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**TO:** Steve Duh, Janet Bebb
**FROM:** Mark Buckley and Tom Souhlas, ECONorthwest
**SUBJECT:** INTERTWINE ECOSYSTEM SERVICE AND RECREATION VALUES

# I. INTRODUCTION

Historically, communities have considered public enjoyment as the primary benefit derived from urban parks and green spaces. Increasingly, however, communities recognize that the natural biophysical structures and ecological processes in parks and green spaces can provide society with beneficial goods and services, known as ecosystem services. In this memorandum we provide a brief overview of the literature on ecosystem services relevant to the Intertwine. First, we introduce the types of ecosystem services provided within the Intertwine. Second we estimate the value of several specific ecosystem services provided by some areas within the Intertwine as well as general values associated with ecosystem services provided by particular land types (e.g. wetlands and riparian habitat). Third, we describe potential demand for the ecosystem services the Intertwine provides and ranges of values for these services.

# II. ECOSYSTEM SERVICES AND TECHNIQUES FOR ESTIMATING THEIR VALUE

The first step in assessing the Intertwine's ecosystem services entails considering the potential range of services that ecosystems in the region can provide. Research conducted by ecologists and economists over the past several decades has confirmed that ecosystems supply a wide variety of services that provide many of the essential basic requirements for living organisms, regulate physical and biological processes, and contribute to the quality of life for individuals and communities.[1] In Appendix A, we provide a list of some of the ecosystem functions and subsequent ecosystem services supplied by the Intertwine.

In some cases, communities and government agencies have established markets for ecosystem services so that beneficiaries compensate suppliers. For example, markets

[1] Millennium Ecosystem Assessment. 2003. *Ecosystems and Human Well-being*. De Groot, R., M. Wilson, and R. Boumans. 2002. "A Typology for the Classification, Description and Valuation of Ecosystem Functions, Goods and Services." Ecological Economics 41: 393-408; Kusler, J. 2003. Assessing Functions and Values. Institute for Wetland Science and Public Policy and the Association of Wetland Managers, Inc.; and Postel, S. and S. Carpenter. 1997. "Freshwater Ecosystem Services." in Nature's Services: Societal Dependence on Natural Ecosystems. Edited by G.C. Daily. Washington, D.C.: Island Press, pgs. 195-214.

now function for water quality and quantity, air quality, habitat, biodiversity, and carbon sequestration. Because ecosystem services do not typically have the same characteristics as traditional private services, markets do not tend to form and function in a way that allow forces of supply and demand to reveal prices and values.[2] Consequently, society does not have as ready access to value estimates for ecosystem goods and services as readily as say apples, haircuts, or automobiles. Economists have developed techniques for estimating ecosystem service values based on the characteristics of the service and benefiting population. The U.S. Environmental Protection Agency provides guidelines for appropriate ecosystem service valuation techniques.[3]

# III. Values Associated with Several Ecosystem Services

In this section we provide tables detailing the values associated with specific ecosystem services as well as more general estimates of the values associated with particular ecosystems represented in the Intertwine. Where possible, we represent these values on a per acre basis. We have used a wide range of literature and have made efforts to adapt the original literature to the specific contextual characteristics of the Intertwine. The values in the tables below are not necessarily additive, rather, they are presented to give the reader an idea of the magnitude of values associated with specific ecosystem services and general land cover types. In this section, we describe the values associated with the following set of specific ecosystem services:

- Ecosystem functions providing recreation
- Ecosystem functions providing stormwater treatment
- Ecosystem functions providing carbon sequestration
- Ecosystem function providing air purification

## A. Recreation

Opportunities for recreation are the ecosystem service most commonly derived from urban parks and green spaces. This service represents the social component of the Intertwine and the derived values of the ecosystem based on human interaction with it. Table 1 shows the consumer surplus[4] associated with various recreation activities, the value beyond any expenditures, and therefore does not include expenditures such as time, equipment, or transportation. The consumer surplus associated with a day spent sightseeing, for example, averages about $69 among Pacific Coast residents. Across the nation, the surplus of a day spent sightseeing ranges up to $239. Many factors –

[2] Goods and services are considered private, efficiently priced and allocated by markets only when they are rival (one person's consumption affects the consumption of another person) and excludable (one person can prevent consumption by another person). Ecosystem services are typically not excludable, and often not rival either.

[3] *EPA Science Advisory Board. 2009.* Valuing the Protection of Ecological Systems and Services. *May.*

[4] Consumer surplus is the value to the consumer of a good or service beyond the price paid. If the price paid is zero, then all of the value is considered consumer surplus. Calculating consumer surplus requires estimating the price an individual is willing-to-pay, and considering the difference to price paid.

especially the ease of access, congestion, quality, and quantity – influence the value individuals derive from the recreational opportunities provided by urban parks and green spaces. A hiker, for example, may derive more benefit if she spends a day in relative solitude on a lengthy, undisrupted trail than on a short and crowded trail. All else equal, the Intertwine increases the total value of the recreational benefits derived from urban parks and green spaces to the extent that it increases access, reduces congestion, or otherwise improves the quality and quantity of recreational opportunities, so that more users take advantage of the opportunities and existing users access these areas more frequently.

**Table 1. Consumer Surplus Values Associated with Ecosystem Functions Providing Recreation ($/recreation day)**

| Activity | Pacific Coast Mean | National Mean |
|---|---|---|
| Biking | $14 | $21 |
| Fishing | $43 | $50 |
| Hiking | $34 | $40 |
| Motorized boating | $34 | $40 |
| Nonmotorized boating | $52 | $59 |
| Picnicking | $34 | $40 |
| Sightseeing | $34 | $40 |
| Swimming | $12 | $19 |
| Wildlife viewing | $34 | $40 |
| General recreation | $34 | $40 |
| Other recreation | $34 | $40 |

Source: Rosenberger, R., and J. Loomis. 2001. *Benefit Transfer of Outdoor Recreation Use Values: A Technical Document Supporting the Forest Service Strategic Plan (2000 Revision)*. General Technical Report: RMRS-GTR-72. U.S. Department of Agriculture, Forest Service.

Note: includes consumer surplus only, which does not include expenditures.

## B. Water Quality

The Intertwine contributes to improved water quality via numerous pathways. Park lands can absorb and filter stormwater and surface water runoff, shade streams, and provide natural water storage. These services, in turn, can improve wildlife habitat, public health, and aesthetics.

The City of Portland, as well as the other municipalities in the Metro region, face requirements to control stormwater pollution under the Clean Water Act. Given the region's rainy climate, this can be a challenge. The problem increases as the region experiences more impervious surface that delivers more surface contaminants to waterways. Conventional approaches for reducing stormwater pollution come at high cost: Portland currently is investing $1.4 billion (the Big Pipe) to reduce the potential for

high stormwater flows to cause sewage to enter the Willamette River.[5] Stormwater pollutants include industrial, household, and automotive chemicals, sediment, and other waste products. Such contamination can cause sedimentation problems, low levels of dissolved oxygen, and eutrophication. Toxic substances in stormwater pollution can kill or otherwise harm aquatic life and other dependent species, and render water bodies unsafe for swimming and fishing. Degraded water quality can also increase costs for businesses that use water for industrial purposes or agencies that provide drinking water. Such conditions can lead to violations of water quality standards and trigger regulatory sanctions.[6]

The Intertwine limits the amount of impervious surfaces in the region, and Intertwine lands can intercept stormwater, so that it infiltrates into the ground, where ecological processes can provide natural pollutant treatment. By providing these services, park areas and green spaces address both the water quantity and water quality components of the region's stormwater problems. Furthermore, these services provided by the Intertwine enable the region's citizens to avoid the costs of alternative, conventional approaches. Table 2 illustrates some general values associated with avoided costs attributable to natural stormwater treatment from research across the county. Recently, we conducted a review of stormwater costs in the Puget Sound basin and found that costs for new, conventional efforts to control stormwater range from $2,700 to $38,000

**Table 2. Values Associated with Ecosystem Functions Providing Stormwater Treatment ($/treated acre)**

| Treatment Option | Low Range of Unit Costs | Median Unit Costs | High Range of Unit Costs |
|---|---|---|---|
| Extended-detention ponds | $6,600 | $11,400 | $22,500 |
| Wet ponds | $4,650 | $12,525–$16,700 | $57,500 |
| Constructed wetlands | $6,000 | $8,700–$11,600 | $38,400 |
| Bioretention | $19,900 | $25,400 | $41,750 |
| Simple surface filtration | $10,900 | $18,150 | $29,000 |
| Structural sand filtration | $58,100 | $72,000 | $79,900 |
| Underground sand filtration | $100,800 | $234,000 | $270,000 |
| Infiltration | $29,850 | $38,100–$50,800 | $83,500 |
| Swales | $21,800 | $36,300 | $72,600 |

Source: ECONorthwest, with data from Schueler, T., D. Hirshman, M. Novotney, and J. Zielinski. 2007. *Urban Subwatershed Restoration Manual No. 3: Urban Stormwater Retrofit Practices, Appendix I.* Center for Watershed Protection and U.S. Environmental Protection Agency, Office of Watershed Management. July. Retrieved May 15, 2008, from http://www.cwp.org/Downloads/ELC_USRM3.pdf

[5] City of Portland. 2010. *Combined Sewer Overflow*. Retrieved on October 6, 2010 from http://www.portlandonline.com/cso/.

[6] Wanielista, M.P. and Y.A. Yousef. 1993. *Stormwater Management*. New York: John Wiley& Sons, Inc.; Paul, M.J. and J.L. Meyer. 2001. "Streams in the Urban Landscape." *Annual Review of Ecology and Systematics* 32: 333-365.

per acre treated, and the costs for stormwater retrofits range from $17,900 to $137,000 per acre treated.[7]

## C. Carbon Sequestration and Air Filtration

Research shows that Oregon, Washington, and other western states are already experiencing noticeable changes in climate and suggests that more impacts will occur in the future.[8] Research has identified several types of anthropogenic greenhouse gas emissions that contribute to climate change; chief among them is the emission of carbon dioxide (CO2). Since 1850, the concentration of CO2 in the atmosphere has increased from 280 to 379 parts per million, and has grown by an average of 1.9 parts per million per year since 1995.[9] Markets for carbon offsets help estimate the value of carbon sequestration. Table 3 summarizes these values from some of the carbon markets currently operating. The bottom row of Table 3 shows an estimate of the social cost of carbon emissions, considering the value of emissions in terms of the costs of externalities borne by the public. For our analysis, we use a middle value for CO2 emissions of $45 per metric ton, which is higher than the value in any existing market, but well below the estimated social cost of carbon emissions.

**Table 3. Price of Carbon Dioxide in Various Markets and Trading Programs**

| Carbon Market or Offset Provider | Price per Metric Ton of Carbon Dioxide |
|---|---|
| Chicago Climate Exchange[1] | $0.10 - $0.25 |
| American Carbon Registry[2] | $4 |
| Non CCX Over The Counter Voluntary Markets[1] | $6.10 |
| Climate Action Reserve[3] | $6.30 |
| Average OTC Credit Price in the U.S. in 2008[5] | $6.90 |
| Potential Waxman Markey Price[4] | $15 (in 2011) - $26 (in 2019) |
| EU Emissions Trading Scheme[5] | $18.50 - $21.00 |
| Social Cost of $CO_2$ Emissions[6] | $91 |

[1] Chicago Climate Exchange. Homepage. 2010. Retrieved on January 22, 2010, from www.chicagoclimatex.com.
[2] Hamilton, K., M. Sjardin, A. Shapiro, and T. Marcello. 2009. *Fortifying to Foundation: State of the Voluntary Carbon Markets 2009*. Ecosystem Marketplace & New Carbon Finance. May.
[3] Garcia, Kristen. 2010. Program Manager, Climate Action Reserve. Personal Communication. January 7.
[4] Congressional Budget Office. 2009. *H.R. 2454: American Clean Energy and Security Act of 2009*. June 5.
[5] Ecosystem Marketplace. 2010. Carbon Homepage. Retrieved on January 22, 2010, from www.ecosystemmarketplace.com/.
[6] Stern, N.H. 2006. *Stern Review: The Economics of Climate Change.* Cambridge: Cambridge University Press.

[7] ECONorthwest. 2008. Benefit Analysis of the Action Agenda. Puget Sound Partnership.

[8] *See*, for example, the assessments of climate science and other reports prepared by the U.S. Climate Science Program: http://www.climatescience.gov, and the reports of the Intergovernmental Panel on Climate Change: http://www.ipcc.ch.

[9] Intergovernmental Panel on Climate Change (IPCC). (2007). *Climate Change 2007: Synthesis Report.* Core Writing Team, Pachauri, R., & Reisinger, A. (Editors). IPCC, Geneva, Switzerland.

The value of carbon sequestration by trees and vegetation ultimately depends on the type of vegetation, the age of the vegetation, and the density of vegetation. Table 4 describes the potential value of carbon sequestration services provided by a new densely-planted forest made up of alder maple and cottonwood saplings. The value in year 1 ranges from about $1 to $1,040 per acre. As the trees grow, however, the value of their carbon sequestration services grows to up to $19,000 per acre per year.

**Table 4. Values Associated with Ecosystem Function Providing Carbon Sequestration ($/acre/year)**

| | $tCO_2$ per acre | Low $ | Medium $ | High $ |
|---|---|---|---|---|
| Year 1 | 11 | $1.15 | $515.64 | $1,042.75 |
| Year 30 | 66 | $6.63 | $2,981.98 | $6,030.23 |
| Year 60 | 208 | $20.85 | $9,382.92 | $18,974.36 |
| 60-Year Total | 4,971.45 | $497.15 | $223,715.43 | $452,402.31 |

Source: ECONorthwest

In addition to CO2, trees remove other pollutants, such as carbon monoxide, nitrogen dioxide, ozone, particulate matter, and sulfure dioxide, from the air. Table 5 shows the rate of removal of these air pollutants as well as the value of the service. For example, new forest growth in the Pacific Northwest can remove about 2.4 kilograms of carbon monoxide per acre per year which is worth about $2. In total, forest growth in the Pacific Northwest provides about $67–$267 worth of air purification services per acre per year.

**Table 5. Value Association with Ecosystem Function Providing Air Purification ($/acre/year)**

| | Rate of Pollutant Removal (kg/acre/year) | Value of Pollutant Removal ($/kg/year) | Value of Pollutant Removal ($/acre/year) |
|---|---|---|---|
| Carbon Monoxide | 2.4 | $1 | $2 |
| Nitrogen Dioxide | 2.7 – 7.7 | $7 | $19 – $52 |
| Ozone | 2.8 – 17.4 | $7 | $19 – $117 |
| Particulate Matter | 4.8 – 19.4 | $5 | $22 – $88 |
| Sulfur Dioxide | 2.8 – 10.1 | $2 | $5 – $17 |
| **Total** | **N/A** | **N/A** | **$67 – $276** |

Source: Nowak, D., D. Crane, and J. Stevens. 2006. "Air Pollution Removal by Urban Trees and Shrubs in the United States". *Urban Forestry and Urban Greening.* 4: 115-123.

## D. Salmon Habitat

Some areas of the Intertwine contain rivers and streams that provide salmon habitat. Other Intertwine characteristics assist in the maintenance and preservation of salmon habitat elsewhere such as riparian forests and wetlands and their associated ecosystem functions, such as through improved downstream water quality. Salmon habitat is

important insofar as it helps sustain healthy populations of salmon, an important part of the region's ecosystem. Furthermore, humans value salmon in many different contexts. Some individuals want to fish for salmon, others have a cultural connection to salmon, and others appreciate salmon's biological importance to marine, aquatic, and terrestrial food webs.

A recent assessment of relevant research concluded that the different components of the overall value of Columbia River salmon total about $3,345 per fish. This value reflects the willingness of Oregonians and Washingtonians to pay to protect the species, plus half that willingness to pay applied to residents of other states.[10] The result represents the total asset value of the salmon losses. While a precise estimate of effect of the Intertwine on salmon populations is not possible, the water-quality improvements and habitat provided by the Intertwine directly contribute to protecting and improving salmon populations.

## E. Value of Ecosystem Services by Land Type

Above, we described the value of particular ecosystem services. Here, we present examples of how these values can accumulate within a specific ecosystem, and how that ecosystem can then be valued. Valuation by land type is difficult and relies on several strong assumptions. For example, it often assumes homogeneity of ecosystem services provided throughout the area in consideration. Oftentimes, however, the ecosystem services provided by a land type vary, sometimes dramatically, due to specific characteristics within the area in consideration and the affected population. Thus, the estimates of value for different land types necessarily embody considerable uncertainty.

Wetlands are a well-studied habitat type that provides well-documented values for some of the types of ecosystem services provided by the Intertwine. Table 6 provides several estimated values for the ecosystem services provided by wetlands. The first set of rows estimates the values associated with several different wetlands that researchers assumed provide only a single type of service. In many cases, a wetland may provide multiple services, however. The range of values associated with single-service wetlands is about $18–$9,200 per acre per year. Another estimate, based on the net primary productivity of the Pacific Northwest suggests that the ecosystem service values of wetlands in the Portland Metro area may be about $2,400–$4,800 per acre per year. These estimates come from meta-analyses of many individual site-specific studies.[11]

Similarly, riparian forests (the vegetated areas adjacent to rivers and streams) provide several different types of ecosystem services. One way to estimate the values of these ecosystem services is to evaluate the willingness of individuals, municipalities, or other agencies to pay for restoring riparian habitat. The City of Portland avoided purchasing a $200 million filtration treatment system for its water supply by protecting 102 square

[10] Goodstein, E. and L. Matson. 2007. "Climate Change in the Pacific Northwest: Valuing Snowpack Loss for Agriculture and Salmon." In J.D. Erickson and J.M. Gowdy (eds.) *Frontiers in Ecological Economic Theory and Application.* Cheltenham, UK: Edward Elgar Publishing

[11] Further discussion of values across ecosystem types available in WWF: Schuyt, K. and L. Brander. 2004. *The Economic Values of the World's Wetlands.* WWF. Retrieved 10 April 2010 from http://assets.panda.org/downloads/wetlandsbrochurefinal.pdf.

**Table 6. Value of Ecosystem Services Associated with Wetland Habitat ($/Acre/Year)**

| Woodward 2001 | | |
|---|---|---|
| **Single Service Wetland Type** | **Mean Value** | **Range of Values** |
| Flood | $645 | $146–$2,865 |
| Water Quality | $684 | $207–$2,260 |
| Water Quantity | $208 | $10–$4,216 |
| Recreational Fishing | $585 | $156–$2,201 |
| Commercial Fishing | $1,276 | $177–$9,214 |
| Bird Watching | $1,988 | $866–$4,562 |
| Amenity | $5 | $2–$23 |
| Habitat | $502 | $156–$1,609 |
| Storm | $389 | $18–$8,433 |
| **Ingraham 2008** | | |
| Overall Value of Ecosystem Services Provided by Wetlands in General | | $2,400–$4,800 |

Source: Woodward, R., and Y. Wui. 2001. "The Economic Value of Wetland Services: A Meta-Analysis". *Ecological Economics.*. 37: 257-270; and Ingraham, M. and S. Foster. 2008. "The Value of Ecosystem Services Provided by the U.S. National Wildlife Refuge System in the Contiguous U.S." *Ecological Economics.* 67(4):608-618.

miles of its watershed. This avoided cost constitutes an economic benefit of $3,000 per acre for water filtration services.[12] Similarly, Clean Water Services, a water-resource management utility in northwestern Oregon avoided investing in a chiller for a water treatment plant on the Tualatin River by planting riparian vegetation to shade and cool the river, for a savings of $50 million.[13]

## IV. Overall Value of Intertwine Ecosystem Services

The value of ecosystem services is ultimately derived from the interactions between the demand for and supply of ecosystem services. The Metro population is over two million (Table 7), and growing, with much of the attraction of the area seen to be attributable to its natural amenities. Research in the Pacific Northwest suggests an increasing demand for recreation opportunities based on appreciation of nature, and access to these amenities close to home.[14] These studies also suggest a relatively greater demand for such recreational and natural amenities among minority and low-income populations,

[12] ECONorthwest, with data from the Portland Water Bureau, http://www.portlandonline.com/water/index.cfm?c=29784; and Krieger, D. 2001. *Economic Value of Forest Ecosystem Services: A Review*. The Wilderness Society.

[13] Niemi, E., K. Lee and T. Raterman. *Net Economic Benefits of Using Ecosystem Restoration to Meet Stream Temperature Requirements.* ECONorthwest.

[14] Washington State Recreation and Conservation Office. 2008. *Defining and Measuring Success: The Role of State Government in Outdoor Recreation*. June; Lindberg, K. 2007. *Oregon's Statewide Comprehensive Outdoor Recreation Plan: Outdoor Recreation and an Aging Population*. Oregon State University, Cascade Campus. February.

suggesting that the Intertwine contributes to improving environmental justice concerns. Overall, there is interest in stewardship for a clean and healthy environment in the Metro region.[15]

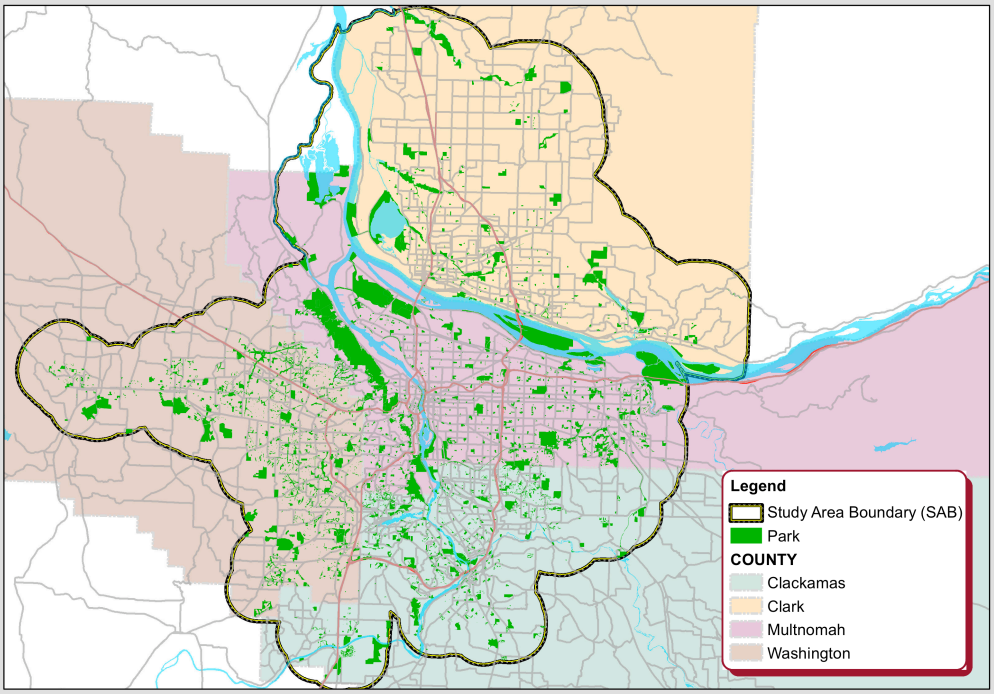
Utilizing available spatial data, we calculated the total park acreage in the Intertwine study area for Metro and portions of Clark County in Washington: 56,857 acres (Figure 1). Spatial data for the complete set of areas currently included in the Intertwine system do not have the level of detail necessary to precisely identify the overall area of each ecosystem subtype. Therefore, applying the values for those ecosystem services provided by the Intertwine with available values in the literature must be done on aggregate.

**Table 7. Demographic Estimates for Portland Metro**

| | |
|---|---|
| **Overall Population** | 2,209,114 |
| **Race and Ethnicity Data** | |
| White Alone | 1,852,693 |
| Hispanic or Latino | 231,272 |
| African American | 61,827 |
| American Indian or Alaska Native | 29,567 |
| Asian | 112,569 |
| Native Hawaiian/Pacific Islander | 7,627 |
| Other single race | 61,953 |
| Two or more races | 82,878 |
| **Economic Data** | |
| Median Household Income | $58,758 |
| Per Capita Income | $29,635 |

Source: ECONorthwest with data from U.S. Census Bureau. 2010. 2008 Community Survey 1-Year Estimates.

**Figure 1. Total Park Acreage in Intertwine Study Area**




**Park coverage within Study Area Boundary (SAB): 56,857 Acres**

Bi-state Intertwine Study Area
Portland Metro Intertwine Analysis

0 2.5 5 Miles

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[15] See Hansa | GCR and ECONorthwest. 2008. Private Motivations to Invest in Stormwater Management Facilities: A Qualitative Exploration and Quantitative Assessment. City of Portland, Bureau of Environmental Services.

Selecting for additive services from the tables above, we compiled an itemized list of ecosystem services for Intertwine lands (Table 8). The values are divided between services serving primarily local populations (e.g., storm water capture and treatment), and services not constrained to or concentrated among local populations (e.g., carbon sequestration). The values are not site-specific, and are not all provided by all park acreage within the Intertwine. The lands of the Intertwine though are likely to have relatively higher values than the low end of the range in several cases.

Higher values are likely due to the relative scarcity of these services for urban areas (these services are more scarce in Metro than in rural areas) and greater populations in proximity (there is more demand for these services in Metro than in rural areas with lower population density). Considering the low end of the range applied to the acreage (to account for incomplete coverage across the area of all services) yields a total value of approximately $1.5 billion for local services and $1.8 billion including non-local services.

The high end of the range would increase these values by an order of magnitude. To the extent that identified services are not generally present, the estimate should be revised down, and to the extent that other services are present but not monetized, the true value would be greater.

**Table 8. Per Acre Values for Ecosystem Services in the Intertwine**

| | Low Estimate | High Estimate |
|---|---|---|
| **Local Services** | | |
| Stormwater Treatment | $6,600 | $22,500 |
| Air Purification | $1,027 | $4,229 |
| Flood | $2,237 | $43,903 |
| Bird Watching | $13,270 | $69,907 |
| Amenity | $31 | $352 |
| Habitat | $2,391 | $24,656 |
| Storm | $276 | $129,226 |
| **Total Local** | **$25,831** | **$294,773** |
| **Non-Local Services** | | |
| Carbon Sequestration | $53 | $19,453 |
| Water Quantity | $153 | $64,605 |
| Commercial Fishing | $2,712 | $141,193 |
| Recreational Fishing | $2,391 | $33,728 |
| **Total Non-local** | **$5,310** | **$258,980** |
| **Total Local and Non-local Services** | **$31,141** | **$553,753** |

Source: ECONorhtwest, representing total value over a roughly twenty year timeframe.

# APPENDIX A

**Table A-1. Summary of Functions, Goods, and Services of Ecosystems**

| Functions | Examples of Goods and Services Produced |
|---|---|
| Production and regulation of water | Natural and human-built features of an ecosystem capture precipitation; filter, retain, and store water; regulate levels and timing of runoff and stream flows; and influence drainage. |
| Formation & retention of soil | Wetlands and biota accumulate organic matter, and prevent erosion to help maintain productivity of soils. |
| Regulation of atmosphere & climate | Biota produce oxygen, and help maintain good air quality and a favorable climate for human habitation, health, and cultivation. |
| Regulation of disturbances | Wetlands and reservoirs reduce economic flood damage by storing flood waters, reducing flood height, and slowing a flood's velocity. |
| Regulation of nutrients and pollution | Wetlands and riparian vegetation improve water quality by trapping pollutants before they reach streams and aquifers; natural processes improve water quality by removing pollutants from streams. |
| Provision of habitat | Wetlands, riparian vegetation, streams, and reservoirs provide habitat for economically important fish and wildlife. |
| Food production | Biota convert solar energy into plants and animals edible by humans. |
| Production of raw materials | Streams and biota generate materials for construction, fuel, and fodder; streams possess energy convertible to electricity. |
| Pollination | Insects facilitate pollination of economically important wild plants and agricultural crops. |
| Biological control | Water-related birds and microorganisms control pests and diseases. |
| Production of genetic & medicinal resources | Genetic material in wild plants and animals provide potential basis for drugs and pharmaceuticals. |
| Production of ornamental resources | Products from water-related plants and animals provide materials for handicraft, jewelry, worship, decoration, and souvenirs. |
| Production of aesthetic resources | Wetlands, riparian vegetation, streams, and reservoirs provide basis for enjoyment of scenery from roads, housing, parks, trails, etc. |
| Production of recreational resources | Streams, reservoirs, riparian vegetation, fish, waterfowl, and other wildlife provide basis for outdoor sports, eco-tourism, etc. |
| Production of spiritual, historic, cultural, and artistic resources | Wetlands, riparian vegetation, streams, and reservoirs serve as basis for spiritual renewal, focus of folklore, symbols of group identity, motif for advertising, etc. |
| Production of scientific and educational resources | Wetlands, riparian vegetation, streams, and reservoirs provide inputs for research and focus for on-site education. |

Source: Adapted by ECONorthwest from De Groot, R., M. Wilson, and R. Boumans. 2002. "A Typology for the Classification, Description and Valuation of Ecosystem Functions, Goods and Services." *Ecological Economics* 41: 393-408; Kusler, J. 2003. *Assessing Functions and Values.* Institute for Wetland Science and Public Policy and the Association of Wetland Managers, Inc.; and Postel, S. and S. Carpenter. 1997. "Freshwater Ecosystem Services." in *Nature's Services: Societal Dependence on Natural Ecosystems*. Edited by G.C. Daily. Washington, D.C.: Island Press, pgs. 195-214.