveyance" conditions. These conditions exist when the Black River Pump Station is allowed to pump Springbrook Creek drainage into the Green River, providing the only downstream hydraulic connection from the ESGRW.

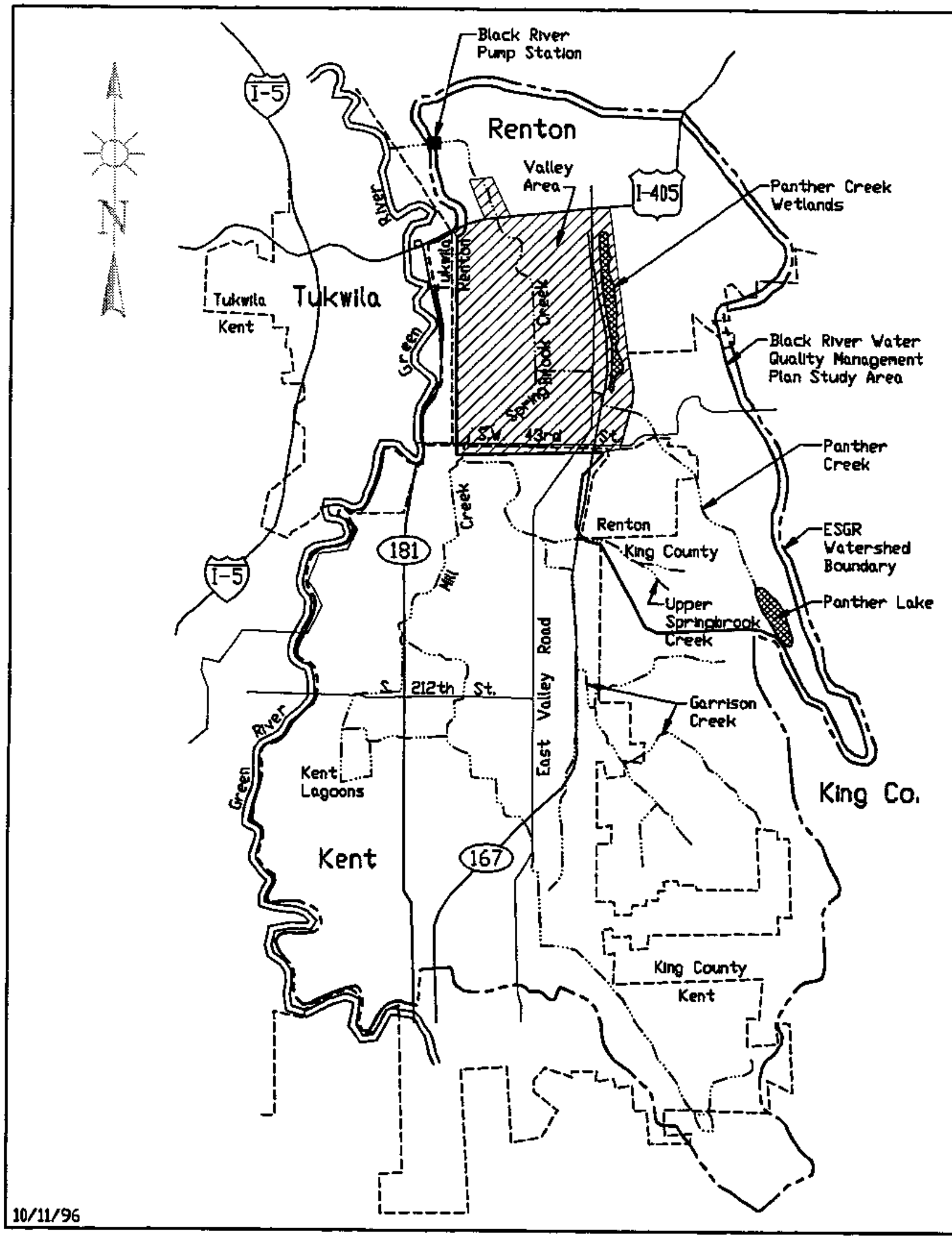

Figure 3. Location of Springbrook Creek in the Renton Valley (Source: R.W. Beck 1996.)

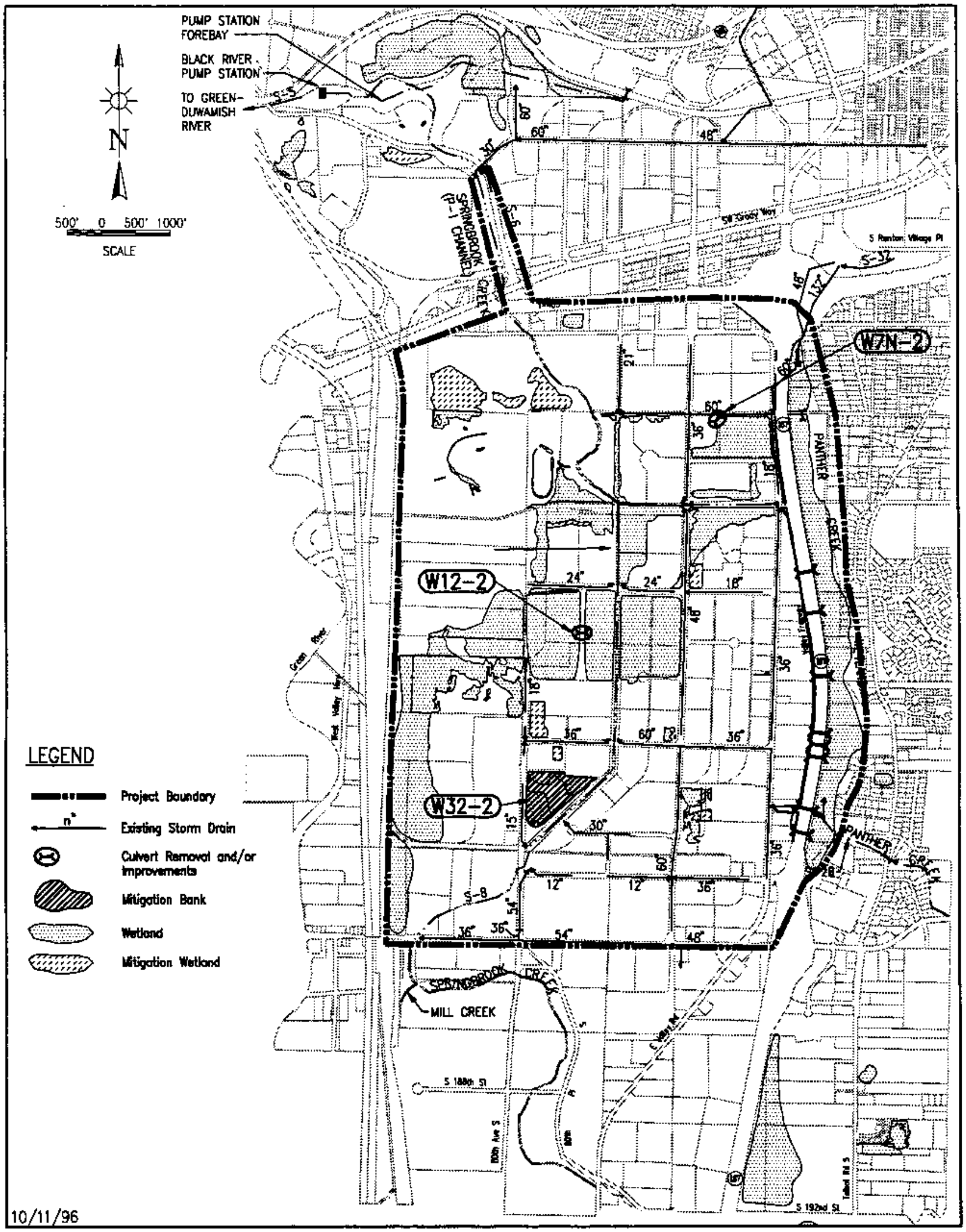

Figure 4. Wetlands in the East Side Green River Watershed (Source: R.W. Beck 1996.)

The City of Renton is assuming in its land use planning the future conversion of 590 acres of undeveloped lowland area in the valley into industrial and commercial development, representing 42% of the total valley area. This is an increase of more than 100% based on the land use conditions that existed in 1989. Total impervious surface coverage in the larger watershed, including roads, roofs and driveways, has been projected to increase by approximately 45% above current conditions, from 5300 acres to 7740 acres, based on currently adopted land use plan assumptions of full buildout. This will have a significant effect on the volume of stormwater runoff eventually flowing into Springbrook Creek. The Renton Valley has a long history of flooding problems which will be compounded by the expected increase in stormwater flows, manifested by an increase in the frequency and surface water elevation of flood events. Current water levels in the Springbrook Creek could rise by as much as 3 feet in a 10-year flood event, based on full buildout conditions, which will result in the overtopping of SW 34th Street and Oaksdale Avenue. An increase of almost 4 feet of surface water elevation is predicted for the forebay of the Black River Pump Station during a 100-year flood, assuming full buildout and the presence of pumping restrictions. High water levels in Springbrook Creek result in the flooding of adjacent tributaries, such as the East Valley Road and SW 43rd St. systems. Accordingly, the City of Renton is pursuing a comprehensive plan of flood control measures.

The City is currently reviewing a draft of the ESGRW project plan and accompanying EIS, which outlines alternative proposals to meet the City's flood control goals. Alternatives include measures to lower water levels in Springbrook Creek, correct flooding associated with Panther Creek and the SW 23rd St. Drainage Channel, and address pipe system improvements. Additionally, the plan proposes several wetland hydraulic modifications as well as a wetland mitigation banking project. These hydraulic modifications involve improving the connection of two separate wetlands to the Springbrook Creek drainage system, which will allow the wetlands to provide additional floodwater storage. The wetland mitigation bank will involve expanding a third wetland to provide additional water storage, as well as creating off-channel habitat and providing water quality improvement. It is important to note that the project plan proposes selecting a package of alternatives from among the several categories noted above. The lowering of the Springbrook Creek surface water levels will in fact decrease floodwater storage capacity, which will be offset, in part, by the additional wetland storage volume. The total projected increase in floodwater storage capacity resulting from the three wetland modification alternatives is approximately 130 acre-feet, for a 16.8% increase during a 100-year flood.

The three wetlands proposed for hydraulic modification are delineated as wetlands 7N, 12 and 32 (Fig. 4). Modifications of wetlands 7N and 12 consist of culvert replacements that would allow more off-channel water storage through increasing flow rates between the central channel and the wetlands. The modifications would provide approximately 15 additional acre-feet of storage in 7N, and 50 acre-feet more in wetland 12. Wetland 32 is the site of the proposed wetland mitigation project. Excavation of fill material will restore a hydraulic connection with Springbrook Creek, and provide an additional 65 acre-feet of floodwater storage. The total cost of the proposed wetland modifications exceeds two million dollars, with most expense associated with the wetland 32 excavation. The detailed cost breakdowns are shown in table 7. Table 8 provides an analysis of the proposed modifications, in a format that leads to a proxy for the economic value of the storage capacity of the existing wetlands.

Table 7. Cost estimates for the Springbrook Creek wetland modification proposal

Wetland	(1) Construction Costs	Administrative Costs (2)	Total Costs
W 32	$1,739,000	$249,000	$1,988,000
W 7N	$26,000	$8,000	$34,000
W 12	$8,000	$2,000	$10,000

Table 8. Valuation of flood storage based on wetland hydraulic modifications

Wetland	Effect of proposed alternative (in additional acre-ft.0	Cost
W32	65 acre-ft.	$1,988,000
W7N	15 acre-ft.	$34,000
W12	50 acre-ft.	$10,000
Total	130 acre-ft.	$2,032,000

Increase in storage capacity	130 acre-ft. /772 acre-ft.=	16.8%

Cost of added storage capacity:	$2,032,000/130 acre-ft=	$15,631 per acre-ft.

Hydraulic condition		
Total wetland acres:	292 acres	
Total acre-ft. of water storage:	772 acre-ft.	
Average water storage per acre:	2.64 acre-ft./acre	
Value of Total Wetlands: @$15,631 per acre-ft.	@772 acre-ft=	$12,066,954
Value per acre	@292 acre=	$41,325
Alternative Value per acre calculation	$15,631 per acre-ft. x 2.64 acre-ft./acre=	$41,325

Economic Valuation Based on Flood Water Storage Capacity Modifications

Wetland 32 is located south of SW 34th St., west of Springbrook Creek, north of SW 40th St., and east of Oaksdale Avenue SW. The city-owned site is approximately 14 acres, consisting of half upland meadow and half emergent young scrub and forested wetland, and situated 7 to 8 feet above the normal creek water surface elevation. This relatively level area is the result of the 1970's Orilla Fill Project. An approximately 3-foot tall berm exists along the creek, the result of side-cast dredge disposal from the creek. The proposed mitigation project will enhance and expand the wetland, creating mitigation credits for use in compensating other wetland impacts in the drainage basin area. An estimated 65 acre-feet of additional water storage capacity, under the conditions of a 100-year flood, will be provided through excavation of past fill material, thereby restoring a hydraulic connection to the main drainage channel. The total cost of this project is estimated to be $1,988,000 (Table 8).

Wetland 7N occupies approximately 12 acres of privately owned land south of SW 19th St. to the east of East Valley Road. The wetland is connected by a small storm drain to the Rolling Hills Creek, which flows through a much larger storm drain, but the small size of the connecting pipe and the elevation of the wetland keep it isolated from the main drainage system and provide little off-channel storage. The proposed modifications will replace the small connecting pipe with one at least three times larger in diameter, situated at the same elevation as the old pipe. This will preserve the existing wetland conditions but allow an additional 15 acre-feet of off-channel storage during a 100-year flood event. The total cost of the culvert replacement is estimated to be $34,000 (Table 8).

Wetland 12 is approximately 35 acres, split between wetlands 12a and 12b by a north-south berm apparently constructed in the 1970s. This city-owned parcel lies south of SW 27th St. to the west of Springbrook Creek surrounded by vacant land and open space. A small 18-inch diameter culvert running east-west through the berm connects the two wetland sections. Wetland 12b to the east provides occasional off-channel storage for Springbrook Creek, but the small size of the connecting culvert mostly isolates 12a from the larger system. The proposed modifications would replace the small culvert with several ones of twice the diameter, or possibly an open channel or weir. This would restore the hydraulic connection between 12a and 12b, providing approximately 50 acre-feet of additional storage in a 100-year flood, for an estimated total cost of $10,000.

The total increase in floodwater storage capacity from the above three proposals is approximately 130 acre-feet in a 100-year flood, for a total cost of $2,032,000. This represents a 16.8% increase in storage capacity over the 772 acre-feet that the current wetland system would provide in a 100 year flood, under future land use conditions of full buildout (see Table 8). Prior to any modifications, the existing 292 acres of wetlands would provide an average of 2.64 acre-feet of storage per acre for a 100-year flood. The average cost of the added storage capacity resulting from the modifications can be calculated at $15,631 per additional acre-foot. At this level of average cost, the current wetland storage capacity of

772 acre-feet can be valued at $12,066,954, or $41,325 per acre.[9] After the modifications, the same 292 acres will be able to store 902 acre-feet of water during a 100-year flood, at an average of 3.09 acre-feet per acre. At $15,631 per acre-foot this equates to per acre value of $48,284, or an overall value of $14,098,954 for all 292 acres.

As in the Lynnwood case, the average per acre-foot proxy value of $15,631 represents the marginal cost of additional water storage capacity resulting from the specified project proposals. We are in effect viewing this value as the cost of replacing an acre-foot of storage that could be lost as a result of further impacts to the existing inventory of wetlands in the Renton Valley. This results from our inferring the value of the current wetlands inventory to Renton's residents on the basis of the city's willingness to pay to enhance its inventory of acreage available for flood storage through the identified projects. In actuality, as the existing inventory of wetlands available for flood storage shrinks, options for enhancing flood storage will also disappear. We would therefore expect project costs to rise on a per acre basis, perhaps dramatically. These increased project costs could well lend to increased per acre values for the flood storage provided by the remaining wetlands inventory as well.

The approach used is equivalent to that applied in the Lynnwood case. For reasons noted above, the formula utilizes actual acre-feet of storage, existing and added, rather than percentage changes:

$$\frac{\$2{,}032{,}000}{130\ \cancel{\text{acre-feet}}} \times \frac{772\ \cancel{\text{acre-feet}}}{292\ \text{acres}} = \$41{,}325/\ \text{acre}$$

Note that, all other things equal, if the acre-feet of storage per acre in the Valley wetlands system were to decrease, the value per acre for flood storage also decreases. At the extreme, where wetlands remain but cease to have effective storage capacity for floodwaters, the value per acre approaches zero. The tradeoff between declining efficiency of the remaining wetlands to provide storage (2nd factor in formula) and increasing marginal costs of adding additional storage to the system (1st factor in formula) determines the ultimate behavior of the proxy values derived from the formula. If the effect of wetlands policies were to permit conversion of wetlands not currently contributing significantly to flood storage in the Valley, but whose potential to contribute via future engineered enhancements was large, the value of remaining wetlands for flood storage could be expected to rise very rapidly.

9 The same per acre value can be calculated by multiplying the average additional cost per acre-foot by the per acre storage capacity of 2.64 acre-feet (see lower portion of Table 8).

Comparison of Lynnwood and Renton Cases, and Implications of the Analysis

The Lynnwood hydrological analysis that we used to produce cost estimates emphasizes the effects of flood control options in reducing flows, while the Renton analysis, done in a context where the Green River Interlocal Agreement rules out options that would convey flood flows directly to the Green River, places the emphasis on adding to existing flood storage. Although conveyance and storage are inter-related (increasing flood storage generally means that flows will be reduced while increasing flows generally tends to decrease the amount of flood water in storage), we lack data that would permit direct translation of either set of cost calculations into the terms of reference used in the other. This complicates direct comparison, though the ratio analysis we did is essentially equivalent in the flow vs. storage-based formulations.

Additional difficulties in comparing the two cases arise from the fact that two specific storm events were utilized in the Lynnwood analysis, while a 100-year reference storm was utilized in the Renton study. Although more recent hydrologic studies done for Lynnwood have included 2-, 10-, 25-, and 100-year reference storms, the computer simulations in those studies do not include the "without wetlands" analysis that we needed to baseline flow reduction effects against a specific reference flow. Also, the kind of information that permitted us to isolate on the North Scriber Creek wetland in the Lynnwood analysis was not available from the Renton studies. Thus we could only calculate a "whole system" value for the Renton Valley wetlands.

Although there is good agreement between $/acre whole system estimates for the three analyses (ranging from about $36,000/acre for the 1984 storm at the Lynnwood system to about $51,000/acre for the 1986 Lynnwood storm), the fact that these two estimates bracket the Renton estimate ($41,000/acre) could be coincidence. Nevertheless, the qualitative behavior of the formulas used is similar, whether based on flow or storage. If the wetlands acreage whose value is being estimated is degraded in ways that impair its effectiveness either in reducing flow rates or in storing flood waters, relatively lower per-acre proxy values will result. If additional capacity, either to reduce flows or in the form of increased storage, can be added in a cost-effective way, then the proxy value estimates, based as they are on augmentation costs, will be proportionately lower. In addition, it must be borne in mind that our cost estimates are based on planning projections, and not actual experience with project construction.

Despite the differences in the way the values were estimated, and despite differences in the strategies available to enhance flood protection in the two situations, the Scriber Creek and Renton Valley systems seem to be in about the same state with respect to the implicit values their wetlands systems now have for flood protection. In either case the preponderance of evidence suggests roughly the same futures with respect to the ability of wetlands to provide flood protection. Policies which permit wetlands to disappear that are presently contributing little to mainstream flood protection, but which have the potential to do so in the future via engineered hydrologic enhancements, would lead to rapidly rising values of the remaining wetlands for flood protection as increasingly marginal wetlands are called into service in the name of flood protection enhancement. At some point the remaining wetlands would be so inefficient in contributing to flood protection that "next best" protection alternatives would no longer depend on wetlands at all, relying instead on totally engineered floodwater conveyance or storage systems. Such systems are likely to be very expensive.

The proxy value estimates we have obtained are in line with the values reported in a variety of other economic studies of wetlands values, as a comparison of Tables 4 and 9 shows. In Table 9, the proxy values derived via ratio analysis are annualized at a variety of discount rates to convert them to units of $/acre/year, the same units reported in Table 4. The estimates in Table 9 are based on standard assumptions regarding discount rates and the lifespan of the proposed projects (assumed to be 30 years). Discount rates ranging from 0% (at which total project value is simply distributed equally into each year) to 10% are utilized. If the discount rate is chosen to reflect lending rates typical of relatively low-risk government projects, the 7% rate may be the most appropriate of those we used. As is typical of estimates of this kind, results are sensitive to the discount rate. As the discount rate increases, benefits that occur in the future are worth less and less to us in the present in comparison to benefits that accrue in the near term.

Table 9. Discounted annual wetland proxy value estimates ($/acre/year)

Lynnwood: Scriber Creek Watershed				Renton: Springbrook Creek Watershed		
North Scriber Creek Wetland	Discount Rate	1984 Storm Simulation	1986 Storm Simulation	Total Renton Valley Wetlands	Discount Rate	100 year Storm Simulation
Proxy Value per Acre ($/acre)	n.a.	$11,754	$7,830	Proxy Value per Acre ($ acre)	n.a.	$41,325
Annualized Proxy Values per Acre (1) ($/acre/year)	0%	$392	$261	Annualized Proxy Values per Acre (1) ($/acre/year)	0%	$1,378
(2)	3%	$600	$399	(2)	3%	$2,108
(3)	5%	$765	$509	(3)	5%	$2,688
(4)	7%	$947	$631	(4)	7%	$3,330
(5)	10%	$1,247	$831	(5)	10%	$4,384

Total Scriber Creek Wetlands	Discount Rate	1984 Storm Simulation	1986 Storm Simulation
Proxy Value per Acre ($/acre)	n.a.	$35,612	$51,095
Annualized Proxy Values per Acre (1) ($/acre/year)	0%	$1,187	$1,703
(2)	3%	$1,187	$1,703
(3)	5%	$2,317	$3,324
(4)	7%	$2,870	$4,118
(5)	10%	$3,778	$5,420

Note: (1) Annualized at 0% over 30 years, with a future value of $0
(2) Annualized at 3% over 30 years, with a future value of $0
(3) Annualized at 5% over 30 years, with a future value of $0
(4) Annualized at 7% over 30 years, with a future value of $0
(5) Annualized at 10% over 30 years, with a future value of $0

The comparatively lower value of the North Scriber Creek wetland in isolation when compared to the whole-system values that are discussed above (approximately $8,000/acre to $12,000/acre depending on storm event) derives in part from the relative ease with which the efficiency that it presently has in reducing storm flows can be further enhanced via modest re-engineering (56-62% enhancement for a $195,000 investment, depending on storm event). Also, the associated benefit is much more localized in character, as the estimates of changes in flow upon which our calculations are based were made for a location directly below the wetlands exit. Because of the way we estimated these proxy values, we expect that whole-system values will be inherently higher than the values attached to highly efficient and easily enhanced individual system components, of which the North Scriber Creek wetland is an example. In addition, the North Scriber Creek wetland is close to the headwaters of Scriber Creek and the benefits of hydrologic enhancements there dissipate as one moves downstream.[10] We might therefore expect that the value of this isolated wetland would be less than the value that derives from the whole system, especially given the relative inefficiencies in reducing flows of most other system components. Gottfried (1992) cautions however that valuing components of a watershed system in isolation can lead to either over-or under-estimation.

Although our Lynnwood analysis does not, strictly speaking, provide such a comparison (as flows, and therefore benefits, are measured at different points in the stream), there is value in quantifying in dollars and cents the difference between the flood protection value of efficient individual wetlands like the North Scriber Creek wetland and that of the larger wetlands systems in which they are embedded. In Western Washington's most urbanized corridors, many of the remaining wetland fragments are highly degraded. The value differences between the best and the worst (or selected individual wetlands vs. the whole system) provide a quantitative measure of the effects that increasing scarcity of high-quality wetlands is having on communities' ability to protect themselves from flooding.

The Lynnwood calculations for the 1984 and 1986 storm events give per-acre value differences of 3 times and 6.5 times, respectively, as one moves from the per-acre value of the highly efficient North Scriber Creek wetland to the value per acre of the whole-system which includes that piece. The difference is dramatic, though again interpretation must be tempered by the knowledge that we did not have the data that would permit direct comparison of benefits at the same points in the system. The flood protection benefits of hydrologic enhancement to the North Scriber wetland diminish as one moves downstream toward Brier.

Given the necessity of having to cost out "best available" system flood protection augmentation in order to estimate the economic value of existing system flood protection, our valuation approach could be argued to be less than ideal. It relies on expected rather than actual expenditures and on expenditures rather than on evidence more directly indicative of societal willingness to pay. Moreover, we are using community willingness to invest in

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[10] Recent additional analysis done by R.W. Beck and not discussed in this report shows that the effects on reduced flood flows of enhancing the North Scriber Creek wetland via the proposed "v" channel damp out rapidly as one moves downstream in North Scriber Creek, dissipating almost completely by the time the stream crosses into the City of Brier. The greater the size of the projected storm, the more pronounced the damping effect (R.W. Beck 1997).

marginal improvements in flood protection to infer the value that the community places on the flood protection that already exists. We believe however that there are countervailing advantages to a method that highlights the real costs of engineering wetlands to provide the flood protection services that have been lost due to past and present wetlands degradation. Although the evidence we have been able to assemble is relatively sparse, these costs appear to escalate as the ability of wetlands systems to do the job of flood protection on their own declines. Cost inefficiency in augmenting wetlands' flood protection ability, which likely increases as wetlands systems become ever more fragmented and opportunities for hydrologic enhancement fewer, is reflected directly in higher proxy values per acre for the flood protection service provided by the wetlands that remain. These values provide price-sensitive market signals that there exists a strong economic rationale for communities in Western Washington to protect wetlands today in order to avoid what are likely to be much higher costs of flood protection in the future.

Glossary of Economic Terms

Benefit - in benefit-cost analysis, "benefit" is synonymous with value, or the maximum willingness to pay for a good or service, including environmental resources and services. It derives its monetary units from the willingness of consumers and producers to exchange income and revenue for goods, services, and inputs, but "benefit" could, in principle, be measured in terms of any constraint on choices, including leisure time. Total benefits include expenditures.

Benefits transfer - involves obtaining an existing estimate of the economic value of the consequences of a project or policy implemented in a different location (the study site), and using this estimate, perhaps after some adjustment, as an approximation of the economic value of some other project or policy in question (the policy site).

Bequest value - a type of passive use value which captures the desire to endow the resources or resource service to future generations.

Consumptive use - involves the physical use of a natural resource or the environment. Fishing and duck hunting are good examples.

Contingent valuation method - a direct technique used to estimate the economic value money measures of changes in welfare which describes a hypothetical situation to respondents and elicits how much they would be willing to pay either to obtain or to avoid the change.

Demand -in economics, the usual inverse relationship between quantity consumed (or otherwise used or even preserved) and a person's maximum willingness to pay for incremental increases in quantity. Market prices often (but not always) reveal the increments of willingness to pay. Other factors influencing willingness to pay include income, prices of substitutes, and, in recreational fishing, catch rate. Unlike planning where demand refers to the size of the quantity variable, economic demand is a behavioral relationship.

Ecological-economic modeling - modeling that includes analysis of both parameters and linkages within and between complex ecological systems and economic systems.

Economic efficiency - in economics, an objective evaluation of the net national benefits of a public project or government regulation.

Economic-impact analysis - a technique used to determine how some regulation, development, or management action changes regional income and other economic activities including revenues, expenditures, and employment. Input-output models are used to establish the linkages between input supplies, outputs, and households in a regional economy that can be used to predict the impact of changes on economic activity (e.g., industry revenues and household incomes) within the region.

Economic value -see value

Energy analysis - a technique used to estimate the energy embodied in the annual gross primary production (as a proxy for economic value) of wetlands.

Environmental valuation - procedures for valuing changes in environmental goods and services, whether or not they are traded in markets, by measuring the changes in the producer and consumer surpluses associated with these environmental goods.

Existence value - value motivated by altruism or the unselfish concern for other people's use of a resource or resource service or the resource itself.

Hedonic price method - a technique for estimating the relationship between the price of a good (e.g. housing) and the characteristics of the good (e.g. number of bedrooms, air quality, proximity to amenities, etc.). Can sometimes be used to value changes in environmental characteristics.

Market values - benefits from goods or services bought and sold in normal commerce so that there is a revealed price that reflects consumers willingness to pay for the quantity offered and suppliers marginal production costs.

Mean unit value technique - a mean value estimate for some particular recreational service, which is used as a proxy for the value of that recreational service in some other management or policy setting.

Net benefits - total maximum willingness to pay minus expenditures. See also value.

Net willingness to pay (net WTP) - the amount an individual or society would be willing to pay for some change in the state of the world and/or the use of some resource, beyond that which they actually do pay.

Nonconsumptive use - does not involve direct physical use of a natural resource or the environment. Wildlife viewing and hiking are good examples.

Nonmarket goods and services - goods and services not traded in well functioning, traditional markets which therefore have no observable market price.

Nonmarket values - benefits that accrue to individuals for goods, services, experiences or states of nature that are not normally traded in markets.

Opportunity cost - the highest value a productive resource (such as labor, capital, land) or a natural resource could return if placed in its best alternative use.

Passive use value - the value of knowing that something exists in a particular state even though there is no sensory contact with the resource.

Primary market analysis - a technique for measuring economic value of market goods and services using observable price and quantity data to estimate relevant demand and supply relationships, and consumer and producer surplus.

Private rate of time reference - reflects the value to private individuals of current consumption of natural resources relative to future consumption.

Resource replacement cost method - a technique used to approximate the economic value of natural resources and resource services based on the costs to restore, rehabilitate or replace the resource or resource service in question.

Revealed preference technique - an indirect technique used to estimate the economic value of nonmarket resources and resource services which links the use of the nonmarket resource or resource services to some closely related market choice.

Supply - schedule of the quantities of goods and services that a business is willing to sell at various prices. Other factors that affect supply include input prices.

Trade-off - the individual or societal act of expressing value by comparing alternatives and making decisions about how to allocate resources. The amount of value a resource or resource service has to an individual is measured by the maximum an individual would give up or what s/he is willing to pay in terms of other things to ensure having a resource or resource service.

Travel cost model - a methodology that relies on travel-related costs as a surrogate for price in a nonmarket situation in order to estimate demand and money measures of willingness to pay.

Use value - value derived from either the consumption of a good, the utilization of a service, or that otherwise involves some sensory contact with the resource. For example, when surplus and producer surplus.

Value - what one is willing to give up in order to obtain a good, service, experience, or state of nature. Economists try to measure this in dollars.

Welfare economics - a field of inquiry within the broad scope of economics that is concerned with money measures of individual and social well-being, particularly in changes in well-being due to implementation of public policies.

Willingness to pay (WTP) - in economics, what consumers are willing and able to pay for goods and services (including environmental goods and services) or what producers are willing and able to pay for inputs.

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