ECOLOGICAL ECONOMIC EVALUATION

Maury Island, King County, Washington

June 2004

King County

Department of Natural Resources and Parks
Water and Land Resources Division

Note:
Some pages in this document have been purposefully skipped or blank pages inserted so that this document will copy correctly when duplexed.

ECOLOGICAL ECONOMIC EVALUATION

Maury Island, King County, Washington

June 8, 2004

Prepared for:

King County

Department of Natural Resources and Parks
Water and Land Resources Division
King Street Center, KSC-NR-0600
201 South Jackson Street, Suite 600
Seattle, WA 98104-3855
206-296-8378 TTY Relay: 711
dnr.metrokc.gov/wlr

Prepared by:

Herrera Environmental Consultants, Inc.
2200 Sixth Avenue, Suite 1100
Seattle, Washington 98121
Telephone: 206/441-9080

Northern Economics Inc.
1801 Roeder Avenue
Bellingham, Washington 9822-2257
Telephone: 360/715-1808

Spatial Informatics Group, LLC
1990 Wayne Avenue
San Leandro, California 94577
Telephone: 510/427-3571

File: 0406_MauryEcoReport.pdf

Contents

Tables

Figures

Abbreviations

GIS	Geographic Information System
KCORPP	King County Office of Regional Planning and Policy
PSRC	Puget Sound Regional Council
WRIA	Water Resource Inventory Area

Executive Summary

Ecological economics explicitly addresses the relationships between natural ecosystems and human economic systems by accounting for the natural environment as a form of *natural capital* and valuing the ecosystem goods and services delivered by ecological systems. From an ecological economics perspective, the goods and services provided by Maury Island landscapes are not only critical to the functioning of the Puget Sound ecological systems, but they also contribute significantly to the human welfare of Maury Island residents, King County's citizens, and others, both directly and indirectly as forms of natural capital. Ecological systems potentially represent a significant, yet currently non-quantified or unaccounted portion of the total economic value of King County assets. Estimating the *economic* value of ecosystem goods and services is increasingly recognized as a necessary condition for environmental decision-making, sustainable business practice, and land-use planning at multiple geographic scales and socio-political levels of analysis.

A project team consisting of representatives from Herrera Environmental Consultants, Northern Economics, Inc., and Spatial Informatics Group, LLC, worked with staff from King County Department of Natural Resources and Parks, Water and Land Resources Division, to estimate the total economic value of ecosystem goods and services on and around Maury Island. The project area included all of Maury Island and extended to the nearshore environment surrounding the island. The project team also estimated the potential loss to the economic value of ecosystem goods and services from development on Maury Island.

As shown below in Summary Table 1, the literature review conducted for this study found that of the 10 land cover classes within the Maury Island study area, three can be classified as "high value," two can be classified as "moderate value," and four can be classified as "low value." High value habitats include: Beaches that are located near dwellings[1], Beach habitats, and Freshwater Wetlands. Moderate value habitats include: Coastal Riparian and Nearshore Habitat. Low value land covers include Grasslands, Forests, Freshwater Streams, Saltwater Wetlands, and Coastal Open Water. Land that has been developed or disturbed is given an ecosystem value of zero and classified as a low value habitat[2]. Restricting development areas with higher value ecosystems would reduce the societal impact of development; focusing development in areas where there are lower value ecosystems would reduce economic impacts to society.

The study area consisted of 2,460 hectares and the largest land cover types were in Forest, Nearshore Habitat, Grassland, and Disturbed areas. The ecosystem types with the highest value include Nearshore Habitat, Beach near dwellings, Beach, and Forest.

[1] For the purposes of this study, Beaches were separated into two categories—near dwellings and others—because the literature suggests that the economic value that society places on beaches differs dramatically depending on the proximity to dwellings.

[2] Land cover class value estimates do not include all possible factors (see Section 1.2.3 and Table 5 below) and the values would change if the values for all factors were available.

Summary Table 1. Ecological economic values for Maury Island.

Land Cover Type	Ecosystem Value per Hectare	Total Hectares	Total Value for Maury Island Ecosystem
Disturbed	$ 0	253.5	$ 0
Beach	$ 88,203	26.8	$ 2,371,000
Beach near dwelling	$ 117,254	64.6	$ 7,576,000
Coastal Riparian	$ 9,395	132.4	$ 1,245,000
Forest	$ 1,826	1043.8	$ 1,906,000
Freshwater Stream	$ 1,594	41.4	$ 66,000
Freshwater Wetland	$ 72,786	3.6	$ 269,000
Grassland/Herbaceous	$ 117	321.4	$ 38,000
Nearshore Habitat	$ 16,282	565.2	$ 9,205,000
Saltwater Wetland	$ 1,413	6.7	$ 9,500
Total Value		2,460	$22,685,000

Source: Spatial Informatics Group.

As shown above in Summary Table 1, the annual value of the existing ecosystem goods and services within the Maury Island project area is estimated to be $22.68 million per year. Adding these annual values for a period of 100 years and discounting the total to account for the time value of money provides a Net Present Value (NPV) of the ecosystem goods and services within the Maury Island project area. The NPV over the next 100 years for the ecosystem goods and services is estimated to be between $649 million and $831 million in 2004 dollars, depending upon the discount rate selected.

As shown below in Summary Table 2, developing Maury Island to the maximum extent possible within the current zoning codes would result in a NPV loss of value of ecosystem goods and services of between $11.4 million and $23.5 million, depending upon the discount rate used. This equals between 1.8 percent and 2.8 percent of the total 100-year net present value of the project area ecosystem.

Summary Table 2. Loss estimates for various development scenarios

Scenario	NPV of Losses	NPV of Terrestrial Status Quo	Loss as Percent of Terrestrial Status Quo	NPV of Study Status Quo	Loss as Percent of Study Status Quo
Scenario 1 – Full Development of Maury Island	$11.4 to $23.5 million	$194.2 to $248.6 million	5.9 to 9.5%	$649.3 to $831.1 million	1.8 to 2.8 %
Scenario 2 – Development of Glacier Mine	$0.9 to $1.1 million	$194.2 to $248.6 million	0.5%	$649.3 to $831.1 million	0.14%
Aggregated Scenario 1 and Scenario 2	$12.3 to $24.6 million	$194.2 to $248.6 million	6.3 to 9.9%	$649.3 to $831.1 million	1.9 to 3.0%

Developing the Glacier Mine would reduce the NPV of Maury Island ecosystem goods and services by between $0.9 million and $1.1 million. This amount represents roughly 0.14 percent of the total 100-year net present value of the project area ecosystem (see Summary Table 2 above). It must be noted that this estimate assumes that the mine would be remediated during the 35-year mining process in accordance with current restoration standards and specifications. For this study, it was assumed that after the Glacier Mine site is restored and rehabilitated it would provide 80 percent of its current ecosystem value. If remediation is not done or proves to be unsuccessful, the lost value of ecosystem goods and services would increase substantially.

Under a combined scenario where the Glacier Mine is developed and all other parcels on Maury Island are developed to the maximum degree allowed under current zoning, the NPV loss to the ecosystem would be between $12.3 million and $24.6 million, depending upon the discount rate used. This represents a loss of between 1.9 and 3.0 percent of the total value of ecosystem goods and services associated with the Maury Island study area. Full development of Maury Island would not significantly reduce ecosystem values of the island and the surrounding nearshore environment.

Ecological economics estimates the direct and indirect effects of development, but does not estimate any induced effects. Therefore, if development on Maury Island induces other development outside the Maury Island project area, it would not be accounted for in the ecological economic estimates. The analysis also does not account for any degradation of the nearshore ecosystem as a result of nearby upland development.

Decision-makers and the public may consider the results of this study as additional information when evaluating future development proposals. The Ecological Economic Evaluation of Maury Island is intended to be a baseline study from which further research could be based. Additional research topics might include market analyses of specific resources, such as geoducks, eelgrass habitat, or development within the shoreline area. The Maury Island analysis could also be combined with or incorporated into the ecosystem economic evaluation that is currently proposed for Water Resource Inventory Area (WRIA) 9.

Introduction

Over 3.2 million people live in the counties that border the central Puget Sound and the population is expected to grow to 4.5 million by 2030 (PSRC 2003). Pressures to build residential or commercial structures on undeveloped land continue despite a weakened local economy. These pressures can be expected to increase in the future as the local economy improves and the local population increases. When policymakers update comprehensive plans or revise zoning requirements, or decision-makers review proposals to build on undeveloped land, they are often forced to consider the tradeoffs between the benefits provided by healthy naturally functioning ecological systems and those associated with building more homes, paving more roads or parking lots, and expanding commercial activities. Compounding the difficulty of making this assessment is the fact that quantitative information about the economic values associated with the goods and services provided by the natural environment has conventionally been difficult to obtain.

The primary purpose of this study is to help address that problem by providing a baseline estimation of the economic value of the goods and services provided by natural capital resources on and around Maury Island in order to provide decision-makers with new information about the economic value of these resources so that they can make better-informed decisions. This study is also designed to help educate and inform King County representatives, management, staff, and citizens about the emerging field of ecological economic evaluation and the analytical tools and work products that are currently available.

A secondary purpose of this study is to present an ecological economic framework for identifying the elements of the nearshore ecology so that future research can further analyze and evaluate how changes to these elements effect ecological economic values.

Chapter 1 of this report describes how the study area (Section 1.1) and development scenarios (Section 1.3) were selected, and provides a background discussion of ecological economics and ecosystem service valuation methodology (Section 1.2).

Chapter 2 summarizes the existing conditions of the nearshore and terrestrial ecosystems (Section 2.1) and the current socioeconomic conditions of Maury Island (Section 2.2). These elements are addressed in detail in Appendices B and C. Information about the current economic value of the nearshore and terrestrial ecosystems is presented in Section 2.3. This section also provides the Economic Value Estimates for Ecosystem Services on and around Maury Island.

Chapter 3 describes value of lost ecosystem services for two future development scenarios on Maury Island.

1. Study Approach

1.1 Study Area and Approach

The region of focus for this study includes all of Maury Island and seaward to the waterward limits of the nearshore zone. This report estimates the ecological economic value of the natural capital resources of the entire island and the surrounding nearshore.

The nearshore zone is defined here as extending 200 linear feet inland from the mean higher high water[3] (MHHW) mark and seaward to the lower edge of the photic zone. The photic zone includes surface waters that receive light and in the Puget Sound/Vashon Island area, this zone usually extends to a depth of between –10 meters mean lower low water (MLLW) to –30 meters MLLW. For the purposes of this study, the lower edge of the nearshore environment is defined as –15 meters (approximately -55 feet) below MLLW.

Defining the project area in Quartermaster Harbor presented a dilemma for the project team. The majority of Quartermaster Harbor, located on the western side of Maury Island, is shallower than –15 meters MLLW, and the initial inclination was to establish the project boundary at the shoreline of Vashon Island. However, it is more appropriate to associate the ecological value of Quartermaster Harbor with both Vashon Island and Maury Island. Therefore, the project boundary was set at the lowest depth of the harbor and the eastern portion assigned to the Maury Island project area; areas deeper than –15 meters MLLW are below the edge of the nearshore zone and not included in the project area.

The socioeconomic profile and analysis included in this report, evaluates Blocks 1 and 4 of Census Tract 277.02, which covers all of Maury Island and is consistent with the biological project area described above. A map of Maury Island and the surrounding area is shown in Figure 1.

The project approach is addressed below in sections 1.2.2 Value Transfer and Geographic Information Systems and 1.3 Valuation of Development Scenario Losses, following the general background discussion of ecological economic valuation methodology.

[3] Because Maury Island is surrounded by the marine waters of Puget Sound, water levels fluctuate with the tides. Tidal fluctuations have a variety of measures for specific uses. For this study, the two measures of fluctuation include Mean Higher High Water and Mean Lower Low Water. Mean Higher High Water is defined as the arithmetic mean of the higher high water heights of the tide observed over a specific 19-year cycle. Only the higher high water of each pair of high waters of a tidal day is included in the mean; if both high water marks in a tidal day are included in this calculation, it is called the Mean High Water. The MHHW is important because it marks the edge of the shoreline and property boundaries between public and private lands in Washington that border marine waters. Mean Lower Low Water is defined as the arithmetic mean of the lower low water heights of the tide observed over a specific 19-year cycle. The MLLW is an important mark for navigating in shallow water and currently serves as the baseline for describing the height of marine waters. Tidal datums at the gauge closest to Maury Island (Tahlequah 90B) indicate that MHHW is 11.89 feet (3.62 meters) and MLLW is 0.00 feet.

1.2 Ecological Economics and Ecosystem Service Valuation Methodology

Ecological economics is a field of study that explicitly addresses the relationships between natural ecosystems and economic systems (Costanza 1989). While it builds on both conventional economics and conventional ecology, ecological economics differs in that it views the human economy as part of a much larger ecological whole and focuses on finding practical solutions to complex system problems through the iterative process of analysis, synthesis and application. Accounting for the natural environment as a form of *natural capital* and the valuation of ecosystem goods and services delivered by ecological systems is one of the core areas of research in the field (El Sarafy 1991).

From an ecological economics perspective, the goods and services provided by King County landscapes are critical to the functioning of the Puget Sound ecological systems. But importantly, they also contribute significantly to human welfare, both directly and indirectly as forms of natural capital, and therefore potentially represent a significant, yet currently non-quantified or unaccounted portion of the total economic value of King County assets. While there are many ways that humans can value landscapes – i.e., spiritual and cultural – the ability to estimate the *economic* value of ecosystem goods and services is increasingly recognized as a necessary condition for environmental decision-making, sustainable business practice and land-use planning at multiple geographic scales and socio-political levels of analysis (see Millennium Ecosystem Assessment 2003).

The population and development pressures that Maury Island and other coastal areas throughout King County and the greater Puget Sound area are now experiencing raise significant challenges for planners and decision-makers. The population of Vashon and Maury Islands is expected to increase by 44 percent by 2030 (PSRC 2003). Communities must often choose between competing uses of the coastal environment and the myriad goods and services provided by healthy, functioning ecosystems. "Should a shoreline be cleared and stabilized to provide new land for development, or should it be maintained in its current state to serve as wildlife habitat?" "Should a wetland be drained and converted to commercial uses or should more wetland area be created to provide freshwater filtration services?" "Should a shoreline area be mined for building materials and the production of lime, mortar and cement or should it be protected as a natural area to provide recreational opportunities and habitat features that support aquatic species including renewable seafood?"

To choose from among these competing options, it is important to know not only what ecosystem goods and services will be affected but also what they are actually worth to different members of society. When confronting decisions that pit different ecosystem services against one another, decision-makers cannot escape making a *choice* based on values; whenever one alternative is chosen over another, that choice indicates which alternative is deemed to be worth more than other alternatives. In short, the ecosystem valuation issue cannot be avoided, because as long as decision-makers are forced to make choices about alternative environmental states, they are doing valuation. This report assesses and quantifies the economic and ecological benefits associated with coastal ecosystem goods and services using established methods.

This report develops and uses a conservative, baseline ecological-economic assessment of the ecosystem goods and services for Maury Island. The goal for this project is to use the best available methods, data sources, and spatial analysis techniques to generate defensible value estimates that can then be integrated into land use planning and environmental decision-making at the study site.

1.2.1 Coastal Ecosystem Goods and Services

The coastal islands, estuaries and beaches scattered throughout Puget Sound region provide many different goods and services to people. An ecosystem service, by definition, contains "the conditions and processes through which natural ecosystems, and the species that make them up, sustain and fulfill human life" (Daily 1997). Ecosystem goods, on the other hand, represent the material products that can be obtained from natural systems for human use (DeGroot et al. 2002).

The concept of ecosystem goods and services is fundamental to the ecological economic approach to environmental valuation used in this report because it establishes a clear link between ecological systems and economic value. As Morris et al. (1996) state in their King County report:

> Typically, when estimating the value of an ecosystem, economists have tended to concentrate on those components of the ecosystem that have immediate and obvious value to individuals or society, and for which values can be readily estimated…In contrast ecological models have tended to concentrate on aspects of ecosystems that are important to ecosystem functions but that are not directly valued by people…One significant impediment to environmental valuation of natural ecosystems is the lack of knowledge about *specific technical linkages between ecosystems and the services they provide to people* (p. 28; italics added).

The components of the ecosystem, meaning specific natural resources, that economists have traditionally focused on are those for which a market exists. In this report, ecosystem goods and services are used to establish this technical linkage between people and ecological systems. The project builds on recent advances in the peer-reviewed ecological economic literature (Wilson and Carpenter 1999; Wilson et al. 2004), to develop reliable estimates of ecosystem goods and services on and around Maury Island, King County. Taken together, this bundle of ecosystem goods and services represent the total net value that King County citizens derive, directly or indirectly, from natural coastal systems at the study site.

Figure 2 represents the ecological economic framework used in this report, including consideration of ecological structures and processes, ecological functions, ecosystem goods and services, human welfare, land use decisions and the dynamic feedbacks between them. After extensive international peer review, the concept of ecosystem services has recently been adopted by the United Nations' sponsored Millennium Ecosystem Assessment (MA) program (see <http://www.millenniumassessment.org>; Millennium Ecosystem Assessment 2003). The figure presented below shows how ecosystem goods and services form a pivotal link between human and ecological systems throughout King County. Coastal ecosystem structures and processes are influenced by long-term, large-scale biophysical drivers (i.e., tectonic pressures, global weather patterns, and solar energy) which in turn create the necessary conditions for providing the ecosystem goods and services people value. Through laws, land use management and policy decisions, individuals and social groups make tradeoffs between these values to maximize human value goals. In turn, these land use decisions directly modify the ecological structures and processes by engineering and construction and/or indirectly by modifying the physical, biological and chemical processes of the landscape[4].

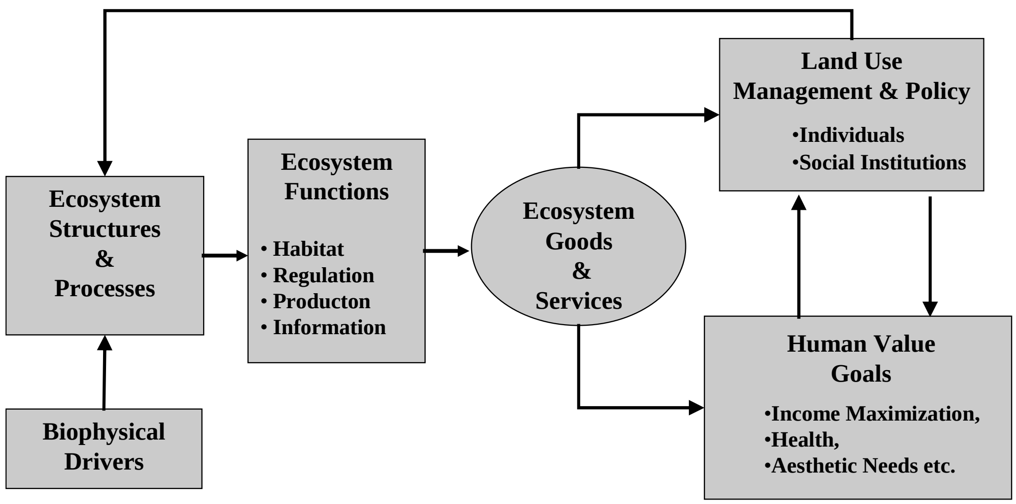

Figure 2. Framework for integrated assessment and valuation of coastal ecosystem functions, goods, and services.

The first step towards an assessment of ecosystem goods and services at Maury Island involved translating ecological complexity at the site (structures and processes) into a more limited number of ecosystem functions. These functions, in turn, provide the goods and services that are valued by people. In the ecological literature, the term 'ecosystem function' has been subject to various, and sometimes contradictory, interpretations (De Groot et al. 2002). Sometimes the concept is used to describe the internal functioning of the ecosystem (e.g., maintenance of energy fluxes, nutrient (re)cycling, food-web interactions), and sometimes it relates to the benefits derived by humans from the properties and processes of ecosystems (e.g., food production and waste treatment).

In this report, ecosystem functions are defined as the capacity of natural processes and components to provide goods and services that directly or indirectly satisfy human needs. Using this definition, ecosystem functions are conceived as an actual product of ecological processes

[4] Adopted by scientists worldwide, the Millennium Ecosystem Assessment charter specifically states: "The MA focuses on ecosystem services (the benefits people obtain from ecosystems), how changes in ecosystem services have affected human well-being, how ecosystem changes may affect people in future decades, and response options that might be adopted at local, national, or global scales to improve ecosystem management and thereby contribute to human well-being."

and ecosystem structures (see Figure 2). Each function is the result of the natural processes of the total ecological sub-system of which it is a part. Natural processes, in turn, are the result of complex interactions between biotic (living organisms) and abiotic (chemical and physical) components of ecosystems through the universal driving forces of matter and energy.

Although a range of ecosystem functions and their associated goods and services have been referred to in literature, experience suggests that it is convenient to group ecosystem functions into four primary categories:

1. *Regulation functions:* the capacity of ecosystems to regulate essential ecological processes and life support systems through bio-geochemical cycles and other biospheric processes.

2. *Habitat functions:* natural ecosystems provide refuge and reproduction habitat to wild plants and fish species and thereby contribute to the (in situ) conservation of biological and genetic diversity and evolutionary processes.

3. *Production functions:* Photosynthesis and nutrient uptake convert energy, carbon dioxide, water and nutrients into a variety of carbohydrate structures that are then used by secondary producers to create a large variety of ecosystem goods for human consumption, ranging from food and raw materials to energy resources and genetic material.

4. *Information functions:* natural ecosystems provide an essential "reference function" and contribute to the maintenance of human health and well being by providing opportunities for recreation, spiritual enrichment, and aesthetic experience.

The ecosystem function concept thus provides the ecological basis for the classification of potentially useful aspects of natural ecosystems to humans; observed ecosystem functions are reconceptualized as "ecosystem goods or services" when human values are implied. A key insight here is that the concept of ecosystem goods and services is inherently anthropocentric; it is the presence of people as valuing agents that enables the translation of basic ecological structures and processes into value-laden entities.

The concept of ecosystem goods and services used in this report is therefore inherently *people-oriented*; it is the presence of human beings that enables the translation of basic ecological structures and processes into value-laden entities. Through laws and rules, land use management and policy decisions, individuals and social groups make tradeoffs between competing ecosystem values. In turn, these land use decisions directly modify the structures and processes of the natural environment by engineering and construction and/or indirectly by modifying the physical, biological and chemical processes of the natural system.

Accounting for the value of ecosystem functions and services is useful for resource management in King County for three fundamental reasons. First, it helps synthesize essential ecological and economic concepts, allowing researchers and managers to link human and ecological systems in a viable and relevant manner. Second, it draws upon the latest available ecosystem science. Third, politicians, business leaders and citizens can use the concept to evaluate economic and political tradeoffs between landscape development and conservation alternatives.

The ecosystem functions and the related goods and services used in this report are listed below in Table 1[5].

Table 1. Ecosystem functions and services at Maury Island.

Ecosystem Function	Ecosystem Service
Regulation	Climate and Atmospheric Regulation: ▪ Carbon dioxide sinks ▪ Oxygen production ▪ Ambient volatile organic compound (VOC) uptake
	Disturbance Moderation: ▪ Storm and flood protection ▪ Regulation of runoff and river discharge
	Freshwater Regulation and Supply: ▪ Water catchments ▪ Ground water recharge
	Waste Assimilation: ▪ Reduction of dissolved oxygen ▪ Pathogen and toxin filtration ▪ Trapping sediments and pollutants
	Nutrient Regulation: ▪ Nutrient filter ▪ Remineralization of organic and inorganic matter
	Soil Retention and Formation: ▪ Erosion control ▪ Top soil formation
Habitat	Habitat Refugium: ▪ Nursery, feeding and breeding ground for salmon, herring, etc. ▪ Maintenance of biodiversity and genetic resources ▪ Habitat for resident and migratory species
Production	Food and Raw Materials: ▪ Edible shellfish ▪ Salmon, herring, and other marketable fish species
Information	Recreation and Amenity: ▪ Recreation and water sports (kayaking, beach, snorkeling/diving, recreational fishing, etc.) ▪ Aesthetic quality—proximity of houses to environmental amenities

[5] Alternative lists of ecosystem goods and services have been proposed (see, for example, Costanza et al. 1997 and De Groot et al. 2002); but this list was selected for its specific applicability to landscape analysis using available land cover and land use data.

As the above list shows, the ecosystem goods and services identified at Maury Island affect King County citizens, as well as citizens of the greater Puget Sound region, at multiple spatial scales: from climate regulation and carbon sequestration at the national and international scale, flood protection, water supply, and nutrient regulation at the County and regional scale and disturbance moderation and recreation opportunities at the local scale. Ecosystem goods and services also span a range of direct connection to human welfare, with climate and atmospheric gas regulation being less tangibly connected, while food, raw materials, genetic resources, recreational opportunities, and aesthetic and cultural values are more directly connected. One of the primary goals for this project was to link this classificatory system with available land cover/land use data to identify goods and services associated with specific land uses (see Section 1.2.2). Geographic Information System tools are frequently used to both map and analyze available data (Wilson, Troy, and Costanza 2004) and an ecosystem services value map for the Maury Island project area was produced. This framework can now be used to develop ecological economic values for the existing ecosystem and, subsequently, evaluate tradeoffs among alternative land use decisions in the county.

Viewed in light of the many ecosystem goods and services provided by naturally functioning ecosystems, the development pressures that Maury Island is now experiencing raise significant challenges for planners and decision-makers. The citizens of King County will inevitably be forced to choose between competing uses of the natural environment at Maury Island.

1.2.2 Value Transfer and Geographic Information Systems

As mentioned at the outset, the primary purpose of this report is to shed light on the economic benefits of ecosystem goods and services associated with the nearshore habitat and inland landscape at the Maury Island site. Yet, the problem immediately arises: how to estimate the economic value of things that are generally not traded in the marketplace? While a fair amount of research has been done on the economic value of ecosystem services globally (Daily 1997; Costanza et al. 1997), little peer-reviewed work has been done to explicitly estimate the economic value of ecosystems located in Puget Sound itself, or even in Washington state. Because relatively little ecosystem service valuation research has been done locally, values were required to be "transferred" from outside the state to the Maury Island site. To achieve this, the project team used secondary analysis of published results drawn from the peer-reviewed economic literature.

This approach has become a common and reliable methodology for conducting ecological economic valuations. The growing sophistication of economic valuation techniques documented by Morris et al. in their 1996 report to King County is matched by the rising costs of conducting new studies for site-specific environmental changes. Only rarely can policy analysts or land use managers afford the luxury of designing, funding and implementing an original study for estimating the economic value of ecosystem goods or services for a specific area. Instead, they must often rely on the information that can be taken from past empirical studies done at different times in different locations. Primary valuation research using one or more of the techniques described by Morris et al. (1996), while being a "first best" strategy, is also very expensive and time consuming. Secondary analysis of available valuation literature is a 'second best' strategy that can nevertheless yield very important information in many scientific and management contexts. When analyzed carefully, information from past studies published in the literature can form a meaningful basis for directing environmental policy and management. As Morris et al. (1996) note:

> Given the expense and time associated with estimating values of nonmarket natural resources and services, benefits transfer is a reasonable technique by which to determine such values…In some cases, a high-quality benefits transfer study may in fact yield better estimates of economic values than a poor-quality, site-specific study…Also benefits transfer methods may be particularly useful in management and policy contexts in which estimates of economic benefits not generated by an original study may be sufficient to make a judgment regarding the advisability of a management action or project (p. 24-25).

Value transfer is an accepted methodology that obtains an estimate for the economic value of non-market goods or services through the analysis of a single study, or group of studies, that have been previously carried out to value similar goods or services[6]. The "transfer" itself, refers to the application of economic values and other information from the original study site to the selected site. The critical underlying assumption of the value transfer approach is therefore that the economic value of ecosystem goods or services at the study site can be inferred with sufficient accuracy from the analysis of existing valuation studies.

Results from a value transfer application are *de facto* less accurate than primary valuation analyses, yet they are clearly justified under practical circumstances where primary analysis is out of reach and precision is less critical to the decision-maker. Transfer studies provide an economical way to conduct valuation research when a full-fledged empirical study is not practical or necessary. By applying the results of previous studies to a new policy context, with some adjustment, they economize on the time and expense of data collection and new estimation.

Thus, it is increasingly clear that with sufficient limitations and recognition of the context sensitivity of value estimates, existing peer-reviewed valuation studies can provide a credible basis for policy decisions involving sites other than the study site for which the values were originally estimated. The critical underlying assumption of the transfer method is that as the richness, extent and detail of information increases within the source literature, the accuracy of the value transfer technique will likewise improve.

In this report, value transfer information from 43 sources (see Appendix A) was used to derive estimates of the economic values of ecosystem goods and services for Maury Island (Desvouges et al. 1998). To do so, the project team used the NaturalAssets Database®, a proprietary relational database developed by the Spatial Informatics Group that stores economic values

[6] Following Desvousges et al. (1998), the term "value transfer" is adopted instead of the more commonly used term "benefit transfer" which is used by Morris et al. (1996) to reflect the fact that the transfer method is not restricted to economic benefits, but can also be extended to include the analysis of potential economic costs, as well as welfare functions more generally.

derived from the peer-reviewed literature to provide King County planners with the ability to account and track environmental assets and liabilities. The NaturalAssets Database® contains the best-available economic information about environmental assets in a relational decision support system so that the research team can query, assess and report the economic value of ecosystem goods and services in specific geographic contexts, thereby providing maps, graphs and figures that can be used to track environmental assets and liabilities.

The critical underlying assumption of the NaturalAssets Database® is that the economic value of ecosystem goods or services at the study site can be inferred with sufficient accuracy from the analysis of existing valuation studies. The research team developed a set of decision rules for querying economic results from the published literature contained in the NaturalAssets Database® that allowed the economic value of ecosystem services at Maury Island to be estimated with sufficient accuracy. Valuation studies selected and used for this study were:

- Peer reviewed and published in recognized journals
- Focused on temperate regions in either North America, Canada or Europe
- Focused primarily on non-consumptive use.

Using these criteria, data derived from a set of viable studies were then standardized to 2001 U.S. dollar equivalents per hectare (one hectare is equal to 2.471 acres) to provide a consistent basis for comparison[7]. The result was a query sensitive database containing valuation data points that were coded by temporal (i.e., time of study), spatial (i.e., place where study was done) and methodological (i.e., method used) criteria thereby allowing the research team to derive a lower bound and upper bound estimate of dollar values for the study site. Given the aforementioned restrictions, this approach yields a conservative estimate of baseline economic values for Maury Island.

After empirical valuation studies were selected, inputted into the database, and standardized estimates selected for value transfer, the resulting value estimate were assigned to the appropriate Geographic Information Systems (GIS) land cover categories at the study site in a spatially explicit manner. The final economic estimates were developed by using GIS to match the spatial resolution and coverage of the original research with the characteristics of the Maury Island site (see section 1.3.2 below).

Land cover areas were enumerated and ecosystem service values for a given parcel were calculated by multiplying the value per-unit area for that ecosystem service by the area of the given cover type for the project area. The total ecosystem service value of a given cover type for the project area was determined by aggregating the individual ecosystem service values for that cover type (for example, water filtration and recreational values for forests). Total ecosystem service value for Maury Island was determined by adding up all cover-specific total ecosystem service values for the project site. Total ecosystem service values were divided by the total area to indicate the prevalence of high-ecosystem service value cover types within the area. While

[7] All dollar values are standardized using Consumer Price Index tables published by the U.S. Department of Labor: <http://www.bls.gov/cpi/home.htm>.

this is necessarily an inexact measure, and valuations are not definitive, the approach provides an estimate of baseline ecosystem service values and a good comparative index of the relative value (and cost) of various management alternatives.

1.2.3 Study Limitations

As mentioned throughout this document, this study provides a limited, baseline estimate of the ecosystem values of the Maury Island area. No primary research was done for this study. Ecosystem goods and services values were obtained from peer-reviewed published literature and information from unpublished studies, reports, or documents was not incorporated into this study. A great deal of information about natural resources, such as eelgrass, geoducks or clams, is contained in this unpublished literature.

Little direct research has been done in the Puget Sound area, so this study relied upon estimated values transferred from studies from outside the region.

Because the study relied upon the primary research of others, it was not possible to include all of the elements of the environment that would be relevant to the Maury Island ecosystem. Table 5 below shows the value estimates that were and were not available for this study. For example, there is no value estimate for soil retention and formation for the Forest land cover, although one would expect that this is a valuable ecosystem service of forests.

In some instances, these missing value estimates can be expected to have a major effect on the overall value of a land cover type. For instance, Table 6 shows that Beaches near Dwellings and Beaches are the two highest value land covers. The value of beaches is based solely on recreational values and would probably be much higher if there were ecosystem value estimates for soil retention and formation similar to the $48,500 value shown for the Beaches near dwellings classification.

Estimating the development to be allowed within the 200’ shoreline zone regulated by the Shoreline Management Act was beyond the scope of this study and the simplifying assumption was made that development would not occur within this area.

1.3 Valuation of Development Scenario Losses

The two loss valuation scenarios presented below in Section 3 are intended to estimate the potential short- and long-term loss of ecosystem goods and services associated with Maury Island ecological resources under different development scenarios. This task builds on earlier work described in Section 2.0 and, in addition, incorporates methodologies developed for federal natural resource damage assessment cases and habitat equivalency analysis.

This task is similar to a type of analysis that could occur if there was a specific event that damaged ecological resources, such as the release of a regulated toxic substance into the Maury

Island ecosystem. If such an event occurred, and if the event injured the ecosystem (i.e., caused the provision of fewer goods and services than it would have in its original state), then the trustee of the environment (i.e., the state or federal governments) could sue the responsible party for lost public values under CERCLA as defined by 43 CFR Part 11 (1996). The trustee could analyze the affected area, determine the total lost use values caused by the release of the substance into the ecosystem, and pursue recompense from the responsible party. Current federal law allows trustees to pursue losses from the time of injury until the resource recovers fully, or in the case of permanent injury, in perpetuity. The methodology used for this study was similar. Losses that would occur would be predicted, based on a defined scenario, from the moment of injury until the presumed recovery point, or in perpetuity, in the case of permanent losses. Because loss scenarios are not always instantaneous but can develop over a period of time (such as a phased land use action), the calculation of expected damages can reflect this timing.

This task involves three primary phases of analysis: the scenario definition, the GIS analysis, and natural resource damage assessment analysis. These phases are described in greater detail below.

1.3.1 Scenario Definition

Arguably the most important part of this task is the scenario definition phase. At present, there is not a “real-world” disturbance of, or release of a toxic substance into, the environment to be analyzed. Thus, the development disturbance and the associated changes to the ecosystem had to be defined collaboratively by King County staff and the project team. Through meetings, and joint review of environmental documents and reports, the following scenario parameters were defined:

- Geographic area of the disturbance
- Ecosystem goods and services provided by the disturbed area
- Magnitude of the disturbance
- Spatial distribution of the disturbance and associated ecosystem service losses
- Temporal duration of the disturbance and associated ecosystem service losses.

In combination, these attributes form the basis of a detailed scenario on which to base the loss scenario analysis.

1.3.2 GIS and Ecological Economics Analysis

Technological advances in computer hardware and GIS software have enabled a rapid growth in GIS applications of environmental management (Eade and Moran 1996; Kreuter et al. 2001). The growth of GIS applications has paralleled the development and use of economic valuation methods for ecosystem services. In this report, the valuation estimates drawn from the NaturalAssets Database® were merged with information derived from Land Remote-Sensing Satellite (LANDSAT) derived land cover imagery projected in GIS layers to yield spatially explicit economic values of the Maury Island landscape.

Aggregated, global measures of ecosystem services (see Costanza et al. 1997), while useful as approximations of the importance of ecosystem goods and services, can actually obscure the heterogeneous nature of the underlying ecological structures and functions that provide those services and provide misleading results. For instance, an aggregate measure of ecosystem services at the national level may indicate significant amounts of a land cover type associated with water storage and retention, such as wetlands. This measure does not tell us, however, whether those cover types are distributed evenly throughout the nation or are all clustered in one region. Obviously, those two possibilities have significantly different ramifications for resource use and landscape management. Not only does a clustered pattern of wetlands imply that some regions have more wetlands than others, but it also means that the social cost of losing one wetland is much higher in the areas of scarcity than in the areas of clustering.

For this project, ecosystem service valuations were made spatially explicit by disaggregating the Maury Island landscape and its nearshore environment into constituent land cover types at the parcel scale (i.e., individual land parcels were identified and associated ecosystem service values estimated). This kind of spatial disaggregation greatly increases the potential for management applications of ecosystem service valuation by allowing decision-makers to map and visualize the explicit location of ecologically important landscape elements and overlay them with the ecosystem services that people value. Disaggregation is also important for descriptive purposes, for the pattern of variation is often much more telling than any aggregate statistic. The land cover classes for Maury Island are presented below in Table 2.

By mapping land covers and their associated ecosystem services throughout the Maury Island site, the project team identified areas where there is scarcity or abundance of a service-yielding cover type. Projecting this information into the future, the research team used GIS information and the future scenarios to transform these descriptions into map equivalents. The NaturalAssets Database®-GIS analysis shows the hectares of different ecosystem goods and services in any particular area and how many hectares would suffer a complete or partial loss of the provision of these services for the development alternatives. At the same time, the results from the determination of existing conditions show the monetary value of the ecosystem goods and services provided by each ecosystem type. This data was then transferred to spreadsheets for analysis.

1.3.3 Development Scenario Loss Analysis

Figure 3 shows graphically how lost ecosystem services are valued across time. The purpose of the analysis is to quantify the loss from the time the site is developed until the resources recover, or if the resources are not expected to recover, to a specific point in the future. The same measures of lost service values and discounting methodology were therefore used for the two development scenarios.

Table 2. Maury Island land cover.

Study Land Cover Classes	Description
1. Forest	1. Conifer Forest 2. Deciduous Forest 3. Mixed forest
3. Open Grassland/Herbaceous	4. Shrubs 5. Herbaceous vegetation/ grass
3. Beach	6. Beach—area between MHHW and MLLW
5. Beach near dwellings	7. Beach proximate to dwellings [a]
6. Freshwater	8. Open inland water
7. Freshwater Wetland	9. Wetland-fresh palustrine shrub 10. Wetland-fresh palustrine forested or emergent 11. Wetland-fresh palustrine, permanently flooded open water and rooted vascular plants
8. Saltwater Wetland/Marsh	12. Unconsolidated shore, Regularly flooded
9. Coastal Riparian	13. 200 foot area inland from MHHW
10. Estuarine Nearshore Habitat	14. Intertidal salt estuaries 15. Estuarine, Intertidal, Aquatic bed, Algal 16. Stream mouths
10. Non-Estuarine Nearshore Habitat	17. Sea Cucumber habitat 18. Geoduck habitat 19. Herring Spawning ground 20. Salmon rearing ground
11. Nearshore Open Water	21. Open salt water within study boundary
11. Developed	22. Urban/impervious/degraded

[a] Beaches near residences provide aesthetic benefits to residents and have a higher value than beaches that are located away from residences.

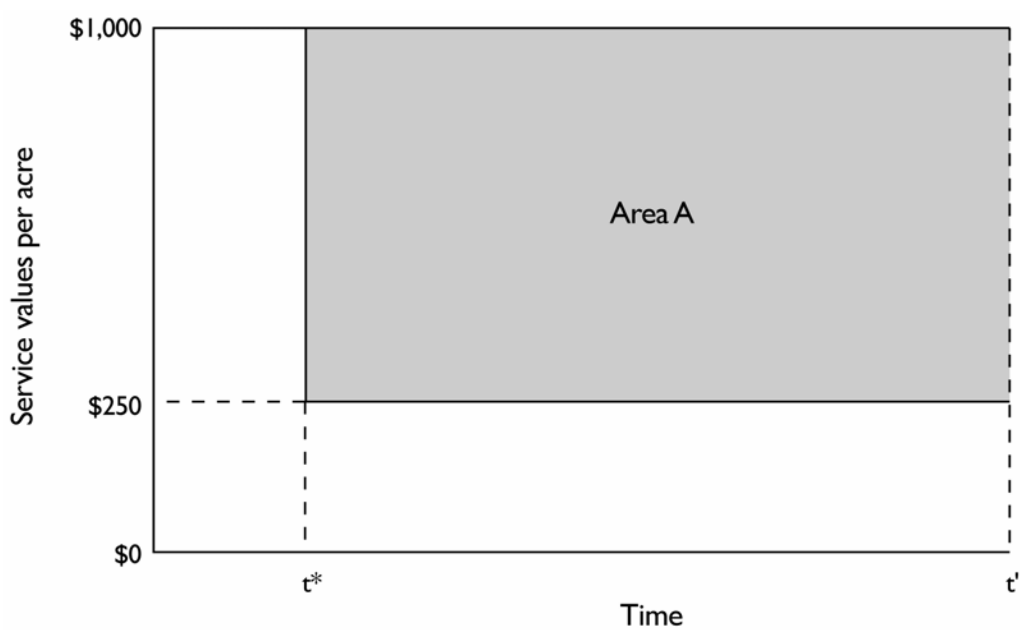

Figure 3. Lost service definition—permanent injury.

In Figure 3, there is an ecosystem that provides services worth $1,000 per year per hectare. Assume that the ecosystem is one hectare and that in year t* a disturbance occurs which injures the ecosystem. The injury results in a 75 percent reduction in the value of services provided per hectare (represented by Area A). This injury would reduce service values to $250 per hectare per year and is a permanent injury (i.e., the resource does not recover). Thus, the loss per year, in constant dollars, is $750 from the entire ecosystem or $15,000 over a twenty-year period. Area A represents these losses over a twenty-year period from t* to t', where t* equals year 1 and t' equals year 20. If it is assumed that there is a 3.5 percent discount rate, then this amount is equal to $9,814 in year t* dollars. A discussion of discount rates is provided below in Section 3.1.1. Table 3 details these calculations on a year-by-year basis with t*=1 and t'=20.

Table 3. Example of Discounted Lost Ecosystem Services Analysis-Permanent Injury (all values are in constant (year T(o)) dollars).

Year	Uninjured Value of Provided Services	Injured Value of Provided Services	Annual Value of Lost Services	Present Value of Lost Services
0	$1,000	$1,000	$0	$0
1 (t*)	$1,000	$250	$750	$750
2	$1,000	$250	$750	$714
3	$1,000	$250	$750	$680
4	$1,000	$250	$750	$648
5	$1,000	$250	$750	$617
6	$1,000	$250	$750	$588
7	$1,000	$250	$750	$560
8	$1,000	$250	$750	$533
9	$1,000	$250	$750	$508
10	$1,000	$250	$750	$483
11	$1,000	$250	$750	$460
12	$1,000	$250	$750	$439
13	$1,000	$250	$750	$418
14	$1,000	$250	$750	$398
15	$1,000	$250	$750	$379
16	$1,000	$250	$750	$361
17	$1,000	$250	$750	$344
18	$1,000	$250	$750	$327
19	$1,000	$250	$750	$312
20 (t')	$1,000	$250	$750	$297
Total	$21,000	$5,750	$15,000	$9,814

Assume that the ecosystem experiences the same disturbance, with the injury resulting in a 75 percent reduction to $250 per hectare per year in the value of ecosystem goods and services. However, this time the ecosystem begins to recover at a rate that will return it to its pre-disturbance condition in 20 years. Assuming a linear recovery of ecosystem services, Area B in Figure 4 represents these losses over a twenty-year period from t* to t'. The non-discounted total loss is equal to $9,059. The loss amount is less than in the previous example because of the natural recovery of the area. If it is assumed that the same 3.5 percent discount rate is used, then this amount is equal to $7,015 in year t* dollars.

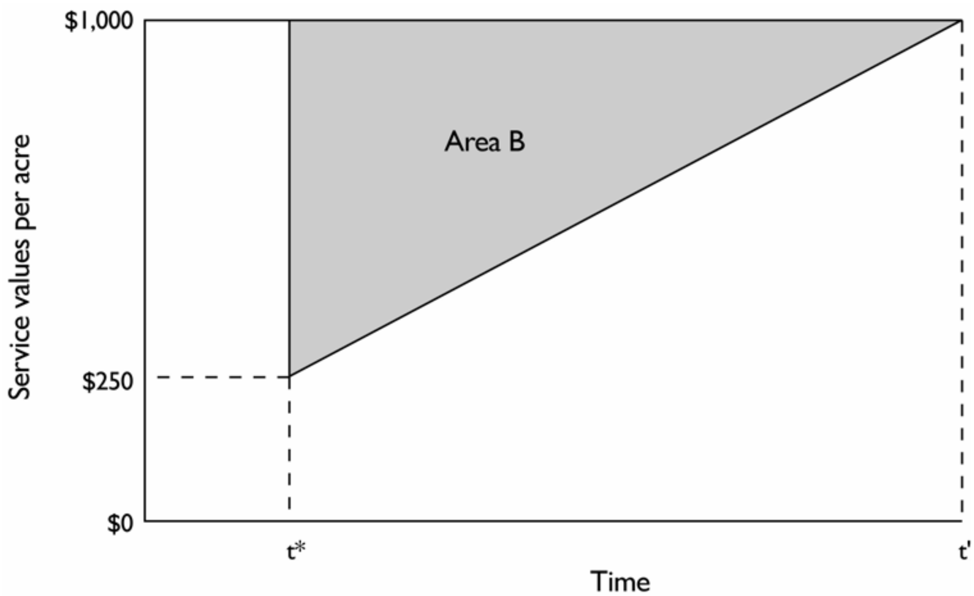

Figure 4. Lost service definition—natural recovery.

Table 4 details these calculations on a year-by-year basis with t*=1 and t'=20 under a situation where there is natural recovery of the ecosystem.

Table 4. Example of discounted lost ecosystem services analysis—natural recovery (all values are in constant dollars).

Year	Uninjured Value of Provided Services	Injured Value of Provided Services	Value of Lost Services	Present (discounted) Value of Lost Services
0	$1,000	$1,000	$0	$0
1 (t*)	$1,000	$250	$750	$750
2	$1,000	$269	$731	$731
3	$1,000	$289	$711	$677
4	$1,000	$311	$689	$625
5	$1,000	$335	$665	$574
6	$1,000	$361	$639	$526
7	$1,000	$388	$612	$480
8	$1,000	$417	$583	$435
9	$1,000	$449	$551	$391
10	$1,000	$483	$517	$350
11	$1,000	$520	$480	$309
12	$1,000	$560	$440	$270
13	$1,000	$602	$398	$233
14	$1,000	$648	$352	$196
15	$1,000	$697	$303	$161
16	$1,000	$750	$250	$126
17	$1,000	$807	$193	$93
18	$1,000	$868	$132	$60
19	$1,000	$934	$66	$29
20 (t')	$1,000	$1,000	$0	$0
Total	$21,000	$11,941	$9,059	$7,015

The analysis in Section 3 will follow these examples. The scenarios are defined to the greatest extent practical, using GIS analysis to determine the total hectares affected by ecosystem goods and services, and then using an appropriate discount methodology to estimate the potential losses associated with the scenarios.

2. Values of Existing Conditions

2.1 Ecosystem Goods and Services

2.1.1 Introduction

The primary intent of the Maury Island Ecological Economic Evaluation is to focus on the nearshore along the southeast portion of the island. The entire island has been included in the analysis, however, in order to provide a more complete picture of the economic values associated with Maury Island ecological resources, and therefore a more useful point of comparison for evaluating possible development loss scenarios. This document includes a detailed discussion of nearshore ecological resources and a cursory discussion of the terrestrial ecosystem. Additional information about the terrestrial ecology of Maury Island is available in Chapter 5 of the Maury Island Glacier Northwest Gravel Mine Final Environmental Impact Statement (King County 2000).

The scope of this study spans from the uplands of Maury Island to the nearshore zone. The nearshore zone extends from 200 linear feet inland from the shoreline to the lower limit of the photic zone in the subtidal area. For the purpose of this study, the nearshore zone encompasses the zone wherein direct functional interactions (e.g., sediment supply, nutrient input) occur between the upland aquatic interface (i.e., the riparian zone) and the marine habitats (William and Thom 2001; Williams et al. 2001). Hence, the nearshore environment extends landward to include coastal landforms such as coastal bluffs, the backshore, sand spits and coastal wetlands, as well as marine riparian zones on or adjacent to any of these areas. In addition, the nearshore environment includes subestuaries such as the tidally influenced portions of stream mouths (Williams et al. 2001). The Washington State Shoreline Management Act defines the upland edge of the management area/zone for marine shorelines to be 200 feet landward of OHWM (see RCW 75.20).

Marine plant and animal assemblages in the nearshore along Maury Island are primarily distributed along substrate types, depth, and salinity. Wave or current energy gradients also influence the functional outcome and distribution of species within the natural communities of Maury Island. Terrestrial plant and animal assemblages are primarily distributed by vegetative cover and tolerance for human contact and disturbance. A natural community can then be defined as a distinct and recurring assemblage of plants and animals naturally associated with each other and with a particular physical environment (Dethier 1990) in either terrestrial or aquatic environments.

Appendix B assesses the plant and animal assemblages that are known or assumed to inhabit the Maury Island project area.

2.1.2 Methodology

Existing ecological systems (i.e., ecosystems) and natural resources within the study area were identified and characterized by first identifying the existing nearshore habitats, reviewing natural resource inventory data available and then describing expected natural resources (i.e., species) given the available habitat, as a function of the ecological processes controlling their assemblages. The characterization of the physical attributes of the aquatic nearshore habitats as well as the identification of factors controlling plant and animal distribution in estuarine and nearshore marine habitats were based on *A Marine and Estuarine Habitat Classification System for Washington State* (Dethier 1990). This system builds on the U.S. Fish & Wildlife Service's National Wetland Inventory system (Cowardin et al. 1979), with modifications to relevant marine and estuarine systems. In addition, the estuarine Habitat Assessment Protocol (Simenstad et al. 1991) was used to identify functions and characteristics of the estuarine and nearshore marine habitats.

2.1.2.1 Identification of the Existing Nearshore Zone Habitats

For the purpose of this study, the characterization of the ecological attributes of marine riparian areas where based on *Marine Riparian: An Assessment of Riparian Functions in Marine Ecosystems* (Brennan and Culverwell In Press).

The characterization of the physical attributes of the aquatic nearshore habitats as well as the identification of factors controlling plant and animal distribution in estuarine and nearshore marine habitats were based on *A Marine and Estuarine Habitat Classification System for Washington State* (Dethier 1990). This system builds on the U.S. Fish & Wildlife Service's National Wetland Inventory system (Cowardin et al. 1979), with modifications to relevant marine and estuarine systems. In addition, the estuarine Habitat Assessment Protocol (Simenstad et al. 1991) was used to identify functions and characteristics of the estuarine and nearshore marine habitats.

In the Puget Sound, many areas are difficult to categorize as either estuarine or marine. On one hand, marine systems encompass all coastal areas not appreciably diluted by freshwater which includes open coastal areas, straits, and euhaline inland waters. Marine systems can extend from the outer edge of the continental shelf to: 1) the landward limit of tidal inundation or wave splash or 2) the seaward limit of the estuarine system (Dethier 1990).

On the other hand, estuarine systems generally consist of water that is semi-enclosed by land but have open, partly obstructed, or sporadic access to the ocean, and which seaward is at least occasionally diluted by freshwater runoff from land. Estuarine systems include river-mouth estuaries, lagoons, and large bodies of water such as Puget Sound.

Due to its relative location in the Puget Sound area, its configuration in relation to Vashon Island, and local drift cell and local fetch, Maury Island can be characterized as having a nearshore zone with marine characteristics along the eastern side of the island and a nearshore zone with estuarine characteristics in Quartermaster Harbor along the western side of the island.

The type and characteristics of the Maury Island nearshore habitats as well as the ecological processes and species assemblages differs somewhat from the eastern to the western side of the island.

The existing nearshore zones of the shoreline of Maury Island were identified (study area). This included the nearshore habitats (and their communities) that are located from the riparian to the shallow subtidal zones, as follows (adapted from Dethier 1990, Williams et al. 2001, Kosloff 1983, and Ricketts and Calvin 1968):

- The marine riparian zone, extending landward from the toe of the bluff or bank to approximately 200 horizontal feet into Maury Island
- The supratidal zone, extending from the mean higher high water (MHHW) to the toe of the bluff or bank (i.e., backshore area)
- The eulittoral zone (intertidal), extending from the mean lower low water (MLLW) to the MHHW
- The shallow subtidal zone, extending from 15 meters (below MLLW) to the MLLW.

Not all segments of the Maury Island shoreline are characterized by having a bluff as part of their coastal geomorphic configuration. In addition, the supratidal area and banks or bluffs can be considered part of the riparian zone. Therefore, for the purpose of this study, the natural resources and ecological systems that occur in these two zones (i.e., riparian zone and supratidal zone) were included into one category: riparian and supratidal zone. The other zones were described individually.

2.1.2.2 Review of Available Data – Assessment of Documented Species

Several nearshore data sources and literature were reviewed to assess information on the documented presence and generalized characterization of the habitat types and species on the eastern shoreline of Maury Island.

The literature review was also used to assess potential habitat utilization by those species that have not been documented in the study area, or for which no habitat utilization data were found.

The following key documents were reviewed and extensively used in this study:

- Reconnaissance Assessment of the State of the Nearshore Report Including Vashon and Maury Islands (WRIAs 8 and 9; King County 2001)
- The Washington State Shore Zone Inventory (WDNR 2001)
- Oblique Aerial Photography (WDOE 1993)

- Vertical Aerial Photograph (King County 1998)
- Marine Shoreline Inventory Report WRIA 9 (Anchor 2004)
- *Marine Riparian: An Assessment of Riparian Functions in Marine Ecosystems* (Brennan and Culverwell In Press)
- A Marine and Estuarine Habitat Classification System for Washington State (Dethier 1990).

2.1.2.3 Characterization of the Natural Resources and Assessment of Expected Species

Nearshore zone habitats were characterized first, by identified nearshore zone, and then by habitat type. Expected species per habitat type were assessed through the results of the data and literature review and the analysis of available habitat as a function of the ecological processes controlling the species assemblages. Lists of expected (assumed) species were summarized in tables based on habitat availability analysis (see Appendix B).

2.1.3 Characterization of the Natural Resources by Ecological System

The study area is located on Maury Island (next to Vashon Island), Puget Sound in King County, Washington. Following is a discussion of the natural resources associated with the nearshore zone that were identified in Maury Island within the study area.

2.1.3.1 Marine Riparian and Supratidal Zone

The riparian and supratidal zone include the riparian habitats in the upland areas as well as the habitat associated with the backshore area above MHHW along the shoreline. The Washington State Shoreline Management Act defines the upland edge of the management area/zone for marine shorelines to be 200 feet landward of OHWM (see RCW 75.20). Therefore, for the purpose of this study the nearshore area extends to approximately 200 horizontal feet into Maury Island from the toe of the bluff or bank.

The following habitat types occur within this zone.

2.1.3.1.1 Marine Riparian Habitats

Marine riparian habitats occur at the interface between terrestrial and aquatic ecosystems. In undisturbed areas, they are often characterized by dense vegetation that may include willow (*Salix* spp.), red alder (*Alnus rubra*), black cottonwood (*Populus trichocarpa*), roses (*Rosa* spp.), and Douglas spirea (*Spirea douglasii*) (Williams et al. 2001). Marine riparian habitats in the upland areas along the shoreline likely provide some of the same functions that freshwater riparian areas provide (Desbonnet et al. 1994) as well as additional functions unique to nearshore systems (Brennan and Culverwell In Press). Riparian vegetation improves the quality of aquatic habitats by increasing slope stability, providing erosion protection (Myers 1993; Manashe 1993; Broadhurst 1998), and buffering against pollution and sediment runoff (Federal Interagency Stream Restoration Working Group 1998). Overhanging riparian vegetation provides shading that regulates microclimates important to intertidal surf smelt spawning (Penttila 2001). Overhanging vegetation also plays an important role in invertebrate habitat utilization because in exposed areas, solar radiation/desiccation limits the invertebrate distribution in the upper beach area (Foster et al. 1986). Marine riparian vegetation also provides prey input from shoreline vegetation, and large woody debris (LWD) recruitment that provides roosting, nesting, foraging, spawning and attachment substrate for invertebrates and plants. LWD can also serve to stabilize beaches and help build berms and backshore areas (Brennan and Culverwell In Press).

The marine riparian zone provides the following ecological functions:

- Improvement/protection of water quality
- Bank and bluff stability
- Soil and slope stability
- Sediment control
- Microclimate and shade
- Wildlife habitat
- Nutrient input
- Fish prey production
- Habitat structure (e.g., LWD)
- Substrate for riparian vegetation and associated functions.

2.1.3.1.2 Backshore, Banks, and Bluffs Habitats

Banks and bluffs are typically steeply sloping areas located between the intertidal zone and the upland. Banks and bluffs can be comprised of sediments of varying grain sizes, as well as rock and boulders. Bluffs provide sand and small gravel that support forage fish (Pacific sand lance, *Ammodytes hexapterus*, surf smelt, *Hypomesus pretiosus*), and rock sole (*Lepidopsetta bilineata*) spawning habitat. Other functions performed by banks and bluffs include providing protection to uplands, sediment supply to beaches (Macdonald et al. 1994), habitat for bluff-dwelling animals (including nesting birds), and groundwater supply into estuarine and marine waters. These habitats are maintained by the dynamics of several forces including wave energy, surface runoff, and stabilizing vegetative cover (Macdonald et al. 1994; Myers 1993; Manashe 1993).

The backshore area can provide sand storage, and in areas where the coastal geomorphology includes the presence of a bluff, the backshore area is a point of entry for sediment into the system. Indeed, outside of delta regions, in Puget Sound the major source of sediment to the shores is likely the coastal bluffs. According to the Washington State Department of Ecology, almost 621 miles of coastal bluff in Puget Sound experience shallow land sliding (Shipman 2001).

In addition to sand, LWD generally accumulate in the backshore areas at extreme high tides, and can help stabilize the shoreline (Zelo et al. 2000; Macdonald et al. 1994). Although not well documented in marine systems, LWD provides structurally complex roosting, nesting, refuge, and foraging opportunities for wildlife; foraging, refuge, and spawning substrate for fishes; and foraging, refuge, spawning, and attachment substrate for aquatic invertebrates (Brennan and Culverwell In Press). Logs imbedded in beaches also provide a source of organic matter, moisture, and nutrients that assist in the establishment and maintenance of dune and marsh plants (Williams and Thom 2001).

Backshore areas, banks, and bluffs provided the following ecological functions:

- Upland protection
- Sand and LWD storage and associated functions
- Source of sediment to beaches
- Habitat for bluff-dwelling animals
- Substrate for riparian vegetation and associated functions
- Canopy cover and shade for the upper intertidal and supratidal zones
- Source of groundwater seepage into the estuarine and marine waters.

2.1.3.1.3 Tidal Marsh Habitat

Tidal marshes include salt and freshwater marsh habitats that experience tidal inundation. Marshes accrete sediment and organic matter and thereby build land both upward and outward. They are maintained primarily by adequate hydrology as well as sediment supply (Williams et al. 2001).

Salinity affects saltmarsh plant species composition and the lower limits of distribution. In addition, surface (river and stream channel) and ground water (seepage) discharge influence salinity, thereby influencing plant species composition and distribution (Williams et al. 2001).

Common tidal marsh plants of Washington include lyngby's sedge (*Carex lyngbyei*), salt grass (*Distichlis spicata*), Baltic rush (*Juncus balticus*), American three-square bulrush (*Scirpus americanus*), maritime bulrush (*S. maritimus*), arrowgrass (*Triglochin maritimum*), tufted hairgrass (*Deschampsia caepitosa*), pickleweed (*Salicornia virginica*), Pacific silverweed (*Potentilla pacifica*), red fescue (*Festuca rubra*), and common reed (*Phragmites* sp.) (Simenstad 1983; Simenstad et al. 1991; Dethier 1990). According to Thom (1981), primary production rates for regional tidal marshes range from 529 to 1,108 g C m^{-2} yr^{-1} (grams of carbon/m^2 /year). Juvenile salmon have been shown to reside in tidal marshes and exhibit substantial growth while foraging on prey resources both produced in, and imported to, the marsh system (Shreffler et al. 1992; Simenstad and Cordell 2000).

General tidal marsh functions encompass those commonly listed for wetlands, which include (Simenstad 1983; Simenstad and Cordell 2000; Williams et al. 2001):

- Primary production
- Juvenile fish and invertebrate production support
- Adult fish and invertebrate foraging

- Salmonid osmoregulation and overwintering habitat
- Wildlife support
- Groundwater recharge
- Nutrient cycling
- Detrital food chain production
- Wave buffering
- Flood attenuation
- Water quality.

2.1.3.1.4 Stream Mouth (Subestuaries)

Subestuaries are those areas of river and stream mouths that experience tidal inundation, including their deltas and any associated marshes. Here, fresh and saltwater mix, providing a range of salinities. In these subestuaries areas, streams broaden thus attenuating localized flooding. Often subestuaries are associated with wetlands, which further slow peak flows (Williams et al. 2001).

Mouths of streams and creeks may develop geomorphically as a result of sediment transport. In protected bays, freshwater and saltwater are stratified in the water column at the river mouth, providing a means for sediment to settle out of the river plume thus contributing to the formation of deltas. This process also forms the mud shoals and tidal flats that exist at the heads of protected bays. Like marshes, subestuaries provide juvenile salmonid rearing and feeding areas, can support eelgrass beds if salinities are high enough, and provide refuge, feeding, and production areas to a wide variety of birds, fish, mammals, invertebrates, and reptiles (Williams et al. 2001).

The following list highlights functions typically associated with subestuaries:

- Floodwater attenuation
- Critical transition areas for anadromous salmonids
- Water quality improvement
- Rearing areas for juvenile salmonids and other estuarine dependent species of fish and wildlife
- Support to eelgrass
- Refuge for multiple species.

2.1.3.2 Intertidal Zone

The intertidal (eulittoral) zone extends from the mean lower low water (MLLW) to the MHHW. The following habitat types occur within the intertidal zone (adapted from Dethier 1990 and Simenstad et al. 1991).

Benthos habitat provides substrate and support to a variety of plant and animal species that occur in or on the substrate. For the purpose of this study, benthos habitat is assumed to be included within other habitat types discussed in this report and therefore is not discussed separately.

2.1.3.2.1 Cobble, Gravel, and Sand Substrate Habitat

A number of fishes, including forage fish such as surf smelt and sand lance spawn on mixed sand-gravel Puget Sound habitats (Pentilla 1995; Lemberg et al. 1997). Shorebirds are commonly observed feeding on invertebrates produced on these habitats (Herman and Bulger 1981). Two species of algae, *Ulva* spp. and *Fucus gardneri*, predominate on this habitat either attached to cobble (primarily *Fucus gardner*) or free-floating in viable patches deposited along the beach (*Ulva* spp.). The production rates of these seaweeds on cobble shorelines can be as high as eelgrass meadows (Thom et al. 1984). Bivalve production is often high on cobble and gravel beaches where adequate organic matter deposition occurs.

Cobble, gravel, and sand habitats provide the following functions:

- Substrate for algae, macroinvertebrates, and fish
- Surf smelt and sand lance spawning habitat
- Food for bird species.

2.1.3.2.2 Eelgrass/Macroalgae Habitat

Green and red species of macroalgae can occur in close association with eelgrass meadows (see Dethier 1990 for characterization of species distribution) and can provide similar ecological functions to a variety of marine species (Simenstad et al. 1991). Therefore, for the purpose of this study, eelgrass and macroalgae species (with the exception of kelps which are discussed separately later in this report) are considered under one habitat category; eelgrass/macroalgae habitat.

Eelgrass beds typically occur in protected areas characterized by shallow, semi-enclosed embayments with low to moderate energy beaches. These environments allow for the accretion and stabilization of mud and sandy-mud (i.e., mudflat habitats), sand, mixed fine gravels, and the colonization of eelgrass. The stable substrates of these protected environment provide rich benthic infaunal and epibenthic communities and provide prey resources for juvenile fishes seeking protection in the eelgrass beds (Simenstad et al. 1979). The provision of shelter, food, and current mediation account for much of the diversity and production of eelgrass habitats (Simenstad 1994). Eelgrass habitats serve as nursery and migratory corridor for many of salmonids and other fish species, and provides a number of widely recognized and valued functions, including primary production, nutrient processing, wave and current energy buffering, organic matter input, habitat for fish and invertebrates, and food for birds (Phillips 1984). This habitat plays a role in the life cycle of Pacific salmon (*Oncorhynchus spp.*) and Pacific herring (*Clupea harengus pallasi*) as well as other commercially important species.

Eelgrass forms small patches to large meadows in the low intertidal and shallow subtidal zones. Its productivity can equal or exceed the productivity rates of most other aquatic plants, with rates reported in the Pacific Northwest ranging from 200 to 806 g C m^{-2} yr^{-1} (Thom 1984, Kentula and McIntire 1986; Thom 1990). Organic carbon produced by eelgrass can enter the food web through the microbial decomposition and processing of both particulate and dissolved eelgrass materials. This organic matter has been shown to be incorporated in the diet of fish and other marine animals including juvenile salmon (Simenstad et al. 1988).

The eelgrass shoots, stems, and leaves serve to increase the substrate available for epiphytic algae and associated fauna. They also reduce wave and current action, trap sediments and detritus, and maintain high dissolved oxygen concentrations through photosynthetic activity. Through shading at low tides, the eelgrass also minimizes temperature fluctuations that would otherwise occur with direct sunlight. The detritus resulting from eelgrass dieback provides detrital carbon energy directly to important detritivores such as harpacticoid copepods, gammarid amphipods, and isopods and indirectly to those carnivores preying on benthic organisms (Simenstad et al. 1979).

Macroalgae serve many of the same habitat functions as eelgrass (Simenstad et al. 1991), but are adapted to many different substrates and depth ranges depending upon the species. Macro algae can typically grow on hard substrates (natural rock, riprap and cobble) in the lower intertidal and shallow subtidal zones, within, above, and below the tidal elevation where eelgrass occur. In addition, macroalgae can grow in close association with eelgrass. Macroalgae habitats play a role in the life cycle of Pacific herring and likely in other commercially important species.

Eelgrass/macroalgae habitat provides the following main ecological functions:

- Primary production
- Nutrient processing
- Organic mater input
- Wave and current energy buffering
- Sediment trapping
- Habitat for fish and invertebrates,
- Substrate for macro algae species
- Food for bird species.

2.1.3.3 Shallow Subtidal Zone

The shallow subtidal zone extends from 15 meters (below MLLW) to the MLLW. Because there are few distinct transitions with depth among subtidal assemblages, the cutoff is to some extent arbitrary. Although precise lower limits vary with site, water clarity, and season, according to Dethier (1990), in the Puget Sound most brown macro algae (kelps) do not occur below this depth (i.e., 15 meters below MLLW), and primary production generally is reduced.

The following habitat types occur within the shallow subtidal zone.

2.1.3.3.1 Eelgrass/Macro Algae Habitat

Eelgrass habitats of the eastern shoreline of Maury Island occur in both the intertidal and subtidal zones (see above for description and functions).

Kelp Habitat—Kelp habitats are predominantly subtidal habitats. Kelps are the largest member of brown algae in the Pacific Northwest and may form large forest that provide three-dimensional habitat for a variety of marine and estuarine species. One of the most important kelp species is the bull kelp. Bull kelp (*Nereocystis luetkeana* (Mertens) P. & R.) is a brown alga that forms small patches to large forests in the shallow subtidal zone in Puget Sound and contributes important primary production to pelagic and nearshore food webs. Its complex structure also provides refuge and feeding habitat for fishes (especially rockfishes (West et al. 1995, Buckley 1997), spawning substrate for herring, and buffering of wave and current energy (Duggins 1980; Harrold et al. 1988; Jackson and Winant 1983). In addition to fish species, many invertebrates such as crabs, snails, bryozoans, sponges, tunicates, anemones, and shrimp use the blades as living habitat. Seasonal fluctuations are prominent in this habitat, particularly those associated with the annual die-off macroalgae (Simenstad et al. 1979)

Kelp habitat provides the following main ecological functions:

- Primary production
- Habitat for fish, particularly rockfish, but also salmon species
- Habitat for invertebrates
- Contribute to pelagic food webs through particulate and dissolved carbon
- Herring spawning substrate
- Wave and current energy buffering
- Extraction of chemical for commercial use
- Food supply for human consumption.

2.2 Current Socioeconomic Conditions

The economic value of the goods and services provided by the Maury Island ecosystem are not created in a vacuum. They are best appreciated in the context of not only the ecological conditions in the study area, but also the human (e.g., socioeconomic) conditions within which these values arise. For, as an ecological economics perspective reminds us, it is at the interface between human and natural systems where conflict and change often occurs. Ecological conditions are very often influenced by human activity and underlying socioeconomic conditions and factors. For example, coastal areas are generally subject to intense development pressures by humans and the ecological conditions within such areas would be very different if humans were not interested in living or doing business there. Even within the broad scope of human activities along the coastline, there is a similarly wide range of potential impact to the coastal system. For example, ecological conditions would be very different on Maury Island if the human community consisted of a single, small, high-density development on the island with the rest of landscape in "pristine" conditions than if the whole island was in industrial or agricultural use. This section describes the current socioeconomic conditions on the island in order to provide an appropriate context for understanding the economic values of ecosystem goods and services at Maury Island.

2.2.1 Summary of Socioeconomic Conditions

Maury Island is a unique area within King County, Washington. It is a relatively rural island that has experienced a fairly low level of urban development, due to its location and available resources, particularly the limited water supply. Instead it has attracted retirees, and an affluent working population, desiring the rural island setting, and an alternate location to that which is typically available in the Seattle and the urban Puget Sound region.

The majority of the Maury Island working population commutes the relatively long distance to a work location within King County (approximately 60 percent), while a smaller but substantial proportion works from home (over 14 percent). The "work-at-home" portion of the population is three times higher on Maury Island that it is in surrounding counties. The island also has a significant portion of the population that is not involved in the labor force. Nearly one-third of island residents are not in the labor force. This percentage is much higher than the portion of the King County's population that is not in the labor force. Based upon the age structure of the island, the analysis indicates that many of these people who are not in the labor force are retirees.

When compared to King and Kitsap counties in general, Maury Islanders have a higher education level, higher income levels, and higher housing values than the average values for King or Kitsap Counties. These attributes are generally indicative of a population that has the time and resources to spend on issues related to the local environmental and ecological setting. This assessment has been born out by the public's involvement in the crafting of environmental impact statement for the Glacier Northwest Gravel Mine. The public submitted many comments on the EIS with regards to the area's environmental, ecological, and recreational attributes. The analysis indicates that citizens of Maury Island will continue to be involved in the long-term stewardship of the island's cultural, environmental, and ecological resources.

A more detailed and complete analysis of the island's socioeconomic description can be found in Appendix C.

2.3 Descriptive Financial Valuation of the Nearshore and Terrestrial Ecosystems

Following the value-transfer approach outlined above in Section 1.2.2, the research team developed a set of decision rules for selecting empirical studies from the NaturalAssets® Database that allowed the research team to estimate the economic value of ecosystem goods and services at the Maury Island site for each specified land cover feature. The research team reviewed the literature contained within the database and selected those valuation studies that were:

- Peer reviewed and published in internationally recognized journals
- Focused on temperate regions in either North America, Canada or Europe
- Focused primarily on non-consumptive use.

The search yielded 43 viable studies that were used in this report (see Appendix A). The results are standardized to 2001 U.S. dollar equivalents to provide a consistent basis for comparison[8]. Economic values are further standardized to per hectare equivalents using information provided in the original studies as well as using supplementary information where needed. As Table 5 below shows, the end result was a data set containing 71 estimates for ecosystem goods and services distributed across the 10 land cover classes used in this report. Figure 5 shows the average ecosystem value per hectare by parcel.

Table 5. Coverage of value estimates for Maury Island site.

Landcover features	Climate and atmospheric reg.	Disturbance prevention	Water regulation and supply	Waste assmilation	Nutrient regulation	Soil retention and formation	Habitat Refugium	Food and raw materials	Recreation	Aesthetic and Amenity
	Ecosystem services									
Forest	●		●				●		●	●
Open Grassland	●		●	●		●			●	
Beaches						●			●	●
Beaches near dwellings									●	●
Freshwater			●				●		●	●
Freshwater Wetlands		●	●	●			●		●	●
Saltwater Wetlands		●	●	●					●	
Coastal Riparian		●	●	●		●	●		●	●
Nearshore Habitat							●	●	●	
Coastal Open Water					●			●	●	

● Economic estimates used in NaturalAssets® Value Transfer

The matrix of information depicted in Table 5 shows that several ecosystem service values have been estimated for different land cover classes on Maury Island but that currently, the state of knowledge for land cover/ecosystem service relationships is incomplete. In the matrix, closed circles represent ecosystem goods and services that have been empirically measured in the economic valuation literature and are included in this report. Open cells represent conditions where an economic value estimate was not found under our search criteria. This does not mean that there is no possible value for the specified land cover/ecosystem service relationship within the matrix, but rather that such values were not present under our restrictive search guidelines.

[8] Dollar values were standardized using Consumer Price Index (CPI) tables published by the U.S. Department of Labor: <http://www.bls.gov/cpi/home.htm>.

Given this limitation, the results presented in this report should be taken as conservatively low, baseline economic estimates that underestimate the true value of the ecosystem goods and services associated with Maury Island resources. These values can be modified as time progresses and more empirical estimates of specified land cover/service relationships are revealed[9].

Once the research team selected appropriate empirical valuation studies, inputted them into the NaturalAssets® Database and standardized the data to 2001 equivalents for value transfer, the project team then assigned the resulting ecosystem service value estimates to appropriate land cover categories. This required carefully establishing the spatial resolution and coverage of the original reported study site so that per hectare equivalents could be established. Following conventional practice in the value-transfer literature (see Costanza et al. 1997; Woodward and Wui 2001), the original study is carefully scrutinized and where necessary, supplemented with additional information, to derive the exact spatial extent of the original value estimate so that explicit per hectare equivalents could be determined. Since the area of original study is often limited to a specific site, the researcher is required to identify the spatial extent of the original site in question and then, limit the ecosystem values estimate to that site[10].

For example, value estimates from Breaux, Farber and Day (1995) were used in this report to estimate the economic benefits associated with waste assimilation capacity of coastal wetlands. In their original analysis, the authors describe the study site for replacement cost estimate of marginal productivity of coastal habitat as 2,860 acres of coastal wetlands in Dulac, Louisiana (p. 289). Using the 9 percent discount rate, the total annualized capital value of the ecosystem value surplus associated with wastewater assimilation capacity of saltwater wetlands are estimated to range from $121 million to $187 million per year. Using the spatial extent of the site as a divisor (2,860 acres), the average value waste assimilation capacity of saltwater wetland can then be estimated to range from a lower bound of $42.29 to $65.39 per acre per year, which converts to $104.45 to $161.51 per hectare per year in 1990 dollars. Adjusting for inflation, this converts to a range of $171.80 to $265.60 per hectare per year in 2001-dollar equivalents. These are the final figures used to estimate the waste assimilation value associated with saltwater wetland in Table 6 below.

Table 6 summarizes the value transfer results from the NaturalAssets® Database for ecosystem services grouped by land cover type. To generate these results, for each land cover type a lower bound and upper bound economic value for each ecosystem service was first estimated and then these values were used to calculate an average total dollars per hectare per year value estimate. The final summary results are shown in column 6 of Table 6. Comparing these economic estimates, it appears that beach areas represents the highest per-unit value of all represented land cover types on Maury Island. This finding is consistent with the economic valuation literature and can be explained by the large economic values associated with recreation and amenity values

[9] This information might be used by King County to prioritize research and funding for the primary data collection of nonmarket values that could be used to fill in the matrix, thereby increasing the coverage of the current state of knowledge.

[10] While spatial context and site information is increasingly being reported in the economic literature, this has not always been the case. As a result, some valuation studies are not able to be used in this type of analysis because they lack spatial specificity.

Table 6. NaturalAssets® Database economic value estimates for Ecosystem Services.

Land Cover	Ecosystem Service	# sources	Lower Bound	Upper Bound	Avg. Total $/yr/ha*
Forest	Climate and Atmospheric Reg	5	$484.80	$2,181.56	$1,333.18
	Water Regulation and Supply	1	$13.12	NA	$13.12
	Habitat Refugium	1	$2.44	$16.80	$9.62
	Recreation	3	$3.20	$923.02	$463.11
	Aesthetic and Amenity	1	$7.38	NA	$7.38
					$1,826.40
rassland/Herbaceous	Climate and Atmospheric Reg	1	$8.24	$8.24	$8.24
	Water Regulation and Supply	1	$3.53	$3.53	$3.53
	Waste Assimilation	1	$102.40	$102.40	$102.40
	Recreation	1	$2.35	$2.35	$2.35
	Soil Retention and Formation	1	$1.18	$1.18	$1.18
					$117.70
Beach	Recreation	1	$77,016.00	$99,391.00	$88,203.50
					$88,203.50
Beach near dwelling	Aesthetic and Amenity	2	$45,504.00	$92,004.50	$68,754.25
	Soil Retention and Formation	1	$48,500.00	NA	$48,500.00
					$117,254.25
Freshwater Stream	Water Regulation and Supply	3	$211.32	$938.32	$211.32
	Habitat Refugium	2	$594.96		$594.96
	Recreation	1	$424.60		$424.60
	Aesthetic and Amenity	1	$0.54	$0.68	$0.61
					$1,231.49
Freshwater Wetland	Disturbance Prevention	1	$15,389.00	NA	$15,389.00
	Water Regulation and Supply	1	$5.30	NA	$5.30
	Waste Assimilation	2	$9,384.50	$47,225.00	$28,304.75
	Habitat Refugium	1	$1,536.00	$44,700.00	$23,118.00
	Recreation	1	$1,137.00	NA	$1,137.00
	Aesthetic and Amenity	5	$5,495.19	$4,170.00	$4,832.60
					$72,786.65

Table 6. NaturalAssets® Database economic value estimates for Ecosystem Services (continued).

Saltwater Wetland	Disturbance Prevention	2	$353.00	$765.30	$559.15
	Water Regulation and Supply	1	$310.70	$908.70	$609.70
	Waste Assimilation	1	$171.80	$265.60	$218.70
	Recreation	2	$18.51	$32.83	$25.67
					$1,413.22
Coastal Riparian	Disturbance Prevention	2	$230.00	$504.08	$230.00
	Water Regulation and Supply	1	$395.30	$4,353.20	$2,374.25
	Waste Assimilation	1	$83.00	$368.00	$225.50
	Habitat Refugium	1	$2,657.14	$5,028.57	$3,842.85
	Recreation	2	$30.22	$131.80	$81.01
	Aesthetic and Amenity	1	$1,691.00	NA	$1,691.00
	Soil Retention and Formation	2	$456.21	$1,171.95	$814.08
					$9,258.69
Nearshore Habitat	Habitat Refugium	3	$239.80	$12,209.77	$239.80
	Recreation	3	$710.00	$12,045.23	$710.00
	Food and Raw Materials	4	$3,680.48		$3,680.48
					$4,630.28
Coastal Open Water	Nutrient Regulation	2	$720.62	$1,674.52	$1,197.57
	Recreation	4	$574.38	$226.96	$400.67
	Aesthetic and Amenity	1	$162.50	NA	$162.50
					$1,760.74
*** All estimates are standardized to $2001**					

Source: Spatial Informatics Group 2004.

associated with beach shoreline (see Kline and Swallow 1998). Interestingly, the data also show that the per-unit value of freshwater wetlands is also quite significant on the island. This is consistent with previous ecological economic analyses that reveal the numerous ecosystem services associated with healthy, functioning wetland systems (see Woodward and Wui 2001).

The coastal riparian and nearshore habitat results are also quite revealing. The coastal riparian zone appears to be a particularly important one for Maury Island in terms of the breadth of ecosystem services that it provides, resulting in an overall per-unit value of $9,395 per hectare per year. The per-unit value of nearshore habitat is also interesting because even though the value-transfer data were limited to three ecosystem service types, the per-unit value is quite significant at $16,282 per hectare per year. Given that the value-transfer for nearshore habitat in this report was restricted to non-market services provided, this economic estimate can be considered a conservative lower boundary and would likely be modified upward if market-based empirical estimates of specific nearshore species were included[11].

Taken together, the results presented here are best interpreted as an approximation of the economic value of ecosystem services provided by naturally functioning ecological systems at Maury Island. Very little direct economic valuation research has been conducted at the site to date and this report therefore turned to published, peer-reviewed data to extrapolate meaningful value estimates. Given these restrictive search criteria, the estimates presented above are reliable, conservative estimates of the total economic value associated with natural capital at Maury Island.

Table 7 below presents the Maury Island ecosystem service valuation summary, per hectare. The economic value of the 10 land cover classes used in this report vary from a low of $0 per hectare for Disturbed areas to $117,000 per hectare for Beaches that are located near dwellings. Other low value habitats include: Forests ($1,826 per hectare); Freshwater Streams ($1,594 per hectare); Saltwater Wetlands ($1,413 per hectare); and Grassland ($117 per hectare). Moderate value habitats include: Coastal Riparian ($9,258 per hectare) and Nearshore Habitat ($16,282 per hectare). In addition to the Beaches that are located near dwellings, other high value habitats include Beach Habitats ($88,203 per hectare); and Freshwater Wetlands ($72,786 per hectare). Restricting development in area with high value ecosystems would reduce the societal impact of development; focusing development in areas where there are low value ecosystems would reduce economic impacts to society. A detailed table showing the various components of the ecosystem services valuation is presented in Appendix D of this report.

The annual total economic value to society from the Maury Island ecosystem is estimated to be $22.68 million. Of this total, the most valuable habitats are Nearshore ($9.2 million), Beach near dwelling ($7.5 million), Beach ($2.3 million), Forest ($1.9 million), and Coastal Riparian ($1.2 million). The other habitats (Disturbed Areas, Freshwater Streams, Freshwater Wetland, Grasslands, and Saltwater Wetland), add less than $1 million annually to the value of the Maury Island ecosystems.

[11] For example, by expanding the scope of this analysis to include market based values, landing values for species such as salmon, herring and geoduck could be estimated to provide a compliment to the non-market values estimated here.

Table 7. Maury Island ecosystem service valuation summary.

Land Cover Type	Ecosystem Value per Hectare	Total Hectares	Total Value for Maury Island Ecosystem
Disturbed	$ 0	253.5	$ 0
Beach	$ 88,203	26.8	$ 2,371,000
Beach near dwelling	$ 117,254	64.6	$ 7,576,000
Coastal Riparian	$ 9,395	132.4	$ 1,245,000
Forest	$ 1,826	1,043.8	$ 1,906,000
Freshwater Stream	$ 1,594	41.4	$ 66,000
Freshwater Wetland	$ 72,786	3.6	$ 269,000
Grassland/Herbaceous	$ 117	321.4	$ 38,000
Nearshore Habitat	$ 16,282	565.2	$ 9,205,000
Saltwater Wetland	$ 1,413	6.7	$ 9,500
Total Value		2,460	$22,685,000

Source: Spatial Informatics Group 2004.

3. Future Scenarios

3.1 Future Scenarios

The section analyzes the economic value of lost ecosystem services associated with two potential development scenarios that represent the overall range of likely impacts that could occur from land use changes on Maury Island in the foreseeable future. Scenario 1 assumes that study area will experience a full-build out of developable land under current zoning ordinances as defined by King County's zoning atlas and a GIS layer of zoning for the island obtained from the County, but assumes that the Glacier Northwest mine would remain in its current condition. Scenario 2 assumes that Glacier Northwest mines and restores their gravel pit in accordance with the projections outlined in King County's Department of Development and Environmental Services' *Report and Decision for Shoreline Conditional Use Permit and Shoreline Substantial Development Permit*, the *Maury Island Gravel Mine- Final Environmental Impact Statement*, and related documents. This second scenario assumes that the rest of Maury Island would remain unchanged. The results from Scenarios 1 and 2 are then combined to reflect the overall loss of ecosystem values associated with full buildout of the Island and the Glacier Mine compared with maintaining the status quo for perpetuity.

3.1.1 Methodology and Key Assumptions

The scenario development methodology is defined in Section 1.2 of this report. As stated in that section, standard discounting methods were used to calculate the net present value of the losses over time. Discounting allows the analysis to account for time preference of money. This is the belief that a dollar today is worth more than a dollar next year because of the opportunity cost of investing that dollar today as opposed to tomorrow and a preference to have goods and services now rather than later. There is wide debate over what are appropriate discount rates for long-term projects. Some federal projects use discount rates much higher than this analysis while ecological economists often promote the use of much lower discount rates in the one or two percent range. The study therefore estimates the present value of the losses using two different discount rate assumptions to provide a range of losses instead of a single point estimate. In both scenarios, a 100-year time frame was used from the time of the first loss to allow for inter-generational accounting of the losses. Table 8 shows the two discount rate assumptions used for this study. The first discount rate structure uses the standard discount rate for Federal Government projects set by the White House's Office of Management and Budget (OMB 2004). The current OMB discount rate for projects expected to last 30 years or longer is 3.5 percent. This rate was applied to the entire one hundred year period. The second rate structure relies on a methodology preferred by ecological economists and defined by Rabl (1996). The methodology suggests that current traditional discount rates, such as the OMB rate, do not account for intergenerational issues and preference. Rabl (1996) suggests using a two-step process that relies on a conventional (OMB) social discounting rate for the short-term (i.e., 30 years) and then an intergenerational discount rate based on growth rate of gross national product per capita. Using this methodology a discount rate of 3.5 percent was used for the first thirty years and then a rate of 2.3 percent for the remaining 70 years. Gross national product per capita in the U.S. has risen at a rate of 2.3 percent per year over the past 30 years. Rabl calculated that over the past 130 years the GNP per capita rose at a rate of roughly 1.8 percent per year. The former rate is more appropriate for this analysis as the latter rate includes periods in the U.S. history that encompass massive immigration influxes relative to the size of the national population and the last-part of the industrial revolution. In the future, trends in the U.S. economy and population growth are probably more likely to look like the past 30 years than the past 130 years simply because both the country's net population growth rate and economy have matured. Generally, speaking the higher the discount rate the lower the net present value of losses.

Table 8. Study discount rates.

Method	Rate for First 30 Years	Rate for Remaining 70 Years
Federal OMB Discount Rates (Traditional)	3.5%	3.5%
Ecological Economics Discount Rates (Rabl)	3.5%	2.3%

3.2 Scenario Definitions and Analysis Results

3.2.1 Scenario 1: Full Development under Current Zoning Ordinances and Existing Environmental Regulations

Scenario 1 assumes that Maury Island will develop to the full extent allowed under current zoning ordinances and existing environmental regulations. For example, a 30-acre undeveloped parcel currently zoned as R-10 would be subdivided into three ten-acres parcels with one dwelling unit per parcel. Average impervious surface ratios associated with existing built out parcels within each zoning category were then applied to parcels within those categories that are currently undeveloped.[12] Scenario 1 assumes that the development occurs at a constant rate over the next 20 years. Figure 6 shows the current zoning regime on Maury Island. The island's interior is dominated by the R-10 designation, which allows one dwelling unit for every 10 acres. The island's shoreline is predominantly R-2.5, or less than R-2.5. Two areas are designated as mineral zones. This scenario assumes no change at those sites. There are also smaller areas designated as R-4 in the island's northeast corner. Currently, one of the areas that appears to be

[12] There are many regulations at multiple levels of government that control the configuration of and impacts associated with site development. For the most part these have not been specifically accounted for in this analysis. For example, King County's sensitive areas code regulates clearing in and adjacent to sensitive areas such as streams and wetlands; however this code typically regulates the manner in which a site can be developed but not whether it can be developed or at what density. Thus, assuming future clearing and creation of impervious surface to be equivalent to past clearing and creation of impervious surface for each zoning category was felt to be the most practicable and reasonable analytic approach. One exception to this is that the analysis assumed that development would not occur within the nearshore areas (200 linear feet inland from the Ordinary High Water mark) covered by the Shoreline Management Act. The potential loss of ecosystem value resulting from development within this zone is not included in this analysis and would be an appropriate issue to be addressed in follow up studies. Additionally, this analysis did not include secondary effects of development such as shoreline armoring which often occur with nearshore development.

most under built relative to allowable densities is the Dockton Creek Area, along the middle portion of the northwest shore of the island.

The act of developing land generally means the loss of some or all of the ecosystem services the land might have provided. For example, if there were a hectare of land that was a meadow and that meadow was paved over for use as a parking lot, then the hectare would not provide the same ecosystem services that it had previously provided. Society would have lost those ecosystem services. Using the assumptions described above, the study estimated that if all developable parcels were developed at the same time, the value of ecosystem services would be reduced by roughly $548,000 per year in 2004 dollars. However, Scenario 1 assumes that the development takes place gradually over 20 years. Table 9 shows the estimated net present value of the losses associated with this gradual development and using the two social discount rate assumptions. The OMB rate indicates a net present value of losses of approximately $11.4 million while the Ecological Economics rate provides an estimate of approximately $23.5 million. In context, the analysis estimates the island's terrestrial ecosystem, if left in its current state forever, will provide a net present benefit of $194 million over the next 100-years using the OMB method and $248 million using the Ecological Economics rate while the entire studied ecosystem (both terrestrial and nearshore) will provide between $649 million and $831 million over the same period. The loss associated with full development under current zoning regulations is roughly equivalent to six and 10 percent of the 100-year net present value of the estimated terrestrial ecosystem services and between 1.8 and 2.8 percent of the whole ecosystem as studied.

Table 9. Loss estimates – full development under current zoning ordinances and existing environmental regulations.

Method	NPV of Losses	NPV of Terrestrial Status Quo	Loss as Percent of Terrestrial Status Quo	NPV of Study Status Quo	Loss as Percent of Study Status Quo
Federal OMB	$11.4 million	$194.2 million	5.9%	$649.3 million	1.8%
Ecological Economics Rate	$23.5 million	$248.6 million	9.5%	$831.1 million	2.8%

3.2.2 Scenario 2: Full Build Out of the Glacier Northwest Property

Scenario 2 assumes that Glacier Northwest will develop and mine the 68.8 hectares of the 95.1-hectare site on the southeastern edge of Maury Island over the next thirty-five years.[13] This time horizon would result in the mining of 2.15 hectares per year on average[14]. This information is from the final environmental impact statement (FEIS), specifically Figure 2.1, including which

[13] The 35-year time horizon is the same horizon outlined by the proposed alternative in the Final Environmental Impact Statement (King County 2000). The analysis assumes that all mining and reclamation activities would be completed by the end of the 35th year.

[14] The Final EIS notes that development of the site would occur in stages. Hence, the assumption of a linear mining rate differs from what could probably be expected in a real world situation.

lands Glacier Northwest plans to develop. In addition, this analysis assumes that no mining takes place within the 400-foot boundary between shoreline and the mining area as defined in Glacier Northwest's February 25, 2004 revision to its grading permit application (L92G0075).

The FEIS indicates that the company plans to start mining near the center of the parcel before moving to the southern and western portions of the parcel and then finally to the northern and eastern portions. As described in the FEIS, the company would mine the area in a rotating fashion. The company would only be allowed to expose 25.9 hectares of land at any given time. Each newly opened area is called a cell. As previously stated, this scenario assumes that each year the company would disturb roughly 2.15 hectares of land. Thus, in this analysis each cell is 2.15 hectares. The scenario also follows the EIS in that it assumes that the company would spend 0.5 years stripping and preparing the cell for mining, two years of mining and 1.5 years of reclamation work. The analysis assumes that during this four-year period that the cell would not provide any ecosystem services. After this period, each cell would begin to gradually recover and provide more ecosystem services each year. The analysis assumes that this recovery would take place over a 10-year period until the cell reached a level of 80 percent recovery. At this point the cell would provide ecosystem services at 80 percent of the original level and value. The analysis assumes that each cell would never fully recover to the initial level during the 100-year time frame and would remain at an 80 percent level through the end of the analysis.[15]

Table 10 shows the portion of status quo services provided by each cell from pre-mining to post reclamation. The cell provides 100 percent of its status quo service value before mining. During cell preparation, mining, and reclamation it provides no ecosystem service values. After reclamation the cell provides an increasing amount of services each year until each reaches the 80 percent level where it stays for the rest of the analysis period.

In addition to studying the proposed mining area, this scenario also analyzed the lost ecosystem services associated with the Glacier Northwest's proposed renovations of the facility's dock as defined in the December 2, 2003 revision to the dock proposal. This analysis assumes that the 7,000 square feet of nearshore habitat immediately under and around the dock would cease providing measurable ecosystem services. EIS documents indicate that the dock would disturb roughly 7,000 square feet of nearshore habitat. The assumption that the area affected by the dock would cease to provide a measurable ecosystem service likely overstates its impact. Non-toxic substrates such as steel pilings and concrete provide habitat for marine organisms and a forage base for predators. The analysis makes this assumption to provide a conservative upper bound estimate of the dock's effect. The analysis should note that the current dock displaces more nearshore habitat than the proposed dock. This fact means that a new dock would have less impact in that area than the current dock.

---

[15] Discussions with King County scientists indicate the mine restoration projects seldom return the affected area to prior levels within the 100-year time frame addressed by this analysis. In fact the exact rate at which affected areas recover is a matter of considerable debate.

Table 10. Activity status and portion of Glacier Mine on Maury Island.

Year	Activity	Percent of Status Quo Service Value Provided
Pre-Mining	None	100%
Year 1	Stripping and Mining	0%
Year 2	Mining	0%
Year 3	Mining and Reclamation	0%
Year 4	Reclamation	0%
Year 5	Recovery	8%
Year 6	Recovery	16%
Year 7	Recovery	24%
Year 8	Recovery	32%
Year 9	Recovery	40%
Year 10	Recovery	42%
Year 11	Recovery	50%
Year 12	Recovery	58%
Year 13	Recovery	64%
Year 14	Recovery	72%
Years 15+	Recovery	80%

Using these assumptions, if the entire site were instantaneously mined, it is estimated that the lost ecosystem services would total $703,000 a year in 2004 dollars and consume roughly 69 hectares[16]. If the development occurs over a 35-year period then land would be developed at a rate of roughly 2.15 hectares per year. Average ecosystem service values in all undeveloped areas average $2,100 per hectare per year[17]. Table 11 shows the estimated net present value using the two social discount rate assumptions described above. The OMB discount rate indicates a net present value of the losses of approximately $900,000 while the Ecological Economics discount rate provides an estimate of approximately $1.1 million. As previously mentioned, the analysis estimates the island's ecosystem, if left in its current state, will provide a net present benefit of between $194 and $248 million over the next 100-years, while the entire studied ecosystem will provide between $649 million and $831 million during the same period. The loss associated with full mining and reclamation over the 35-year period is roughly equivalent to one-half percent of the 100-year net present value of the estimated terrestrial

[16] Note that while the "instantaneous losses" associated with this scenario are higher than those associated with Scenario 1 the net present value of these losses is less because they are spread over a 35 year time-span instead of 20 year time-span. The net-present value of the losses associated with Scenario 2 would be higher than those associated with Scenario 1 if the losses occurred over the same time frame. Increasing the rate of extraction from the mine or the rate of development on the island will increase the net present value of the losses.

[17] Note that this value is slightly lower than the range provided for the parcel in Figure 5. Glacier NW planned extraction will avoid a 400 foot buffer of higher value nearshore habitat. Thus, the acreage that will be disturbed has a lower average value than the parcel's average value or the value of the nearshore habitat.

ecosystem services and roughly 0.14 percent of the value of services provided by the whole ecosystem.[18]

Table 11. Loss estimates—full development of Glacier Northwest Mine.

Method	NPV of Losses	NPV of Terrestrial Status Quo	Loss as Percent of Terrestrial Status Quo	NPV of Study Status Quo	Loss as Percent of Study Status Quo
Federal OMB Discount Rate	$0.9 million	$194.2 million	0.5%	$649.3 million	0.14%
Ecological Economics Discount Rate	$1.1 million	$248.6 million	0.5%	$831.1 million	0.14%

The net present value of losses specifically associated with the dock is between approximately $90,000 and $125,000 over the 100-year period. These amounts are roughly 10 percent of total losses associated with proposed mining activities.

3.2.3 Aggregated Scenarios 1 and 2 Analysis

Full build out of Maury Island, in accordance with current zoning would actually entail both realizing all of the underbuilt residential development (the first scenario described above) and realizing full mining and ultimately reclaiming all lands disturbed by mining of the Glacier site (the second). Thus, aggregating the results of the two scenarios yields the best current estimate of full build out impacts. If both scenarios occurred as described above, the aggregate, 100-year, net present value of the losses would range from $12.3 million to $24.6 million. This amount is equivalent to between 6.3 percent and 9.9 percent of the total expected values provided by the island's terrestrial ecosystem or 1.9 to 3.0 percent of the total expected value of benefits and services provided by the entire study area (see Tables 12 and 13).

Table 12. Aggregate loss estimates—both scenarios occurring as described (terrestrial comparison).

Method	NPV of Residential-Development Losses	NPV of Mining-Related Losses	Total NPV of Losses	NPV of Terrestrial Status Quo	Loss as Percent of Terrestrial Status Quo
Federal OMB Discount Rate	$11.4 million	$0.9 million	$12.3 million	$194.2 million	6.3%
Ecological Economics Rate	$23.5 million	$1.1 million	$24.6 million	$248.6 million	9.9%

[18] There was considerable debate within the project team over the appropriate rate of natural recovery. A slower recovery rate would mean higher loss estimates. Thus, for comparison purposes and an upper bound, the study provides loss estimates if there was no restoration or remediation at the mine site after mining. The analysis estimates that the 100-year net present value of losses under these conditions would be between $2.3 million and $3.3 million. While these numbers are significantly higher than estimates provided for Scenario 2, the losses still represent less than 0.4% of the total net present value of the study area.

Table 13. Aggregate loss estimates—both scenarios occurring as described (full study comparison).

Method	NPV of Residential-Development Losses	NPV of Mining-Related Losses	Total NPV of Losses	NPV of Study Status Quo	Loss as Percent of Study Status Quo
Federal OMB Discount Rate	$11.4 million	$0.9 million	$12.3 million	$649.3 million	1.9%
Ecological Economics Rate	$23.5 million	$1.1 million	$24.6 million	$831.1 million	3.0%

4. Summary and Conclusions

The study area covered a total of 2,460 hectares. Of this total, the largest category was Forest (1,043 hectare), Nearshore Habitat (565 hectare), Grassland (321 hectare), and Disturbed (253 hectare).

As shown below in Table 14, the economic value of the 10 land cover classes used in this report vary from a low of $0 per hectare for Disturbed Grasslands to $117,000 per hectare for Beaches that are located near dwellings. Other low value habitats include: Forests ($1,826 per hectare); Freshwater Streams ($1,594 per hectare); Saltwater Wetlands ($1,413 per hectare); and Grassland ($117 per hectare). Moderate value habitats include: Coastal Riparian ($9,258 per hectare) and Nearshore Habitat ($16,282 per hectare). In addition to the Beaches that are located near dwellings, other high value habitats include Beach Habitats ($88,203 per hectare); and Freshwater Wetlands ($72,786 per hectare). Restricting development in areas with higher value ecosystems would reduce the societal impact of development; focusing development in areas where there are lower value ecosystems would reduce economic impacts to society.

Table 14. Ecological economic values for Maury Island.

Land Cover Type	Ecosystem Value per Hectare	Total Hectares	Total Value for Maury Island Ecosystem
Disturbed	$ 0	253.5	$ 0
Beach	$ 88,203	26.8	$ 2,371,000
Beach near dwelling	$ 117,254	64.6	$ 7,576,000
Coastal Riparian	$ 9,395	132.4	$ 1,245,000
Forest	$ 1,826	1043.8	$ 1,906,00
Freshwater Stream	$ 1,594	41.4	$ 66,000
Freshwater Wetland	$ 72,786	3.6	$ 269,000
Grassland/Herbaceous	$ 117	321.4	$ 38,000
Nearshore Habitat	$ 16,282	565.2	$ 9,205,000
Saltwater Wetland	$ 1,413	6.7	$ 9,500
Total Value		2,460	$22,685,000

Source: Spatial Informatics Group 2004.

The annual total economic value to society from the Maury Island ecosystem is estimated to be $22.68 million. Of this total, the most valuable habitats are Nearshore ($9.2 million), Beach near dwelling ($7.5 million), Beach ($2.3 million), Forest ($1.9 million), and Coastal Riparian ($1.2 million). The other habitats (Disturbed Areas, Freshwater Streams, Freshwater Wetland, Grasslands, and Saltwater Wetland), add less than $1 million annually to the value of the Maury Island ecosystems.

4.1 Future Scenarios

The annual value of the ecosystem goods and services within the Maury Island project area is estimated to be $22.68 million per year and the 100-year net present value (NPV) of the value of the ecosystem goods and services is estimated to be between $649 million and $831 million, depending upon the discount rate used.

Developing Maury Island to the maximum extent possible within the current zoning codes but maintaining the Glacier Mine in forest would result in a 100-year NPV loss of value of ecosystem goods and services of between $11.4 million and $23.5 million, depending upon the discount rate used. This equals between 1.8 percent and 2.8 percent of the total 100-year value of the ecosystem value of the project area.

Developing the Glacier Mine would result in a NPV loss of between $0.9 and $1.1 million or 0.14 percent of the total 100-year value of the study area. It must be kept in mind that this estimate is based on the assumption that the mine would be remediated during the 35 year mining process and that disturbed areas would be 80 percent restored within 10-years after mining operations are finished. If remediation is not done adequately or proves to be unsuccessful, the lost value of ecosystem goods and services increases substantially.

Under a combined scenario where the Glacier Mine is developed and all other parcels are developed to the maximum degree allowed under current zoning, the NPV loss to the ecosystem would be between $12.3 million and $24.6 million, depending upon the discount rate used. This represents a loss of between 1.9 and 3.0 percent of the total value of ecosystem goods and services associated with the Maury Island study area. This is a conservative, baseline estimate that would change if additional data were available. Data gaps include the ecosystem values for some types of land cover, market values of commercial species that reside or travel through the Maury Island nearshore ecosystem, and the efficacy of mine reclamation efforts to restore ecosystem functions.

4.2 Conclusions

1. The estimated value of the Maury Island terrestrial and nearshore ecosystems is $22.68 million per year with a 100-year net present value of between $649 million and $831 million.

2. Full development of Maury Island, to the extent allowed by current zoning and environmental regulations) would reduce the 100-year net present value of the ecosystem goods and services of the Maury Island area ecosystem by between 1.9 and 3.0 percent. While this level of reduction in ecosystem values is relatively minor with respect to the entire island, localized effects for any specific portion of the island could be considerably greater depending upon the nature of the development and

the affected ecological resources. The estimated effects represent a relatively small portion of the island's total ecosystem services for several reasons. First, the island's current zoning regulations would prevent substantial large-scale residential or commercial developments. Total losses would rise significantly if land that is currently zoned in the R-5 and R-10 classifications were rezoned to allow much denser development levels. Second, this development scenario does not include significant amounts of increased shoreline armoring. An increase in shoreline armor and dense beachfront development would result in significantly higher loss values. A future change in either of these elements would significantly increase loss values.

3. Proposed mining of Glacier Northwest's Maury Island property (as defined by the Final Maury Island Environmental Impact Statement) and development of the proposed dock would reduce the 100-year net present value of the studied ecosystem goods and services by roughly 0.14 percent. The losses associated with the mining of the property are mitigated by the proposed reclamation and remediation procedures. If reclamation and remediation procedures take longer or are not as effective as assumed by the analysis then the estimated losses would be much higher. However, even if no reclamation and remediation procedures were performed, and the mined site provided no ecosystem services, losses would not be more than 0.3 percent of the 100-year net present value of the studied ecosystem. While this affects only a relatively minor portion of the total ecosystem services the localized effects would be significant, not only to the ecosystem, but also to the citizenry which are accustomed to receiving benefits from those areas.

4. The areas with the greatest per hectare ecosystem values are the beaches, especially beaches that are near dwellings. The other high value ecosystem is Freshwater Wetlands.

5. The areas with the greatest total ecosystem values are Nearshore Habitat, Beaches near dwellings, Beaches, and Forests.

6. Of the ten ecosystem services associated with each of ten land cover features in this analysis, slightly more than half did not have relevant peer-reviewed literature from which to derive a valuation. Thus the overall values associated with each land cover class are underestimated, and the relative valuations of the various classes (i.e., which are highest and lowest) could be refined with further data collection. In some instances, these missing value estimates can be expected to have a major effect on the overall value of a land cover type. For instance, Beaches near Dwellings and Beaches are the two highest value land covers. The value of beaches is based solely on recreational values and would probably be

much higher if there were ecosystem value estimates for soil retention and formation similar to the $48,500 value shown for the Beaches near dwellings classification.

5. References

Anchor Environmental, L.L.C. (Anchor). 2004. Marine Shoreline Inventory Report WRIA 9 (Final). Prepared for Seattle Public Utilities, WRIA 9. Funded by King Conservation District Salmon Recovery Funding Board. March 2004.

Associate Earth Science, Inc (AES). 2000. Biological Evaluation – Maury Island Dock Repairs. Prepared for Northwest Aggregates Co., Associate Earth Science, Inc, Kirkland, Washington. August 10, 2000.

Brennan, J. and H. Culverwell. In press. Marine Riparian: An assessment of riparian functions in marine ecosystems. King County Department of Natural Resources and Parks and Puget Sound Water Quality Action Team.

Brennan, J. Unpublished. Beach Seine Data for Maury Island. King County Department of Natural Resources and Parks.

Broadhurst, G. 1998. Puget Sound nearshore habitat regulatory perspective: A review of issues and obstacles. Puget Sound/Georgia Basin Environmental Report Series: No. 7. Puget Sound/Georgia Basin International Task Force, Seattle, Washington.

Buckley, R.M. 1997. Substrate associated recruitment of juvenile *Sebastes* in artificial reef and natural habitats in Puget Sound and the San Juan Archipelago, Washington. Doctoral Dissertation. School of Fisheries, University of Washington, Seattle, Washington.

Cedarholm, C.J., D.H. Johnson, R.E. Bilby, L.G. Dominguez, A.M. Garrett, W.H. Graeber, E.L. Greda, M.D. Kunze, B.G. Marcot, J.F. Palmisano, R.W. Plotnikoff, W.G. Pearcy, C.A. Simenstad, and P.C. Trotter. 2000. Pacific salmon and wildlife: Ecological contexts, relationships, and implications for management. Special Edition Technical Report, Prepared for D.H. Johnson and T.A. O'Neil (Manag. Dirs.), Wildlife-Habitat Relationships in Oregon and Washington. Washington Department of Fish and Wildlife, Olympia, Washington.

Census 2000. Available at: <http://factfinder.census.gov/servlet/DatasetMainPageServlet?_program=DEC&_lang=en&_ts=>. April 2004.

Costanza, R. 1989. What is Ecological Economics? Ecological Economics 1:1-7.

Costanza, R., R. d'Arge, R. de Groot, S. Farber, M. Grasso, B. Hannon, K. Limburg, S. Naeem, R.V. O'Neill, J. Paruelo, R.G. Raskin, P. Sutton, and M. van den Belt. 1997. The Value of the World’s Ecosystem Services and Natural Capital. Nature, 38, 253-260.

Cowardin, L.M., V. Carter, F.C. Golet, and E.T. LaRoe. 1979. Classification of wetlands and deepwater habitats of the United States. U.S. Department of Interior, Fish and Wildlife Service. FWS/OBS - 79/31.

Daily, G.C. 1997. Nature's Services: Societal Dependence on Natural Ecosystems. Washington D.C.: Island Press.

De Groot, R., M.A. Wilson, and R.M.J. Boumans. 2002. A typology for the classification, description, and valuation of ecosystem functions, goods and services. Ecological Economics, 41, 393-408.

Desbonnet, A.V., Lee P. Pogue, D. Reiss, J. Boyd, J. Willis, and M. Imperial. 1995. Development of coastal vegetated buffer programs. Coastal Management 23, no. 2: 91-109.

Desvousges, W.H., F.E. Johnson, and H.S. Banzhaf. 1998. Environmental Policy Analysis with Limited Information: Principles and Applications of the Transfer Method. Northhampton, Massachusetts: Edward Elgar.

Dethier, Megan N. 1990. A Marine and Estuarine Habitat Classification System for Washington State, Washington Natural Heritage Program, Department of Natural Resources, Olympia, Washington.

Draft Environmental Impact Statement for Maury Island Lone Star Gravel Mine prepared for the Department of Ecology. July 1999.

Duggins, D.O. 1980. Kelp dominated communities: Experimental studies on the relationships between sea urchins, their predators, and algal resources. Dissertation Abstracts International Doctoral Dissertation. 41/11-b:3995. Zoology Department, University of Washington, Seattle, Washington.

Eade, J.D. and D. Moran. 1996. Spatial Economic Valuation: benefits transfer using Geographic Information Systems. Journal of Environmental Management, 48, 97-110.

Economic Development Council of King County. 2004. Available at: <http://www.edc-sea.org/Research_Data/economic_demographics.cfm>. April 2004.

El Sarafy, S. 1991. The environment as capital. In Costanza, R. (ed.), *Ecological Economics: The Science and Management of Sustainability*. Columbia University Press, New York.

EVS Environmental Consultants, Inc. 2000. Maury Island mine impact study. Nearshore impact assessment. Prepared for Pacific Groundwater Group, Seattle, Washington. March 2000.

Federal Interagency Stream Restoration Working Group. 1998. Stream corridor restoration: Principles, Processes, and Practices.

Final Environmental Impact Statement for Maury Island Glacier Northwest Gravel Mine prepared for the King County Department of Development and Environmental Services. June 2000.

Foster, M.S., A.P. DeVogelaere, C. Harlod, J.S. Pearse, and A.B. Thum. 1986. Causes of spatial and temporal patterns in rocky intertidal communities of central and northern California. Volume 2 of 2. Outer Continental Shelf Study MMS 85-0049, Contract No. 14-12-0001-30057. Minerals Management Service, U.S. Department of the Interior,

Garrison, K.J. and B.S. Miller. 1982. Review of the early life history of Puget Sound fishes, Vol. Contract No. 80-ABA-3860 NMFS (NOAA). University of Washington, School of Fisheries, Seattle, Washington.

Harrold, C., J. Watanabe, and S. Lisin. 1988. Spatial variation in the structure of kelp forest communities along a wave exposure gradient. Marine Ecology 9(2):131-156.

Herman, S.G. and J.B. Bulger. 1981. Grays Harbor and Chehalis River improvements to navigation environmental studies: The distribution and abundance of shorebirds during the 1981 spring migration at Grays Harbor, Washington. Herman, Steven G. Olympia, Washington. 90pp.

Jackson, G.A. and C.D. Winant. 1983. Effect of a kelp forest on coastal currents. Continental Shelf Research 2(1):75-80.

Jones & Stokes and AR. 1999. Eelgrass/macroalgae survey report. Lone Star Gravel Mine. Maury Island, Washington. Prepared for King County Department of Development and Environmental Services, Renton Washington. Prepared by Jones & Stokes Associates, Inc. in association with Aquatic Research, Olympia, Washington, August 31 (JSA 98-306-001)

Kentula, M.E. and C.D. McIntire. 1986. The Autecology and Production Dynamics of Eelgrass (*Zostera marina* L.) in Netarts Bay, Oregon. Estuaries 9(3):188-199.

King County. 1998. Vertical aerial photograph of Maury Island.

King County Dept of Natural Resources (KCDNR). 2001. State of the nearshore ecosystem: eastern shore of central Puget Sound, including Vashon and Maury Islands (WRIAs 8 and 9). Final Review Draft. Report prepared by Battele Marine Sciences Laboratory, Pentec Environmental, Striplin Environmental Associates, Shapiro Associates for King County Department of Natural Resources. KCDNR, Seattle, Washington.

King County Beach Assessment. 2004. Available at: <http://dnr.metrokc.gov/wlr/waterres/beaches/dockton.htm>.

KCORPP Land Use Appendix from Habitat Limiting Factors and Reconnaissance Report Part V. 2000.

Kozloff, E.N. 1983. Seashore Life of the Northern Pacific Coast. University of Washington Press, Seattle, Washington.

Kreuter, U.P., H.G. Harris, M.D. Matlock, and R.E. Lacey. 2001. Change in Ecosystem Service Values in the San Antonio Area, Texas. Ecological Economics, *39*, 333-346.

Lemberg, N.A., M.F. O'Toole, D.E. Pentilla, and K.C. Stick. 1997. 1996 Forage fish stock status report. Stock Status Report No. 98-1. Washington Department of Fish and Wildlife, Olympia, Washington. 83pp.

Macdonald, K.B., D. Simpson, B. Paulsen, J. Cox, and J. Gendron. 1994. Shoreline armoring effects on the physical coastal processes in Puget Sound, Washington. Coastal Erosion Management Studies, Volume 5. Shorelands and Coastal Zone Management Program, Washington Department of Ecology, Olympia, Washington.

Manashe, E. 1993. Vegetation management: A guide for Puget Sound bluff property owners. Shorelands and Coastal Zone Management Program. Washington Department of Ecology, Olympia, Washington.

Myers, R.D. 1993. Slope stabilization and erosion control using vegetation: A manual of practice for coastal property owners. Shorelands and Coastal Zone Management program, Washington Department of Ecology, Olympia, Washington.

Miller, B.S., C.A. Simenstad, L.L. Moulton, K.L. Fresh, F.C. Funk, W.A. Karp, and S.F. Borton. 1978. Puget Sound baseline program. Nearshore fish survey. Baseline Report No. 10. University of Washington, School of Fisheries, Fisheries Research Institute, Seattle, Washington.

Miller, B.S., C.A. Simenstad, and L.R. Moulton. 1976. Puget Sound Baseline Program: nearshore fish survey, Annual Report July 1974-September 1975. Fisheries Research Institute, University of Washington, Seattle, Washington.

Millennium Ecosystem Assessment. 2003. Ecosystems and Human Well Being: A Framework for Assessment. Island Press, Washington, D.C.

Morris, F.A., K.F. Wellman, H. Kirwin-Taylor, and M.D. Curran. 1996. The role of environmental valuation in marine water resource management King County, Washington. Issue paper prepared for Water Pollution Control Division King County Department of Natural Resources. Battelle Seattle Research Centre, Seattle, Washington.

Natural Resource Damage Assessments. Title 43 Code of Federal Regulations, Pt. 11, 1996.

Nightengale. B.J. and C.A Simenstad. 2001. Over-water Structures: Marine Issues. Prepared for the Washington Department of Fish and Wildlife, Washington Department of Ecology, and Washington Department of Transportation. University of Washington Wetland Ecosystem Team School of Aquatic and Fishery Sciences.

Pentilla, D.E. 1995. Investigations of the spawning habitat of the Pacific Sand Lance (*Ammodytes hexapterus*) in Puget Sound. *In:* Proceedings of Puget Sound Research 1995. pp855-859. Puget Sound Water Quality Authority, Seattle, Washington.

Penttila, Daniel E. 2001. Effects of Shading Upland Vegetation on Egg Survival for Summer-spawning Surf Smelt on Upper Intertidal Beaches in Puget Sound. Washington Department of Fish and Wildlife, Marine Resources Division.

People for Puget Sound. 2002. Vashon and Maury Island Rapid Shoreline Inventory. Prepared for King County Water and land Resource Division. July 2002.

Phillips, R.C. 1984. The ecology of eelgrass meadows in the Pacific Northwest: a community profile. Washington, D.C., National Coastal Ecosystems Team, Division of Biological Services, Research and Development, Fish and Wildlife Service, U.S. Department of the Interior: 86.

Puget Sound Regional Council. 2004. 2003 Sub-County Forecasts. Released December 19, 2003. Available at: <http://www.psrc.org/datapubs/data/scf03-1.xls>. Accessed May 19, 2004.

Ricketts, E.G. and J. Calvin. 1968. Between Pacific Tides. 4th ed., revised by J. Hedgpeth. Stanford University Press, Palo Alto, California. 614pp.

Shi, Yun-Bing. 1987. Population dynamics of juvenile English sole, *Parophrys vetulus*, in the estuaries and adjacent nearshore areas of Washington. University of Washington, Seattle, Washington.

Shipman, H. 2001. Coastal landsliding on Puget Sound: a review of landsliding occurring between 1996 and 1999. Olympia, Shorelands and Environmental Assistance Program, Washington Department of Ecology: 87.

Shreffler, D.K., C.A. Simenstad, and R.M. Thom. 1992. Foraging by juvenile salmon in a restored estuarine wetland. Estuaries 15(2):204-213.

Simenstad, C.A., B.S. Miller, C.F. Nyblade, K. Thornburgh, and L.J. Bledsoe. 1979. Food web relationship of northern Puget Sound and the Strait of Juan de Fuca, EPA Interagency Agreement No. D6-E693-EN. Office of Environmental Engineering and Technology, U.S. EPA.

Simenstad, C.A. 1983. The ecology of estuarine channels of the Pacific Northwest coast: A community profile. FWS/OBS-83/05. U.S. Fish and Wildlife Service, Olympia, Washington. 181pp.

Simenstad, C.A., J.R. Cordell, R.C. Wissmar, K.L. Fresh, S.L. Schroeder, M. Carr, G. Sanborn, and M.E. Burg. 1988. Assemblage structure, microhabitat distribution, and food web linkages of epibenthic crustaceans in Padilla Bay National Estuarine Research Reserve, Washington. FRI-UW-8813. Wetland Ecosystem Team, Fisheries Research Institute, School of Fisheries, University of Washington, Seattle, Washington. 60pp.

Simenstad, C.A., C.D. Tanner, R.M. Thom, and L.L. Conquest. 1991. Estuarine habitat assessment protocol. United States Environmental Protection Agency, Seattle, Washington.

Simenstad, C.A. 1994. Faunal associations and ecological interactions in seagrass communities of the Pacific Northwest coast. Seagrass science and policy in the Pacific Northwest: proceedings from a seminar series. S. Wyllie-Echeverria, A.M. Olson, and M.J. Hershman. Seattle, U.S. Environmental Protection Agency. SMA 94-1: 63.

Simenstad, C.A. and J.R. Cordell. 2000. Ecological assessment criteria for restoring anadromous salmonid habitat in Pacific Northwest estuaries. Ecological Engineering 15:283-302.

The Online Encyclopedia of Seattle/King County History. 2004. Available at: <http://www.historylink.org/_output.CFM?file_ID=3909>. April 2004.

Thom, R.M. 1981. Primary productivity and organic carbon input to Grays Harbor Estuary, Washington. Environmental Resources Section, Seattle District, U.S. Army Corps of Engineers, Seattle, Washington.

Thom, R.M. 1984. Primary production in Grays Harbor Estuary, Washington. Bulletin of the Southern California Academy of Science 83:99-105.

Thom, R.M. 1990. A review of eelgrass (*Zostera marina* L.) transplanting projects in the Pacific Northwest. Northwest Environmental Journal 6:121-137.

U.S. Census Bureau Glossary. 2004. Available at <http://factfinder.census.gov/home/saff/main.html?_lang=en>. Accessed April 29, 2004.

Vashon-Maury Island Community Council website. 2004. Available at: <http://www.vmicc.org/>. April 2004.

Washington State Department of Ecology (WDOE). 1993. Oblique Aerial Photography. Shorelands and Environmental Assistance Program. September 2000.

Washington State Department of Natural Resources (WDNR). 2001. The Washington State Shore Zone Inventory. Washington State Department of Natural Resources, Nearshore Habitat Program: Olympia, Washington.

West, J.E., R.M. Buckley, D.C. Doty, and B.E. Bookheim. 1995. Ecology and habitat use of juvenile rockfishes (*Sebastes* spp.) associated with artificial nursery habitats in Puget Sound, Washington. *In:* Proceedings of Puget Sound Research 1995. pp191-202. Puget Sound Water Quality Authority, Seattle, Washington.

Williams, G. and R. Thom. 2001. Marine and Estuarine Shoreline Modification Issues. Washington Department of Fish and Wildlife, Washington Department of Ecology, and Washington Department of Transportation Battelle Marine Sciences Laboratory Pacific Northwest National Laboratory, Sequim, Washington.

Williams, G.D., R.M. Thom, J.E. Starkes, J.S. Brennan, J.P. Houghton, D. Woodruff, P.L. Striplin, M. Miller, M. Pedersen, A. Skillman, R. Kropp, A. Borde, C. Freeland, K. McArthur, V. Fagerness, S. Blanton, and L. Blackmore. 2001. Reconnaissance Assessment of the State of the Nearshore Ecosystem: Eastern Shore of Central Puget Sound, Including Vashon and Maury Islands (WRIAs 8 and 9). J.S. Brennan, Editor. Report prepared for King County Department of Natural Resources, Seattle, Washington.

Wilson, M.A. and S.R. Carpenter. 1999. Economic Valuation of Freshwater Ecosystem Services in the United States 1971-1997. Ecological Applications, 9, 772-783.

Wilson, M.A, A. Troy, and R. Costanza. 2004. The Economic Geography of Ecosystem Goods and Services: Revealing the Monetary Value of Landscapes through Transfer Methods and Geographic Information Systems. *In*: Dietrich and Van Der Straaten (eds.), Cultural Landscapes and Land Use. Kluwer Academic Publishers (In Press).

Zelo, I. and H. Shipman. 2000. Alternative bank protection methods for Puget Sound shorelines. Shorelands and Environmental Assistance Program, Washington Department of Ecology, Olympia, Washington. 130pp.