Valuing New Jersey's Natural Capital:

An Assessment of the Economic Value of the State's Natural Resources

April 2007

State of New Jersey
New Jersey Department of Environmental Protection
Jon S. Corzine, Governor
Lisa P. Jackson, Commissioner

Overview of the New Jersey Natural Capital Project

Introduction

New Jersey is blessed with a wealth of breathtaking and highly valuable natural resources. Our beaches, forests, wetlands and other natural resources provide countless benefits to the public. In order to make wise policy, planning, and regulatory decisions, it is important to understand the worth of these resources. This report summarizes the results of a two-year study that aims to quantify the value of these resources. As a way of expressing the value, it estimates the dollar value of the services and goods produced by New Jersey's natural capital. Natural capital consists of components of the natural environment that provide long-term benefits to society. Many of the benefits provided by natural capital come from ecological systems or ecosystems, a dynamic complex of plant, animal, and microorganism communities and their nonliving environment, all interacting as a functional unit. Forests, wetlands, and lakes are examples of ecosystems.

The benefits provided by natural capital include both goods and services. Goods are commodities like timber and fish that can be weighed and transported; most of the goods considered in this study are bought and sold by private parties in market transactions. In contrast, ecosystem services or ecoservices include such things as temporary storage of flood waters by wetlands, long-term storage of climate-altering greenhouse gases in forests and numerous others. Ecosystem services provide economic value both to private parties and to society as a whole.

In this report, the amount of land of ecosystem providing the goods or services is measured in acres and its economic value is expressed in dollars. In addition to the annual dollar value (given throughout the report in constant 2004 dollars), this report also estimates the current worth or "present value" of the natural capital, i.e., the amount of money that would have to be invested now at a given interest rate to generate an equal level of monetary benefits annually. The present values in this report are based on an assumed interest rate of 3 percent per year over an indefinitely long time horizon. The 3 percent rate is the rate most commonly used by economists in converting future benefits and costs to society into present values.

This report is divided into three main parts. Part I presents essential background information, summarizes the detailed findings of Parts II and III and their limitations, and explores in a preliminary way the policy implications of the natural capital project and the future research needs in this area. Part II focuses on ecosystem services and Part III deals with ecosystem goods.

Summary of Part I: Overall Results

Taking the estimated values of goods and services together, the total value of New Jersey's natural capital appears to be about $20 billion per year (present value $680 billion), plus or minus $9 billion per year (present value $300 billion). The annual value of the services provided by New Jersey's natural capital is conservatively estimated at between $8.6 billion (present value $288 billion) and $19.8 billion (present value $660 billion). Freshwater wetlands and marine ecosystems have the highest ecoservice values. The annual value of the goods provided by New Jersey's natural capital is estimated at between $2.8 billion (present value $93 billion) and $9.7 billion (present value $322 billion). Farmland, marine waters, and quarries provide the highest values of goods.

In addition to goods and services provided by our state's natural capital, wildlife-related tourism is estimated to generate about $3 billion of gross economic activity in New Jersey annually. This activity represents about $1 billion of wage and salary income annually or about 37,000 jobs. The jobs are not an additional benefit since the related income is included in the activity figure. Another common benefit measure, namely total value added, which is the annual contribution to New Jersey's Gross State Product, cannot be determined. The net benefits to New Jersey are probably substantially less than these gross values because some of the spending and the related income flow to businesses outside the state. Nonetheless, wildlife-related tourism plays a significant role in the New Jersey economy.

Summary of Part II: Ecosystem Services

In estimating the value of the services provided by New Jersey's ecosystems, the study team used three different approaches: value transfer, hedonic analysis, and landscape modeling.

A. Value Transfer

Value transfer identifies high-quality studies of ecoservices values using a variety of valuation methods and applies the results to New Jersey. Value transfer is the preferred valuation technique where, as in this case, performing original research for an extended geographic region with many varied ecosystem types would be prohibitively expensive and time-consuming. For this study, the research team screened more than 300 studies and selected 100 of them covering the types of ecosystem present in New Jersey. The results of this analysis are summarized below; all figures are in 2004 dollars. A breakdown of values for individual services within the ecosystem can be found in the full report. The figures include only ecosystem services; they do not include ecosystem goods or secondary economic activity related to a given ecosystem.

Wetlands provided the largest dollar value of ecosystem services: $9.4 billion per year for freshwater wetlands and $1.2 billion per year for saltwater wetlands. Valuable service provided by wetlands includes the buffering of floods, storm surges, and other events that threaten the public. These values were the services of water filtration and water supply for freshwater wetlands, and waste treatment for saltwater wetlands.

Marine ecosystems provided the second-largest dollar amount of ecosystem services: $5.3 billion per year for estuaries/tidal bays and about $390 million per year for other coastal waters, including the coastal shelf out to the 3-mile limit. Nutrient cycling (i.e., waste dilution and removal) was the most important service provided by marine ecosystems, worth $5.1 billion per year.

Forests cover is the largest area of any ecosystem type in New Jersey and provides ecosystem services valued at $2.2 billion per year. Habitat services are currently the most important of these services and are valued at $1.4 billion per year. Other important services provided by forests include water supply, pollination and aesthetic and recreational amenities.

Urban green space covers relatively little of New Jersey but has a relatively high dollar value per acre and provides an estimated $420 million of ecosystem services annually, principally aesthetic and recreational benefits.

Beaches (including dunes) provided by far the highest ecoservice value per acre. Their small area limited their annual ecoservice value to about $330 million, mainly buffering of floods and storm surges and aesthetic and recreational benefits

Agricultural land includes both cropland (estimated at $78 million per year of ecosystem services) and pastureland (estimated at $45 million per year). These values relate solely to the services provided by farmland, mainly habitat services from cropland ($75 million per year) and waste treatment services from pasture land ($26 million per year). These figures do not include the value of the food provided by farms, which is covered in Part III of the report (see below).

Open fresh water and riparian buffers provide services with an estimated annual value of $66 million and $51 million respectively, mainly water supply and aesthetic and recreational. Part III of the report covers the value of the water itself as an ecosystem good.

After studying the state's various ecosystems, the total value of New Jersey's ecosystem services is estimated at $19.8 billion per year. For a number of reasons, the dollar amounts presented above are almost certainly conservative and they understate the true value of New Jersey's ecosystem services. These reasons include gaps in the valuation literature as well as a number of technical factors discussed at the end of Part II of the report.

B. Hedonic Analysis

"Hedonic" analysis is one method that is widely used to estimate the effect of environmental conservation on property values. The term "hedonic" derives from the

Greek word for pleasure (as in hedonism), the idea being that certain environmental features are so attractive that people will pay to be close to them. The approach separates the effect on property values of proximity to environmental "amenities" (such as protected open space or scenic views) from other factors that affect housing prices. In this study, we analyzed the effect on actual residential housing prices of closeness to beaches, protected open space (specifically, large, medium and small parks), water bodies, and unprotected forests and wetlands.

Due to data and resource limitations the team focused on seven local housing markets located in Middlesex, Monmouth, Mercer and Ocean Counties. In the aggregate, those markets are demographically similar to the state as a whole. The results obtained from the analysis generally support the hypothesis that homes close to attractive environmental features usually sell for more than homes further away, all-else being equal. For example, in four of the seven markets, sale prices for homes within 300 feet of a beach were from $81,000 to $194,000 higher than homes more than 300 feet away.

Proximity to lakes and streams can also make homes more desirable. In one of the local real estate markets for which the team had sufficient data, houses located within 100 feet of a water body sold for $33,000 more than homes located more than 100 feet away. In a second market, the difference increased to as much as $92,000 for homes located five miles away from a water body. However, in a third market, homes located 100 feet away from a water body sold for over $63,000 less than homes located 5 miles away. The results for proximity to water bodies thus varied somewhat, and determining the reasons for these differences would require further analysis.

The results for closeness to open space were more complex than proximity to water features because there are many different types of open space. In two markets with sufficient data for analysis, houses located in Environmentally Sensitive zones as defined by the Office of State Planning had selling prices between $8,600 and $34,500 higher than houses not located in such zones. However, closeness to *unprotected* forests and wetlands was consistent in having *no* strong effect on property values across markets.

Closeness to parks (another type of open space) was positively valued in some markets but not others. In the local markets for which sufficient data could be obtained, closeness to small parks tended to have a consistently positively effect on housing prices, while the opposite was true for closeness to medium and large parks. Determining the reasons for these differing results would require additional analysis.

A recognized inherent limitation of this type of statistical analysis is that the results cannot be readily translated into dollar values per acre and so are difficult to compare with the results of the value transfer analysis presented above. The limited tests the team was able to perform to address this problem suggest that the valuations obtained from the hedonic analysis translate into larger per acre dollar amounts than we obtained from the value transfer analysis, suggesting that the latter may be conservative and on the low side, as compared with the "true" values.

C. Landscape Modeling

The type of modeling performed in this study used a landscape simulation model to assess the relationships over time between specific patterns of land use and the production of ecosystem services in watersheds. The model includes variables that quantify how indicators, such as water quality, may vary as land use, climate, and other factors change both in their locations and over time.

The modeling results show that different land use allocations and spatial patterns of land cover can significantly affect the level of ecosystem services. For example, many studies have found that forests in general have beneficial effects on water quality. However, the results, described in Part II, suggest that the effects of forest cover on water quality vary depending different factors. These factors include the total forest cover in an area, the forest configuration (small dispersed forest patches vs. larger forest clusters), forest location relative to other land uses such as farming and to the points where water quality is measured.

There is still much uncertainty in this area. Further studies are needed to take into account the whole range of ecosystem services and to account properly for the precise variations in land cover and ecosystem location, but the results show that patterns of land use can affect ecosystem services significantly.

Conclusions on Ecosystem Services

Ecosystems provide a wide variety of economically valuable services, including waste treatment, water supply, buffering of floods and storm surges, plant and animal habitat, and others. The services provided by New Jersey's ecosystems are worth, *at a minimum*, from $8.6 billion to $19.8 billion per year. For the most part, these services are not currently accounted for in market transactions. These annual benefits translate into a present value for New Jersey's natural capital of *at least* $288 billion to $660 billion, not including marketed ecosystem goods (see Part III below) or secondary economic impacts.

Wetlands (both freshwater and saltwater), estuaries/tidal bays, and forests are by far the most valuable ecosystems in New Jersey's portfolio, accounting for over 90 percent of the estimated total value of ecosystem services.

Higher property values are associated with proximity to beaches and open water. Proximity to open space such as parks and environmentally sensitive areas has positive effects on property values in some local markets but not in others. Positive effects on value are more likely where the open space is legally protected from development.

Summary of Part III: Natural Goods

Ecosystem goods were divided into seven categories: water, minerals, farm products, non-farm animals, non-farm plants, fish, and wood. In each case, care was taken not to double-count ecosystem services covered in Part II. To measure the value of goods we calculated their Total Direct Economic Value. Total Direct Economic Value consists of actual market value plus a quantity known to economists as consumer surplus. Consumer surplus is the difference between the price consumers are willing to pay and the actual price. The method used in this study to estimate consumer surplus is extremely complex and is described in Part III of the report.

Results for Specific Ecosystem Goods

Water Resources Based on information in the 1996 Statewide Water Supply Plan, New Jersey's natural environment provides between 547 and 641 billion gallons of "raw" (i.e., unprocessed) water annually. The Total Direct Economic Value of that water in 2004 dollars is estimated to fall between $262 and $695 million per year. The median estimate is $381 million per year. The present value of annual benefits is between $9 and $23 billion; the median estimate is $13 billion.

Mineral Resources New Jersey's quarries provide commercially valuable amounts of construction and industrial sand, gravel and crushed stone. Based on data from the United States and New Jersey Geological Surveys, the Total Direct Economic Value of that production in 2004 dollars is estimated at between $481 million per year and $1.1 billion per year; the median estimate is $587 million per year. The present value of the benefits is between $16 and $37 billion and the median estimate is $20 billion.

Agricultural Products Based on information from the U.S. Department of Agriculture, the Total Direct Economic Value of the annual output of New Jersey's farms in 2004 dollars is estimated to be between $885 million and $6.5 billion per year; the median estimate is $3.7 billion. The present value of the annual benefits is estimated at between $30 and $216 billion with a median estimate of $123 billion.

Non-Farm Animals Based on harvest data from NJDEP's Division of Fish and Wildlife and retail prices from the U.S. Bureau of Labor Statistics for related meat products (adjusted to approximate wholesale prices), the Total Direct Economic Value of the game animals and birds and fur-bearing animals harvested in New Jersey is estimated to be about $21 million per year. The present value of these benefits is estimated at about $703 million.

Commercial Fish Harvest Based on harvest and price data from the National Marine Fisheries Service, the annual harvest of finfish and shellfish by New Jersey's commercial fishing vessels has an estimated Total Direct Economic Value in 2004 dollars of about $750 million per year. The present value of those benefits is estimated at about $25 billion. Of that amount, shellfish represent about 62percent by weight and 85percent by value.

Recreational Fish Harvest Based on data from various sources, New Jersey's recreational anglers harvest saltwater and freshwater fish with an estimated Total Direct Economic Value in 2004 dollars of about $207 million per year with a present value estimated at about $7 billion.

Non-Farm Plants New Jersey's landscapes provide an unknown amount of useful non-farm plants, including flowers, medicinal plants, and others. The data on these products are meager, and it is not currently feasible to estimate their economic value. Methods are being developed to estimate such values (where volume data are available), but those methods are still in the developmental stage.

Fuelwood In 2003, New Jersey used about 1.6 million cords of wood and wood wastes as an energy source, primarily for electric power generation and residential heating. The share of that fuelwood originating in New Jersey cannot be determined, and this analysis assumes that 100percent of it comes from in-state sources. Based on that assumption and price estimates from various sources, 2003 fuelwood consumption had a Total Direct Economic Value of about $95 million per year, for a present value of about $3 billion.

Sawtimber "Sawtimber" refers to commercially marketable timber other than fuelwood. Between 1987 and 1999, New Jersey's marketable timber resources increased by an average of 204 million board feet per year, of which hardwoods (i.e., deciduous trees) represented about 89 percent.[1] Based on wholesale prices for the various tree species, that annual growth had a Total Direct Economic Value of between $96 and $293 million per year. The median estimate is $147 million per year. The present value of these benefits is between $3 and $10 billion, with a median estimate of $5 billion.

Conclusions on Ecosystem Goods

The values presented above total $5.9 billion per year in Total Direct Economic Value for ecosystem goods with a range of $2.8 to 9.7 billion per year. In terms of ecogoods production, New Jersey's natural capital is worth $196 billion in present value, ranging between $93 to 322 billion. Farm goods and fish command the largest shares, followed by minerals and water; wood and non-farm animals have the lowest shares, and the value of non-farm plants cannot be estimated.

The value provided varies by ecosystem, depending on the types of natural goods provided, total acreage of the ecosystem, and the average value per acre. Farmland and marine ecosystems generate the highest values in terms of total value, followed by barren land (which includes quarries), forests, and freshwater wetlands. In terms of value per acre, barren land ranks first due to the presence of quarries, followed by farmland, marine ecosystems, and open fresh waters.

Conclusion

[1] One board-foot equals the amount of wood in a log measuring 1 ft x 1 ft x 1 in, or 144 cu in.

The results of this study should be treated as first estimates and not as final definitive valuations. They do not include secondary economic benefits supported by direct expenditures on ecogoods, which results in an understatement of economic value. A valuation study such as this one can never be regarded as a closed book, any more than a valuation analysis in business or any other sphere: as conditions change, so do values, and the process of change is continuous. Nonetheless, it is clear that New Jersey's natural capital, both living and non-living, makes a substantial contribution every year to New Jersey's economy and quality of life by providing natural goods worth several billion dollars both annually and in present value terms.

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PART I:

OVERVIEW

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Acknowledgments

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Executive Summary for Part I

In 2004, the New Jersey Department of Environmental Protection partnered with the Geraldine R. Dodge and William Penn Foundations to undertake an important project to assess the economic value of New Jersey's natural resources. As a result of generous funding from the two foundations, DEP entered into a contract with the Gund Institute for Ecological Economics, Rubinstein Institute of Environment and Natural Resources at the University of Vermont ("UVM"). The UVM researchers were charged with examining the ecosystem services portion of the project, and DEP staff were charged with examining the ecosystem goods part of the project. (Ecosystem services are the processes and functions by which natural ecosystems sustain and fulfill human life; goods are physical commodities that can be weighed, packaged, and transported.)

The result of this collaborative project is a three-part set of reports. This Part 1 serves as an overall summary of the Parts II and III, which are the final report for UVM's ecosystem services study and DEP's ecosystem goods study, respectively. This Part 1 serves to provide essential background information, summarize the combined detailed findings of Parts II and III and their limitations, and explore the policy implications of the project's findings

Section I: Introduction to Natural Capital

The concept behind the field of natural capital is that various naturally-occurring assets provide economic value over an extended period, a period that for some assets is essentially perpetual on any meaningful human time scale. The term **"natural capital"** is being increasingly used to describe these assets. In this report, the physical amount of natural capital is measured in acres, and its economic value is expressed in dollars. This report quantifies the economic value of natural capital as the present value of the goods and services it generates; all present values in this report are based on discounting at 3% per year (the most widely used rate in this type of analysis) in perpetuity.

The benefits provided by natural capital include both goods and services. (As noted above, ecosystem services are processes and functions by which natural ecosystems sustain and fulfill human life, while goods are physical commodities that can be weighed, packaged, and transported.) Goods come from both ecosystems (e.g., timber) and abiotic (non-living) sources (e.g., mineral deposits). While abiotic systems also provide some critical services, many of the services provided by natural capital come from ecological systems ("ecosystems"). On an overall basis, New Jersey's ecosystems are more valuable as providers of services than as sources of harvestable goods.

Sections II-IV: Results of the Studies

The final reports in Parts II and III include extensive discussions on the project's findings. In general, the key findings of the studies are as follows:

- The *annual* value of the ecoservices provided by New Jersey's natural capital is estimated at between \$8.6 billion/year (present value \$288 billion) and \$19.8 billion/year (present value

$660 billion). Freshwater wetlands and marine ecosystems have the highest ecoservice values on both an annual and a present value basis. For a number of reasons, these estimates reflect estimated market values only and do not include consumer surplus, another major component of total economic value. If consumer surplus could be included, the estimated values would in all probability be significantly higher than those given above.

- The annual value of the goods provided by New Jersey's natural capital is estimated at between $2.8 billion/year (present value $93 billion) and $9.7 billion/year (present value $322 billion). Farmland, marine waters, and mines and quarries provide the highest values. These estimates reflect both estimated market values and consumer surplus and therefore present a more complete picture of total economic value.

- Taking the values of goods and services together, the total value of New Jersey's natural capital is estimated at about $20 billion/year (present value $681 billion), plus or minus $9 billion/year (present value $300 billion). This wide range of estimates is not unexpected, given the complexity of the many economic benefits being quantified.

For a number of reasons, the authors believe that even the high-end estimates are probably conservative. Those reasons include incomplete coverage of ecosystems and ecoservices in the economics literature; increased scarcity value as natural lands are developed; and inability of the study to include certain components of economic value. For example, public health benefits related to ecosystems were excluded from this study because of conceptual problems involved in their quantification. Similarly, as Section III shows, inclusion of certain ecoservices provided by New Jersey's forests could add between $630 and $840 million of benefits annually (present value $21-28 billion).

As another example of an important benefit not included in Parts II or III, wildlife-related tourism is estimated to generate about $3 billion of gross economic activity annually representing about $1 billion of wage and salary income annually or about 37,000 jobs. (The jobs are not an additional benefit since the related income is included in the activity figure.) Another common benefit measure, namely total value added (the annual contribution to New Jersey's Gross State Product), cannot be determined. Section IV presents the details of these estimates.

Section V: Potential Policy Applications

As expected, the results of this research points to important immediate and long term applications for statewide public policy and local land use decision-making. This report describes over a dozen potential uses of the findings, affecting conservation and land use planning and regulation, land management, and other areas. Some of these applications may be more promising than others and some may have more immediate application than others.

By conducting this research and presenting it to the public, it is the Department's hope to generate a statewide dialog on how New Jersey can best incorporate natural capital considerations into state and local policy and decision-making. The potential uses outlined in this report are not formally endorsed by the Department; rather they are included here as considerations for public policy and to prompt a dialogue with stakeholders.

Beyond the potential uses outlined in this report, the Department has already begun to incorporate and consider incorporation of the results of this project into its decision-making. Among these more immediate applications, the Department expects to use the project's findings to inform rulemaking, acquisition priorities, and interaction with regional and local planning entities.

Section VI: Future Research Needs

1. The valuation estimates presented in Parts II and III of this report are not the final word on the subject, and this section suggests areas for further research to improve the coverage and reliability of the valuations. The section concludes by noting that while our understanding of the value of New Jersey's natural capital will never be perfect, that fact is not a reason for postponing action to conserve critical natural capital before it is lost forever.

Section I: Introduction to Natural Capital

This section begins the first part of a three-part report on the New Jersey's Natural Capital Project. Part I presents essential background information, summarizes the detailed findings of Parts II and III and their limitations, and explores the policy implications of the natural capital project and the future research needs in this field.

The Concept of Natural Capital

Before we can discuss "natural capital", we need to understand the concept of "capital" in general and the related concept of "assets". In economics, *assets* are entities that possess "exchange" (i.e., market) value and that form part of the wealth or property of their owner (Pearce 1992). *Capital* assets are assets that generate a flow of economic benefits over an extended period. In contrast, the value of operating assets such as gasoline, office supplies, and food is usually used up relatively quickly.

Perhaps the most familiar types of capital assets are *physical* capital such as machinery, buildings, equipment, etc., and *financial* capital; other types of capital recognized by economists include *human* capital (e.g., a population's numbers, skills, training, etc.) and *social* or *cultural* capital (e.g., the ability to own property and enforce contracts and the other institutions that make private economic activity possible).[1] In each case, the use of the term "capital" emphasizes the fact that the assets in question provide value over an extended period.

In recent years, many economists have begun using the term *natural* capital to call attention to the fact that various naturally-occurring entities also provide economic value over an extended period, a period that for some assets is essentially perpetual on any meaningful human time scale. The term "natural capital" differs from the older term "natural resources" in that the latter views nature as essentially a source of raw materials which lack value until they are extracted from their natural environment and put to use. "Natural capital" also differs from "natural environment" in emphasizing nature's role as an active source of economic value.

These distinctions are of great practical importance. If we view something as a long-term source of benefit, we are more likely to invest in maintaining its productive capacity than if we view it as raw material to be used up in the near future. For example, if a forest is seen only as a source of short-term profits on timber sales, there is no particular reason to delay harvesting the resource and reaping the benefits. However, to the extent that the forest is seen as a capital asset, the owner has an incentive to limit the amount of logging in some way to preserve the forest's long-term profitability. This incentive is increased if the forest is seen as an asset that provides things of value in addition to wood, e.g., recreational opportunities. [2]

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[1] This taxonomy of capital follows the treatment of many modern environmental economists (e.g., Pearce and Barbier 2000) while departing from the more traditional division of "factors of production" into land, labor, and capital, where "capital" meant only produced goods or financial capital (Pearce 1992).

[2] The incentive effect is reduced to the extent that the owner of the forest cannot capture at least some of the value of the benefits provided to society by charging enough for their provision to realize a profit.

Many of the benefits provided by natural capital come from ecological systems ("ecosystems"); an ecosystem is a dynamic complex of plant, animal, and micro-organism communities and their nonliving environment, all interacting as a functional unit (UNEP 2001-2005). The benefits provided by natural capital include both goods and services:

- "Ecosystem goods (such as food) and services (such as waste assimilation) represent the benefits human populations derive, directly or indirectly, from ecosystem functions" (Costanza et al. 1997).

- "Ecosystem services are the conditions and processes through which natural ecosystems, and the species that make them up, sustain and fulfill human life. They maintain biodiversity and the production of ecosystem goods, such as seafood, forage timber, biomass fuels, natural fiber, and many pharmaceuticals, industrial products, and their precursors" (Daily 1997). Examples of ecosystem services ("ecoservices") include temporary storage of floodwaters by wetlands, long-term storage of climate-altering greenhouse gases in forests, dilution and assimilation of wastes by rivers, and numerous others. Part II presents a detailed listing of ecoservices.

- Goods are physical commodities that can be weighed, packaged, and transported. Some classification systems treat nature's provision of goods as a type of service ("provisioning" services); for convenience this study treats goods separately. Although goods can come from both ecosystems (e.g., timber) and abiotic (non-living) sources (e.g., mineral deposits), for convenience all goods deriving directly from natural sources are referred to in this report as "natural goods", "ecosystem goods", or "ecogoods".

Part II of this report covers ecoservices, emphasizing the services provided by living systems, i.e., ecosystems. Part III deals with natural (i.e., biotic and abiotic) goods. Sections III and IV of Part I discuss some other sources of economic benefits related to natural capital, including the benefits stemming from ecotourism.

Relation to Other Concepts

Natural capital is different from but related to a number of other concepts used in discussions of environmental value; the following paragraphs briefly highlight some of those other concepts and how natural capital relates to them.

Sustainability. It is common to state as a fundamental criterion for sustainability the preservation of capital (see, e.g., Pearce and Barbier 2000). Ecological economists go further and distinguish two types of sustainability—weak and strong. In weak sustainability, the total amount of capital is preserved, but substitution of one type of capital for another is permitted. Thus, built capital such as roads and housing could substitute for an equal dollar amount of natural capital. In contrast, strong sustainability requires that each type of capital be preserved, including natural capital. In fact, some analysts would go even further and require that previously degraded natural capital be restored to some historical level deemed to be necessary in some sense.

"Green" GNP or GDP. The best-known measures of economic output are Gross National Product (GNP) or Gross Domestic Product (GDP). These metrics are based on the total volume of marketed goods and services produced in a given time period, usually a year. GNP and GDP treat nature as a collection of exploitable resources rather than capital assets; wealth is deemed to be generated only when those resources are harvested and sold for money. In contrast, there are a number of other measures of societal *income* that adjust GNP or GDP in various ways to arrive at a measure of economic activity that takes into account the degradation of natural and other capital. For example, the dollar impact of pollution might be estimated and deducted from GNP or GDP. Examples of such indicators include the Indicator of Sustainable Economic Welfare, the Genuine Progress Indicator, Genuine Savings, the Environmental Sustainability Index, and others.[3] These are all *flow* concepts, i.e., they measure the annual flow of benefits.

Ecological Footprint. This concept was developed and popularized by Wackernagel and Rees (1996). The essential idea is that humanity's use of natural resources is measured in terms of the amount of land (or land-equivalents) needed to sustain a given level of consumption, e.g., the amount of land needed to grow our food, to supply clean water, to absorb our wastes, etc. Ecological footprints are measured in acres and in that respect are similar to natural capital as described below. A main difference is that footprints are not usually monetized, i.e., they are not assigned dollar values; another main difference is that footprint analysis starts with a given consumption level and estimates the amount of land and water needed to support it, whereas natural capital valuation starts with the land and water themselves and attempts to estimate their dollar values. Ecological footprint is essentially a *stock* concept, i.e., it measures the stock of resources needed to support consumption.

As contrasted with these measures, natural capital is a *stock* concept; the goods and services that it provides are the annual benefit *flows*. In this report, the physical amount of natural capital is measured in acres, and its economic value is expressed in dollars. This report quantifies the economic value of natural capital as the present value of the goods and services it generates; no attempt is made to assess whether New Jersey's natural capital is adequate or inadequate.

The Natural Capital Project

As the most densely populated state in the U.S., New Jersey is under more or less constant pressure to convert undeveloped land to residential, commercial, and other uses; the potential for such conversion is one of the top environmental issues for the state's residents and businesses. The case made for development projects usually includes quantitative projections of claimed economic *benefits*, such as jobs, property tax revenues, etc. The arguments made against development increasingly include quantitative projections of claimed economic *costs,* such as the cost of new schools, new or expanded highways, etc.

While projected environmental costs are often part of the case made against land conversion, this type of cost is often expressed in qualitative terms; where it is quantified, the figures cited (e.g., acres of wetlands lost) are usually not expressed in monetary terms. This makes it essentially impossible to quantitatively compare environmental costs with other asserted costs and benefits. Some would say that this inability is for the best, since it protects environmental

[3] See Daly and Cobb (1989), Redefining Progress (2006), World Bank (2006), and CIESIN (2006).

assets from being lost due to hasty or otherwise deficient benefit-cost analyses. Others believe that the natural environment can most effectively be protected if its value as natural capital—expressed in monetary terms—is widely understood.

Recognizing the value of expressing natural resource value in monetary terms, the Department entered into a partnership with the Geraldine R. Dodge and William Penn Foundations to undertake this effort to quantify the economic value of New Jersey's natural resources. With the generous support of the two foundations, DEP engaged the expertise of Dr. Robert Costanza of the University of Vermont to be the principal investigator of the study.

Components of Natural Capital

In economics and finance, the value of a capital asset is determined by the value of the future benefits which the asset is expected to provide; in effect, the benefits represent income in the accounting sense, while the asset values make up part of the balance sheet. Natural capital provides two main types of direct benefit: *services* (such as removal of suspended solids by wetlands) and *goods* or commodities (such as timber). In addition, natural capital can be divided into *biotic* (living) systems such as forests and wetlands and *abiotic* systems such as underground aquifers and mineral deposits. These distinctions give rise to the following classification scheme:

Table 1: Types of Natural Capital and Direct Economic Benefits

Natural Assets	Value from services	Value from goods
Biotic systems, e.g., wetlands	ecosystem services, e.g., sediment removal	ecosystem goods, e.g., fish
Abiotic systems	dilution of air pollutants	provision of groundwater

In addition to these types of *direct* benefit, the natural environment also provides the essential setting for the production of what might be called *indirect* benefits, such as those generated by ecotourism. The benefits of ecotourism differ from the benefits of ecosystem services and natural goods because they derive from the fact that visitors to natural sites spend money in connection with their visits; and those expenditures in turn generate further economic activity as the dollars involved are re-spent. If visitors to natural sites spent a bare minimum on their activities (e.g., getting to the site and back but nothing else), the benefits of ecotourism would decline substantially, but the ecosystems involved would be unchanged, as would the value of the natural goods and ecoservices they provide. For these and other reasons, assessing the economic effects of ecotourism requires different methods from those used for ecosystem services and natural goods.

In the allocation of project responsibilities, UVM has focused on ecosystem services and their contribution to the value of New Jersey's natural capital, while Department staff have focused on natural goods (including both ecosystem goods and goods produced by abiotic systems) and ecotourism. Because of resource and time constraints and the less developed state of the relevant valuation methodologies, the project has paid relatively little attention to the contribution to natural capital value made by services provided by abiotic systems. Appendix A discusses some of the issues involved in quantifying this component of natural capital.

Part I of this report continues by summarizing the approach and results of the other parts of this study. Part II consists of UVM's final report on the value of the services provided by New Jersey's ecosystems. Part III presents the final report by Department staff on the value of the goods provided by New Jersey's natural capital. Parts II and III also translate the value of the services and goods into valuations for the natural assets that provide these benefits.

Section II: Approach and Results

After a brief discussion of methodology, this section summarizes the main results of the detailed studies presented in Part II (on ecosystem service values) and Part III (on natural goods values). Sections III and IV will discuss the approach and results for some other sources of value. Sections V and VI will discuss some of the implications, uses, and limitations of the findings.

Approach for Ecoservices and Ecogoods

As noted in Section I, the value of a capital asset is determined by the value of the services and goods which that asset provides over time. This simple statement reflects a number of important principles and assumptions, as described in the following paragraphs.

Level of analysis. Technically, each locality is unique, but to conduct any kind of analysis at that level of specificity is not realistic at present. Since the goods and services provided vary by ecosystem, the two studies presented in this report used that level of aggregation, e.g., all New Jersey forests, all New Jersey wetlands, etc. Where possible, important distinctions are made at the ecosystem level, e.g., between forested and unforested wetlands.

Natural capital metric. To estimate the dollar value of New Jersey's natural capital, we need to know how much natural capital the state has in a *physical* sense. The generally used metric for this, and the metric used in the present studies, is acreage. As with the level of analysis, this metric treats all acres of a given ecosystem type as fungible, even though each acre may be unique in some relevant sense.

The assumption of fungibility is the most practical at this stage in the application of natural capital concepts to specific geographic areas and can be seen as a first-order approximation. Part II does present two types of analysis that go beyond this assumption: one that analyzes differences in natural capital value based on proximity to human habitation, and another that models differences in ecosystem productivity based on spatial location relative to other ecosystems. However, the main results of the study treat all acres of a given ecosystem type as having the same value.

Ecosystem matrix. In addition to distinguishing among ecosystems, we need to distinguish among the services that each type of ecosystem provides. For example, forests sequester carbon but do not provide fish; the opposite is true for lakes and streams. Every ecosystem provides a unique set or "portfolio" of goods and services, and most ecoservices and natural goods are provided by more than one ecosystem. Therefore, we need to think of the task of valuing natural capital task in terms of an "ecosystem matrix" as shown in Table 2 (next page); valuation can be thought of as filling in the cells in this matrix. Of course, some cells cannot be filled in; tidal estuaries, for example, do not provide pollination services. Most cells, however, could conceivably contain dollar values.

(text continues after Table 2)

Table 2: Ecosystems and Sources of Economic Value (condensed list)									
Source of Economic Value	**Wetlands (all types)**	**Forest lands**	**Riparian buffers**	**Farmland (all types)**	**Urban parks**	**Open fresh waters**	**Beaches-dunes**	**Marine waters**	**Mines & quarries**
Ecosystem services: Aesthetic / recreational Biological control Cultural / spiritual									
Disturbance regulation Gas/climate regulation Habitat / refugia									
Nutrient cycling Pollination Soil formation									
Waste treatment Water regulation Water supply									
Natural goods: Farm products Fish (fresh/saltwater) Game and fur									
Raw minerals Raw water Timber/fuelwood									
Ecotourism value									
TOTAL VALUE									

Note: this table summarizes the analytic framework for the natural capital study; the detailed numerical results are presented below.

Basic valuation formula. The basic mathematical relationship for each cell in the ecosystem matrix is extremely simple (* means multiplied by):

$ value/year for good or service X provided by ecosystem Y =

Acres of Y * Units of X provided/acre/year * $ value/unit of X

The acreage of most of New Jersey's major ecosystem types was provided by the Department's Bureau of Geographic Information Systems (BGIS); in the present studies, the values of the other two parameters for a given cell in the ecosystem matrix were obtained either from prior studies or from original analyses by the authors of Parts II and III. To simplify the reporting of results, these parts often collapse the second and third parameters into one, which changes the equation above into the following:

$ value/year for good or service X provided by ecosystem Y =

Acres of Y * $ value/acre/year

This change does not affect the substance of the analysis but only the summary data reported.

Treatment of time. As noted in Section I, capital assets produce value over an extended period, and each year's values must therefore be combined to produce a single "present" value for the asset. In keeping with the standard practice in economics and other fields, this is accomplished by mathematically "discounting" the values of goods and services provided in future years. Parts II and III both contain detailed discussions of how this is done; in essence, the annual future benefits stream is assumed to be constant, and that constant value is discounted at 3% per year in perpetuity to obtain the present value of the natural asset.

Goods vs. services. The need to avoid double-counting of benefits is always a consideration in studies such as the present ones, and the researchers involved in this project have taken care to avoid such double-counting. One type of double-counting concerns the relationship between goods values and service values; later sections discuss some other types of double-counting that need to be avoided.

The issue involving goods and service values is best explained by example. As described in Part II, forests provide a number of valuable services, such as carbon sequestration, control of soil erosion, and others. As described in Part III, forests also provide economically useful timber. The question is how much of each a given forest can provide at the same time. A healthy and sustainably managed forest or other ecosystem can provide both types of benefits over extended periods, and the current studies assume that the levels of service provision discussed in Part II and the levels of goods provision discussed in Part III are compatible.

Results by Ecoservice or Ecogood

We first present the results of Parts II and III by type of ecoservice or natural good, beginning with the ecoservices analyzed in Part II, which provides definitions of the services.

Table 3: Total Annual Ecoservice Values		
Ecoservice	**MM 2004 $/yr**	**Pct.**
Nutrient cycling	$5,074	25.6%
Disturbance regulation	3,383	17.1%
Water regulation	2,433	12.3%
Habitat/refugia	2,080	10.5%
Aesthetic/recreational	1,999	10.1%
Waste treatment	1,784	9.0%
Water supply	1,739	8.8%
Cultural/spiritual	778	3.9%
Gas/climate regulation	246	1.2%
Pollination	243	1.2%
Biological control	35	0.2%
Soil formation	8	0.04%
Totals	**$19,803**	**100%**

As Table 3 shows, a few services appear to account for the majority of the ecoservice benefits. However, if some of the gaps in coverage discussed below could be addressed, these rankings might change, e.g., if newer studies found the less-well-investigated services to have higher values per acre than the existing literature indicates. It should be noted that the value per acre for a given service depends on the ecosystem providing the service. For example, forested land sequesters much more carbon per acre than farmland, even though both provide carbon sequestration services.

These differences in service intensities[4] may have implications for service delivery planning; for example, achieving a given carbon sequestration goal might require fewer acres of forest than of farmland, if both were available for this purpose. These differences could also be related to cost per acre to develop benefit-cost ratios for different ecosystems providing a given service. In addition, such data can help decision makers compare the cost and benefit of service provision by ecosystems to provision by artificial facilities. These and related topics are discussed further in Sections V and VI below.

Table 4 on the next page presents the estimated values of the various natural goods analyzed in Part III. It should be noted that whereas the figures in Table 3 are essentially market values for the services in question, Table 4 presents both market values (MV) and estimated consumer surplus (CS); as explained in detail in Part III, the latter is a second major component of total economic value (TEV).

[4] Differences in dollar value of service per acre per year is actually a proxy for differences in physical service intensities, e.g., tons of carbon sequestered per acre per year. However, unless different ecosystems provide different levels of *quality* levels for a given service, the dollar values should be a reasonable proxy for *quantity* levels.

Table 4: Total Annual Ecogoods Values (MM 2004 $/year)				
Natural Good	**MV**	**CS**	**TEV**	**Share**
Farm products	$447.6	$3,228.4	$3,676.0	62.7%
Fish (total)*	157.0	800.7	957.7	16.3%
Minerals	320.9	266.3	587.2	10.0%
Raw water	169.2	211.4	380.6	6.5%
Sawtimber	48.9	97.8	146.7	2.5%
Fuelwood	38.5	56.6	95.1	1.6%
Game/fur animals	3.4	17.7	21.1	0.4%
Total or avg.	**$1,185.5**	**$4,678.9**	**$5,864.4**	**100.0%**
Commercial fish	123.0	627.3	750.3	12.8%
Recreational fish	34.0	173.4	207.4	3.5%

As is evident, farm products account for well over half of the total value of natural goods. Valuation of farm products presents various conceptual issues, which Part III discusses in detail.

Results by Ecosystem

Table 5 (next page) summarizes the results of Parts II and III by ecosystem instead of by type of good or service; annual values ($MM and $/acre) and present values ($Bn and $/acre) are given. The ecosystems are listed in order by the total value of goods plus services. Appendix B describes some of the technical issues involved in combining the results of Parts II and III.

For both goods and services separately and for the two combined, the figures in Table 5 clearly demonstrate a wide range of both values per acre and total values, spanning two orders of magnitude. Every system except beaches/dunes, barren land, and paved urban land provides both goods and services. Beaches/dunes have by far the highest dollar value per acre due to the extremely high value that many people place on the services provided by this ecosystem.

Table 5 also shows that on an overall basis, New Jersey's ecosystems are far more valuable as providers of services than as sources of harvestable goods, a fact that has important implications for land use and environmental protection. For all ecosystems in the aggregate, the total service value of $19.8 billion/yr. shown in Table 5 equals 3.4 times the total goods value of $5.9 billion/yr. The ecosystems with services-to-goods ratios below this average are farmland, barren land (which includes mines and quarries), and open fresh water (a source of recreationally harvested fish); for these ecosystems, the harvestable goods appear to be more valuable than the ecoservices provided. This conclusion is based on our current understanding of the services provided by those ecosystems and is subject to change as research continues.

Finally, Table 5 demonstrates the high value of New Jersey's natural capital: $25.7 billion/year for goods and services combined (just over $4,600/acre/year) and $856 billion in present value ($154,000/acre). Freshwater wetlands and marine ecosystems have the highest total values. Different value estimates are presented below in a limited sensitivity analysis.

Table 5: Value of New Jersey's Natural Capital (excluding ecotourism) (2004 $)

Ecosystem	Area (acres)	NATURAL GOODS*				NATURAL SERVICES				NATURAL GOODS & SERVICES			
		$MM/yr	$/ac/yr	PV $Bn	PV $/ac	$MM/yr	$/ac/yr	PV $Bn	PV $/ac	$MM/yr	$/ac/yr	PV $Bn	PV $/ac
Freshwater wetland[1]	814,479	$191	$234	$6.4	$7,801	$9,422	$11,568	$314.1	$385,593	$9,612	$11,802	$320.4	$393,394
Marine[2]	755,535	850	1,125	28.3	37,512	5,700	7,544	190.0	251,475	6,550	8,670	218.3	288,987
Farmland** [3]	673,464	3,760	5,583	125.3	186,095	483	717	16.1	23,887	4,242	6,229	141.4	209,982
Forest land***	1,465,668	349	238	11.6	7,934	2,163	1,476	72.1	49,201	2,512	1,714	83.7	57,136
Saltwater wetland	190,520	26	139	0.9	4,617	1,168	6,131	38.9	204,355	1,194	6,269	39.8	208,973
Barren land	51,796	587	11,337	19.6	377,893	0	0	0.0	0	587	11,337	19.6	377,893
Urban[4]	1,483,496	20	13	0.7	450	419	283	14.0	9,420	439	296	14.6	9,869
Beach/dune	7,837	0	0	0.0	0	330	42,149	11.0	1,404,969	330	42,149	11.0	1,404,969
Open fresh water	86,232	79	921	2.6	30,689	66	765	2.2	25,510	145	1,686	4.8	56,208
Riparian buffer	15,146	2	118	0.1	3,934	51	3,382	1.7	112,747	53	3,500	1.8	116,681
Total or Avg.	**5,544,173**	**$5,864**	**$1,058**	**$195.5**	**$35,259**	**$19,802**	**$3,572**	**$660.1**	**$119,059**	**$25,667**	**$4,630**	**$855.6**	**$154,317**

1. Freshwater wetlands													
Forested	633,380	154	244	5.1	8,122	7,327	11,568	244.2	385,593	7,481	11,811	249.4	393,715
Unforested	181,099	36	200	1.2	6,679	2,095	11,568	69.8	385,593	2,131	11,768	71.0	392,272

2. Marine													
Estuary/tidal bay	455,700	513	1,125	17.1	37,505	5,310	11,653	177.0	388,448	5,823	12,779	194.1	425,953
Coastal shelf	299,835	338	1,126	11.3	37,524	389	1,299	13.0	43,297	727	2,425	24.2	80,820

3. Farmland**													
Cropland	546,261	3,291	6,025	109.7	200,828	473	866	15.8	28,855	3,764	6,890	125.5	229,683
Pasture/grassland	127,203	469	3,685	15.6	122,827	10	77	0.3	2,551	478	3,761	15.9	125,379

4. Urban													
Urban (impervious)	1,313,946	0	0	0.0	0	0	0	0.0	0	0	0	0.0	0
Urban green space	169,550	20	118	0.7	3,934	419	2,473	14.0	82,420	439	2,591	14.6	86,354

*middle estimates, including consumer surplus; see Part III for details. ***includes wooded farmland.
**ecosystem service values for farmland have been revised since Part II was finalized; see Appendix B for details.

Analysis of the Results

Because of various limitations on data and resources, it was not possible to perform a formal sensitivity analysis (in which the values of selected input parameters are varied to see how the results change) or a formal statistical analysis of the results (e.g., an analysis of confidence intervals). However, two factors do allow us to get a sense of the range of uncertainty in the results:

- The investigators for Part II examined two types of prior studies. Type A studies consist of original research published in peer-reviewed journals; Type C studies consist of meta-analyses (statistical analyses of prior studies) published in peer-reviewed journals.[5]
- The investigators also calculated two summary measures for each cell with estimated values in the ecosystem matrix, namely the mean and the median of the prior estimates.

These two dimensions—type of prior study and summary measure—yield four possible combinations, as shown in Table 6:

Table 6: Sensitivity Analysis for Ecosystem Services (2004 $)

Ecosystem	Area (Acres)	Type A Only Median	Type A Only Mean	Types A & C Median	Types A & C Mean
		2004 $/acre/year		2004 $/acre/year	
Beach/dunes	7,837	$38,002	$42,147	$38,003	$42,147
Coastal shelf	299,835	n/a	n/a	$1,295	$1,299
Cropland	546,261	$23	$23	$865	$866
Estuary/tidal bay	455,700	$281	$715	$11,289	$11,653
Forested land	1,465,668	$481	$1,283	$688	$1,476
Freshwater wetlands	814,479	$8,234	$8,695	$10,969	$11,568
Open fresh water	86,232	$781	$765	$781	$765
Pastureland	127,203	$12	$12	$77	$77
Riparian buffer	15,146	$797	$3,382	$797	$3,382
Saltwater wetlands	190,520	$1,980	$6,527	$2,771	$6,131
Urban green space	169,550	$1,915	$2,473	$1,916	$2,473
Other urban + barren	1,365,742	$0	$0	$0	$0
Total $MM/yr	**5,544,173**	**$8,633**	**$11,413**	**$17,187**	**$19,803**
Present Value $Bn		**$287.8**	**$380.4**	**$572.9**	**$660.1**

As Table 6 shows, using only the medians of the results from Type A studies gives a total ecoservice value of $8.6 billion/yr for a present value of $288 billion. At the other end, using the means of the results from both Type A and Type C studies gives a total ecoservice value of $19.8 billion/yr for a present value of $660 billion. Tables 3 and 5 reported the results obtained using the means of both Type A and Type C studies. The mean is the accepted summary measure in valuation analysis, and using both types of studies permits the broadest possible coverage of ecosystems and ecoservices.

[5] Type B studies (not used in Part II) include unpublished studies and studies published in non-peer-reviewed form, e.g., studies conducted by government agencies. Part III can be viewed as a Type B study.

As to natural goods, Part III presents three estimates as follows: low-end = $2.8 billion/yr (present value = $93 billion); middle = $5.9 billion/yr (PV=$196 billion); and high-end = $9.7 billion/yr (PV=$322 billion). Tables 4 and 5 reported the middle estimates.

Combining these with the estimates from Tables 3-6 gives the following range of estimated total present values:

Table 7: Total Natural Capital Value (2004 $Bn)

Columns = natural goods PVs → Rows = ecoservice present values ↓		Low-end $93	Middle* $196	High-end $322
Type A only/medians	$288	381	484	610
Type A only/means	$380	473	576	702
Mean for table			**679**	
Median for table			**684**	
Types A & C/medians	$573	666	769	895
Types A & C/means*	$660	753	856	382

*indicates estimates presented in detail in Tables 3-6.

Based on this analysis, the total value of New Jersey's natural capital appears to be about $681 billion, plus or minus $300 billion. A range of this magnitude is not surprising given the complexity of the ecosystems being analyzed and the uncertainties in each of the many component estimates that make up these grand totals. For reasons discussed below, the authors believe that even the higher estimates in Table 7 are probably conservative.

Conservatism of the Estimates

The results summarized above have to be regarded as initial estimates of economic value rather than as definitive conclusions. In part, this is due to the fact that those results had to leave out a number of sources of value, including (but not limited to) the following:

1. **Limited coverage**. This is perhaps the most important issue. Some ecosystems and ecoservices have not been very well studied, and some have not been studied at all. For example, the results do not reflect the value of the genetic data contained in New Jersey's natural capital, i.e., its plant and animal life. More comprehensive coverage would almost certainly increase the values shown in this report, since no valuation studies to date have reported values of less than zero.

2. **Scarcity value**. The valuations in Parts II and III probably underestimate shifts in the relevant demand curves as the supply of natural capital declines due to continued conversion of undeveloped land to other uses. Such shifts would in all probability result in an increase in society's willingness to pay for the natural capital that remains. If New Jersey's ecosystems are now smaller than assumed here, their value is therefore probably underestimated in this study. Such reductions appear likely as land conversion and development proceed; climate change may also adversely affect New Jersey's ecosystems, although the precise impacts are harder to predict.

3. **Omitted value components**. Because the value transfer method used for ecoservices in Part II is based on average rather than marginal cost, it cannot provide estimates of consumer surplus. However, this means that ecoservice valuations based on averages are more likely to *underestimate* total ecoservice value. (The valuations for natural goods in Part III *do* include estimates of consumer surplus and are thus more complete.) In addition, for various reasons, the benefits of ecotourism are discussed in Section IV.

4. **Externalities**. Distortions in the market prices used to estimate ecoservice values are unavoidably carried through the analysis. These prices do not reflect environmental externalities and are therefore again likely to be underestimates of "true" values.

5. **Secondary effects**. The values reported in Parts II and III only reflect "direct" effects, but "secondary" effects may also be important for some of the goods and services studied. When costs are incurred to produce and distribute natural goods, or when costs are avoided because natural ecoservices eliminate the need for investment in artificial substitutes, at least some of the expenditures made (or the expenditures made with funds saved) stimulate "secondary" economic activity, e.g., as when farmers purchase supplies or equipment or when employees of mining companies spend their wages on goods and services. These benefits are not reflected in the estimates in Parts II and III.

6. **Existence value**. The results do not fully reflect what economists refer to as "existence value". It is well known that people value the existence of certain ecosystems, even if they never plan to use or benefit from them in any direct way. Estimates of existence value in the peer-reviewed literature are rare, and fully including this "service" would again increase the total values.

All of these factors lead to *under*-estimates of value, and there are relatively few factors that would cause *over*-estimates (Part II presents a fuller discussion). The factors described above and other factors that could affect the results are discussed in greater detail in Parts II and III, as are some of the theoretical arguments surrounding the valuation methods used.

Section III: Other Ecosystem Services

As noted in Section II, the results presented in Part II of this report do not address all of the ecosystem services provided by New Jersey's natural capital. These deliberate omissions reflect various factors, including absence of peer-reviewed studies, unavailability of data, lack of accepted analytic techniques, etc. However, these omissions necessarily lead to an understatement of the total value of New Jersey's natural capital. To illustrate the potential magnitude of this understatement, this section presents analyses of several forest ecoservices for which peer-reviewed studies were not available for inclusion in Part II.

Carbon Storage

As this report was being finalized, the Intergovernmental Panel on Climate Change (IPCC) issued its long-awaited Fourth Assessment Report on the causes and consequences of global climate change (see www.ipcc.ch). The report contains the IPCC's clearest warnings to date on the adverse impacts caused by global warming and the ways in which human emissions of greenhouse gases (GHG's)—especially carbon dioxide—are worsening those impacts.

The results presented in Part II of the current study reflect the estimated value of the *sequestration* (removal from the atmosphere) by New Jersey's forests of carbon dioxide. For technical reasons, the current study does not discuss in detail the value of previous forest *storage* of carbon dioxide. Given the growing recognition of the importance of slowing the growth of GHG emissions, Appendix C presents some crude estimates of the value of the carbon storage service provided by New Jersey's forests, which could range from $3.5 to $10.4 billion in present value terms. Because they have not been published in peer-reviewed journals, these amounts are not included in the totals presented in this report, which again underscores the conservatism of this study's approach to valuing New Jersey's natural capital.

Other Forest Services

Carbon storage is not the only forest-related ecosystem service not discussed in Part II of this study. For example, due to a lack of peer-reviewed studies, Part II's estimated ecoservice value for forest land does not include two important services: 1) slowing stormwater runoff, thus reducing peak flows and decreasing the amount of stormwater storage capacity needed, and 2) removing pollutants like sulfur and nitrogen dioxides, carbon monoxide, ozone, and particulates from the air. Based on a non-peer-reviewed analysis, the value of these services from forests may total about $9.0 billion and $8.5 billion respectively in present value terms. Appendix D shows the derivation of these figures.

Section IV: Ecotourism Benefits

In addition to benefits from natural goods and ecosystem services, New Jersey also realizes other types of economic benefits related to the state's natural capital. Ecotourism is a prime example of this: while nature provides the essential setting for this activity, the benefits stem from the money that ecotourists spend rather than directly from nature *per se*. Spending related to ecotourism contributes to New Jersey's economy by supporting business and employment opportunities that result in the production of cash income. This section presents a preliminary estimate of those benefits. As will be discussed below, only a part of total ecotourism spending in New Jersey generates economic benefits for the state; but those benefits are nonetheless substantial, and their inclusion helps us present a more comprehensive picture of the total value of New Jersey's natural capital.

The most comprehensive recent report on spending by ecotourists in the United States was published in 2003 and was based on a survey conducted by the US Fish and Wildlife Service in 2001 (USFWS 2003a). That report provides data on the level of participation and the estimated spending by wildlife watchers, hunters, and anglers in each state, including New Jersey. [6] The report states that wildlife watchers, hunters, and anglers spent a total of $2.2 billion in New Jersey (in 2001 dollars) on travel-related expenses (meals, lodging, transportation, etc.), equipment, and other items.[7]

There is a well-established method for adjusting spending data and using it to estimate the economic effects of tourism, including ecotourism (see, e.g., Stynes et al. 2007a and 2007b); Appendix E contains a detailed summary. First, an amount estimated to equal the dollars that flow to out-of-state producers and suppliers (see above) is deducted from expenditures. As the remaining dollars (i.e., those captured by the New Jersey economy) are spent and re-spent, they support two types of "secondary" economic activity: purchases by one business from another and by employees and other income recipients (see Appendix E). The number of captured dollars is therefore increased to reflect this "multiplier" effect. The result is then adjusted downwards to eliminate double-counting of purchases and sales among firms and to deduct quantities such as depreciation and taxes that do not represent spendable household income.

Based on this methodology, NJDEP prepared an estimate of the annual benefits attributable to spending in New Jersey by wildlife watchers, hunters, and anglers; Exhibits A and B contain backup for the estimate. Using essentially the same approach (with differences as noted below), others had earlier prepared benefit estimates for all 50 states, including New Jersey (see USFWS 2003b, ASA 2002, and IAFWA 2002). Table 8 summarizes the assumptions and results of the two sets of analyses, together with a third estimate based on the average of the other two.[8]

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[6] Because of a lack of expenditure data, the term "ecotourism" as used here follows the USFWS usage and excludes swimming, skiing, and other types of outdoor recreation not directly related to wildlife.

[7] Of the $1.2 billion spent in New Jersey by wildlife watchers, about $0.8 billion was spent on items not detailed in USFWS (2003a) because of sampling issues. This lack of specificity warrants some caution in using the survey results.

[8] For technical reasons having to do with a desire to avoid "interaction terms", the middle estimate in Table 8 uses the geometric average rather than the more familiar arithmetic average.

Table 8: Estimated Annual Benefits to New Jersey from Ecotourism (2004 $MM)			
Variable	**NJDEP Estimate**	**Averaged Estimate**	**USFWS Estimate**
Ecotourism expenditures	$2,380	$2,342	$2,304
% captured by NJ	58%	77%	100%
NJ Direct Sales	$1,383	$1,798	$2,304
Avg. Sales Multiplier	1.57	1.70	1.85
NJ Total Sales	$2,176	$3,061	$4,254
Value Added/Total Sales	65%	n/a	n/a
NJ Gross State Product	$1,405	n/a	n/a
Sal.+Wages / Total Sales	40%	33%	27%
Salaries & Wages	$865	$1,012	$1,160
Jobs per $MM Total Sales	17.54	12.06	8.30
Total Jobs	38,173	36,910	35,305
Avg. Sal./Wages per Job	$22,657	$27,414	$32,843

As Table 8 indicates, none of the three earlier studies based on USFWS (2003a) presented estimates of the amount added by ecotourism to New Jersey's gross state product (USFWS 2003b, ASA 2002, and IAFWA 2002).

The differences in results in Table 8 stem mainly from two factors. First, the Department's estimate recognizes the fact that a substantial portion of the amount spent by wildlife watchers is remitted to out-of-state suppliers and therefore generates no economic benefits in New Jersey; this well-documented phenomenon is called "leakage". For example, when a bird watcher purchases a pair of European-made binoculars from a New Jersey retailer, the store retains its retail margin, and the rest of the purchase price is remitted to the European manufacturer. For such goods, only the dollars that comprise the retail margin (and the wholesale margin, if any) are "captured" by New Jersey and remain in New Jersey to benefit the state's economy. In the Department's judgment, the implicit USFWS assumption of an overall capture rate of 100% is not plausible.

The other factor leading to the differing results in Table 8 relates to how the two analyses divide up the estimated wage and salary income. Relative to the USFWS estimates, the Department's estimates show more jobs created but at a lower average salary. The backup for the Department's assumptions in this regard are presented in Appendix E and Exhibits A and B.

Based on the averaged estimates, ecotourism (defined here to include wildlife watching and recreational hunting and fishing) accounts for about $3.1 billion of economic activity, which supports about 37,000 jobs; this economic activity accounts directly and indirectly for a significant portion of New Jersey's Gross State Product and an estimated $1 billion of wage and salary income to New Jerseyans.

In interpreting the results in Table 8, two basic limitations must be kept in mind:

- First, where labor, materials, and other resources in an ecotourism area are fully employed, the economic activity associated with visitor spending will most likely use resources that would otherwise be employed elsewhere in the economy; as a result, if the amount of ecotourism changes, there may be *no net gain* in total economic activity but merely a reallocation of economic activity within or among sectors.

- Second, to the extent that ecotourists come from elsewhere in New Jersey, the benefits for the locality where a given ecotourism site is located may be offset by reduced spending elsewhere in the state, e.g., on visits to athletic events, local movie theaters, etc. In that regard, of the $2.2 billion of New Jersey spending (in 2001 dollars) reported in USFWS 2003a, only $0.2 billion came from non-residents; the other $2.0 billion came from New Jersey residents. Therefore, it is all but certain that the total amount of *new* spending in the New Jersey economy in 2001 was substantially less than $2.2 billion.

For these reasons, economists distinguish between economic "impacts" and economic "significance". If all of the resources available to provide goods and services to ecotourists would be fully employed elsewhere in New Jersey but for the existence of ecotourism, and if all the visitors to these sites were New Jersey residents, the net impact of ecotourism on the state economy might be nil, but ecotourism would still represent a significant share of the New Jersey economy. In a significance analysis such as the one presented above, the jobs, business opportunities, and income associated with ecotourism are not necessarily "new" to New Jersey, but they are nonetheless important and would need to be replaced if they did not exist. For further discussion of the difference between economic significance and economic impact, see Stynes et al. (2007A and 2007B) and Wells (1997).

As noted earlier, for reasons relating to the availability of data and analytic techniques, the complexity of the natural assets in question, and the number and type of economic benefits being evaluated, ecosystem services, natural goods, and ecotourism were analyzed differently in this study. As a result, care must be taken in comparing the results for ecotourism to those presented earlier for ecoservices and ecogoods. The issues are somewhat technical in nature and are described in Appendix B.

Section V: Potential Policy Applications

The studies undertaken thus far as part of the natural capital project make an important contribution to our understanding of the economic benefits provided by our natural environment. For them to make an equal contribution to public policy and environmental regulation, they must be applied in some way when decisions affecting our natural capital are made. The application of natural capital valuations to policy and regulatory decisions is still in its early stages, and there is no definitive guide yet in this area. However, some promising steps have been taken or proposed, and this section discusses some of the most interesting potential applications reported in the professional literature.

Planning Applications

Framing the discussion. At its most basic, the findings of this study are easy to summarize: land is economically valuable in its undeveloped state. Land provides economically valuable goods and services, and protection of land in its natural state can make economic as well as environmental sense. These statements may seem obvious, but given the large value of New Jersey's natural capital, they deserve emphasis. Grossman and Watchman (undated) collected a number of case studies in which determination and communication of nature's value apparently affected policy discussions and decisions.

Priority setting. In dealing with land use issues, State and local governments need to establish priorities for action in many areas, including but not limited to the following:

- land acquisition priorities—
    - groundwater recharge areas and critical water supply areas.
    - flood-prone properties needed to maintain stream corridor values and functions.
    - areas with the highest natural capital value, such as wetlands.
- project approval priorities—
    - wetland buffer and riparian corridor restoration and enhancement projects.
    - projects in areas environmentally appropriate for growth.
- planning criteria—
    - sustainable development and environmental protection criteria for state, regional and local planning and DEP grant-making.
    - environmental and sustainability criteria for State economic development initiatives and on-going activities.
- funding criteria—
    - DEP grant-making to local governments.
    - Environmental Infrastructure Trust financing.

While natural capital value is not a sufficient basis by itself for establishing such priorities, it can help in doing so by identifying and quantifying an important class of trade-offs, namely the economic benefits provided by natural capital vs. the asserted benefits of development.

Open space acquisitions. Land acquisition for open space preservation is one of the areas in which New Jersey's State and local governments need to set priorities. Where more than one acquisition opportunity presents itself, purchasers with limited funds must choose among those opportunities. The natural capital value of the tracts or parcels available for purchase could be one criterion, albeit not the sole one, in setting acquisition priorities.

Because open space status is a legal rather than a biophysical or ecological category, it was not taken into account in estimating the value of New Jersey's natural capital; the type of land use/land cover (LULC)—rather than the land's legal status—determines the variety and level of natural goods and services provided. However, the results in Parts II and III of this report can be combined with the Department's data on open space status by LULC to estimate the value of the natural capital represented by New Jersey's open space. Table 9 (next page) presents the results, which reflect both ecosystem services and natural goods.[9]

As Table 9 shows, protected open space and preserved farmland comprise 21% of New Jersey's total land[10] area (27.1% of the state's non-urban area) and at $206 billion makes up 24% of the state's total natural capital of $856 billion. In terms of ecoservices and ecogoods, protected open space in the aggregate has a higher average dollar value per acre ($5,272/acre/year) than unprotected land ($4,458/acre/year) because it includes much less lower-ecovalue land such as impervious urban land.

While these figures represent statewide totals and averages, similar calculations can be made for individual parcels being considered for purchase by State, local, and nonprofit organizations. Once the projected purchase price is known, the natural capital value per dollar of purchase price can be calculated. Since budgets for acquisitions are always limited, the resulting ratios can be used as one criterion in setting priorities among potential acquisition opportunities, as suggested in Ferraro (2006). The type of hedonic analysis described in Part II can also be applied to acquisition programs to assess the impact of such acquisitions on property tax assessed values.

It is important to note that while this approach assumes that an acre of protected wetland or forest provides the same level of goods and services as an unprotected acre, protected land can be expected to provide those benefits over a much longer time frame, giving it a higher present value. How much higher depends on what assumption is made regarding the future of the unprotected land (e.g., conversion to residential or other uses); since that factor is unknown, the incremental value of protection is difficult to estimate except conditionally, i.e., except based on an assumed year of conversion, with sensitivity analyses for a range of conversion dates.[11]

(text continues after table)

[9] Because the ecosystem areas used in Parts II and III derive from different databases than the open space data used to construct Table 9, certain adjustments were made to allocate open space (including ADA areas) among ecosystems. This in turn was necessary because different ecosystems have different natural capital dollar values per acre. For example, portions of Forest and Other Urban open space were reallocated to Urban Green Space because no open space was coded directly to that ecosystem.

[10] As used in this report, "land" includes surface waters, unless the context clearly indicates otherwise.

[11] Some economists have developed empirical models to forecast the date of conversion, e.g., Irwin et al. (2006) and Templeton et al. (2006).

Table 9: Value of Natural Capital Represented by Preserved Farmland and Other Open Space (2004 $)							
Ecosystem	**Farm acres**	**Other acres**	**Total acres**	**$/acre/yr**	**$MM/yr**	**$000 PV/ac**	**$Bn PV**
Freshwater wetland	23,239	242,253	265,492	$11,803	$3,134	$393	$104.5
Forest	13,704	499,969	513,673	1,714	880	57	29.3
Saltwater wetland	1,114	109,473	110,587	6,269	693	209	23.1
Agriculture	77,889	41,875	119,765	6,229	754	210	25.1
Estuary/tidal bay	378	18,626	19,004	12,779	243	426	8.1
Beach/dune	1	4,223	4,223	42,149	178	1,405	5.9
Barren land	343	6,112	6,455	11,337	73	378	2.4
Open Fresh Water	604	34,419	35,023	1,686	59	56	2.0
Urban Greenspace	1,007	51,352	52,359	2,591	136	86	4.5
Riparian buffer	142	5,167	5,308	3,500	19	117	0.6
Coastal shelf	0	1,240	1,240	2,425	3	81	0.1
Other Urban	3,529	34,020	37,549	0	0	0	0.0
Total or Avg.	**121,950**	**1,048,729**	**1,170,679**	**$5,272**	**$6,172**	**$176**	**$205.7**
Rest of State			4,373,494	4,458	19,495	149	649.9
Statewide Total			5,544,173	$4,630	$25,667	$154	$855.6
Preserved share			21.1%		24.0%		24.0%
Forested wetlands 79.7%	18,521	193,067	211,588	11,811	2,499	394	83.3
Unforested wetlands 20.3%	4,718	49,186	53,904	11,768	634	392	21.1
Cropland 81.1%	63,178	33,966	97,144	6,890	669	230	22.3
Pastureland 18.9%	14,712	7,909	22,621	3,761	85	125	2.8

Sources:
Dollar values per acre are taken from Tables 5-6.
Acreage of State-Owned, Federally-Owned, and Nonprofit-Owned Protected Open Space in New Jersey. Published in 1999 by NJDEP / Bureau of Geographic Information Services (BGIS), updated to October 2003.
Acreage through May 2002 for preserved farmland provided by the New Jersey Department of Agriculture.

As noted above, economic data alone are not a sufficient basis for making decisions on specific open space acquisition opportunities. For example, if one goal of an acquisition program is protection of water quality, priority might be given to parcels located within defined riparian corridors, even if those parcels are among the more expensive (on a per-acre basis) than others available for purchase. Ferraro (2006) shows one way of combining economic and "biophysical" data to maximize environmental benefits within a given open space acquisition budget by quantifying the ratio of benefits to acquisition costs.

Conservation planning. Within the broad category of open space acquisition, acquisition of land for species conservation and biodiversity protection presents some of the most important and difficult conceptual issues involving natural capital.[12] The Department (see Niles et al. 2004) has mapped the New Jersey habitats for various categories of endangered and threatened vertebrate animal species, e.g., those classified as endangered or threatened under the Federal Endangered Species Act, those so classified under State rules, etc. The mapping characterizes habitats by assigning them a "landscape" rank ranging from 1 to 5, with 1 representing areas capable of supporting rare species, and 5 representing areas that support the most critically imperiled species (those federally listed as endangered or threatened). The economic value of habitats comprising a given landscape rank can be analyzed in the same manner as the value of generic open space areas (see above), although once again, natural capital value is only one possible criterion for land preservation.

Protecting endangered and threatened species and their habitats is clearly a legitimate policy goal in its own right. However, numerous studies have shown that habitats supporting such species are not necessarily areas of high biological diversity and vice versa.[13] Therefore, conserving land to protect rare species and their habitats will not necessarily conserve the areas with the highest biodiversity value. In other words, the two policy objectives are different. The existing species habitat maps for New Jersey are based on a subset of the taxonomic groups (i.e., vertebrate animals) that make up a given area's full biological diversity, although the presence of endangered and threatened animal species in a given habitat can be viewed as one indicator of biodiversity value, albeit an imperfect one.

If we were able to define and map biodiversity value, it might seem that protection (or restoration) of biodiversity and maintenance (or enhancement) of the existing levels of ecoservices and natural goods would go hand in hand, since it is becoming clear that loss of biodiversity adversely affects ecosystem services (see, e.g., Worm et al. 2006). However, a new study by Chan et al. (2006) shows that conservation planning (in the sense of identifying overall land acquisition strategies and evaluating specific acquisition opportunities) can produce

[12] The term "biodiversity" is used loosely in a variety of ways, including the number of different species in a given area, the numbers of individuals in a given species, etc. The discussion here is sufficiently general that a precise definition is not required.

[13] See, for example, Arthur et al. (2004), Kareiva and Marvier (2003), Lawler et al. (2003), Maddock and du Plessis (1999), and van Jaarsveld et al. (1998).

different outcomes for biodiversity and for other ecosystem benefits, i.e., an acquisition strategy designed to maximize biodiversity may not maximize the total value of ecoservices.[14]

While the methods used by Chan et al. (2006) are too complex to summarize here, they provide a way to evaluate the trade-offs between biodiversity and other ecosystem benefits and to define a "best" acquisition strategy given the policymaker's objectives. Valuation of ecoservices and natural goods, i.e., of natural capital, is a key element of their approach, and natural capital values therefore have an important role to play in conservation planning. Further exploration of this role is an important priority for future research.

Budgeting. Like any capital asset, natural assets experience constant wear and tear throughout their lives; but whereas built capital such as structures and machinery eventually wears out and needs to be replaced, much of New Jersey's natural capital is potentially self-renewing. However, natural capital can exist in a healthier or less healthy state, and public agencies and interested private parties can contribute to ecosystem health, productivity, and longevity. For example, fire control (where fire is not a part of a natural ecological cycle) can extend forest life and thereby contribute to preservation of an economically valuable asset.

In addition, while much of New Jersey's natural capital has been degraded or destroyed over the years, some of it may be able to be restored through human investment and other activities, e.g., through reforestation, removal of unneeded impervious surfaces, provision of protected animal migration routes, temporary fishing moratoriums, etc. Some of these activities require regulation and enforcement, while others require capital investment in supportive infrastructure. In either case, the expenditures bring economic benefits to New Jersey beyond the satisfaction that many people feel at seeing natural environments preserved or restored.

Pollution control. Healthy ecosystems can impound, dilute, and biodegrade a number of air and water pollutants, and this fact is being capitalized on by various government agencies, e.g., New York City's watershed protection program (Chichilnisky and Heal 1998; Daily and Ellison 2002). Such ecosystem services may in some cases be able to function as supplements or alternatives to publicly-funded infrastructure and/or regulatory approaches to pollution control in meeting water and air quality objectives.

Risk management. In some cases, natural capital valuation can help inform decisions involving the safety of built infrastructure and lives. For example, research currently in progress documents the role that coastal wetlands can play in reducing wave height and storm surge, thereby moderating the effects of violent storms on coastal communities. The loss of such wetlands appears to have been a major factor in the damage caused to New Orleans by Hurricane Katrina. If the lost wetlands were valued on the basis of the damage to New Orleans which they might have helped prevent, the value per acre *for this one ecoservice* would exceed the total value for wetlands from all ecoservices presented in Section II. In effect, coastal wetlands can serve as a major component of a naturally "engineered" system of flood control. Such knowledge can help decision-makers avoid decisions that create undue risk for their communities.

[14] Of course, provision of species habitat is itself an important ecosystem service and as such is included in the estimates in Part II; the emphasis here is on the non-monetary value of protection of biodiversity as a consequence of habitat provision.

Municipal zoning. Where adequate data are available, the value of ecosystem services and natural goods for a given municipality can be mapped by property parcel and zoning class. Officials can then estimate the magnitude of the loss of ecosystem services and natural goods if a full build-out occurs. Similar estimates could be prepared based on hypothetical zoning scenarios. Information such as this can be helpful in assessing alternative futures for a given geographic area, thereby informing the development of master plans and zoning ordinances.

Sustainability measurement. Documents such as New Jersey Future (2000) put forward "sustainability" as a goal for New Jersey, and many New Jersey residents would probably endorse that goal, while differing on its definition and its relationship to economic "growth" or "development". An extended discussion of these issues is beyond the scope of this report; however, since environmental protection and enhancement is usually taken as one of the main components of sustainability, maintenance and restoration of natural capital is clearly required for New Jersey to be considered a "sustainable state". Given that, trends in the dollar value of the state's natural capital—both in the aggregate and by ecosystem—could be used as one indicator of movement towards or away from sustainability. Natural capital and the annual flow of benefits that it provides are also being used to supplement standard measures of economic activity such as Gross Domestic Product (see, e.g., Anielski and Wilson 2007).

Management Applications

Ecosystem management. As Farber et al. (2006) note, "Ecosystem management decisions inevitably involve trade-offs across [ecosystem] services and between time periods, and weighing those trade-offs requires valuations of some form" (cf. Foley et al. 2005). In other words, competing management strategies may affect different ecosystem services differently, and the choice among strategies always involves the valuation (usually implicit) of different services. For example, a decision to foster recreational use of a forest by providing access roads, parking, and other visitor facilities may reduce the value of the habitat protection services provided by the forest even as it increases public enjoyment of the ecosystem (and perhaps generates much-needed revenues). Similarly, a decision to allow farmland to revert to forest to increase carbon sequestration and other forestation benefits may entail loss of at least some of the ecoservices and natural goods provided by farmland (The Nature Conservancy 2006).

Farber and his colleagues (2006) argue that it is better for such decisions to be made with as much knowledge of the physical trade-offs as can reasonably be obtained and with explicit attention to the relative economic values of those impacts where these can be quantified. They also present a simplified approach to compiling and integrating these assessments by ecologists and economists, and they show how the approach can be applied to several different ecosystems. Even when the results of the analysis do not dictate the decision on management strategy, "the attempt to formalize changes in [ecosystem] service flows can be a useful management exercise in its own right" (Farber et al. 2006, p. 128). This approach shows great promise, and its applicability in the New Jersey context deserves exploration.

Cost allocation. An implicit assumption throughout this report is that economic value matters even if no money changes hands, i.e., non-cash values are important. For example, under current institutional arrangements, no money changes hands when forests sequester carbon or when wetlands impound floodwaters, even though these services benefit society and could be replaced by built infrastructure only at a considerable cost. This situation is a classic example of a *positive* environmental externality: private parties may under-invest in environmental protection because they do not realize the benefits of that investment (except to a minor extent in their capacity as individual residents of New Jersey).

A similar calculus applies to governmental bodies faced with a choice between preserving land in an undeveloped state or allowing development: development is often believed to produce additional tax revenues, i.e., cash, while undeveloped land produces only non-cash benefits, e.g., carbon sequestration, flood control, etc. The essential issue here is that the benefits provided by undeveloped land are outside the market economy, since no one has to pay to receive them.

In response to this externality, various efforts have been launched to develop systems of payment for ecosystem services (PES). Most of the PES projects thus far appear to be located in developing countries and seem to be motivated to a significant extent by the desire to secure new funding streams for conservation efforts (see, e.g., WWF 2007). In the United States, a concept known as the "ecosystem service district" or ESD has been developed by economists, legal scholars, and others; Heal et al. (2001) present a detailed exposition. Older models for ESDs include districts established to provide such services as conservation, drainage, natural resource management (e.g., parks), erosion control, water supply (e.g., irrigation), and flood control.

As envisioned by the developers of the concept, an ESD is a legal entity with powers established by statute to manage a given ecosystem to provide specified ecosystem services and the ability to charge what would amount to user fees to those who benefit from the services (Heal et al. 2001). Fee revenues would be used to defray the cost of maintaining the ecosystem in a healthy condition and to provide compensation to property owners where appropriate. Since the user fees would represent cash liabilities, they would address the problem of uncompensated externalities described above, thereby creating fiscal incentives for protection of valued ecosystems. Apart from the older models for ESDs cited above, these concepts appear at present to be largely at the theoretical stage in the US.

Tax policy. Like many states, New Jersey relies heavily on the local property tax to fund public sector expenditures, especially those involving local and regional school districts. Broadly speaking, property tax liability is based on the assessed value of the property in question and the tax rate per $100 of value. In many circumstances, assessment is determined by the property's "highest and best use", usually interpreted to mean the use producing the largest economic return. Very often that use may initially appear to entail use of the property for residential or commercial development, since preservation of land in an undeveloped state may at first appear to generate *no* economic benefits.

The results presented in this report make clear, however, that most undeveloped land in fact provides substantial economic value to society in the form of ecosystem services and natural goods, and that value can be estimated. Whether that value will outweigh the asserted value of development in any given case is a factual question, but estimating the value of land protected from development at least indicates to officials that the value of such land is not zero. The standard of "highest and best use" has already been tempered by preservation policy in the case of farmland, and the valuation results presented in this report may provide a factual basis for extending this to non-agricultural ecosystems.

Open space acquisition financing. A substantial body of research, including that presented in Part II, shows that proximity of residential parcels to protected open space usually enhances the value of those parcels, as indicated by differences in actual home sale prices after other factors are controlled for. Allowing for administrative lags, those increases in value should translate into increased property valuations and, assuming a constant tax rate, increased property tax revenues. If the rest of the local government budget remains constant, those increased revenues could be used to pay for the current open space acquisitions and/or to finance future acquisitions. This concept is presented in detail in Geoghegan et al. (2006).

It should be noted that the per-acre prices actually paid for land and the per-acre natural capital values described in this report will not usually be the same. Natural capital values include services to society that are not paid for under current institutional arrangements and that therefore do not form part of the land's private market value. On the other hand, market prices (at least for "undeveloped" parcels) will reflect the estimated value of the option to sell the land to a developer at a later date, which is not a natural asset but rather a financial one.

Eminent domain. Recent court decisions in Connecticut and other states have suggested that land not being used in the "highest and best" manner may be taken by eminent domain for "redevelopment" on the grounds that it constitutes blighted, unimproved, abandoned, or vacant land. The findings in this report indicate however that undeveloped land may have a substantial value that does not always merit characterization as blighted, unimproved, etc.

Natural resource damage assessment. NJDEP actively pursues a policy designed to make private parties pay monetarily for past damage to New Jersey's natural resources, especially the state's groundwater. Whether natural capital valuation can help define the appropriate level of those payments in specific situations is an area that may be worth exploring.

Conclusion

Economics, in the form of natural capital valuation, should not be the only factor in environmental decisions or even the most important; but it seems difficult to deny that it should be one of the major considerations. Even though the field has substantial room for growth (see Section VI below), valuation analysis has already generated results that shed considerable light on the stakes involved in decisions that affect ecosystems and other types of natural capital. The preceding paragraphs have suggested ways in which that information can help inform the decision-making processes in a variety of contexts and thereby hopefully lead to outcomes more beneficial to society as a whole than decisions made without that knowledge.

This section and the next highlight various research needs, and there is unquestionably much more to learn about ecosystems and their economic value. However, the absence of perfect information is not a reason to delay conservation actions. We will never have perfect information on any of the issues raised in this study, and in that respect ecosystem valuation is no different from any other complex area. Second, research and action provide feedback to each other; the influence does not all run from research to implementation.

In this regard, Heal (2000, pp. 125-126) argues that "incentives are critical for conservation" but valuation is "neither necessary nor sufficient". Heal's analysis emphasizes the creation of incentives that will lead self-interested private parties to invest now in conservation, possibly leading to objective valuations of the natural assets conserved and others of a similar nature (Heal 2006). Since New Jersey has conserved a significant amount of natural capital, it is hard to argue that valuation is *essential*, but numerous case studies indicate that valuation is important and helpful for conservation. Heal is surely correct, however, that valuation is not sufficient, and actions like those described in this section are needed to translate a better understanding of nature's economic value into effective conservation of our natural capital.

Section VI: Future Research Needs

No study of this type can be viewed as the final word on the value of New Jersey's natural capital. The amount of natural capital in the state, our understanding of how natural capital provides goods and services and of the factors that affect per-acre productivity, and the sophistication of our valuation methods all change over time. Therefore, the results presented in this report will therefore change as well. This suggests that policy applications of these results need to have the flexibility to accommodate such changes; it also suggests the need for further research, and this section describes some selected research needs.

Carpenter et al. (2006) identify a number of important research needs in the field of ecosystem assessment in general; those needs include a better understanding of such things as ecosystem dynamics (i.e., how ecosystems change over time), and especially abrupt, non-linear, or catastrophic change; trends in human reliance on ecosystem goods and services, especially noon-marketed ones; development of indicators of ecosystem health and productivity; and others. These needs affect all ecosystem valuation studies and are not limited to studies such as those presented in this report.

In terms of the current studies, Section II-IV and Parts II and III identify a number of areas in which further research would be helpful in refining our understanding of the value of New Jersey's natural capital. In addition, the following seem especially important:

Update results to reflect 2002 land use/land cover data. The amount of natural capital in New Jersey is constantly changing; the results in this report generally reflect 1995-1997 data on land use and land cover, and it is likely that more recent information would show less natural capital in the state due to conversion of land to residential, commercial, and other uses.

Attempt to address some of the gaps in the ecosystem grid. The gaps identified in Part II include gas and climate regulation provided by wetlands; disturbance prevention provided by freshwater wetlands; disturbance prevention, water supply, and water regulation provided by forests; and nutrient regulation, soil retention & formation, and biological control provided by a number of ecosystems. Finer breakdowns of certain ecosystems would also be useful in estimating ecoservice values, including deciduous vs. coniferous forests and forested vs. unforested wetlands. Some of these gaps might be able to be filled by high-quality "grey literature", i.e., non-peer-reviewed studies performed by government agencies and other organizations.

Develop landscape models for New Jersey. As Part II's discussion of dynamic spatial modeling shows, landscapes are integrated systems, and the provision of ecoservices and natural goods by one ecosystem is affected by its location relative to other ecosystems and to developed land. As a start, the Maryland model described in Part II could be calibrated and applied to one or more New Jersey watersheds or subwatersheds. Such modeling might also help us to better understand the relationships between production of services and production of goods.

Expand the economic analyses. The results presented in this report do not include the "multiplier effects" (indirect or induced economic benefits) supported by expenditures on natural goods or expenditures funded with savings generated through reliance on natural ecoservices, nor do they reflect the benefits of ecotourism (see NJAS 1996). Also, the results reflect "gross" economic benefits; if adequate information on producer costs could be developed, future studies could deduct those costs from gross benefits to obtain *net* economic benefits. It would useful as well to identify additional valuation studies (perhaps from the "grey" literature) for particular ecoservices based on the replacement cost method, since this gives an indication of the actual cash outlays that are avoided when important services such as water purification and flood control are performed by natural ecosystems, thereby directly affecting government budgets and tax burdens.

Develop an understanding of the impacts of climate change. Global climate change is a reality, and it will affect New Jersey. Changes in temperature, precipitation, growing seasons, populations of plant and animal diseases and predators, extreme weather events such as droughts, floods, and tropical storms, etc. will affect the make-up and amount of New Jersey's natural capital; human efforts to adapt to climate change are also likely to have an impact. We need a better understanding of the likely range for such changes based on our best understanding of the underlying dynamics of the climate system.

Explore the natural capital value of urban ecosystems. Parts II and III both make the understandable simplifying assumption that paved (impervious) surfaces contribute relatively little in the way of natural goods and services. However, a few studies have attempted to explore this area (see, e.g., Baltimore Ecosystem Study), and more might be done. This issue could be of particular relevance in the environmental justice context.

This list could be extended to include research on the policy applications discussed above.

Progress need not occur equally in all areas for the results to be useful. For example, if we develop a way to measure a previously unquantified ecoservice value for a given ecosystem, our inclusion of that value need not wait on our development of similar methods for other ecosystems. From a scientific viewpoint, the goal of our valuation efforts is to develop as comprehensive an inventory of values as possible, and the fact that one ecosystem may not be as fully analyzed as another is no argument against improving our valuations where we can.

In light of these and other gaps in our knowledge, the Department and interested outside agencies should consider formulating and funding an on-going program of ecosystem research to address the above questions and others that may arise. The current studies are an important start, but more can be done to improve both our understanding of the economic value of ecosystems and other natural capital and our ability to apply our understanding in concrete policy and regulatory contexts. The results presented in this report show that the stakes are high enough to warrant such an effort. Along with our human capital and built physical infrastructure, natural capital is an essential part of the foundation for New Jersey's future, and that foundation needs to be fully valued for us to wisely make the decisions that will affect our common future.

Appendix A: Provision of Services by Abiotic Systems

The bulk of Parts II and III of this report focus on biotic (living) systems, i.e., ecosystems. However, New Jersey also includes abiotic (non-living) systems of great importance, including air, water, and climate.[15] Valuing these types of natural capital presents special problems, as this appendix will discuss.

Air. The atmosphere, especially the portion closest to Earth's surface known as the troposphere, provides oxygen to breathe, which is essential for most forms of life. Because of this essentiality, the economic value of air as a natural good is in principle infinite and therefore cannot really be calculated. However, the atmosphere also functions as a pollution "sink" by absorbing (i.e., dispersing and diluting) air pollutants and thereby reducing their ability to cause morbidity (illness), premature mortality, reduced visibility, and other adverse impacts. It is tempting to consider the value of such pollution-related services as the value of the atmosphere as sink.

Any effort to do so, however, immediately runs into serious conceptual problems:

- In a series of Regulatory Impact Analyses under the Clean Air Act, the U.S. Environmental Protection Agency (EPA) has consistently found that well over 90% of the estimated benefits of the Clean Air Act are related to reductions in premature mortality.

- Those benefit estimates are based on the difference in health outcomes experienced with projected pollutant concentrations under the National Ambient Air Quality Standards (NAAQS) and under projected concentrations without NAAQS.

- We obviously cannot quantify the difference in health outcomes or pollution abatement and control costs with and without an atmosphere, nor does it make sense to attribute to the atmosphere any reductions in pollutant concentrations achieved through pollution abatement and control measures on the ground.

The root of the problem is that the adverse impacts of pollution in excess of any given level (whether NAAQS or a historical or natural background level) are caused by the pollution and not by the atmosphere. In theory one might be able to create a model of what New Jersey's air pollution levels would be (given existing or projected emissions levels in New Jersey and the "upwind" states) in the absence of the prevailing winds that blow across the state, and one could then value that feature of the atmosphere (the winds) in terms of the reduction in air pollution to the levels we actually experience. Such an exercise would involve complex air dispersion modeling and arbitrary assumptions for the counter-factual scenario; the values it produced would vary from day to day and season to season and would have a high degree of uncertainty as well. Such an exercise is beyond the scope of this project.

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[15] Land is dealt with in this report in terms of specific ecosystem types, i.e., specific patterns of land use and land cover.

Water. Parts II and III estimate the value of New Jersey's available water supply and the ecosystem services that help make that water available for human and other uses. However, water also functions as a sink for human and other wastes and therefore, like air, raises the issue of valuation of waste sink services. In this case, economists have been able to develop methods for estimating these ecoservice values, and a substantial part of the value of the marine ecosystem services presented in Part II represents waste dilution and "disposal" services provided by New Jersey's estuaries, tidal bays, and ocean waters with respect to one important class of wastes, namely nutrients such as nitrogen and phosphorus. The key difference from atmospheric sink services is that for water we can estimate the physical amount of waste actually removed from New Jersey, and therefore we can also estimate the cost of dealing with that volume of waste using built infrastructure such as sewage treatment plants.

Climate. As a final element of New Jersey's abiotic natural capital, we can cite the state's climate, which is part of the global climate system. As part of the public debate over the proper course of action to address the dangers posed by global warming, there have been a number of attempts to assign a value to the global climate system, or at least to a given level of change in that system. However, those efforts all suffer from various limitations, and this area of economics is still very much in a developmental stage. Therefore, while New Jersey's climate clearly affects the state's infrastructure, energy use, quality of life, etc., we make no attempt in this report to estimate the value of our climate system.

Appendix B: Assumptions Made in Combining Results

The differences between natural services, natural goods, and ecotourism led to several differences in analytic approach that had to be reconciled in combining the results of Parts II and III. This appendix discusses those differences and their treatment.

Scenarios. The value transfer analysis (VTA) for ecosystem services in Part II was based on a large number of earlier studies, including Type A (original peer-reviewed research) and Type C (peer-reviewed meta-analyses) studies. Each such study reported one or more estimated values for a given cell in the ecosystem matrix (see Sec. II), i.e. for a given ecosystem service provided by a given ecosystem, and multiple values could be represented by their mean or their median. This approach produced four sets of results, depending on whether both Type A and Type C studies were counted and whether the mean or the median was used as the summary measure:

Table 10: Ecoservice Results

	Means	Medians
Type A and C studies	X	
Type A studies only		

The results presented in Sec. II for ecoservices are those based on the means for both Type A and Type C studies ("X" in Table 10). Similarly, the results presented for natural goods are those for the middle case reported in Part III rather than for the high-end or low-end cases.

Classifications. In reporting results, Part II grouped barren and urban land but separated urban green space on the rationale that neither barren nor paved urban land produce a significant level of ecosystem services as compared with urban green space. However, urban ecosystems are complex entities that combine impervious and permeable space in complex patterns that differ considerably from truly barren land such as quarries. Therefore, Part I groups urban and urban green space but separates barren land. Similarly, Part II treats forested and unforested wetlands as a single category because the literature on ecosystem services is not yet adequate to support a meaningful distinction between the two. However, Part III separates these ecosystems because forested wetlands produce some amount of timber while unforested wetlands do not.

Farmland. After Part II had been completed, it was determined that a substantial amount of "grassland" classified as pastureland should have been classified as cropland; the error was due to difficulties in interpreting aerial photos of fields containing row crops. To correct this, the total agricultural acreage (pastureland plus cropland) from Part II was reallocated to reflect the breakdown of the two in USDA farm data for New Jersey (81% cropland and 19% pastureland, excluding dwellings, roads, woodlots, etc.). The values per acre from Part II were then multiplied by the new acreages to obtain total values for cropland and pastureland.

Present Values. Parts II and III reported detailed results in the form of dollars / acre / year; Part III also reported present value results (dollars / acre) but Part II did not. For the summary presented in Part I, present values were computed for ecoservices based on the annual values reported in Part II and in a manner consistent with the present value calculations in Part III.

Harvest Levels. Part II used studies involving a wide range of individual sites at various locations, mainly in temperate latitudes. For any given study site, the reported ecoservice values implicitly reflect the level of natural goods harvesting for that site. Those harvest levels may differ from the New Jersey levels, but the data for assessing the degrees of difference is rarely available. Therefore, the summary of results presented in Part I assumes that the harvest levels presented in Part III are compatible with the ecoservice levels presented in Part II.

Value Metrics. The differences in analytic approaches among ecosystem services, natural goods, and ecotourism led to the reporting of different measures of economic value in Parts I-III of this report, as the following table indicates.

Table 11: Comparison of Value Measures
(values for blank cells were not estimated in this study)

	Ecosystem Services	**Natural Goods**	**Ecotourism Benefits**
Total Willingness to Play		Total Economic Value	
- Consumer surplus (CS)		Estimated from MV	
= Market value (MV)	"Shadow" price (≈ market value)	In situ value + harvest or extraction cost	Total sales (net of leakage)[16]
- Cost of goods/services sold		Only available for farm products	Business-to-business sales
= Value added		Net farm income	Value added
- Capital costs & taxes			Capital costs/taxes
= Producer surplus			Income
+ Consumer surplus (CS)		Estimated from MV	
= Net economic value	*Ideal measure of net economic benefit to New Jersey*		
Employment (jobs)			Part of above quantities

Note: boldface indicates best estimate produced in the present study (see below).

If we start with market value as the sole measure available for all three value sources, the determination of net value or net benefit would require adding consumer surplus (CS) and deducting producer costs (PC). In those terms, the three sets of estimates compare as follows:

Table 12: Components of Value Metrics

	CS not included	**CS included**
PC deducted	ecotourism values	net benefit to society
PC not deducted	ecoservice values (market value)	natural goods values

While the natural goods and ecotourism value measures approach the closest to net economic value, the ecoservice analysis produced the most detailed coverage, dealing with 12 ecosystems x 12 ecoservices = 144 combinations, of which only 11 were ruled out a priori.

[16] From the broader perspective of the US economy as a whole, ecotourism spending that leaks from New Jersey still accounts for economic benefits for the US as long as the spending is captured by another state rather than a non-US producer.

It is also worth noting that, like ecotourism, ecosystem services and goods support secondary economic activity. By providing economically important services at relatively low cost, ecosystems save society money which can be spent in other economic activities, while the dollars spent to purchase ecosystem goods support secondary activity as they are re-spent by the firms and employees that harvest or extract the goods in question. Except for ecotourism itself, these secondary effects could not be investigated within the time and resource constraints of the present study. This fact represents a further source of conservatism in the estimated values for ecosystem services and natural goods.

Appendix C: Carbon Storage Benefits

As the main text notes, this study does not address in detail the economic value associated with the long-term storage of previously-emitted carbon dioxide in New Jersey's forests, as distinguished from the on-growing sequestration or removal from the air of additional carbon dioxide (which *is* addressed in Part II). Table 13 below presents some crude estimates of the value of the carbon storage service provided by New Jersey's forests.

Table 13: Value of Forest Carbon Storage Services

Prior Studies Used Metric for Studies	Type A Only Mean	Type A Only Median	Types A+C Mean	Type A+C Median
MT-C stored/ha*	191.34	191.34	191.34	191.34
Acres per hectare	2.471	2.471	2.471	2.471
MT-C stored/ac	77.44	77.44	77.44	77.44
2004 $/MT-C**	$92	$31	$82	$31
2004 $/acre	$7,087	$2,362	$6,378	$2,362
NJ forest acres***	1,465,668	1,465,668	1,465,668	1,465,668
PV (Bn of 2004 $)	$10.4	$3.5	$9.3	$3.5
Amortization rate/yr	3.0%	3.0%	3.0%	3.0%
MM of 2004 $/yr	$312	$104	$280	$104
Avg. remaining life (yr)	50	50	50	50
Net PV (Bn 2004 $)	$5.042	$1.681	$4.538	$1.681
MM of 2004 $/yr	$151	$50	$136	$50

Type A studies = original research published in peer-reviewed journals
Type C studies = analyses of original research published in peer-reviewed journals
MT-C = metric tonnes of carbon (1 MT = ~ 2,205 lbs.)
MT-CO_2 = metric tonnes of carbon dioxide (1 MT-C = ~ 3.667 MT-CO_2)
ha = hectare (1 ha = ~ 2.471 acres); ac = acre
PV = present value; Bn = billions; MM = millions

*estimate by NJDEP using the NCASI Carbon On-Line Estimator (see References);
includes trees (live and dead), woody debris, forest understory, and organic soil carbon.
**carbon prices used in valuation of forest carbon sequestration in Part II;
prices shown are equivalent to between $8 and $25 per MT-$CO_2$.
***NJ forest acreage from Part II, including farm woodlots but excluding forested wetlands.

The estimates presented in the middle of Table 13 are based on the assumption of an indefinitely long life span for the existing trees and other carbon-containing plants in New Jersey's forests. The reality, of course, is that those trees and plants will not live forever; and as they die and decay, some part of the carbon they are currently storing will gradually be released to the atmosphere, reducing the value of the carbon storage service they are providing. Another part of the carbon currently stored may simply be converted to another form, e.g., fallen trees may become woody debris and then soil organic carbon, with some loss of stored carbon as the decay process proceeds.

Estimating the overall rate of reduction of carbon storage benefits is technically challenging, in part because each carbon-containing component of a forest has a different average life span. Carbon is usually accounted for in terms of six distinct carbon "pools": live trees, standing dead trees, fallen dead wood, understory vegetation, forest floor, and soil organic carbon. Carbon in harvested wood (forest products) also has to be accounted for. If the carbon in wood products is not included, the calculation of carbon stock change for the forest area that is harvested will indicate that all of the removed carbon was immediately released to the atmosphere, thus leading to significant overestimation of the emissions to the atmosphere.

If all forest plant life had the same average remaining life, and *if* an equal amount of the carbon currently stored was released each year, the carbon storage benefit could be adjusted to reflect the assumed life span and decay pattern. For example, Table 13 shows the net benefits based on an assumed average remaining life span of 50 years for *all* carbon-containing forest components and assuming that an equal amount of carbon is released to the atmosphere every year during that time. As can be seen, under these assumptions the adjusted or "net" benefits are roughly *half* of the theoretically available amount.

This entire subject is the focus of a great deal of active research, and new estimating techniques are likely to be developed in the coming years, especially as reforestation and afforestation become important sources of "offsets" or "credits" under cap and trade systems for carbon emissions. It is clear, however, that the value of carbon storage may be very large *and* that estimates of that value may be very sensitive to changes in the initial assumptions. Because of the technical complexity of this subject, carbon storage was not addressed in the present study.

Appendix D: Additional Forest Ecoservices

As the main text notes, ecosystems provide economically valuable services that are not fully reflected in this report due to a lack of adequate peer-reviewed studies. Two of the specific examples given were as follows:

- the services that forest land provides by slowing stormwater runoff, which reduces peak flows and thereby decreases the amount of built stormwater storage capacity needed.
- the services that trees provide by removing pollutants such as sulfur dioxide, nitrogen dioxide, carbon monoxide, ozone, and particulates from the air.

If natural ecosystems did not provide these services, they would need to be provided by built infrastructure to provide the same levels of environmental quality. The question is how to estimate the dollar value of the services.

In 2003, the nonprofit organization American Forests, in conjunction with the United States Forest Service, published a study entitled Urban Ecosystem Analysis, Delaware Valley Region: Calculating the Value of Nature, that examined these services and others. The study focused on the Delaware Valley, defined as the region including Bucks, Chester, Delaware, Montgomery, and Philadelphia Counties in Pennsylvania and Burlington, Camden, Gloucester, and Mercer Counties in New Jersey. Table 14 below shows the result of converting the study's findings to a per-acre basis and then applying them to New Jersey's 1.5 million acres of forest.

Table 14: Estimated Value of Stormwater Control and Air Pollution Abatement Services provided by New Jersey Forests (excluding forested wetlands)

Parameter	Stormwater		Parameter	Pollution
9-county study area (acres)	963,163	*	9-county study area (acres)	963,163
Cubic feet stored/acre	3,011		Lbs. removed per acre per yr.	75.8
Bn cubic feet stored	2.900	*	MM lbs. removed/year	73
Replacement cost/cu ft	$2.03		Replacement cost/lb.	$2.29
One-time replacement cost $Bn	$5.900	*	Annual replacement cost $MM	$167
9-county study area (acres)	963,163	*	9-county study area (acres)	963,163
One-time replacement cost/acre $	$6,126		Annual replacement cost/acre $	$173
NJ acreage (Forest only)	1,465,668		NJ acreage (Forest only)	1,465,668
Present value of ecoservice $Bn	**$8.978**		**Annual ecoservice value $MM**	**$254**
Amortization rate/yr in perpetuity	3.0%		Discount rate/year in perpetuity	3.0%
Annual ecoservice value $MM	**$269**		**Present value of ecoservice $Bn**	**$8.471**

Source: * = American Forests (2003); all others = calculations by NJDEP.

The replacement costs are based on the estimated costs of the most relevant built alternatives, e.g., construction of stormwater retention ponds and other engineered systems. The two services have a total annual value of $523 million and a total present value of $17.4 billion. If confirmed through external peer review, these two services alone would add significantly to the total value of New Jersey's natural capital.

Appendix E: Estimated Benefits of Ecotourism

The standard method used to estimate the economic effects of activities such as ecotourism spending is somewhat involved but can be summarized as follows (capitalized terms are standard usage in this field).

Basic Concepts

1. Total Spending is multiplied by the Capture Rate to obtain *Direct Sales*. The capture percentage may be less than 100%, reflecting the fact that visitor spending on some goods and services is paid to out-of-state suppliers and generates no economic benefits in New Jersey; this phenomenon is called Leakage. For example, when a bird watcher purchases a pair of European-made binoculars from a New Jersey retailer, the store receives its "retail margin", and the rest of the purchase price is remitted to the European manufacturer. Only the dollars that comprise the retail margin (and possibly the wholesale margin, if any) would potentially remain in New Jersey to benefit the state economy. Leakage and capture factors vary by type of good or service; since different capture rates apply to the retail and wholesale margins, those margins are subtracted from Total Spending before capture rates are applied to the various spending categories; the margins are multiplied by their own capture rates.

2. The flows of cash payments involved in Direct Sales generate two types of "secondary" economic activity for each dollar spent: the purchases of goods and services by businesses generate "indirect" effects, and the spending of income creates "induced" effects. Examples of these are as follows:

   - A motel that derives its business from overnight visitors to a nearby site must purchase bed linens, electricity, and other inputs, thereby contributing to the demand for the output of producers of linen goods, electric utilities, etc. Such impacts are known as Indirect Sales. (As noted above, only the value added by each such firm is included in GSP.)

   - Similarly, as the employees and proprietor of the motel spend the income *they* receive, a separate stream of economic activity is generated, referred to as Induced Sales. Purchases of food and clothing by motel employees are a good example of such sales.

   The initial "rounds" of both indirect and induced sales are followed by subsequent rounds, although the economic stimulus decreases at each round. The sum of the direct and secondary sales is termed Total Sales.

3. To quantify this *Multiplier Effect*, Direct Sales is multiplied by a *Sales Multiplier* (derived from the economics literature or prior studies) to obtain *Total Sales*; Secondary Sales equals the difference between Total and Direct Sales. For example, a multiplier of 1.5 means that for each dollar of Direct Sales, 50 cents of Secondary Sales are generated, resulting in Total Sales of $1.50. Multipliers vary according to the type of goods or services involved. The multiplier effect decreases at each round of spending, since at each round some of the dollars spent will go to out-of-state suppliers and some will go for the non-income components of Value Added (see below).

4. Total Sales is multiplied by a value-added percentage (less than 100%) to obtain *Value Added*, which constitutes the net contribution to Gross State Product (GSP)), the generally accepted measure of aggregate economic activity in a state. The retail vendors that provide goods and services to ecotourists purchase inputs from other businesses, e.g., food, utilities, etc. The cost of such inputs is reflected in the retail price paid by ecotourists and is therefore part of the retailer's revenue, but the same amount (minus the retail margin) is also revenue for the wholesalers (if any) and for the producer (minus any wholesale margin).. The use of the value-added percentage avoids double- or triple-counting of these revenues so that GSP will include only the value that each business adds to the inputs it purchases, i.e., sales receipts minus input costs. This is the most accurate measure of an industry's contribution to a state's economic output.

5. Value Added is multiplied by an income percentage (less than 100%) to obtain *Income*.[17] This adjustment reflects the fact that Value added includes three main components: compensation to proprietors and employees (including employee benefits), gross operating surplus, and taxes on production and imports. Gross operating surplus includes profits, economic rents, net interest, allowances for capital consumption (related to depreciation), changes in inventory levels, and certain other items. Taxes on production and imports include state and local property, gross receipts, and sales taxes, Federal excise taxes, customs duties, and certain other levies. Given the complex makeup of value added, it is clear that only employee (and proprietor) compensation represents personal income to New Jerseyans. The ratio of such income to total value added varies depending on how labor-intensive a given sector (lodging, restaurants, etc.) is and on the wage and benefit structure for that sector.

6. Economic activity obviously generates and supports jobs. To quantify this effect, Total Sales is multiplied by the Jobs Multiplier, i.e., the number of jobs supported per million dollars of Total Sales, to obtain *Employment* or *Jobs*. Like the other multipliers and percentages mentioned above, this factor varies from industry to industry and is usually taken from the related economics literature and prior economic impact studies. The salaries for such jobs are not additional benefits but rather are included in Total Sales, Value Added, and Income.

Sources of Spending Data

Within the broad category of "ecotourism", various sub-categories can be distinguished. Some Authorities limit ecotourism to *sustainable* ecotourism, e.g., International Ecotourism Society (1991) and World Conservation Union (1996). While this usage focuses needed attention on the damage to natural systems associated with mass tourism, it is more appropriate for present purposes to consider all ecotourism, whether sustainable or not, while recognizing that the true value of ecotourism should ideally be calculated net of ecotourism's negative impacts. Similarly, while some might not consider hunting and fishing as types of ecotourism, the present study is

[17] It should be noted that income is sometimes expressed as a function of sales, i.e., Income = Sales x Income Multiplier, or Jobs = Sales x Jobs Multiplier. However, if the ratio of value added to sales is known, this type of income multiplier can be converted to an equivalent income multiplier expressed as a percentage of value added, and this is the approach used in this report. Similar considerations apply to jobs multipliers.

aiming for the most comprehensive possible coverage of natural capital, and therefore this report includes these activities.

An earlier study by staff at the New Jersey Department of Environmental Protection provided estimates for the value associated with visits to New Jersey's State Parks and Forests (Mates and Reyes 2007). That study, however, was limited by design to State parks, forests, and recreation areas and did not include other State lands (e.g., wildlife management areas), lands owned by other levels of government (e.g., county, municipal, and Federal), or privately-held lands. In addition, it implicitly covered all types of outdoor recreation, including both ecotourism and such activities as swimming, cross-country skiing, etc. For these reasons, it is not an ideal source of value estimates for the present study.

As noted in the main text, the 2001 survey conducted by the US Fish and Wildlife Service (USFWS 2001) is the most comprehensive study of the economic benefits of ecotourism. That study, which provides detailed data on estimated spending by wildlife watchers, hunters, and anglers in each state, including New Jersey, is the main data source used in the present analysis.

Sources of Multipliers

The economic effects of ecotourism vary by type of spending, and this analysis therefore requires that values be available *by expenditure type* for seven parameters as follows:

- wholesale margin, retail margin, and capture (or leakage) rate
- sales multiplier (ratio of total to direct sales)
- value-added multiplier (ratio of value added to total sales)
- income multiplier (ratio of income[18] to total sales or to value added)
- employment or jobs multiplier (usually expressed as jobs supported per million dollars of total sales or income)

Information of this type is not readily available through non-commercial sources; even the Bureau of Economic Analysis of the US Department of Commerce charges for providing such information. Fortunately, a suitably detailed model developed for the National Park Service is available on-line at no charge; that model contains default values for geographic areas of various sizes, including rural areas, small cities, metropolitan areas, and entire. The model was developed by Daniel Stynes and other economists at Michigan State University; the version currently available is dated 2001 and is called "MGM2" for Money Generation Model, Version 2. See the References below for a link to the full model, a simplified version, and an accompanying manual. With a few exceptions, the parameter values used here are the MGM2 values for entire states (as opposed to smaller urban or rural areas within states).

Based on the spending survey data in USFWS (2001), Exhibit A presents the detailed calculation of the economic benefits to New Jersey of in-state ecotourism, defined to include wildlife watching, hunting, and fishing, but not outdoor recreational activities like swimming,

[18] Ideally, this would be total income, but in the current study only wage and salary income multipliers were available.

skiing, etc. Exhibit B provides detailed explanations of the calculations and notes a few exceptions to the use of MGM2 parameter values. The main text summarizes the results.

Limitations of the Ecotourism Results

The standard method for estimating economic activity value, which is the method used in this study, has a number of inherent limitations. First, as noted in the main text and in Tietenberg (2000), secondary benefits should only be counted if the increase in demand generated by visitor spending leads to the employment of previously unused or underused resources, e.g., labor. This is most likely to occur in areas with high unemployment. If the increase in demand merely results in a reallocation of previously employed resources among economic sectors, the "increase" in economic activity is not a true increase from an economic *impact* perspective, although it can properly be counted in an analysis of economic *significance* (see, e.g., Wells 1997 and Stynes (A) and (B)).

A second limitation derives from the fact that economic activity analysis is a type of partial equilibrium analysis which is based on input-output models. Such models tend to overstate the labor component of value-added because they use average production costs rather than marginal costs. Even computable general equilibrium (CGE) models may do this, although to a lesser degree (Lahr 2006).

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Exhibit A: New Jersey Ecotourism Benefits (2004 $)										
Type of Expenditure	**Gross Spending**	**Wholesale Sector**	**Wholesale Margin**	**Wholesale Margin ($)**	**Retail Sector**	**% Retail Margin**	**$ Retail Margin**	**Spending - Margins**	**NJ % Capture**	**Direct Sales**
1	2	3	4	5	6	7	8	9	10	11
Food-groceries	$107,897	Groceries	11%	$12,317	Groceries	29%	$30,966	$64,614	53%	$34,246
Food-restaurants/bars	70,590	n/a	n/a	0	n/a	n/a	0	70,590	100%	70,590
Lodging-camping	21,870	n/a	n/a	0	n/a	n/a	0	21,870	100%	21,870
Hotel/motel/cabin/B&B	26,769	n/a	n/a	0	n/a	n/a	0	26,769	100%	26,769
Transportation	107,524	Petrol prod	9%	9,600	Gas sta.	19%	20,645	77,279	29%	22,411
Privilege/other fees (A)	87,956	n/a	0%	0	n/a	n/a	0	87,956	100%	87,956
Boating costs (Note B)	156,464	Petrol prod	9%	13,970	Gas sta.	19%	30,041	112,453	29%	32,611
Heating/cooking fuel	551	Petrol prod	9%	49	Gas sta.	19%	106	396	29%	115
Bait / ice (Fishing only)	43,078	Groceries	11%	4,917	Groceries	29%	12,363	25,798	53%	13,673
Total "trip" costs	**622,698**		**7%**	**40,853**		**15%**	**94,121**	**487,724**	**64%**	**310,241**
Activity equipment	347,279	Misc.	14%	47,246	Sport'g gds	39%	134,744	165,289	4%	6,612
Auxiliary equipment (C)	46,214	Apparel	18%	8,135	Cloth'g stor	46%	21,074	17,005	7%	1,190
Special equipment (D)	316,792	Motor veh.	15%	47,200	Motor veh.	21%	66,526	203,066	3%	6,092
Magazines/books	21,153	Misc.	14%	2,878	Sport'g gds	39%	8,207	10,068	4%	403
Member dues/contribs.	48,495	n/a	n/a	0	n/a	n/a	0	48,495	100%	48,495
Plantings	23,346	Farm prod	4%	852	Garden sup	32%	7,354	15,140	53%	8,024
Miscellaneous (E)	53,047	n/a	n/a	0	n/a	n/a	0	53,047	100%	53,047
Equip/other-specified	**856,326**		**12%**	**106,311**		**28%**	**237,905**	**512,110**	**24%**	**123,863**
Equip/other-unspecified	901,403	Average	12%	111,907	Average	28%	250,428	539,068	24%	130,383
Wholesale margins								259,071	91%	235,755
Retail margins								582,454	100%	582,454
GRAND TOTAL	**2,380,427**		**11%**	**259,071**		**24%**	**582,454**	**2,380,427**	**58%**	**1,382,696**

A. Equipment rental, guide fees, pack trips, and access fees.
B. Boat launching, mooring, storage, maintenance, insurance, pumpout fees, and fuel.
C. Tents, special clothing, etc.
D. Boats, campers, 4x4 vehicles, cabins, etc.
E. Land leasing and ownership, licenses, stamps, tags, and permits.

continued on next page

Exhibit A: New Jersey Ecotourism Benefits (2004 $), cont.										
Type of Expenditure	**Producer Sector**	**Direct Sales**	**Sales Multiplier**	**Total Sales**	**% Added to GSP**	**$ Added to GSP**	**Salary + Wage %**	**Salary + Wage $**	**Jobs/$MM Tot Sales**	**Tot Jobs Supported**
1	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**
Food-groceries	Food proc.	$34,246	1.57	$53,766	40%	$21,506	57%	$12,258	7.70	414
Food-restaurants/bars	Eating/ drinking	70,590	1.64	115,768	56%	64,830	66%	42,788	21.34	2,470
Lodging-camping	Other lodg'g	21,870	1.61	35,211	41%	14,437	49%	7,074	10.53	371
Hotel/motel/cabin/B&B	Hotels/lodg.	26,769	1.70	45,507	60%	27,304	63%	17,202	16.14	734
Transportation	Petrol refin	22,411	1.37	30,703	26%	7,983	42%	3,353	2.67	82
Privilege / other fees (A)	Recreation	87,956	1.66	146,007	61%	89,064	61%	54,329	21.34	3,116
Boating costs (Note B)	Petrol refin	32,611	1.37	44,677	26%	11,616	42%	4,879	2.67	119
Heating/cooking fuel	Petrol refin	115	1.37	158	26%	41	42%	17	2.67	0
Bait / ice (Fishing only)	Food proc.	13,673	1.57	21,467	40%	8,587	57%	4,895	7.70	165
Total "trip" costs		**310,241**	**1.59**	**493,264**	**50%**	**245,368**	**60%**	**146,795**	**15.15**	**7,471**
Activity equipment	Sport. gds.	6,612	1.62	10,711	52%	5,570	57%	3,175	10.54	113
Auxiliary equipment (C)	Apparel mfg.	1,190	1.58	1,880	42%	790	73%	577	12.46	23
Special equipment (D)	Misc. mfg.	6,092	1.59	9,686	48%	4,649	60%	2,789	10.72	104
Magazines/books	Misc. mfg.	403	1.59	641	48%	308	60%	185	10.72	7
Memb/dues/contribs.	Recreation	48,495	1.66	80,502	61%	49,106	61%	29,955	21.34	1,718
Plantings	NJ turf/sod	8,024	1.78	14,309	65%	9,237	62%	5,684	20.43	292
Miscellaneous (E)	Recreation	53,047	1.66	88,058	61%	53,715	61%	32,766	21.34	1,879
Equip/other-specified		**123,863**	**1.65**	**205,787**	**60%**	**123,375**	**61%**	**75,131**	**20.10**	**4,136**
Equip/other-unspecified	Average	130,383	1.65	215,579	60%	129,246	61%	78,706	20.10	4,333
Wholesale margins	Wholesale	235,755	1.57	370,135	67%	247,990	60%	148,794	10.47	3,875
Retail margins	Retail	582,454	1.53	891,155	74%	659,455	63%	415,457	20.60	18,358
GRAND TOTAL		**1,382,696**	**1.57**	**2,175,920**	**65%**	**1,405,434**	**62%**	**864,883**	**17.54**	**38,173**

see Exhibit B (next page) for explanatory notes

EXHIBIT B: CALCULATION OF ECOTOURISM BENEFITS IN EXHIBIT A	
Column	**Source or Calculation**
1-2	Type of expenditure and amount in 2004 $. Converted from 2001 $ as reported in USFWS (2001). Allocations of food and lodging based on NJDEP analysis of data in source; available on request from the author.
3	Most similar wholesale sector from US Census Bureau (BW/05-A).
4	Wholesale margin for sector in Col. 3, expressed as % of retail prices, derived from data reported in US Census Bureau (BW/05-A).* Margins for Activity goods and Magazines/books derived from average of margins for Misc. durables and non-durables.
5	Col. 2 x Col. 4.
6	Most similar retail sector from US Census Bureau (BR/05-A).
7	Retail margin for sector in Col. 6, expressed as % of *retail* prices, as reported in US Census Bureau (BR/05-A).
8	Col. 2 x Col. 7.
9	Col. 2 – Col. 5 – Col. 8
10	Share of Col. 9 spending captured by the NJ economy; other spending flows out of the NJ economy to other states or countries. Default value is 100%, i.e., complete capture by NJ. Other values are from Stynes et al. (2000) with adjustments as follows: -Boating costs and heating and cooking fuel %'s assumed equal to petroleum products (see above). -Bait and ice %'s assumed equal to groceries; Magazine and book % assumed equal to sporting goods (see above). -Plantings % assumed equal to groceries (most similar category available in Stynes et al. 2000). -Capture %'s for specified and unspecified portions of Equipment/other spending assumed equal.
11, 13	Col. 9 x Col. 10. Equals portion of Col. 9 spending "captured" in the NJ economy.
12	Except for Plantings, most relevant producer sector from Stynes et al. (2000).
14	Multiplier for Col. 12 producer sector from Stynes et al. (2000).
15	Col. 13 x Col. 14. Equals total economic activity, including direct, indirect, and induced sales.
16	Multiplier for Col. 12 producer sector, derived from Stynes et al. (2000) multipliers expressed as %'s of total sales.
17	Col. 15 x Col. 16. Equals portion of Col. 15 that forms part of the NJ Gross State Product (GSP); other portions of Col. 15 are deducted from GSP to avoid double-counting.
18	Multiplier for Col. 12 producer sector, derived from Stynes et al. (2000) multipliers expressed as %'s of total sales.
19	Col. 17 x Col. 18. Equals portion of Col. 17 that represents personal income to salary & wage earners, including employee benefits.
20	Multiplier for Col. 12 producer sector from Stynes et al. (2000).
21	Col. 20 x Col. 15 / 1,000. Represents no. of jobs supported by economic activity shown in Col. 15. Not necessarily equal to no. of jobs that would be lost to NJ if the economic activity ceased; in that case, dollars now spent on ecotourism would likely be redirected to other economic sectors after a transition period.

*Data were reported in the source as %'s of *wholesale* prices; these were converted to %'s of *retail* prices.
Note: multipliers in Cols. 14, 16, 18, and 20 include both indirect and induced effects. Multipliers for Plantings are based on NJDEP's analysis of the results of a study of the New Jersey turfgrass and sod industries by Govindasamy et al. (2001); details are available from the author.

The Value of New Jersey's Ecosystem Services and Natural Capital

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Executive Summary

This report summarizes the results of a two-year study of the economic value of New Jersey's natural capital. Natural capital consists of those components of the natural environment that provide aa long-term stream of benefits to individual people and to society as a whole; the value of natural capital is defined in this report as the present value of that benefit stream. Many of the benefits provided by natural capital come from ecological systems ("ecosystems"); an ecosystem is a dynamic complex of plant, animal, and microorganism communities and their nonliving environment, all interacting as a functional unit.

The benefits provided by natural capital include both goods and services; goods come from both ecosystems (e.g., timber) and abiotic (non-living) sources (e.g., mineral deposits), while services are are mainly provided by ecosystems. Examples of ecosystem services ("ecoservices") include temporary storage of flood waters by wetlands, long-term storage of climate-altering greenhouse gases in forests, dilution and assimilation of wastes by rivers, and numerous others. All of these services provide economic value to human beings. The goods provided by New Jersey's natural capital are covered in a separate study; this report focuses on the services provided the state's ecosystems, covering twelve different types of ecosystem and twelve different ecoservices.

For policy, planning, and regulatory decisions, it is important for New Jerseyans to know not only what ecosystem goods and services will be affected by public and private actions, but also what their economic value is relative to other marketed and non-marketed goods and services, such as those provided by physical capital (e.g., roads), human capital investment (e.g., education), etc. As a way of expressing these relative values or "trade-offs", this study estimated the dollar value of the ecoservices produced by New Jersey's ecosystems. In deriving these estimates, we used three different approaches: value transfer, hedonic analysis, and spatial modeling.

A. Value Transfer

Value transfer identifies previously conducted high-quality studies of the value of ecoservices in a variety of locations using a variety of valuation methods and applies them to New Jersey ecosystems. Value transfer is the preferred valuation technique where (as in this case) performing original research for an extended geographic region with varied ecosystem types would be prohibitively expensive.

For the present study, we identified and used a total of 100 earlier studies covering the types of ecosystems present in New Jersey; 94 of these studies are original research previously published in peer-reviewed journals. Some studies provided more than one estimated ecoservice value for a given ecosystem; the set of 100 studies provided a total of 210 individual value estimates. We translated each estimate into dollars per acre per year, computed the average value for a given ecoservice for a given ecosystem, and multiplied the average by the total statewide acreage for that ecosystem.

Our results are summarized below; all figures are 2004 dollars. The figures include only ecosystem services; they do not include ecosystem or abiotic goods or secondary economic activity related to a given ecosystem.

1. <u>Wetlands</u> provided the largest dollar value of ecosystem services: $9.4 billion/yr for freshwater wetlands and $1.2 billion/yr for saltwater wetlands. The most valuable services were disturbance regulation ($3.0 billion/yr), water filtration ($2.4 billion/yr), and water supply ($1.3 billion/yr) for freshwater wetlands, and waste treatment ($1.0 billion/yr) for saltwater wetlands. (Disturbance regulation means the buffering of floods, storm surges, and other events that threaten things valued by individuals or by society as a whole.)

2. <u>Marine ecosystems</u> provided the second-largest dollar amount of ecosystem services: $5.3

billion/yr for estuaries and tidal bays and about $389 million/yr for other coastal waters, including the coastal shelf out to the three-mile limit. (It should be noted that the fish and shellfish obtained from these ecosystems are covered elsewhere in this report and are not included in these totals.) Nutrient cycling (i.e., waste dilution and removal) was the most important service provided by marine ecosystems, with a value of $5.1 billion/yr.

3. Forests cover the largest area of any ecosystem type in New Jersey, and because of that the total value of the ecosystem services they provide is one of the highest at $2.2 billion/yr, excluding the value of timber. Habitat services are currently the most important of these services ($1.4 billion/yr); other important services provided by forests include water supply and pollination (about $238 million/yr each) and aesthetic and recreational amenities ($179 million/yr).

4. Urban green space covers relatively little of New Jersey but has a relatively high dollar value per acre and provides an estimated $419 million of ecosystem services annually, principally aesthetic and recreational amenities ($361 million/yr). Ecoservice values for other types of urban land and for barren land were not investigated in this study.

5. Beaches (including dunes) provided by far the highest ecoservice value per acre; their small area limited their annual ecoservice value to about $330 million, mainly disturbance regulation ($214 million/yr) and aesthetic and recreational amenities ($116 million/yr).

6. Agricultural land includes both cropland (estimated at $78 million/yr of ecosystem services) and pastureland (estimated at $45 million/yr). These values relate solely to the services provided by farmland, mainly habitat services from cropland ($75 million/yr) and waste treatment services from pasture land ($26 million/yr). They do not include the value of the food provided by farms, which is covered elsewhere.

7. Open fresh water and riparian buffers provided services with an estimated annual value of $66 million and $51 million respectively, mainly water supply ($64 million/yr) and aesthetic and recreational amenities ($51 million/yr). Another part of this report covers the value of water as an ecosystem good.

The total value of these ecosystem services is $19.4 billion/year. If we exclude studies which were not peer-reviewed and/or which did not report on original research, the result is a lower estimate of $11.6 billion/year. However, this exclusion makes it impossible to estimate values for a number of ecosystems and/or ecoservices, and we believe that the higher figure better represents the value of the services provided by New Jersey's ecosystems. If the excluded studies are added back but weighted at 50%, the total value of ecosystem services would be $15.5 billion/year.

Future flows of ecoservices can be discounted (converted to their present value equivalents) in a number of ways; the subject of discounting is controversial and is the subject of active research, with new discounting techniques being proposed regularly. If we use conventional discounting with a constant annual discount rate of 3% (a rate often used in studies of this type), and if we assume that the $19.4 billion/yr of ecoservices continues in perpetuity, the present value of those services, i.e., the value of the natural capital which provides the services, would be $648 billion. Using the same assumptions, the present values of the $11.6 billion/yr and $15.5 billion/yr flows of services (see above) would be $387 billion and $517 billion respectively.

Many decisions on environmental policy and land use are made at the local level, and it is therefore important to translate the statewide results described above into local values. Based on the results of the value transfer analysis, we mapped the aggregate value of ecosystem services by county, by watershed, and by sub-watershed. The maps show substantial differences in ecoservice values based on the predominant types of land cover in different parts of the state. In general, areas containing wetlands, estuaries, tidal bays, and beaches had the highest ecosystem service values per acre. Our maps are based on 1995/1997 land use/land cover (LULC) data, which was the most current data available at the time of our study; consideration should be given to updating both the value estimates and the maps when more recent LULC data become available.

For a number of reasons, the dollar amounts presented above are almost certainly conservative, i.e., they underestimate the true value of New Jersey's ecosystem services. These reasons include gaps in the valuation literature as well as a number of technical factors discussed at the end of the main text in this part of the report.

B. Hedonic Analysis

Hedonic analysis is one method that can be used to estimate the amenity value of ecosystems. This approach statistically separates the effect on property values of proximity to environmental amenities (such as protected open space or scenic views) from other factors that affect housing prices. In this study, we analyzed the effect on actual residential housing prices of proximity to several environmental amenities, including beaches, protected open space (specifically, large, medium and small parks), water bodies, and unprotected forests and wetlands.

To ensure that the effects being attributed to proximity to environmental amenities are not in fact due to non-environmental factors, our analysis adjusted for many other factors related to residential housing prices, including lot size, number of rooms, property taxes, etc. Because this requires very detailed information on a large number of actual market transactions, and because such information is only readily available from commercial data vendors, resource limitations prevented us from conducting a hedonic analysis for the entire state. We therefore focused on seven local housing markets located in Middlesex, Monmouth, Mercer and Ocean Counties; in most respects those markets are demographically similar in the aggregate to the state as a whole.

We ran two types of hedonic analysis using this database. In the first, we defined proximity in terms of various mutually exclusive locational zones, e.g., a house is either within 300 feet of a beach or it is not; in this analysis, the exact distance is not taken into account. In the second type of analysis, we used the exact distance from the amenity, e.g., we distinguished between houses located 100 feet and 200 feet from a beach. Where the two analyses agree, we can have increased confidence in the results. We could not run all of the analyses in each of the seven real estate markets, either because a given market lacked the environmental amenity in question or because it had too few home sales involving that amenity to draw statistically valid conclusions.

The results we obtained in the two analyses demonstrate that homes that are closer to environmental amenities generally sell for more than homes further away, all else being equal. We first present the results based simply on whether a home is within a given distance of an environmental amenity or not:

1. Beach zones (7 markets analyzed). In four markets, sale prices for homes within 300 feet of a beach were from \$81,000 to \$194,000 higher than homes further away. For two markets, homes between 300 and 2,000 feet from a beach had prices that were from \$16,000 to \$44,000 higher than homes further away; however, in one market the selling price for a home so located was \$28,000 *lower*, presumably reflecting market-specific factors not controlled for.

2. Environmentally Sensitive (ES) zones (2 markets analyzed). Houses located in ES zones, as defined by the Office of State Planning, had selling prices that were between \$8,600 and \$34,500 higher than houses not located in such zones.

3. Water zones (1 market analyzed). Houses located within 100 feet of a water body sold for

$33,000 more than homes not so located.

These results show that whether or not a property is located within a given distance of an environmental amenity affects a home's value as measured by its sale price. As noted above, we also tested the impact of the exact distance to amenities, but those results were much less clear. The summary below gives results for two specific distances—100 feet and 5 miles—but results for other distances can also be generated.

1. Proximity to beaches was consistently positively valued. For example, in the two markets we were able to analyze in terms of exact distance to beaches, homes located 100 feet from a beach sold for between $13,000 and $21,000 more than homes located 5 miles away from the beach, with smaller increases in value for homes located at intermediate distances.

2. Proximity to water features was positively valued in two markets, with homes located 100 feet from a water feature selling for between $32,000 and $92,000 more than homes located 5 miles away from the feature. However, in a third market, homes located 100 feet away sold for over $63,000 less than homes 5 miles away, presumably reflecting local factors not captured in the analysis.

3. Unprotected forests and wetlands were consistent in having no strong effects on property values across markets.

4. The market value of proximity to parks varied depending on the size of the park:

   - Proximity to small parks (< 50 acres) was positively valued in four markets (prices between $17,000 and $178,000 higher at 100 feet from the park than at 5 miles) and negatively in one market (selling prices $86,000 *lower* at 100 feet than at 5 miles).

   - Proximity to medium parks (50-2,000 acres) was valued positively in two markets (price difference between $9,000 and $66,000) and negatively in four (price difference between -$19,000 and -$272,000).

   - Proximity to large parks (> 2,000 acres) was valued positively in three markets (price difference between $33,000 and $40,000) and negatively in another three (price difference between -$25,000 and -$176,000).

While we can say that proximity to small parks tends to have a consistently positively effect on housing prices, the mixed or negative results for proximity to medium and large parks are harder to explain other than as the results of confounding effects of unidentified negative factors associated with large open space areas in local housing markets. For example, in some markets medium or large parks might be located further from stores, transportation, or job opportunities. Identification of such confounding factors would require further analysis and resources.

A recognized inherent limitation of hedonic analysis is that the results cannot be readily translated into dollar values per acre and so are difficult to compare with the results of the value transfer analysis. The limited tests we were able to perform to address this problem suggest that the valuations obtained from the hedonic analysis translate into *larger* per acre dollar amounts than we obtained from the value transfer analysis, suggesting that the latter may be conservative, i.e., on the low side.

C. Spatial Modeling

Spatial modeling, as applied in this study uses a landscape simulation model to assess the relationships over time between specific spatial patterns of land use and the production of ecosystem services. We used a model that has been previously designed, calibrated, and thoroughly tested for a watershed in Maryland. While the *absolute* results for watersheds in New Jersey could be substantially different, the *relative* values for ecosystem services in various scenarios are likely to be consistent.

In this analysis we tracked two variables related to ecosystem services: (1) concentration of nutrients (in this case nitrogen), an important indicator of water quality; and (2) Net Primary Productivity (NPP), a proxy for total ecosystem services value. (NPP essentially measures the amount of plant growth and is therefore an indicator of the amount and health of existing vegetation; since animal food webs rely ultimately on vegetation, NPP also measures the growth rate for the resources on which animal life depends.) The model includes variables that can quantify how much these indicators may vary as land use, climate, and other factors change in spatial location and over time.

Our results show that different land use allocations and spatial patterns affect the ecosystem services generated. For the water quality index, this difference can be as large as 40%. Forests located close to a river's estuary zone contribute more to estuary water quality than forests located further away. Further, small river buffers have only a minor impact on water quality and need to be fairly large to be of use, whereas small, dispersed forest patches do more to enhance water quality than larger forest clusters. There is still much uncertainty in these estimates, and more detailed and comprehensive studies are required to take into account the whole set of ecosystem services and to account properly for the precise spatial variations in land cover and location, but these results show that spatial patterns of land use can affect ecosystem services significantly.

Conclusions

1. Ecosystems provide a wide variety of economically valuable services, including waste treatment, water supply, disturbance buffering, plant and animal habitat, and others. The services provided by New Jersey's ecosystems are worth, at a minimum, \$11.6-19.4 billion/year. For the most part, these services are not currently accounted for in market transactions.

2. These annual benefits translate into a present value for New Jersey's natural capital of at least \$387 billion to \$648 billion, not including marketed ecosystem or abiotic goods or secondary economic impacts.

3. Wetlands (both freshwater and saltwater), estuaries/tidal bays, and forests are by far the most valuable ecosystems in New Jersey's portfolio, accounting for over 90% of the estimated total value of ecosystem services.

4. A large increase in property values is associated with proximity to beaches and open water. Proximity to smaller urban and suburban parks has positive effects in most markets, while the value of proximity to larger tracts of protected open space and environmentally sensitive areas depends on the local context.

5. Landscape modeling shows that the location of ecosystems relative to each other significantly affects their level of ecoservice production.

6. Significant gaps exist in the valuation literature, including gas and climate regulation provided by wetlands; disturbance prevention provided by freshwater wetlands; disturbance prevention, water supply, and water regulation provided by forests; and nutrient regulation, soil retention/formation, and biological control provided by a number of ecosystems.

7. While the assessment is far from complete and probably can never be considered final, the general patterns are clear and should receive careful consideration in managing New Jersey's ecosystems and other natural capital to preserve and enhance their long-term value to society.

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Overview of the Study

The New Jersey Context

Between 1986 and 1995, New Jersey converted almost 149,000 acres or almost 4.4% of its forests, farmland, and wetlands to other uses; this works out to 16,545 acres annually or about 0.5%.[1] Acting as individuals, through the private sector, and through their elected and appointed public officials, New Jerseyans are making decisions on a daily basis on the future of their remaining natural environment, and issues involving development and land use are at or near the top of the list of public issues of concern to New Jerseyans.

In making these decisions, New Jersey's residents and public officials are constantly choosing between competing uses of the "natural" environment.[2] Such choices usually (although not always) involve a choice between preserving land in its existing state or converting it to residential or commercial use, including built infrastructure such as roads and highways.

- Should a patch of forest be cleared to provide new land for roads, or should it be maintained in its current state to serve as a recreational resource? About 62,000 acres of forest were cleared for development (or cleared and left barren) between 1986 and 1995, net of developed or barren land that was converted to forest through tree planting programs.
- Should a particular wetland be drained and developed for commercial purposes or maintained "as is" to serve as a wildlife habitat and storm water buffer? Some 22,000 acres of wetland were developed or rendered barren between 1986 and 1995.
- Should a parcel of farmland be sold for housing development or preserved for farming? From 1986 to 1995, about 65,000 acres of farmland were developed or rendered barren. (Another 22,000 acres of farmland were allowed to revert to forest during that period.)

While making choices among these competing land use alternatives does not turn solely on economic considerations, it is obviously essential to have a broad understanding of both the benefits and the costs of development. The benefits usually attributed to development by its proponents are well-known, including provision of housing, economic development, job creation, improving transportation infrastructure, strengthening municipal finances, etc. Some of the costs of development are equally familiar, including increased demand for municipal services, public infrastructure, costs for school system expansion, traffic congestion and longer daily commutes, stress on water supplies, and so forth.

While the benefits of environmental preservation and the environmental costs of development are also familiar—land conversion and the loss of natural features that were previously part of a landscape—they are often not treated in economic terms in the same sense as, say, the cost of a new school or highway. Many of the social and ecological costs of development, including degradation of water quality, silting of rivers and streams, increasing levels of air pollution, and so on, are simply left out of the analysis of the trade-offs accompanying land use decisions. The environmental benefits of preservation—which in many cases are the converse of the costs of development—are often similarly ignored.

In part this omission stems from the fact that the impacts on the natural environment are often difficult to quantify in physical and monetary terms, which makes it hard to know exactly what we are

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[1] The source for all land use and land cover data cited in this section is Hasse and Lathrop (2001). The 1986 and 1995 data used in that source are the most recent official data available on these subjects. Land use and land cover data for 2002 are expected to become available sometime in 2006.

[2] It can be argued that farmland is not "natural" in the same sense as unmanaged forests and wetlands. For purposes of this report, however, farmland is more akin to such landscapes than to urbanized areas.

gaining when we preserve a landscape in its undeveloped state or what we lose when we decide (deliberately or by default) not to protect a natural area. To address this inadequacy, citizens, business leaders and government decision makers need to know whether the benefits of development postulated by its supporters—jobs, income, and tax revenues–will be overshadowed by unseen costs in the future. The challenge, in short, is to make the linkages between landscapes and the human values they represent as explicit and transparent as possible.

This need for information is not limited to environmental issues. For *any* efficient market transaction or public policy decision, both theory and common sense tell us that costs and benefits need to be made transparent to agents; if the market is not transparent; inefficiencies arise because people make uninformed choices leading to suboptimal or "irrational" decisions (Shiller, 2000). The identification and measurement of environmental features of value is thus essential for the efficient and rational allocation of environmental "resources" among the competing demands on natural and cultural landscapes (Daily, 1997; Costanza et al., 1997; Wilson & Carpenter, 1999).

This project aims to present a comprehensive assessment of the economic benefits provided by New Jersey's natural environment. Our goal was to use the best available conceptual frameworks, data sources, and analytic techniques to generate value estimates that can be integrated into land use planning and environmental decision-making throughout New Jersey. By estimating the economic value of environmental features not traded in the marketplace, social costs or benefits that otherwise would remain hidden or unappreciated are revealed, so that when tradeoffs between alternative land uses in New Jersey are evaluated, information is available to help decision makers avoid systematic biases and inefficiencies.

Definitions and Ethical Concerns

Before discussing the value of benefits[3] provided by the natural environment, we need to clarify some underlying concepts and terms. The following definitions are based on Farber et al. (2002).

"Value systems" refer to the norms and precepts that guide human judgment and action. They refer to the normative and moral frameworks people use to assign importance and necessity to their beliefs and actions. Because "value systems" frame how people assign importance to things and activities, they also imply internal objectives. Value systems are thus internal to individuals but result from complex patterns of acculturation and may be externally manipulated through, for example, advertising.

"Value" refers to the contribution of an object or action to specific goals, objectives or conditions (Costanza 2000). The value of an object or action may be tightly coupled with an individual's value system, because the latter determines the relative importance to the individual of an action or object relative to other actions or objects within the perceived world. But people's perceptions are limited, they do not have perfect information, and they have limited capacity to process the information they do have. An object or activity may therefore contribute to meeting an individual's goals without the individual being fully (or even vaguely) aware of the connection. The value of an object or action therefore needs to be assessed both from the "subjective" point of view of individuals and their internal value systems, and also from the "objective" point of view of what we may know from other sources about the connection.

"Valuation" is the process of assessing the contribution of a particular object or action to meeting a particular goal, whether or not that contribution is fully perceived by the individual. If individuals have good knowledge of an object or action's connection to their well-being, one can use their "willingness-to-

[3] As used in this and similar contexts throughout this report, "environmental benefits" means the benefits that the natural environment provides to human beings, either directly or indirectly (e.g., retention of soil by forests), rather than the benefits "to the environment" from controlling pollution, (e.g. reduced particulate emissions from combustion of diesel fuel.)

pay" for the object or action as a measure of its value to them. This willingness to pay can be either revealed through their actions (i.e. housing market choices as in the hedonic analysis discussed later) or stated as a response to surveys of various kinds (i.e. contingent value surveys of the type used in some of the value transfer studies discussed later).

"Intrinsic value" refers more to the goal or basis for valuation itself and the protection of the "rights" of these goals to exist. For example, if one says that nature has "intrinsic value" one is really claiming that protecting nature is an important goal or end in itself. This is sometimes referred to as being "biocentric" rather than "anthropocentric." "Values", (as defined above) are based on the contribution that something makes to achieving goals (directly or indirectly), i.e., they represent *instrumental values*. One could thus talk about the value of an object or action in terms of its contribution to the goal of preserving nature, but not about the "intrinsic value" of nature. So "intrinsic value" is a confusing term. One should more accurately refer to the "intrinsic rights" of nature to qualify as a goal against which to assess value, in addition to the more conventional economic goals. Since an intrinsic value is a goal or end, one cannot measure or quantify the "intrinsic value" of something.

In modern economics the term value is usually taken to mean "*exchange value"*, defined as the maximum amount that an individual would be willing to pay to obtain a benefit or the minimum that the person would be willing to accept to forego the benefit. The data accepted as providing evidence of the amount of value in this sense are often restricted to stated or revealed preferences, but one can (and must, if one hopes to be comprehensive and accurate) encompass valuations from multiple perspectives, using multiple methods (including both subjective and objective), against multiple goals (Costanza, 2000).

Some environmentalists object on principle to assigning economic values to nature. The objection seems to be that it is somehow "unethical" or "vulgar" or self-defeating to attempt to quantify environmental benefits in dollar terms. This type of objection is difficult to address except by saying we see no logical conflict between identifying economic reasons for preserving natural systems and stating ethical reasons; in principle, these are mutually supportive rather than either/or justifications.

The objection may be based partly on the false presumption that quantifying dollar values for natural "assets" automatically implies that they can or should be traded in private markets. However, natural assets are, for the most part, public goods. They are often "non-rival" (one person's use does not preclude other's use) and "non-exclusive" (it is difficult or impossible to exclude people from benefiting from the services). These characteristics are the economist's classic criteria for "public" goods, and most economists would agree that using unfettered private markets to manage these assets will not maximize social welfare.

In common with conventional "manufactured" public goods such as roads, bridges, and other publicly-owned infrastructure, a significant government involvement in the production and management of environmental benefits is therefore necessary. However, just because we decide that we cannot or should not sell a public asset such as the Brooklyn Bridge does not mean we should not quantify its value. Effectively managing and maintaining the bridge requires knowledge of its social costs and benefits, and the same reasoning applies to managing our endowment of natural assets.

The objection may also be based on the idea that "there are some things you can't [and by implication shouldn't] put a price on". While it is certainly true that there are some things we probably never would (or should) sell for money, this is not the same as saying that it is unethical to assign a value (expressed in dollar terms) to some aspect of nature that we value, e.g., preservation of habitat for the bald eagle or another rare species. The alternative to doing so—leaving a blank space in that part of the analysis—is in effect to accept an implicit value of zero in discussing the costs and benefits of preserving that habitat. Saying that the value is infinite or "beyond money" leads to much the same result—the "space" is left blank, albeit with an explanation that the good or service in question cannot be valued.

In our world, resources are always limited, and the resources devoted to habitat preservation can always find other worthy uses. When one alternative is chosen over another, e.g. development vs. preservation of a particular habitat, the choice indicates which alternative is deemed to be worth the most, i.e., which is more valuable. Therefore, "we cannot avoid the valuation issue, because as long as we are forced to make choices, we are doing valuation" (Costanza & Folke, 1997; p. 50). Of course, it may be very difficult (given our present knowledge) to assign a defensible value to some aspects of the environment. However, the record in this field (cf. Appendix A) has been one of development and refinement of valuation methods to address such challenges, and the only way to know whether something can be usefully valued is to make the attempt.[4]

Environmental Sources of Economic Benefits

In earlier eras, economic benefits associated with the natural environment were often described in terms of "natural resources", including both non-living resources such as mineral deposits and living resources such as timber, fertile soil, fish, etc. The emphasis in this conceptual framework is on things of value that can be extracted from the environment for direct use by human beings. In general, the inanimate resources are non-renewable, i.e., they are potentially exhaustible, although exploration may uncover new sources and technological development may create substitutes. Animate resources, on the other hand, are potentially renewable if they are not harvested too rapidly and if other factors (e.g., climate, absence of disease, etc.) are favourable to their renewal.

A different way of looking at environmental benefits has been gaining favor over the last several decades among scientists and economists. In this "natural capital" or "ecosystem services" framework, the natural environment is viewed as a "capital asset", i.e., an asset that provides a flow of benefits over an extended period (Costanza and Daly 1992). While inanimate or "abiotic" resources are not ignored, the emphasis is on the benefits provided by the living environment, usually viewed in terms of whole ecosystems. Ecosystems are defined as all the interacting abiotic and biotic elements of an area of land or water. Ecosystem functions are the processes of transformation of matter and energy in ecosystems. Ecosystem goods and services are the benefits that humans derive (directly and indirectly) from naturally functioning ecological systems (Costanza et al., 1997; Daily 1997, De Groot et al., 2002; Wilson, Costanza and Troy, 2004). The recently released Millennium Ecosystem Assessment represents the work of over 1300 scientists worldwide over four years focused on the concept of ecosystem services and their contribution to human well-being (http://www.millenniumassessment.org/en/index.aspx)

The New Jersey landscape is composed of a diverse mixture of forests, grasslands, wetlands, rivers, estuaries and beaches that provide many different valuable goods and services to human beings. Ecosystem *goods* represent the material products that are obtained from nature for human use (De Groot et al., 2002), such as timber from forests, fish from lakes and rivers, food from soil, etc. An ecosystem *service*, in contrast, consists of "the conditions and processes through which natural ecosystems, and the species that make them up, sustain and fulfil human life" (Daily, 1997).

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[4] Where the benefits of an action are especially difficult to quantify in monetary terms, benefit-cost analysis may have to give way to cost-effectiveness analysis, where the end—e.g. habitat preservation—is taken as a given and the analyst and policymaker look for the least-cost means of achieving that end. In general the present report does not address the costs of environmental preservation, and it therefore represents yet another approach, namely valuation of the natural assets at stake in land use decisions.

The ecosystem services that we evaluate in this project are listed below[5]:

1. ***Climate and atmospheric gas regulation****:* life on earth exists within a narrow band of chemical balance in the atmosphere and oceans, and alterations in that balance can have positive or negative impacts on natural and economic processes. Biotic and abiotic processes and components of natural and semi-natural ecosystems influence this chemical balance in many ways including the CO_2/O_2 balance, maintenance of the ozone-layer (O_3), and regulation of SO_X levels.

2. ***Disturbance prevention****:* many natural and semi-natural landscapes provide a 'buffering' function that protects humans from destructive perturbations. For example, wetlands and floodplains can help mitigate the effects of floods by trapping and containing stormwater. Coastal island vegetation can also reduce the damage of wave action and storm surges. The estimated cost of floods in the U.S. in terms of insurance claims and aid exceed $4 billion per year.

3. ***Freshwater regulation and supply****:* the availability of fresh and clean water is essential to life, and is one of humanity's most valuable natural assets. When water supplies fail, water must be imported from elsewhere at great expense, must be more extensively treated (as in the case of low stream flows or well levels), or must be produced using more expensive means (such as desalinization). Forests and their underlying soil, and wetlands, play an important role in ensuring that rainwater is stored and released gradually, rather than allowed to immediately flow downstream as runoff.

4. ***Waste assimilation****:* both forests and wetlands provide a natural buffer between human activities and water supplies, filtering out pathogens such as *Giardia* or *Escherichia*, nutrients such as nitrogen and phosphorous, and metals and sediments. This service benefits both humans by providing cleaner drinking water and plants and animals by reducing harmful algae blooms, increasing dissolved oxygen and reducing excessive sediment in water. Trees also improve air quality by filtering out particulates and toxic compounds from air, making it more breathable and healthy.

5. ***Nutrient regulation***: the proper functioning of any natural or semi-natural ecosystem is dependent on the ability of plants and animals to utilize nutrients such as nitrogen, potassium and sulfur. For example, soil and water, with the assistance of certain bacteria algae (Cyanobacteria), take nitrogen in the atmosphere and "fix" it so that it can be readily absorbed by the roots of plants. When plants die or are consumed by animals, nitrogen is "recycled" into the atmosphere. Farmers apply tons of commercial fertilizers to croplands each year, in part because this natural cycle has been disrupted by intense and overly-extractive cultivation.

6. ***Habitat refugium***: contiguous 'patches' of landscape with sufficient area to hold naturally functioning ecosystems support a diversity of plant and animal life. As patch size decreases, and as patches of habitat become more isolated from each other, population sizes can decrease below the thresholds needed to maintain genetic variation, withstand stochastic events (such as storms or droughts) and population oscillations, and meet "social requirements" like breeding and migration. Large contiguous habitat blocks, such as intact forests or wetlands, thus function as critical population sources for plant and animal species that humans value for both aesthetic value and functional reasons.

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[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 we selected this list for its specific applicability to landscape analysis using available land cover and land use data.

7. ***Soil retention and formation**:* soils provide many of the services mentioned above, including water storage and filtering, waste assimilation, and a medium for plant growth. Natural systems both create and enrich soil through weathering and decomposition and retain soil by preventing its being washed away during rainstorms.

8. ***Recreation**:* intact natural ecosystems that attract people who fish, hunt, hike, canoe or kayak, bring direct economic benefits to the areas surrounding those natural areas. People's willingness to pay for local meals and lodging and to spend time and money on travel to these sites, are economic indicators of the value they place on natural areas.

9. ***Aesthetic and amenity***: Real estate values, and therefore local tax revenues, often increase for houses located near protected open space. The difference in real estate value reflects people's willingness to pay for the aesthetic and recreational value of protected open space. People are also often willing to pay to maintain or preserve the integrity of a natural site to protect the perceived beauty and quality of that site.

10. ***Pollination**:* More than 218,000 of the world's 250,000 flowering plants, including 80% of the world's species of food plants, rely on pollinators for reproduction. Over 100,000 invertebrate species — such as bees, moths, butterflies, beetles, and flies — serve as pollinators worldwide. At least 1,035 species of vertebrates, including birds, mammals, and reptiles, also pollinate many plant species. The US Fish and Wildlife Service lists over 50 pollinators as threatened or endangered, and wild honeybee populations have dropped 25 percent since 1990. Pollination is essential for many agricultural crops, and substitutes for local pollinators are increasingly expensive.

As the above listing indicates, ecosystem goods and services affect humanity at multiple scales, from climate regulation and carbon sequestration at the global scale, to flood protection, soil formation, and nutrient cycling at the local and regional scales (De Groot et al., 2002). They also span a range of degrees of connection to human welfare, with services like climate regulation being less directly or immediately connected, and recreational opportunities being more directly connected.

The concept of ecosystem services is useful for landscape management, sustainable business practice and decision making for three fundamental reasons. *First*, it helps us 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*, public officials, business leaders and citizens can use the concept to evaluate economic and other tradeoffs between landscape development and conservation alternatives.

Driven by a growing recognition of their importance for human life and well-being, ecologists, social scientists, and environmental managers have become increasingly interested in assessing the economic values associated with both ecosystem goods and services (Bingham et al, 1995; Costanza et al., 1997; Farber et al., 2002) and increasingly skilled in developing and applying appropriate analytic techniques for performing those assessments.

Organization of This Report

Our approach to valuing New Jersey's ecosystem services includes four main components as follows:

1. A framework for classifying environmental benefits and the types of landscape that generate them;

2. A "value transfer" methodology for valuing ecosystem services that emphasizes that no single study alone can capture the total value of a complex ecological system;

3. A spatial context for landscape valuation using land cover data and Geographic Information Systems (GIS); and

4. An assessment of the effects of spatial pattern and proximity effects on ecosystem services and their value.

Our results include the following:

1. Tables synthesizing the results of more than 150 primary studies on the value of each ecosystem type and ecosystem service flow included in our study;
2. Tables compiling the value of ecosystem service flows for the entire state;
3. Maps of the current value of ecosystem service flows in New Jersey based on these estimates;
4. The results of a primary study of ecosystem amenity values we performed using New Jersey data and hedonic analysis techniques;
5. An analysis of the effects on ecosystem service values of differences in spatial patterns of land use; and
6. The results of converting annual flows of ecosystem service values to estimates of the value of New Jersey's stock of natural capital.

Methods and Results

Measuring Values for Ecosystem Services

In addition to the production of marketable goods, ecosystems provide natural functions such as nutrient recycling as well as conferring aesthetic benefits to humans. Ecosystem goods and services may therefore be divided into two general categories: *marketed* and *non-marketed.*

While measuring market values simply requires monitoring market data for observable trades, non-market values of goods and services are much more difficult to measure. When there are no explicit markets for services, more indirect means of assessing values must be used. A spectrum of valuation techniques commonly used to establish values when market values do not exist are identified in Table 1.

As the descriptions in Table 1 suggest, each valuation methodology has its own strengths and limitations, often limiting its use to a select range of ecosystem goods and services within a given landscape. For example, the value generated by a naturally functioning ecological system in the treatment of wastewater can be estimated using the Replacement Cost (RC) method, which is based on the price of the cheapest alternative way of obtaining that service, e.g. the cost of chemical or mechanical alternatives. A related method, Avoided Cost (AC), can be used to estimate value based on the cost of damages due to lost services. Travel Cost (TC) and Contingent Valuation (CV) surveys are useful for estimating recreation values, while Hedonic Pricing (HP) is used for estimating property values associated with aesthetic qualities of natural ecosystems. In this project, we synthesized studies which employed the full suite of ecosystem valuation techniques. We also performed an original hedonic analysis of the relationship between property sales prices and ecological amenities.

Table 1: Non-Market Economic Valuation Techniques

Avoided Cost (AC): services allow society to avoid costs that would have been incurred in the absence of those services; flood control provided by barrier islands avoids property damages along the coast.

Replacement Cost (RC): services could be replaced with man-made systems; nutrient cycling waste treatment can be replaced with costly treatment systems.

Factor Income (FI): services provide for the enhancement of incomes; water quality improvements increase commercial fisheries catch and incomes of fishermen.

Travel Cost (TC): service demand may require travel, whose costs can reflect the implied value of the service; recreation areas attract distant visitors whose value placed on that area must be at least what they were willing to pay to travel to it, including the imputed value of their time.

Hedonic Pricing (HP): service demand may be reflected in the prices people will pay for associated goods: For example, housing prices along the coastline tend to exceed the prices of inland homes.

Marginal Product Estimation (MP): Service demand is generated in a dynamic modeling environment using a production function (i.e., Cobb-Douglas) to estimate the change in the value of outputs in response to a change in material inputs.

Contingent Valuation (CV): service demand may be elicited by posing hypothetical scenarios that involve some valuation of alternatives; e.g., people generally state that they would be willing to pay for increased preservation of beaches and shoreline.

Group Valuation (GV): This approach is based on principles of deliberative democracy and the assumption that public decision making should result, not from the aggregation of separately measured individual preferences, but from *open public debate.*

Value Transfer Approach

In this report, we use value transfer to generate baseline estimates of ecosystem service values in the state of New Jersey (Desvouges et al., 1998). Value transfer involves the adaptation of existing valuation information or data to new policy contexts[6]. In this analysis, the transfer method involves obtaining an economic estimate for the value of non-market services through the analysis of a single study, or group of studies, that have been previously carried out to value similar services. The transfer itself refers to the application of values and other information from the original 'study site' to a new 'policy site' (Desvouges et al., 1998; Loomis, 1992; Smith, 1992).

With the increasing sophistication and number of empirical economic valuation studies in the peer-reviewed literature, value transfer has become a practical way to inform decisions when primary data collection is not feasible due to budget and time constraints, or when expected payoffs are small (Kreuter et al., 2001; Moran, 1999). As such, the transfer method is a very important tool for policy makers since it can be used to reliably estimate the economic values associated with a particular landscape, based on existing research, for considerably less time and expense than a new primary study.

The value transfer method is increasingly being used to inform landscape management decisions by public agencies (Downing & Ozuna, 1996; Eade & Moran, 1996; Kirchoff et al., 1997; Smith, 1992). Thus, it is clear that despite acknowledged limitations such as the context sensitivity of value estimates, existing studies can and do provide a credible basis for policy decisions involving sites other than the study site for which the values were originally estimated. This is particularly true when current net present valuations are either negligible or (implicitly) zero because they have simply been ignored. The critical underlying assumption of the transfer method 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 at other sites. Clearly, as the richness, extent and detail of information increases within the source literature, the accuracy of the value transfer technique will likewise improve.

While we accept the fundamental premise that primary valuation research will always be a 'first-best' strategy for gathering information about the value of ecosystem goods and services (Downing and Ozuna, 1996; Kirchhoff, 1997; Smith, 1992), we also recognize that value transfer has become an increasingly practical way to inform policy decisions when primary data collection is not feasible due to budget and time constraints, or when expected payoffs are small (Environmental Protection Agency, 2000; National Research Council, 2004). When primary valuation research is not possible or plausible, then value transfer, as a 'second-best' strategy, is important to consider as a source of meaningful baselines for the evaluation of management and policy impacts on ecosystem goods and services. The real-world alternative is to treat the economic values of ecosystem services as zero; a status quo solution that, based on the weight of the empirical evidence, will often be much more error prone than value transfer itself.

Summary of the Value Transfer Approach

As Figure 1 below shows, the raw data for the value transfer exercise in this report comes from previously conducted empirical studies that measured the economic value of ecosystem services. These studies were reviewed by the research team and the results analyzed for value transfer to the State of New Jersey. By entering the original results into a relational database format, each dollar value estimate can be identified with unique searchable criteria (i.e., type of study, author, location, etc.), thus allowing the team to associate specific dollar estimates with specific conditions on-the-ground. For example, all forest-related value estimates in this report come from economic studies that were originally conducted in

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[6] Following Desvouges et al. (1998), we adopt the term 'value transfer' instead of the more commonly used term 'benefit transfer' 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 value functions themselves.

temperate forests similar to those in New Jersey. To achieve this, once analyzed, the valuation data were integrated with land cover data for New Jersey. Tables and maps were then generated from this fusion of economic and geographic information.

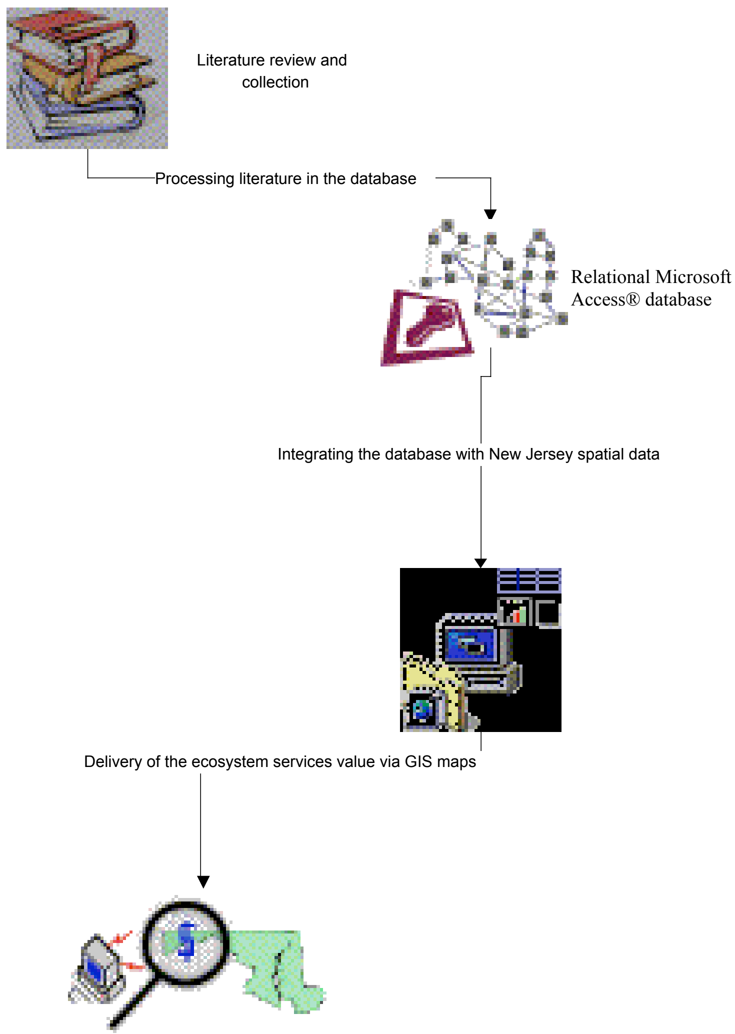

Figure 1: Stages of Spatial Value Transfer

The research team developed a set of decision rules for selecting empirical studies from the literature that allowed us to estimate the economic value of ecosystem services in the state of New Jersey. Using scientific data search engines such as ISI Web of Science® and by cross-checking the largest value transfer database online (i.e., EVRI ™) the research team reviewed the best available economic literature and selected valuation studies which were:

- Focused on temperate regions in North America
- Focused primarily on non-consumptive use

The quality of original studies used in the value transfer exercise always determines the overall quality and scope of the final value estimate (Brouwer, 2000). In our review of the literature, we were able to identify three general categories of valuation research, each with its own strengths and weaknesses (Table 2). Type A studies are peer-reviewed empirical analyses that use conventional environmental economic techniques (e.g., Travel Cost, Hedonic Pricing and Contingent Valuation) to elicit individual consumer preferences for environmental services. Type B studies are commonly referred to as the 'grey literature' and generally represent non peer-reviewed analyses such as technical reports, PhD Theses and government documents using conventional environmental economic techniques that also focus on individual consumer preferences. Type C studies represent secondary, summary studies such as statistical meta-analyses of primary valuation literature that include both conventional environmental economic techniques as well as non-conventional techniques (Energy analyses, Marginal product estimation) to generate synthesis estimates of ecosystem service values.

Table 2: Value-Transfer Data Source Typology

Type A	Type B	Type C
• Peer-Reviewed Journal Article or Book Chapter	• Non Peer-Reviewed (PhD Thesis, Raw Data, Technical Report etc.)	• Secondary (meta) Analysis of Peer reviewed and Non Peer Reviewed studies
• Uses Conventional Environmental Economic Valuation Methods	• Uses Conventional Environmental Economic Valuation Methods	• Uses Both Conventional and Non-Conventional Valuation methods
• Restricted to conventional, Preference-based Values	• Restricted to conventional, Preference-based Values	• Includes conventional Preference-based, non-conventional preference-based, and Non-Preference-based Values

The research team used two alternative approaches to capture possible variation in results across the different literature types: (1) we first limited our value transfer analysis to peer-reviewed studies that use conventional environmental economic methods (hereafter Type A studies) and (2) we then added a few additional Type B studies and Type C meta-analyses of ecosystem service values that were readily accessible (hereafter Type A-C). The results presented below are separated into Type A and Type A-C categories to generate a more complete picture of the complete range of ecosystem service values associated with the New Jersey landscape. For specific information on all the studies included in this report please see technical appendices B and C.

Land Cover Typology

Since ecosystem services are analyzed at the landscape scale for this project, a key challenge for the research team is to link the ecosystem service estimates to available land cover/land use data in New Jersey so that we can map ecosystem services (Wilson et. al. 2005). Thanks to the increased ease of using Geographic Information Systems (GIS) and the availability of land cover data sets derived from satellite images, ecological and geographic entities can more easily be associated with ecosystem services and the values they provide to people.

In simplified terms, the technique used to generate average ecosystem service value for a given geographic area involves combining one land cover layer with another layer representing the geography to which ecosystem services are aggregated – e.g., a watershed. While the aggregation units themselves are likely to be in vector format, because vector boundaries are most precise, the land cover layer may be either raster or vector.[7] Spatial disaggregation by watershed increases the contextual specificity of ecosystem value transfer by allowing us to visualize the exact location of ecologically important landscape elements and overlay them with other relevant themes for analysis—biogeophysical or socioeconomic.

A New Jersey-specific land cover typology was developed by the research team for the purposes of calculating and spatially assigning ecosystem service values. This typology is a variant of the New Jersey Department of Environmental Protection (NJDEP) classification for the 1995/97 Land use/Land cover (LULC) by Watershed Management Area layer.[8] The new typology condenses a number of DEP classes that have similar (or no) ecosystem service value and creates several new classes to reflect important difference in ecosystem service values that occur within a given DEP class. The development of the land cover typology began with a preliminary survey of available GIS data for New Jersey to determine the basic land cover types present and the level of categorical precision in those characterizations. This process resulted in a unique 13-class land cover typology for the State of New Jersey.

Table 3: New Jersey Land Cover Typology

Land Cover Type
Beach
Coastal Shelf
Cropland
Estuary and tidal bay
Forest
Freshwater wetland
Open water
Pasture/grassland
Riparian zone
Saltwater wetland
Urban greenspace
Urban or barren
Woody perennial

[7] The vector data model represents spatial entities with points, lines and polygons. The raster model uses a Cartesian grid to represent a landscape.

[8] At the time the research for this report was conducted, 1995/1997 land use/land cover data was the most recent available.

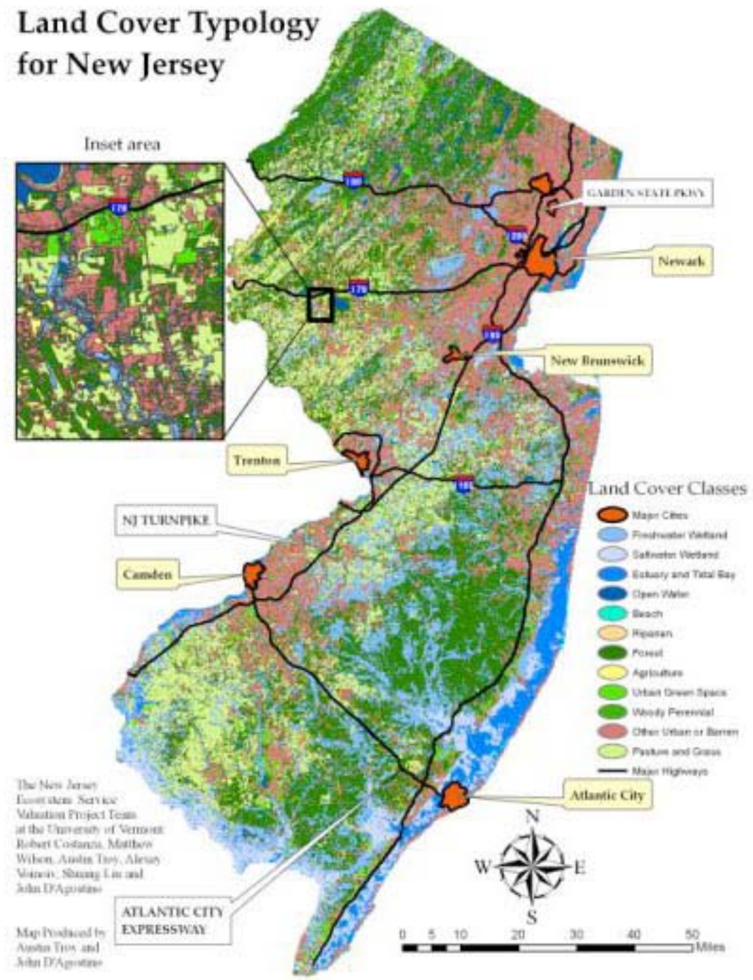

Figure 2: Land cover map of New Jersey

Most categories in this typology represent aggregations of pre-existing categories drawn from the NJDEP LULC map. For instance, the "beach" category in the new typology includes both the "beach" and the "vegetated coastal dunes" categories. However, several categories were developed using ancillary data sources in combination with the DEP land use/land cover map.

1. The first of these was the pasture/agricultural grassland category. While the NJDEP LULC map has a single category for both row crop agriculture and pastureland or hayfields, the valuation database contains studies differentiating between these two categories. To make this distinction geographically, we conducted overlay analysis between the LULC layer and the DEP's grasslands layer (which was based on a combination of the LULC data and data on sightings of imperiled or endangered grassland species). All map polygons designated as agricultural in the LULC that had their geometric centers within a grasslands polygon were designated as pasture/grassland.

2. The second category requiring ancillary data was urban greenspace. This layer was created by overlaying the urban centers boundary layer from the New Jersey Office of Smart Growth with the LULC map. All forest, wetland, and grassland polygons whose center fell within an urban center boundary were selected and recoded as urban green space.

3. The third category requiring ancillary data was riparian zones. This layer was created by buffering the DEP's layer of third order or higher rivers. One hundred foot-buffers were created around rivers of fourth and fifth order, and fifty foot buffers were created around third order watercourses. A geometric union overlay was then conducted between the LULC and buffer layers. All resulting polygons falling within the buffer were classified as riparian unless they were coded as wetlands, which was given precedence due to its higher ecoservice value.

4. The last category requiring ancillary data was the coastal shelf, which was created using the three-mile territorial waters buffer polygons present in the DEP's HUC-14 watershed management area layer.

Value Transfer Analysis - Results

Using the list of land cover classes described above, the research team conducted queries of the best available economic valuation data to generate baseline ecosystem service values estimates for the entire study area in New Jersey.

The research team obtained data from a set of 94 viable Type A studies and 100 viable Type A-C studies; as some publications provided multiple values, we were able to obtain 163 and 210 individual ESV estimates respectively (see below Tables 8 and 9). All results were standardized to average 2004 U.S. dollar equivalents per acre/per year to provide a consistent basis for comparison below[9]. The aggregated baseline ESV results for all land cover types represented within the study area are presented below in Tables 4 and 5.

Each table presents standardized average ESV data for ecosystem services associated with each of the unique land cover types generated in this analysis. For purposes of clarity and following convention in the literature (e.g., Costanza et. al. 1997; Eade and Moran 1999; Wilson et. al. 2005) all results presented in this report represent the statistical mean for each land cover/ecosystem service pairing unless otherwise specified. Because each average value can be based on more than one estimate, the actual number of estimates used to derive each average ecosystem service value is reported separately in tables 7 and 8 and detailed information for the literature sources used to calculate estimates for each ecosystem service-land cover pair is provided in technical Appendix B.

Moreover, for purposes of transparency, in addition to presenting a single point estimate for each land cover/ecosystem service pair, the minimum, maximum and alternative median dollar values are published for further review in Appendix C. As these technical tables reveal, statistical means do tend to be more sensitive to upper bound and lower bound outliers in the literature, and therefore some differences do exist between the mean and median estimates. For example, the statistical mean for beach ESV is approximately forty two thousand dollars per acre per year, while the statistical median is thirty eight thousand for both Type A and Type A-C studies, a difference of approximately four thousand dollars per year. Given that a difference of approximately four thousand dollars represents the largest mean-median gap in our analysis, however, we are confident that the results reported here would not dramatically change if statistical means were replaced with statistical medians[10].

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[9] All economic valuation data in this report are have been standardized to represent total net present values, not discounted. This allows for the results to be incorporated into forward looking scenarios that might weight future costs and benefits differently when summing over time (Heal, 2004).

[10] While it may also be tempting to narrow statistical ranges by discarding high and low 'outliers' from the literature, the data used in this section of the report were all directly derived from empirical studies rather than theoretical models and there is no defensible reason for favoring one set of estimates over another. Data trimming therefore was not used.

Value Transfer Tables

The valuation results in Table 4 were generated from 94 unique Type A studies collected by the research team. As the summary column at the far right of the table shows, there is considerable variability in ecosystem service values delivered by different land cover types in New Jersey. As expected, the data in the table reveal that, there is a fairly robust spread of ESV's delivered by different land cover types, with each land cover representing a unique mix of services documented in the peer-reviewed literature. On a per acre basis, for example, beaches appear to provide the highest annual ESV flow values for the State of New Jersey ($42,147) with disturbance control ($27,276) and aesthetic/recreation values ($14,847) providing the largest individual values to that aggregated sum respectively[11]. Next, it appears that both freshwater wetlands ($8,695) and saltwater wetlands ($6,527) contribute significantly to the annual ESV flow throughout the State of New Jersey. On the lower end of the value spectrum, Cropland ($23) and grassland/rangeland ($12) provide the lowest annual ESV flow values on an annualized basis. While significantly different from the other land cover types, this finding is consistent with the focus of the current analysis on *non-market* values which by definition exclude provisioning services provided by agricultural landscapes (i.e., food and fodder).

The column totals at the bottom of Table 4 also reveal considerable variability between averages ESV's delivered by different ecosystem service *types* in New Jersey. Once each average ESV is multiplied by the area of land cover type that provides it and summed across possible combinations, both water regulation and aesthetic/recreational services clearly stand out as the largest ecosystem service contributors to New Jersey, cumulatively representing over 6 billion in annual value. At the other end of the spectrum, due to gaps in the peer-reviewed literature soil formation, biological control and nutrient cycling appear to contribute the least value to New Jersey.

[11] This finding is consistent with the Hedonic regression analysis presented in this report.

Value Transfer Tables

Table 4: Summary of average value of annual ecosystem services (Type A)

Ecosystem Services (2004 US$ $acre^{-1}$ yr^{-1})

Land Cover	Area (acres)	Gas/Climate Regulation	Disturbance Regulation	Water Regulation	Water Supply	Soil Formation	Nutrient Cycling	Waste Treatment	Pollination	Biological Control	Habitat/Refugia	Aesthetic & Recreation	Cultural & Spiritual	Totals
Coastal & Marine	**953,892**													
Coastal Shelf	299,835				620									$620
Beach	7,837		27,276									14,847	24	$42,147
Estuary	455,700				49						364	303		$715
Saltwater Wetland	190,520		1					6,090			230	26	180	$6,527
Terrestrial	**4,590,281**													
Forest	1,465,668	60			9				162		923	130		$1,283
Grass/Rangelands	583,009	5				6						1		$12
Cropland	90,455								8			15		$23
Freshwater Wetlands	814,479			5,957	1,161						5	1,571		$8,695
Open Fresh Water	86,232				409							356		$765
Riparian Buffer	15,146		88		1,921							1,370	4	$3,382
Urban Greenspace	169,550	336		6								2,131		$2,473
Urban or Barren	1,365,742													$0
Total	5,544,173	147,511,220	215,245,657	4,852,967,357	1,231,742,644	3,398,941	0	1,160,212,484	238,418,048	0	1,565,783,385	2,143,849,095	34,559,302	11,446,176,912

Notes:

1. Row and column totals are in acre$ yr^{-1} i.e. Column totals ($/yr) are the sum of the products of the per acre services in the table and the area of each land cover type, not the sum of the per acre services themselves.
2. Shaded cells indicate services that do not occur or are known to be negligible. Open cells indicate lack of available information.

Table 5: Summary of average value of annual ecosystem services (Type A-C)

Ecosystem Services (2004 US$ $acre^{-1}$ yr^{-1})

Land Cover	Area (acres)	Gas/Climate Regulation	Disturbance Regulation	Water Regulation	Water Supply	Soil Formation	Nutrient Cycling	Waste Treatment	Pollination	Biological Control	Habitat/Refugia	Aesthetic & Recreation	Cultural & Spiritual	Totals
Coastal & Marine	**953,892**													
Coastal Shelf	299,835				521		723			20			35	$1,299
Beach	7,837		27,276									14,847	*24*	$42,147
Estuary	455,700		286		49		10,658			39	314	292	15	$11,653
Saltwater Wetland	190,520		310					5,413			201	26	180	$6,131
Terrestrial	**4,590,281**													
Forest	1,465,668	54			163	5		44	162	2	923	122	1	$1,476
Grass/Rangelands	583,009	3		2		3		44	13	12		1		$77
Cropland	90,455								8	12	831	15		$866
Freshwater Wetlands	814,479	134	3,657	2,986	1,544			838			113	1,406	890	$11,568
Open Fresh Water	86,232				409							356		$765
Riparian Buffer	15,146		88		1,921							1,370	4	$3,382
Urban Greenspace	169,550	336		6								2,131		$2,473
Urban or Barren	1,365,742													$0
Total	5,544,173	247,419,233	3,383,364,105	2,434,015,054	1,738,649,004	9,249,760	5,073,680,354	1,803,819,315	245,781,449	34,692,849	1,701,061,233	1,993,241,115	777,821,072	19,442,794,544

Notes:

1. Row and column totals are in acre$ yr^{-1} i.e. Column totals ($/yr) are the sum of the products of the per acre services in the table and the area of each land cover type, not the sum of the per acre services themselves.
2. Shaded cells indicate services that do not occur or are known to be negligible. Open cells indicate lack of available information.

The results in Table 5 were generated from the 94 Type A studies in Table 4, augmented by 6 additional Type B and Type C synthesis studies documented in the technical appendices. Even with the addition of this ESV data, beaches continue to provide the highest annual value per year ($42,147) while grassland/rangeland ($77) provides the lowest annual value. However, some interesting differences in results between tables 5 and 6 can be identified. For example, here the land cover category estuaries ($11,653) moves forward in overall rank from the eighth most valuable land cover class to the second most valuable. This shift appears to be driven primarily by the nutrient regulation service ($10,658) documented by the Costanza et al. (1997) synthesis study in Appendix C. Similarly, while Freshwater Wetlands ($11,568) and Saltwater Wetlands ($6,131) retain their overall high ranking in terms of ESV delivery, the addition of the synthesis study results appear to increase the magnitude of their annual ESV's substantially.

The column totals at the bottom of Table 5 again reveal considerable variability between average ESV flows delivered by different ecosystem service *types* in New Jersey; but it is also clear that the addition of synthesis studies and non-peer reviewed analysis have filled in some of the gaps documented above in Table 4. Once each average ESV is multiplied by the area of land cover type that provides it and summed across possible combinations, it appears that both nutrient cycling and disturbance regulation services stand out as the largest ecosystem contributors to annual ESV's in New Jersey, cumulatively representing over 8 billion in annual value. As mentioned above, the largest shift appears to be driven by the nutrient regulation service documented by Costanza et. al. (1997). At the other end of the spectrum, pollination and cultural services appear to contribute the least value to New Jersey.

Spatially Explicit Value Transfer

Once specific land cover types were identified, ecosystem service flow values for land cover types in New Jersey were determined by multiplying areas of each cover type, in acres, by the estimated annualized dollar value *per acre* for that cover type. The economic values used to estimate the values associated with each ecosystem good or service were drawn from the value transfer exercise as described above.

The total ESV of a given land use/land cover type for a given unit of analysis (i.e., watershed) were thus be determined by adding up the individual, ecosystem service values associated with each land use/land cover type. The following formula is used:

$$V(ESV_i) = \sum_{k=1}^{n} A(LU_i) \times V(ES_{ki}) \quad (1)$$

Where:

$A(LU_i)$ = Area of Land cover (i)

$V(ESV_i)$ = Annual value of Ecosystem Services (k) for each Land Use (i).

Resulting values were estimated for each land cover type in New Jersey using the value transfer methods described above. Total ESV flow estimates for each land cover category were estimated by taking the product of total average per acre service value and the area of each land cover type in the state. These results are summarized below in Table 6. The estimates were then mapped by HUC 14 subwatersheds across the state of New Jersey. This was done by combining DEP's watershed management area layer with the modified LULC layer. The output of the operation included the area and the land cover type for each subwatershed. Maps were then created using graduated color classification to show both per acre and total ESV estimates for all New Jersey subwatersheds.

Table 6: Total Acreage and Mean Flow of Ecosystem Services in New Jersey

Name	Acreage	ESV Flows using A studies	ESV Flows using A-C studies
Coastal and Marine			
Coastal Shelf	299,835	$185,843,730	$389,455,682
Beach	7,837	$330,322,259	$330,322,259
Estuary and Tidal Bay	455,700	$325,989,335	$5,310,478,189
Saltwater Wetland	190,520	$1,243,545,862	$1,168,014,271
Terrestrial			
Forest	1,465,668	$1,880,935,494	$2,163,384,341
Pasture/grassland	583,009	$6,751,242	$44,623,493
Cropland	90,455	$2,103,089	$78,302,761
Freshwater Wetland	814,479	$7,081,746,098	$9,421,727,249
Open Fresh Water	86,232	$65,993,537	$65,993,537
Riparian Buffer	15,146	$51,230,004	$51,230,004
Urban Greenspace	169,550	$419,227,482	$419,227,482
Urban or Barren	1,365,742	$0	$0
TOTAL	5,544,173	**$11,593,688,132**	**$19,442,759,268**

Here, the data clearly show that substantial economic values are being delivered to New Jersey citizens every year by functioning ecological systems on the landscape. The estimated range is from a lower bound of approximately ***$11 billion per year*** to an upper bound of over ***$19 billion per year*** depending on the source literature used. Consistent with the value transfer data reported above in Table 4 and Table 5, it appears that ecosystem services associated with both freshwater and saltwater wetland types as well as forest and estuaries tend to provide the largest cumulative economic value.

As the following maps of New Jersey show (Figures 3-6), there is considerable heterogeneity in the actual delivery of ESV's across the New Jersey landscape with particularly notable differences between interior and coastal watersheds across the state. This general pattern of spatial heterogeneity holds true for both Type A value-transfer results and Type A-C value transfer results suggesting that underlying differences are due to underlying landscape patterns on the ground. For example, on close examination, as expected, it appears that watersheds associated with an abundance of freshwater wetlands consistently reveal the highest ESV flow values statewide. This pattern is true for both the Type A study maps and Type A-C study maps. Similarly, when watersheds with considerable estuarine and tidal features are considered, the difference between Type A and Type A-C study stands out in sharp contrast with such watersheds consistently ranking highest in value in Figure 5 and Figure 6.

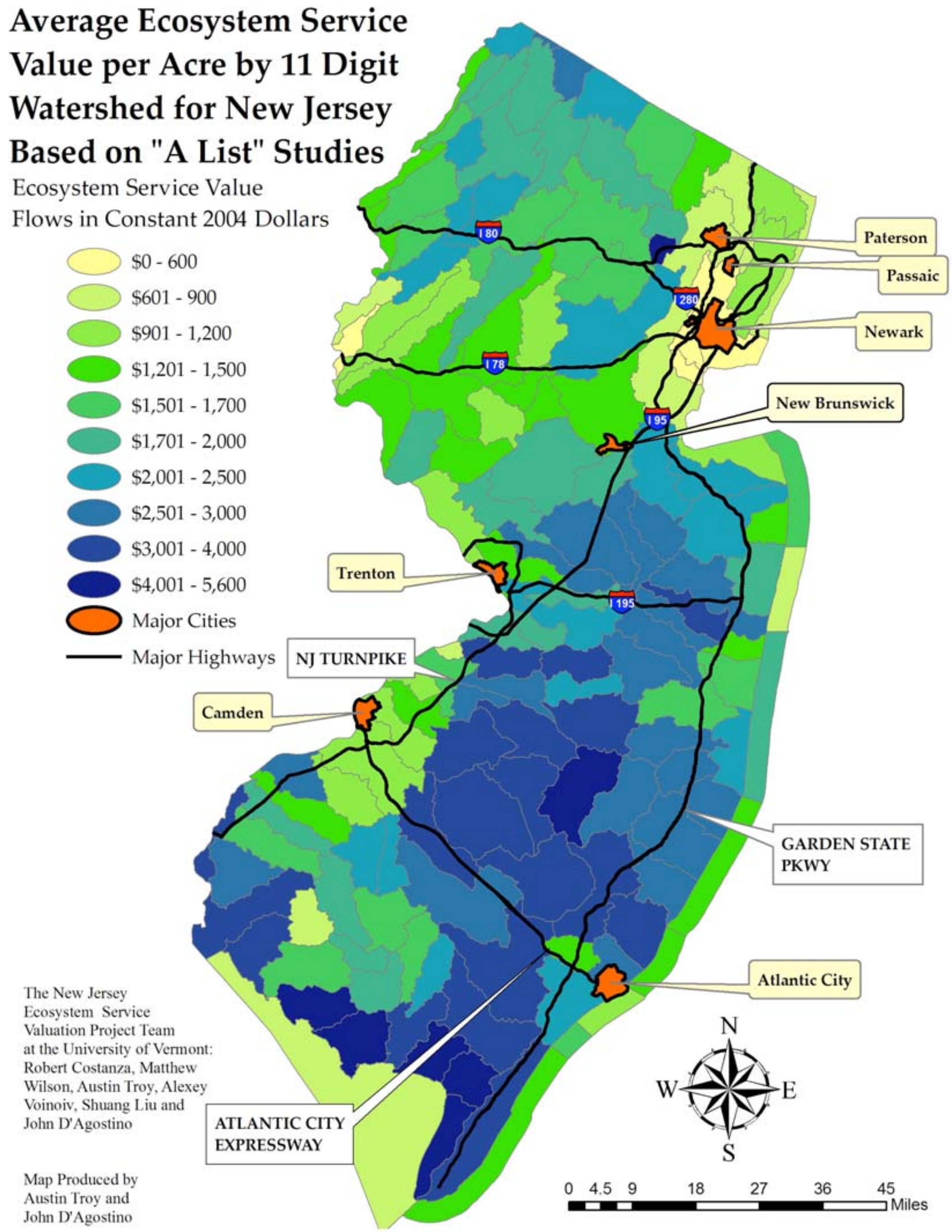


Figure 3: Average Ecosystem Service Value per acre by watershed for New Jersey based on Type A studies

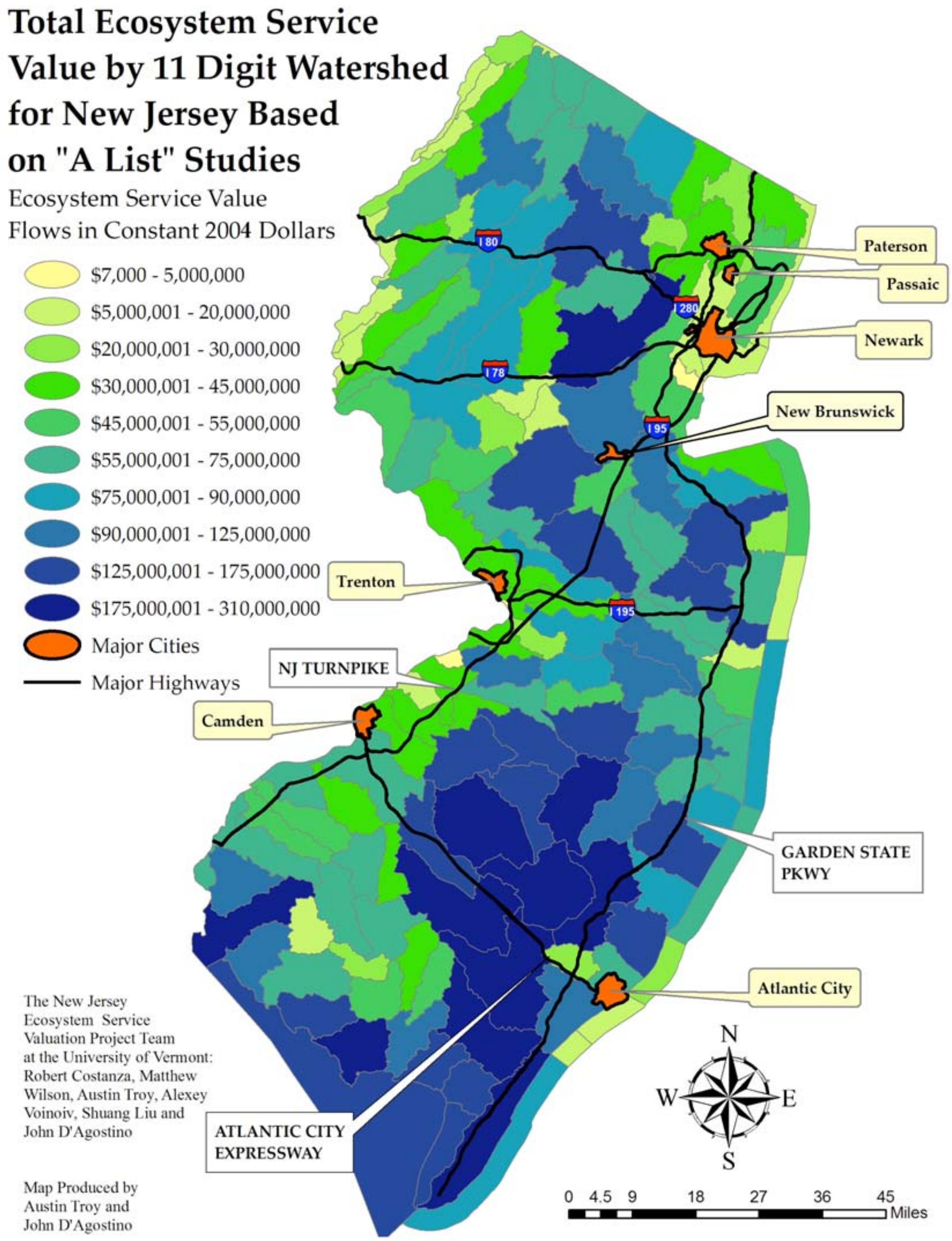


Figure 4: Total Ecosystem Service Value by watershed for New Jersey based on Type A studies

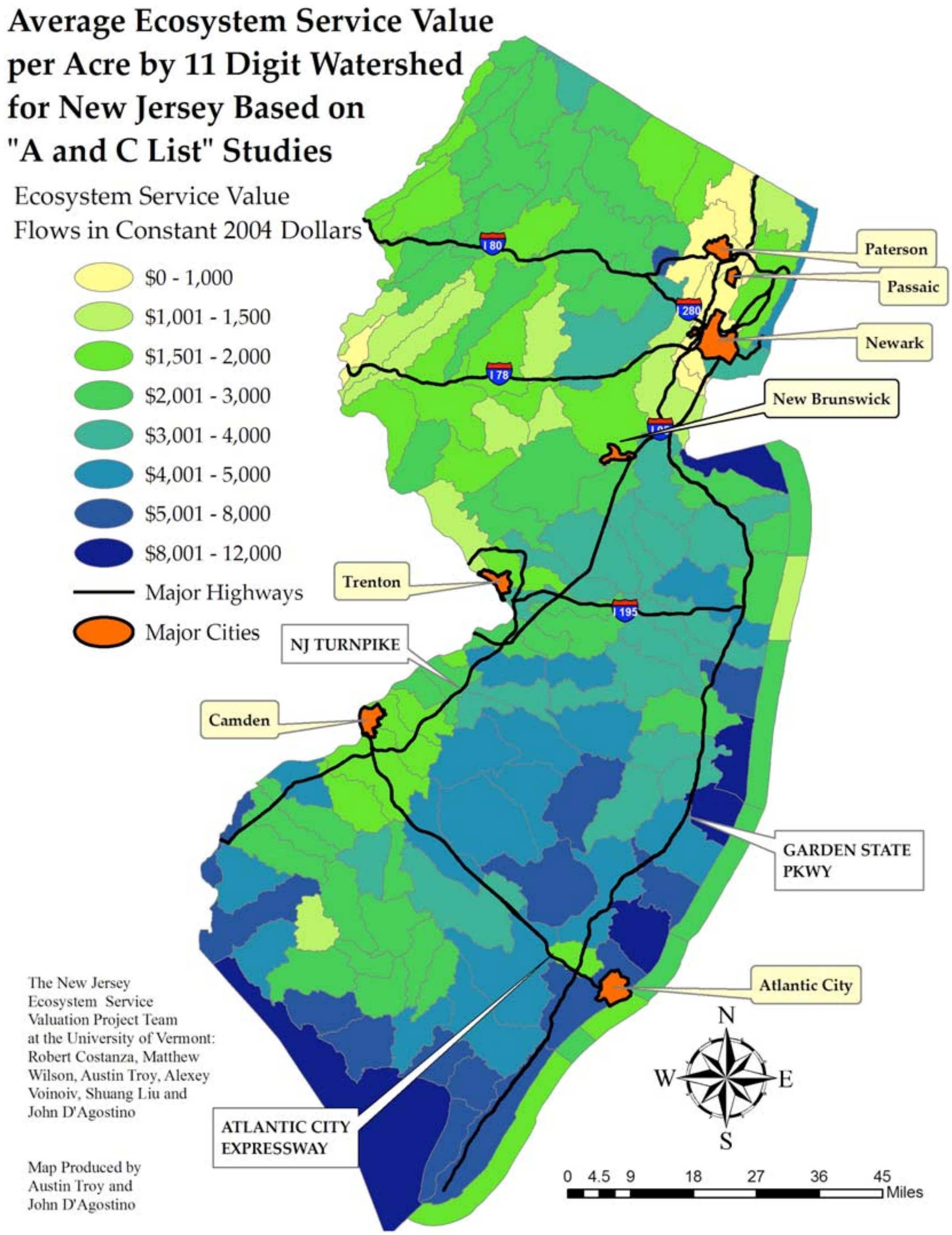


Figure 5: Average Ecosystem Service Value per acre by watershed for New Jersey based on Type A-C studies

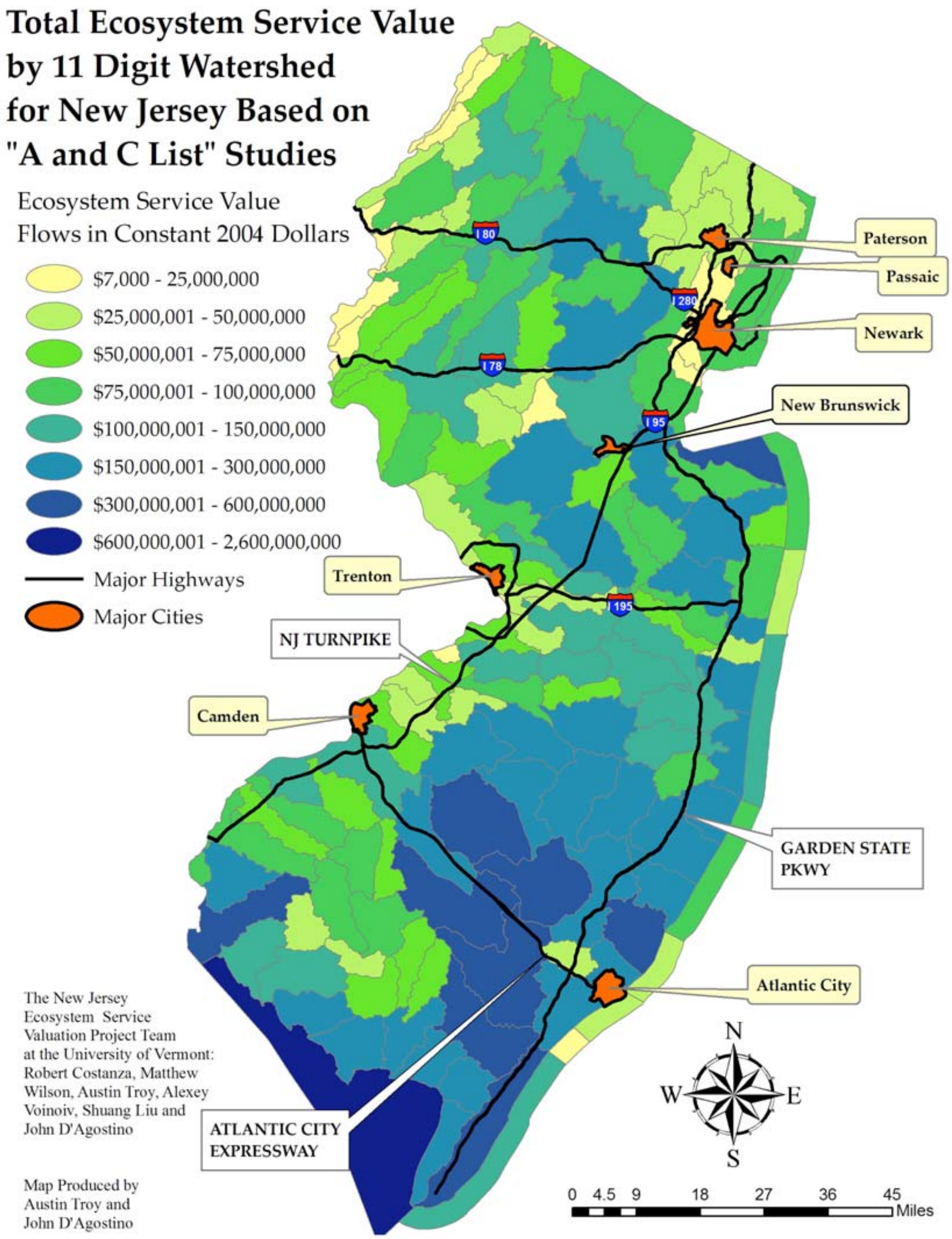


Figure 6: Total Ecosystem Service Value by watershed for New Jersey based on Type A-C studies

Limitations of the Value Transfer Approach

As the previous discussion suggests, not all land cover types generated for the study area could be effectively matched with all possible ecosystem services for each individual land cover type in the study area. This is because the research team's search criteria were focused primarily on Type A economic valuation results, and many landscapes that are of interest from an environmental management perspective simply have not yet been studied for their non-market ecosystem service values. This point is clarified in the following 'gap analysis' tables.

Table 7: Gap Analysis of Valuation Literature (Type A)

	Fresh Wetland	Salt Wetland	Estuary	Open Freshwater	Beac h	Riparian Buffer	Forest	Cropland	Urban Green	Pasture	Coastal Shelf
Gas & climate regulation							31		3	1	
Disturbance prevention		2			2	2					
Water regulation	1								1		
Water supply	6		3	5		9	1				2
Soil retention & formation										1	
Nutrient regulation											
Waste treatment		3									
Pollination							1	2			
Biological control											
Refugium function & wildlife conservation	1	4	5				8				
Aesthetic & Recreational	7	3	9	14	4	8	14	2	3	2	
Cultural & Spiritual		1			1	1					

Total $ Estimates: 163
Total Studies: 94

The data reported in light grey cells in Table 7 show, 163 individual ESV estimates were able to be obtained from 94 peer-reviewed empirical valuation literature for the land cover types included in this study. Areas shaded in white represent situations where we do not anticipate a particular ecosystem service to be provided by a particular land cover type (i.e., pollination by coastal shelf). Areas shaded in dark grey represent cells where we do anticipate a service to be provided by a land cover type, but for which there is currently no empirical research available that satisfies our search criteria.

Table 8: Gap Analysis of Valuation Literature (Type A-C)

	Fresh Wetland	Salt Wetland	Estuary	Open Freshwater	Beac h	Riparian Buffer	Forest	Cropland	Urban Green	Pasture	Coastal Shelf
Gas & climate regulation	1						39		3	3	
Disturbance prevention	1	3	1		2	2					
Water regulation	2								1	1	
Water supply	7		3	5		9	2				3
Soil retention & formation							1			2	
Nutrient regulation			1								1
Waste treatment	1	4					1			1	
Pollination							1	3		1	
Biological control			1				1	1		1	1
Refugium function & wildlife conservation	2	5	6				8	2			
Aesthetic & Recreational	8	3	10	14	4	8	15	2	3	3	
Cultural & Spiritual	1	1	1		1	1	1				1

Total $ Estimates: 210
Total Studies: 100

As the gap analysis for land cover types in Table 8 shows, 210 unique economic valuation data points were identified from 100 empirical sources for use across the cover types generated in this analysis. As the table reveals, by expanding our selection criteria to include synthesis studies (such as Costanza et al. 1997), we were able to fill in several gaps where we anticipated ecosystem services to be delivered by a particular land cover type.

Given the gaps in the available economic valuation data, the results presented in this report should be treated as *conservative estimates*. In other words, the ESV results presented here are likely to underestimate, not overestimate the actual ecosystem goods and services valued by society in the State of New Jersey. As discussed previously, due to limitations of the scope and budget associated with this project, the research team was not able to include technical reports and "grey" literature in this analysis. This data gap is not unique to the present analysis (EPA Science Advisory Board Environmental Economics Advisory Committee, 2004), and we anticipate that in the future, it will be possible to expand the analysis to include more information so that there will be fewer landscape features listed without a complete set of applicable ecosystem service value.

The valuation of ecosystem services is an evolving field of study and to date it has not generally been driven by ecological science or policy needs; instead it has been guided primarily by economic theory and methodological constraints. Therefore, we expect that as the field continues to mature, landscape features of interest from an ecological or land management perspective in New Jersey will increasingly be matched up to economic value estimates. As more primary empirical research is gathered, we anticipate that higher, not lower, aggregate values will be forthcoming for many of the land cover types represented in this study. This is because, as discussed above, several ecosystem services that we might reasonably expect to be delivered by healthy, functioning forests, wetlands and riparian buffers simply remain unaccounted for in the present analysis. As more of these services are better accounted for, the *total* estimated value associated with each land cover type will likewise increase.

Value Transfer Conclusions

The results discussed in this section confirm that a substantial and broad range of ESVs ($11 billion to $19 billion) is being delivered annually to New Jersey citizens from a diverse array of land cover types. This variability is consistent with previous findings in the empirical ecosystem services literature (National Research Council 2004). Moreover, each pairing of a land cover type with an ecosystem service presented in Table 4 and Table 5 provides a unique opportunity to "observe" how the "same" service (e.g., disturbance prevention)—when provided by different land cover types (e.g., beach, freshwater wetland, saltwater wetland, estuary)—can vary substantially in its economic value. As the results clearly show, this variability emerges from the valuation literature itself and is not an artefact of any particular study; people appear to value ecosystem services quite differently in different biophysical contexts, and the ESV estimates presented in this report reflect that inherent variability.

In summary, diversity and variability rather than homogeneity and consistency appear to be the best terms for describing the economic values delivered by New Jersey's ecosystems.

Hedonic Approach

In hedonic analysis, the observed sales price of a residential property is statistically disaggregated into a schedule of implicit marginal prices (Griliches, 1971; Quigley, 1970; Rosen, 1974). These unobserved "implicit prices" represent homebuyers' marginal (i.e., incremental) willingness to pay for a property's structural (e.g. lot size, house characteristics), neighborhood (e.g. tax rate, school quality, city service quality) and locational (e.g. proximity to employment, natural amenities and nuisances) characteristics of the property. Sale prices are a better indicator of a property's "true" market value than assessments or appraisals.

Because the attributes are not traded directly in the market and the implicit prices associated with them are not directly observable, they must be statistically derived. A schedule of implicit prices is derived by regressing observed sales price against this set of predictor variables. The resulting coefficients can be interpreted differently depending on the functional form of the model. In the case of a linear model, the coefficients can then be thought of as a marginal change in price due to a one-unit change in that predictor variable, holding all else constant. For the commonly used semi-log model (where price only is log-transformed), coefficients can be interpreted as percentage changes in the response due to a unit change in the predictor. In a trans-log model, that is when both response and predictor are logged, the coefficient on the logged predictor can be interpreted as an elasticity; that is, a percentage change in the response variable due to a percentage change in the predictor. Another way of thinking of this is that in a semilog model, the effect of a marginal change of an attribute on price depends on the price level at which the change is evaluated. In a trans-log model, the effect of a marginal change of an attribute on price depends on both the price level and the attribute level. The interpretation of functional forms is further elaborated upon in Appendix D.

Aggregate welfare benefits associated with a resource which delivers ecosystem services can then be estimated through second stage hedonic regression. This stage is performed far less frequently than the first stage described above due to its technical complexity, myriad assumptions, and data limitations. Second stage analysis quantifies welfare changes resulting from eliminating or creating a resource in question. In the case of this study, we are interested in resources (e.g. forests, wetlands, beaches, etc.) that already exist. So, to value them we must look at how aggregate welfare would change if these resources were eliminated. The value of the forgone benefits is known as opportunity cost. The economics and econometrics behind this stage are highly technical and are described in Appendix D.

A large number of studies have generated valuation estimates for environmental and recreational amenities using hedonic analysis. This includes valuations of open space (Acharya and Bennett, 2001; Irwin, 2002; Riddel, 2001; Riddel, 2002; Smith et. al., 2002), forests (Englin and Mendelsohn, 1991; Garrod and Willis, 1992; Lee, 1997), wetlands (Earnhart, 2001; Mahan et. al., 2000), and water features and associated water quality (Boyle and Kiel, 2001; Carson and Martin, 1990; Gibbs et. al., 2002; Hurley et. al., 1999; Leggett and Bockstael, 2000; Loomis and Feldman, 2003; Steinnes, 1992). Various studies have also used hedonics to study how environmental liabilities are capitalized into housing values as well, such as transmission lines (Harrison, 2002), nuclear power plants (Folland and Hough, 2000), natural hazard zones (Troy and Romm, 2004), heavily polluting manufacturing plants (Anstine, 2003), hazardous waste sites (Michaels and Smith, 1990; Deaton, 2002), nuclear fuel storage sites (Clark and Allison, 1999) and landfills (Hite et. al., 2001).

Market Segmentation

One of the assumptions of the hedonic model is that the results of a model are valid only for a given housing market. That is, the relationship between price and attributes is assumed constant only within a given market segment. For instance, a third bedroom may be worth $800 in suburban Tulsa and $20,000 in suburban Boston, *ceteris paribus* (i.e. adjusting for distance to downtown, school quality, etc). This limits the reliability of hedonic price estimates for value transfer analysis because one housing market may, for instance, value tree canopy cover completely differently from another. However, if it were possible to easily identify and segment housing markets using a standard typology, one could attempt to transfer value estimates from a study site to a policy site located in a similar type of housing market. Unfortunately, studies and methodologies on geographic housing market segmentation are relatively few (Gaubert et. al., 1996; Goodman and Thibodeau, 1998; Goodman and Thibodeau, 2003; Palm, 1978). Therefore, most studies rely on a combination of census data and anecdotal information from people familiar with the housing market to geographically segment markets. In the case of New Jersey, we took such a hybrid approach.

For this project, we purchased data on a sample of 30,000 real estate transactions in central New Jersey for the years 2001 to 2004. This large sample was needed because of the large number of variables being controlled for in hedonic analysis. The more variables there are, there more observations are needed to obtain variation in all of those variables so that the effect of each can be statistically analyzed, independent of the others. The entire state was not analyzed because it would have been cost prohibitive to obtain valid results at that level. Our central New Jersey study area was segmented into seven distinct submarkets: New Brunswick, Princeton, Freehold, Tom's River, Tom's River Fringe, and Barrier Islands Towns (Figure 7). This was done by selecting for the largest urban cores in the study area, resulting in the first five on that list. Surrounding municipal boundaries were then assigned to each one of those five urban cores. Because this resulted in an extremely disproportionate share of the property transactions falling within one market, Tom's River, that market was further segmented into three sub-markets: Tom's River, Tom's River Fringe and Barrier Island Towns.

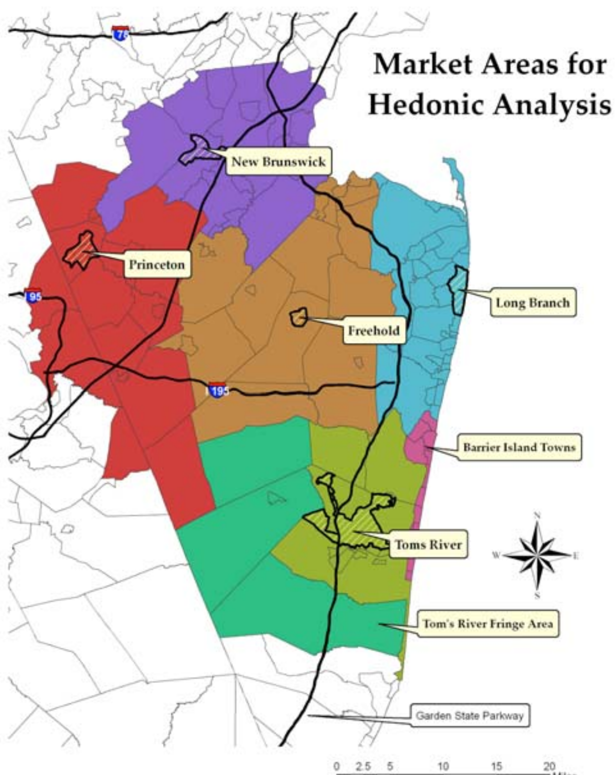


Figure 7: The central New Jersey study area was broken down into seven market areas for hedonic analysis

To ensure that these market areas were generally representative of New Jersey as a whole, comparisons were made based on acreage and percentage of each land cover type, median household income, percent African-American population, percent unemployment, percent with bachelor's degrees, and percent with high school diplomas. Due to time limitations, additional variables were not analyzed. Due to data availability differences, the comparisons were broken somewhat differently for different variables. For land cover, the market area as a whole was compared to New Jersey as a whole. For unemployment, and the two education metrics, values are given for the market area, for New Jersey, and then broken down by each of the four counties included in the market area. For percent African-American and median household income, for which data were more easily available, values are given for the market area, for New Jersey, and then broken down separately by each of the seven sub-markets from the study. Results are given in the three tables below (Tables 9-11).

Table 9: Land Cover Comparison between all of New Jersey and hedonic market area

	New Jersey area	Market area	New Jersey %	Market %
Coastal and Marine				
Coastal Shelf	299,835	-	5	-
Beach	7,837	3,293	0	0
Estuary	455,700	147,228	8	13
Saltwater wetland	190,520	10,392	3	1
Terrestrial				
Forest	1,465,668	222,317	26	20
Pasture/grassland	583,009	87,322	11	8
Cropland	90,455	13,460	2	1
Freshwater wetland	814,479	179,817	15	16
Open freshwater	86,232	11,364	2	1
Riparian buffer	15,146	4,518	0	0
Urban greenspace	169,550	30,023	3	3
Urban or Barren	1,365,742	417,072	25	37
Total	5,544,173	1,126,806	100	100

Table 10: Comparison of education and employment variables between New Jersey and market area with breakdowns by market area county

	% HS diploma	% Bachelor's degree	% Unemployed
Market area	85.1	29.0	4.6
New Jersey	82.1	29.8	4.8
Mercer	81.8	34.0	4.2
Middlesex	84.4	33.0	4.5
Monmouth	87.9	34.6	4.4
Ocean	83.0	19.5	4.9

Table 11: Comparison of income and race variables between New Jersey and market area with breakdowns by seven submarket segments

	Median household income ($)	% African-American
New Jersey	55,146	13.6
Market	60,404	4.9
Princeton	83,364	5.9
New Brunswick	64,111	10.2
Freehold	74,598	4.3
Long Branch	65,269	10.3
Toms River	53,792	2.4
Toms River fringe	54,178	1.6
South Coast	59,071	0.4

The above comparisons document that the market areas selected for analysis are broadly comparable to the rest of the state though there is a small difference (~8%) in the average income between the study area and the state as a whole, and a much more considerable difference in the percentage of African-Americans between the two. Given the large variance in median income both within the state as a whole and within the study area, the relatively small difference in average median incomes should have little effect in biasing results. The race variable, although displaying a greater mean difference is still not a great concern given that within the study area there are two market segments, Long Branch and New Brunswick, near the state average. Given that, in the design phase of the hedonic study, the primary objective to sample contiguous areas with a considerable presence and diversity of natural amenities and landscapes, and that the study design did not attempt to achieve representation of the state relative to income and race, these relatively small differences are to be expected. While it may be difficult to generalize these results to certain areas of the state, such as those with low incomes, high minority levels, or low levels of natural amenities, results can still be generalized to a considerable portion of the state.

Hedonic Methods

In a hedonic analysis, the observed dependent variable is statistically disaggregated into implicit marginal prices for each explanatory attribute. For the New Jersey case study, this was done by regressing property sales price against a set of independent variables describing the lot, neighborhood, socio-economic characteristics, location and environmental amenities. So defined, the hedonic pricing equation is expressed:

$$Ln(P_{it}) = \iota_0 + \iota_1 L_i + \iota_2 N_i + \iota_3 S_i + \iota_4 T_i + \iota_5 E_i + \iota_{it} \qquad (2)$$

Where: P_{it} = Sales price of house *i* at the time of transaction *t*

ι_0 = intercept (note: this term has little significance to the results)

$\iota_{1\ldots n}$ = vectors of regression coefficients

L_i = vector of lot/structural characteristics of house *i*

N_i = vector of neighborhood characteristics of house *i*

S_i = vector of socio-economic characteristics of house *i*

T_i = dummy variable indicating the year in which house *i* was transacted

E_i = vector of environmental characteristics of house *i*

ι_ι = regression error term

As expected, the component variables of each vector differed by submarket because of differing relationships between price and attributes by market. A list of all variable names with descriptions is given in Table 12 below. The specific variables used in each model can be seen by examining the model results in Appendix E Tables 1-7.

Table 12: Variable Names and Descriptions

Variable Name	Description
SalePrce	Residential Property Transaction Price ($)
Lot variables	
Liv.Area	Living Area (sq. feet)
PropTax	Assessed Property Taxes ($/year of transaction)
Imp.Val	Structural Improvement Value of the Property ($)

LotAcres	Property Area (acres)
two.story	Dummy Variable for Two-Story Homes (1/0)
al.siding	Dummy Variable for Homes with Aluminum Siding (1/0)
NEW	Dummy Variable for Home Construction within years 1994-2004 (1/0)
OLD	Dummy Variable for Home Construction > 75 Years Ago (1/0)
House.age	Continuous Variable for Year of Home Construction
Neighborhood (ft.)	
D2AIRPRT	Distance to Nearest Airport
D2URBAN	Distance to Nearest NJDEP-designated Urban Area
D2RETAIL	Distance to Nearest Major Retail Center
D2CLUB	Distance to Nearest Country Club/Golf Course
D2TERMNL	Distance to Nearest Transportation Terminal (Bus Depot, Train Station, etc.)
D2CONTAM	Distance to Nearest Contaminated Site
D2HIX	Distance to Nearest Highway Exit
Socio-economic	
P.VAC	Percentage of Vacant Homes
MED.HH.INC	Median Household Income ($)
P.OWN.OCC	Percentage of Owner Occupied Homes
P.BLK	Percentage of Population of African-American Ethnicity
P.HISP	Percentage of Population of Hispanic Ethnicity
Transaction Date	
X2002	Transaction Occurred in 2002
X2003	" " " 2003
X2004	" " " 2004
Environmental Amenities	
ENV.SENS	Dummy Variable for Property Location within Environmentally Sensitive Region (1/0)
D2UN.WET	Distance to Nearest Unprotected Wetland Area (ft.)
D2UN.FOR	Distance to Nearest Unprotected Forest Area (ft.)
D2WATER	Distance to Nearest Significant Body of Water (ft.)
WATER100	Dummy Variable for Property Location within 100 ft. of Significant Water Body (1/0)
D2SPARK	Distance to Nearest Small Park (< 50 acres)
D2MPARK	Distance to Nearest Medium Park (50 - 2000 acres)
D2LPARK	Distance to Nearest Large Park (> 2000 acres)
D2BEACH	Distance to Nearest Beach (feet)
BEACH1	Dummy Variable for Property Location within 300 ft. of Nearest Beach (1/0)
BEACH2	Dummy Variable for Property Location between 300 and 2000 ft. of Nearest Beach (1/0)
FLOOD.SFHA	Dummy Variable for Property Location within FEMA Special Flood Hazard Area (1/0)

One of the notable variables not included in any of the regressions was school quality. Inclusion of this factor was attempted for five of the seven markets by obtaining elementary school district proficiency averages (percent partially proficient, percent proficient, percent advanced proficient) from the New Jersey Department of Education, assigning them to municipal elementary school districts (roughly the size of individual municipalities), and including them as independent variables. While these variables were significant in most cases, they had only a minute effect on overall model fit (R-squared ~.002) and appeared to make some of the main effects results unstable; they caused some of the coefficients on environmental amenities to lose their significance. Hence, these variables were dropped. It is recommended that any future attempt to model housing markets in the state break down school quality by boundaries for individual elementary schools, rather than elementary school districts, because of the extreme variation that is generally found within a district. Unfortunately, such data was not digitally available for the study area at the time of this study. It should also be taken into account that at the coarse level of entire school districts, school quality was largely being proxied by control variables such as median household income, or percent home ownership. For that reason, adding school quality as an additional independent variable would, as noted above, have little impact on the overall explanatory power of the regression equations.

The details of the regression analysis are very complex and are described further in Appendix E. The main environmental variables found to affect housing prices included distance to small (<50 acres), medium (50-2000 acres), and large parks (2000+ acres), location adjacent to (0-300 feet) or near (300-2000 feet) the beach, distance to the nearest beach, distance to water bodies, adjacency to water bodies (<100 feet), and location within "environmentally sensitive zones" as designated by the New Jersey Office of Smart Growth. This includes large contiguous areas of ecological significance, including critical water supply sources, habitat areas, trout streams, scenic greenbelts, wetlands, etc. An additional variable for distance to unprotected forestland was also included, but because it was either insignificant or had the opposite sign of expected (i.e. forest proximity decreases home value) for different markets, it was excluded. Another main effects variable that was attempted and dropped was distance to nearest wetland. As described in the Appendix, the regression analysis yields a set of statistical coefficients, quantifying the relationship between price and each attribute. It should be kept in mind that because these models used a semi-log functional form (where price is log transformed), that means that each coefficient (given in Appendix E) describes a percentage in price due to a change in the attribute level. This is because in the semi-log specification, the effect of an attribute change on price depends on the price at which it is being evaluated. In most models, some predictors are also log transformed. Where this is the case, the coefficient can be interpreted as elasticity, meaning that the increase in price due to an increase in an attribute depends on both the price and attribute level at which it is evaluated.

Data

A data set covering more than 30,000 residential property transactions from Mercer, Middlesex, Monmouth, and Ocean counties between January 2001 and August 2004 was obtained from First American Real Estate Solutions' RealQuest database. Attributes included sale value ($), calculated property tax ($), total living space area (sq. feet), property improvement value ($), lot acreage, transaction date, property street name, town and zip code, etc. Properties for which necessary lot attributes were absent were excluded. The real estate set was then address geocoded in ArcMap, using a detailed streets layer containing address range information from Geographic Data Technology (GDT) Inc. This yielded a GIS layer showing a point for the location of each transaction. The geocoded transactions were then examined for missing or flawed attribution; systematically flawed attributes were corrected when possible while properties for which sale value, transaction date, or similarly necessary analysis characteristics was not provided were exempted from the final transaction set, yielding a final set of 27,733 central New Jersey transactions for the January 2001 – August 2004 period.

Spatial data was obtained from the New Jersey Department of Environmental Protection's Bureau, including land cover by watershed, shore type, state water bodies and wetlands, census block groups, contaminated sites, state and local parks. Other data layers were obtained from the New Jersey Office of Smart Growth, including urban core boundaries, sewer service area boundaries, and environmentally sensitive areas, and from GDT, including transportation terminals, major retail centers, country clubs, and airports.

A number of locational variables were attributed to each transaction point using the "spatial join" function in ArcGIS (ESRI, Inc.). This was done to calculate distances to both amenities and disamenities, including nearest small, medium, and large protected areas (e.g., parks, conserved lands); unprotected wetlands and forests; water bodies; environmentally sensitive areas; contaminated areas; country clubs; airports; transportation terminals; major retail centers; defined urban areas; major highways, and numerous others. Overlay analysis was used to determine whether each house was located within a number of environmentally-relevant zones, including high-risk FEMA-delineated flood zone, the Coastal Areas Facility Review Act (CAFRA) zone, the two beach proximity zones, and the water proximity zone. Based on work by Troy & Romm (2004), the beach variable was defined in two ways: for each property, the distance to the nearest beach was calculated in addition to two dummy variables designating property locations within 300 feet and between 300 and 2000 feet from the beach ecosystem. This accounts for both an adjacency effect as well as a distance to access effect. All continuous distance variables were measured in feet and variables indicating property location within a zone were given as a binary variable (i.e., a variable which can only take on the values zero or one).

Hedonic Analysis - Results

Overall, our hedonic models had strong R-squared values ranging between 0.70 and 0.87. An R-squared value of 1.0 would mean that the regression equation was able to account for 100% of the variation in the dependent variable, e.g. housing price. The models were constructed such that almost all included control variables were significant and of the expected algebraic sign (positive or negative). Complete results with all coefficients and test statistics for each market are given in Appendix E.

Not all environmental amenity variables were significant or of the expected sign. Table 13 below, which shows all main effects variables for all markets, highlights in grey all variables that have the opposite of expected sign. It also shows with NA all those variables which were not significant or not applicable. The following are major results:

The variable for distance to large parks has the correct sign and significance for three markets. For another three, large parks are valued negatively and for one they are not statistically significant. Small parks are statistically significant with the correct sign in five markets. Medium parks have the correct sign and are statistically significant for one market only. In the pooled model, where all markets are regressed simultaneously, only small parks have the correct sign and are statistically significant. Moreover, both the variable on distance to small parks and acreage of nearest small park have the correct sign.

The Beach 1 zone is significant and of expected sign for each market where there is a beach, while the Beach 2 zone has the correct sign and is significant for two of the three markets where it is applicable.

The variable for proximity to water bodies is significant and of the correct sign for two markets, and not significant in the others. The dummy variable for water proximity zones is significant in only one market, where it has the correct sign.

Environmentally sensitive zone. The environmentally sensitive zone dummy variable is significant for two markets, for which it has the correct sign for both.

Distance to Beach. Finally, the distance to beach variable, which was only significant in two markets (because the zonal dummy variable tended to be a better predictor), was of expected sign in both.

Table 13 also gives price differentials for environmental amenities showing how average price, holding all else constant, increases or decreases with proximity or adjacency to an environmental amenity. This was completed by solving the hedonic equation for each market, holding all control variables at their mean values, while varying the distance to an amenity, and then comparing the change in price due to that location shift. For zonal dummy variables (1/0), comparisons were given by solving the equation for a property both in and out of the zone and comparing the results.

Table 13: Main Effects Variable Differentials by Market

Continuous Variables			Market and Price Effect in 2004 USD						
Resource	Moving From:	Moving To:	Princeton	New Brunswick	Freehold	Long Branch	Tom's River	Tom's River Fringe	South Coast
Beach	1000 ft	100 ft	743	458	NA	NA	NA	NA	NA
Beach	1 mile	100 ft	4,260	2,623	NA	NA	NA	NA	NA
Beach	5 mile	100 ft	21,249	13,068	NA	NA	NA	NA	NA
Water	1000 ft	100 ft	(24,991)	NA	NA	NA	13,952	NA	40,847
Water	1 mile	100 ft	(44,121)	NA	NA	NA	23,556	NA	67,843
Water	5 mile	100 ft	(63,527)	NA	NA	NA	32,483	NA	92,104
Small Park	1000 ft	100 ft	NA	21,,006	617	2,216	NA	(2,391)	7,489
Small Park	1 mile	100 ft	NA	35,240	3,533	12,562	NA	(14,251)	32,861
Small Park	5 mile	100 ft	NA	48,297	17,539	59,291	NA	(86,417)	178,541
Medium Park	1000 ft	100 ft	2,450	(738)	(929)	NA	309	(7,643)	(6,491)
Medium Park	1 mile	100 ft	13, 905	(4,278)	(5,386)	NA	1,775	(13,381)	(39,603)
Medium Park	5 mile	100 ft	66,001	(22,492)	(28,339)	NA	8,875	(19,110)	(272,485)
Large Park	1000 ft	100 ft	1,437	(10,132)	(1,318)	1,486	NA	14,922	(4,458)
Large Park	1 mile	100 ft	8,202	(17,728)	(7,672)	8,478	NA	25,054	(26,935)
Large Park	5 mile	100 ft	40,023	(25,300)	(41,163)	32,804	NA	34,363	(175,763)
Dummy variables	**Zone size**								
Environmentally sensitive zone	Defined by map		NA	NA	NA	34,525	8,562	NA	NA
Beach 1 zone	0-300 ft from beach		NA	NA	81,202	99,574	194,066	NA	100,169
Beach 2 zone	300-2000 ft from beach		NA	NA	(28,397)	15,900	NA	NA	44,107
Water zone	100 ft from water		NA	NA	NA	32,912	NA	NA	

NA= not applicable or not significant
Expected sign
Opposite of Expected Sign

Unsurprisingly, the results indicate that beaches are very highly valued by the property market. In the case of Tom's River, being adjacent to a beach increases property value by almost $200,000. Being within 2000 feet of a beach can also increase property value by over $40,000, holding all else constant. Water body proximity seems to be positively valued. Where significant, environmentally sensitive zones appear to be positively valued, although it is hard to interpret what that means, since this zone includes so many diverse landscape types. Nevertheless, that result indicates that areas of ecological significance are, in general valued positively. It may also indicate that people value the fact that the environmental sensitive zone designation limits future development opportunities in the area and gives some assurances of continued future integrity. As mentioned in the methods section above, otherwise unprotected natural lands, including forests and wetlands, receive no positive valuation at all, indicating that *natural landscapes are not highly valued if they are subject to potential future development*.

Finally, perhaps the most equivocal results relate to protected parks and open space. While we expected to find a positive valuation for all open space in all markets, the actual results were extremely variable. Overall, small parks tend to be the most highly valued, perhaps because they are seen by homebuyers as representing a compromise between urban access and rural or suburban amenities. Medium and large parks can be either positively or negatively valued, depending on the market. The differences may depend on a number of factors. First, large and medium park proximity may be proxying something else, since it is unlikely that residents would negatively value parks in and of themselves. We tried to control for distance to urban areas, highways, and urban amenities. But these efforts are still not sufficient to adequately control for all the locational factors that draw people towards cities. Most notably, we did not have the time or resources to develop a robust indicator of access to employment opportunities, and the quality of those opportunities which is one of the most important determinants of housing price. Hence, where large and medium parks are valued negatively, this may be because those variables are proxying "ruralness" or low levels of economic development, even despite the use of similar control variables. In cases where those variables are the correct sign, it is probably because the control variables are more adequate for those markets.

Another difference may be due to differences in the preferences of homeowners within a given market. For instance, the Princeton market, which has the highest income of any of the markets, also is the only market that positively values both large and medium parks. Hence, the degree or sign of valuation may relate to socio-economic differences that inform preferences. Next, it may relate to the abundance of open space. In areas where open space is already abundant, proximity to protected open space has relatively little value, since almost any house in the area will have functionally similar open space access. Finally, the difference might be due to differences in the characteristics of the parks themselves. Some parks may be well kept and others not. Some parks may be dominated more by impervious surface and non-natural features and other not. Some parks may have high crime or be associated with other problems. In small parks, these differences are more likely to average out because of the large number of them.

Second Stage: Hedonic per Acre Value Estimates

In theory, the first stage hedonic results can be used to derive per acre aesthetic amenity and recreational ecosystem service values. Due to the time consuming nature of this undertaking, we conducted a preliminary second stage analysis for some of the relevant land covers.

A number of serious technical challenges have confronted us in attempting this stage. For instance, we found that households valued proximity to protected areas—not just natural cover types. Unfortunately, "protected areas" is not an ecological category that occurs in our ecosystem service valuation typology. An analysis of land cover in protected areas finds that the cover types in our study area tend to be quite diverse within the park boundaries, including forests, urban green space, open water, riparian zones, and considerable areas of wetlands. Hence, when looking at how a set of households value a given park, we are really looking at a composite of cover types, which makes it difficult to value any one park in a definitive fashion. This is complicated by the fact that valuation estimates vary by real estate market, many markets appear not to value them, or value them negatively, probably due to co-linearity in the models, and many big parks are on the boundaries between two or more markets, so that valuing such parks becomes almost analytically intractable. This would not have been the case had we found positive values for generic unprotected forests or wetlands, since these types are common throughout the state and do not have to be part of a larger object (e.g. park) to be considered.

While we could not estimate per acre values for all cover types in this study, we were able to derive them for the urban green space and beach types using second stage methods. Because the beach coefficients that were analyzed for the second stage were binary or "dummy" variables, the methodology was far simpler and only required adding up price differentials. However, the green space analysis, based on first stage analysis of small parks, involved continuous variables and was far more involved. The former is described first.

Using coefficients for the two beach zone dummy variables from the South Coast market and the Long Beach market we estimated the amount that each house in the data set increased in value due to proximity to the beach. To account for the fact that there are many more houses than appear in the data sample, we used census block group data to determine the ratio of the count of actual household units to sample households in each block group. This number was then multiplied by the occupancy rate for each block group to eliminate buildings that are either permanently vacant or that are vacant for much of the year. The resulting multipliers were then assigned back to sample houses. The total value of the beach in this market was then estimated by multiplying the value increase per sample house due to beach proximity by the household ratio multiplier, which varied by block group. These were then summed and divided by the acreage of beach in each market to obtain a stock value. Yearly flows were obtained by multiplying the resulting number by a 3% discount rate. The results indicated a yearly amenity value flow of $43,718/acre in the Long Branch market and $31,540/acre in South Coast market, both of which are relatively close to the transferred value used in this study of $42,147. At a 5% discount rate, these numbers go up to $72,864/ acre and $52,567/acre respectively, which are higher than the transferred value. Results are described in Table 14.

Table 14: Estimated per acre stocks and flows of urban greenspace and beaches based on first and second stage hedonic methodology

	Urban Greenspace-acreage method	Urban Greenspace-distance method	Beach Long Branch	Beach-South Coast
Stock	$914,000,000	$1,010,000,000	$910,797,000	$440,512,813
Acres	2,738	2,738	625	419
Per acre stock value	$333,820	$368,882	$1,457,275	$1,051,343
Per acre flow (3%)	$10,015	$11,066	$43,718	$31,540
Per acre flow (5%)	$16,691	$18,444	$72,864	$52,567

Urban green space values were determined by looking at small parks (less than 50 acres) within the hedonic study area. While not all of them fell within designated "urban cores," by overlaying sample parks on aerial photos within GIS software, it could be seen that almost all are in fairly urban or heavily suburbanized settings, making it reasonable assume that these small parks are functionally representative of an "urban greenspace" category as used in ecological economics valuation literature. Two different approaches were tried. In the first, the second stage hedonic methods described in the Methods section were applied to the distance to nearest small park variable. For the five markets where small park distance had the expected sign and was significant (Princeton, Freehold, Long Branch, New Brunswick and South Coast), the partial derivative of price with respect to small park distance was taken for each model (including, trans-log, semi-log and quadratic models). The resulting equation was then solved for every observation to give the shadow price. Observations from all five markets were combined in a spreadsheet and shadow price was regressed against the distance to nearest small park variable and median household income (as a demand shifter) for the pooled data. The pooling of all data served the purposes of avoiding the identification problem described in the Methods. The functional form used for this regression was semi-log. The coefficients of this equation were then used to derive the inverse demand curve, which was integrated at the mean distance value, aggregated by households, and divided by park acreage.

The second method attempted to look at the park size attribute to estimate welfare measures, rather than the distance attribute, in order to triangulate results from the latter. In many of the market-specific hedonic models, the park size variable was not significant. However, when data from all markets were pooled and regressed together for first stage hedonic analysis, this yielded a significant coefficient with the correct sign on the park size variable. Because of the identification problem that would have resulted in doing a second stage regression with pooled data, in this case we instead solved each observation for the contribution of park acreage to its price and then aggregated using the multipliers described above, again dividing by total small park area.

As we had hoped, the numbers were extremely similar for the two methods, and were considerably higher than the transferred values of $2,473 per acre for urban greenspace. Using a 3% discount rate the park distance method yielded a yearly flow of $11,066 per acre and the park area method yielded a yearly flow of $10,014 per acre. At 5%, these become $18,444 and $16,691 per acre. These are also given in Table 14.

Ecosystem Modeling Approach and Results

The ecosystem valuation methods described earlier in this report have been criticized on various grounds.

- The value transfer approach is sometimes criticized because it uses values for the "average" ecosystem of a given type, e.g., wetlands; since every ecosystem of a given type is unique in some respects, it is argued that average values cannot capture that uniqueness.
- The hedonic value approach relies on the assumption that consumer perceptions of differences in environmental quality are reflected in housing prices; however, several important ecosystem services are not perceived directly by humans and therefore presumably will not show up in hedonic prices.

The services which cannot be directly perceived include climate regulation, disturbance prevention, freshwater regulation and supply, and waste and nutrient regulation. These services are directly connected to an ecosystem's primary production, nutrient dynamics, and hydrology; these ecosystem "functions" in turn directly affect the quality and quantity of services provided by the ecosystem. Ecosystem functioning is driven by such factors as land use, geology, species mix, etc.

Modeling Approach

Scientists who perform ecosystem valuation studies are beginning to develop techniques to assess the impacts of some of the many relevant site-specific factors on the quantity and quality of ecosystem functions and services. As part of this project, we undertook one such type of analysis called spatial modeling. In essence, this technique uses complex computer software to model the physical interactions of ecosystems and human communities in a given landscape in a dynamic mode (i.e., a mode in which the physical state of the landscape components at a given point in time directly determines the physical state of the landscape at subsequent moments).

The specific software we used is a spatially explicit, process-based model previously developed to integrate data and knowledge over several spatial, temporal and complexity scales and to aid in regional ecosystem and land use management (Costanza et al., 2002). The model addresses the effects of both the magnitude and spatial patterns of human settlements and agricultural practices on hydrology, plant productivity, and nutrient cycling in the landscape. The spatial resolution is variable, with a maximum of 200m x 200m to allow adequate depiction of the pattern of ecosystems and human settlement on the landscape. The temporal resolution is different for various components of the model, ranging from hourly time steps in the hydrologic sector to yearly time steps in the economic land use transition module.

The model just described is capable of general application, and has been calibrated for the Patuxent River watershed in Maryland, several of its subwatersheds, including Hunting Creek subwatershed, and a few watersheds in Vermont. In this context, calibration refers to determining the numerical constants in a given mathematical relationship, which is used in the model to describe certain processes. Since there are always uncertainties involved in choosing the right formalism and comparing the model results with data, which are also uncertain, calibration is used to improve model accuracy and to incorporate some of specific features of a landscape or a particular case study, which could not be picked by the choice of processes and their formalizations. A model thus calibrated for one watershed cannot be directly applied to another watershed without extensive and expensive recalibration based on local data for the new watershed and its component subwatersheds. We can nonetheless use a model calibrated to a particular watershed in another state to derive non-quantitative relationships applicable to New Jersey. We do this by "exercising" or experimenting with the existing model to create spatial pattern and context-based relationships of a type that could be applied in New Jersey, and could be certainly improved if and when the model is recalibrated with New Jersey parameter values based on New Jersey data. (The analytic methods used in these experiments are extremely complex and are described in detail in Appendix D.) Since Maryland and New Jersey are geographically and climatically very similar, such transfers of non-quantitative model results can safely be incorporated in the present study.

For example, using the model, we could create wetlands or forests of varying patch size and observe how freshwater regulation and supply services vary in the model watershed. We can thus identify the type of relationship (e.g., linear, exponential, etc.) that exists between patch size and freshwater regulation and supply services. We performed this type of modeling experiment for several of the ecoservices mentioned above, varying the assumptions on the spatial patterns of land use within the model watershed. Although it is beyond the scope of the current project, the resulting set of functional relationships could be built into a GIS-based system to allow values for these services to be adjusted to take New Jersey-specific spatial effects into account.

Determinants of Ecosystem Services and Functions

The level and economic value of ecosystem services of a given type provided by a given ecosystem depends on a variety of factors, including the ecosystem's size, "health," and location relative to human communities and other ecosystems. At the extreme, each specific ecosystem, e.g., each patch of forest or wetland, would need to be evaluated on its own to assign it a value. This degree of detail is impractical for a region as large as New Jersey, which is why the transferred value analysis used the average of values from prior studies.

Running a model of this type provides an opportunity to quantify several indicators related to ecosystem functioning and ecosystem services. In particular, the model we used for the project can track two variables that are related to certain important ecosystem services.

- Concentration of nutrients (in this case nitrogen) is an important indicator of water quality and how the watershed performs towards amelioration of water pollution.
- Net Primary Productivity (NPP) has been suggested in several studies (cf. Costanza et al. 1998) as a proxy for total ecosystem services value. NPP describes how fast the vegetation grows and therefore is an indicator of the existing amount of vegetation and its health.

The model we built includes variables that can tell how these indicators may change under different scenarios of land use, climate, and other changes in space and time. We can "exercise" our model, e.g., run it under various climatic conditions, and "drive" it by changing patterns of land use to help us better understand how such factors impact the ecosystem services under consideration. To help us understand how allocation of land use affects the two proxies for ecosystem services described above, we first ran 17 scenarios for the model watershed, grouped into a baseline and three sets of experiments as follows:

- Baseline: one scenario representing existing land uses in the model watershed as of 1990, and one representing a hypothetical baseline with the entire watershed forested (Figure 8).
- Extent of land conversion: seven scenarios varying the percentage of forest converted to agriculture from 15% to 100% (Figure 8).
- Location of land conversion: two scenarios converting 30% of forest to agriculture but varying the location of the preserved forest between uplands and lowlands (Figure 9).
- Buffers: six scenarios varying the nature (agriculture or forest), size (one, two or three cells), and location (lowland or midland) of stream buffers in the watershed (Figure 9).

We have been focusing on the conversion between forested and agricultural land uses, while similar experiments could be conducted for other types of landuse change, say conversions from forest to residential. Once again, this choice was primarily driven by the existing data and the confidence in model performance, which was the highest for these two land use types in Hunting Creek watershed. In Table 15 we present an overview of these scenarios, as well as the values for NPP and Total Nitrogen Runoff generated for each scenario. The scenarios are also depicted in Figures 8 and 9 in map form; green represents forest, yellow represents agriculture, and blue represents streams. Gray and black cells stand for low and high density residential, respectively; these land uses were fixed in space in our experiments.

Table 15: Summary of Scenarios Analyzed with the Ecosystem Model

Map Code	# cells	N total (mg/m)	N station (mg/m)	NPP ($kg/m^2/y$)	Scenario description
LU90	1172	1228	208	2.58	1990 land use for model watershed
LU_F	1653	972	154	3.48	Entire model watershed forested
LU_F15	1389	1028	180	2.95	About 15% of forest randomly converted to agriculture
LU_F20	1334	1048	185	2.83	About 20% of forest randomly converted to agriculture
LU_F30	1132	1092	289	2.41	About 30% of forest randomly converted to agriculture
LU_F35	1041	1178	280	2.23	About 35% of forest randomly converted to agriculture
LU_F50	807	1207	264	1.74	About 50% of forest randomly converted to agriculture
LU_F50a	838	1241	339	1.82	About 50% of forest randomly converted to agriculture (an alternative trial)
LU_Agro	0	1493	443	0.00	All forest converted to agriculture
LU_F30a	1132	1393	307	2.48	Forest preserved on upland; while about 30% total converted to agriculture on lowland
LU_F30b	1132	990	287	2.38	Forest preserved on lowland; while about 30% total converted to agriculture on upland
LU_F30ha	1132	1079	213	2.35	Small agricultural buffer
LU_F30hf	1132	1100	272	2.41	Small forest buffer
LU_F30hfm	1132	1037	274	2.41	Medium forest buffer
LU_F30hgbig	1132	1096	288	2.40	Large forest buffer
LU_F30hfbiglow	1132	1084	290	2.40	Large forest buffer, lowland priority
LU_F30hfbigmid	1132	1015	287	2.39	Large forest buffer, midland priority

Key:
mg/m = milligrams of nitrogen per meter of water column in stream
$kg/m^2/y$ = kilograms of NPP per square meter per year
N station = nitrogen mg/m at the mid-watershed gauging station

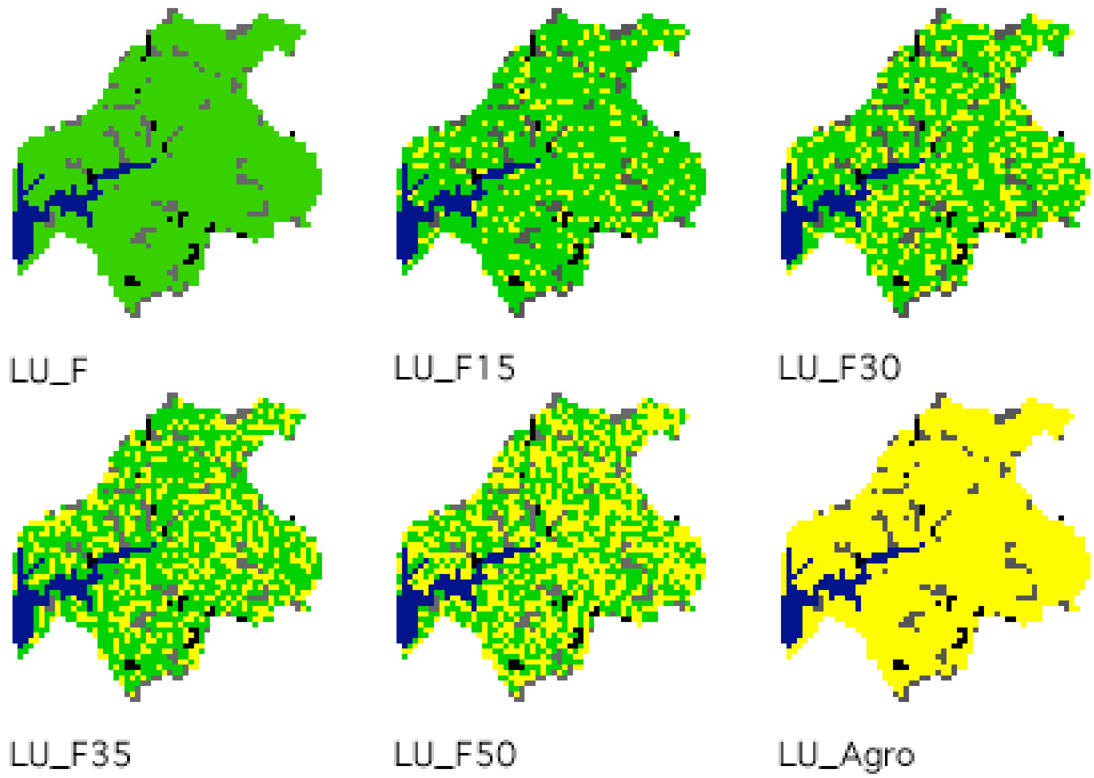


Figure 8: Scenarios for analysis of spatial allocation change

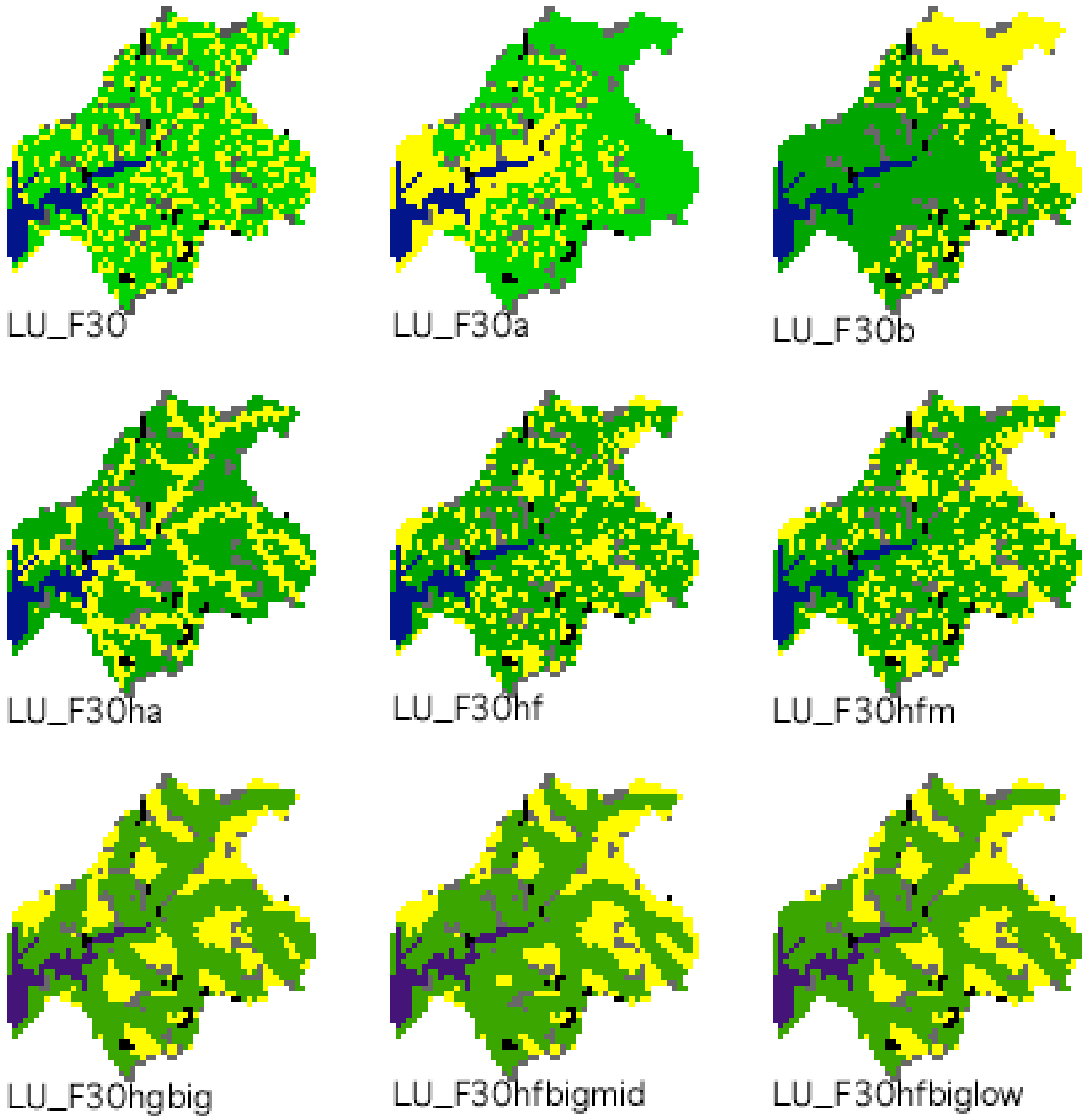


Figure 9: Scenarios for analysis of spatial pattern change

Net Primary Production (NPP)

As noted earlier, net primary production (NPP), excluding agriculture and urban areas, can be treated as an indicator of ecosystem health and ecosystem service levels (Costanza et al., 1998). NPP in the Hunting Creek watershed is primarily provided by the forested areas. Different land use patterns result in quite significant spatial variations in NPP; however, total NPP for the watershed does not seem to be related to the spatial patterns and is almost entirely driven by the total number of cells in the forest land use type (Figure 10). The small variations in NPP that we see in Figure 10 and Table 15 are caused by slight differences in the factors that determine nutrient and water supply in scenarios where different spatial allocations of a constant number of forested cells are assumed.

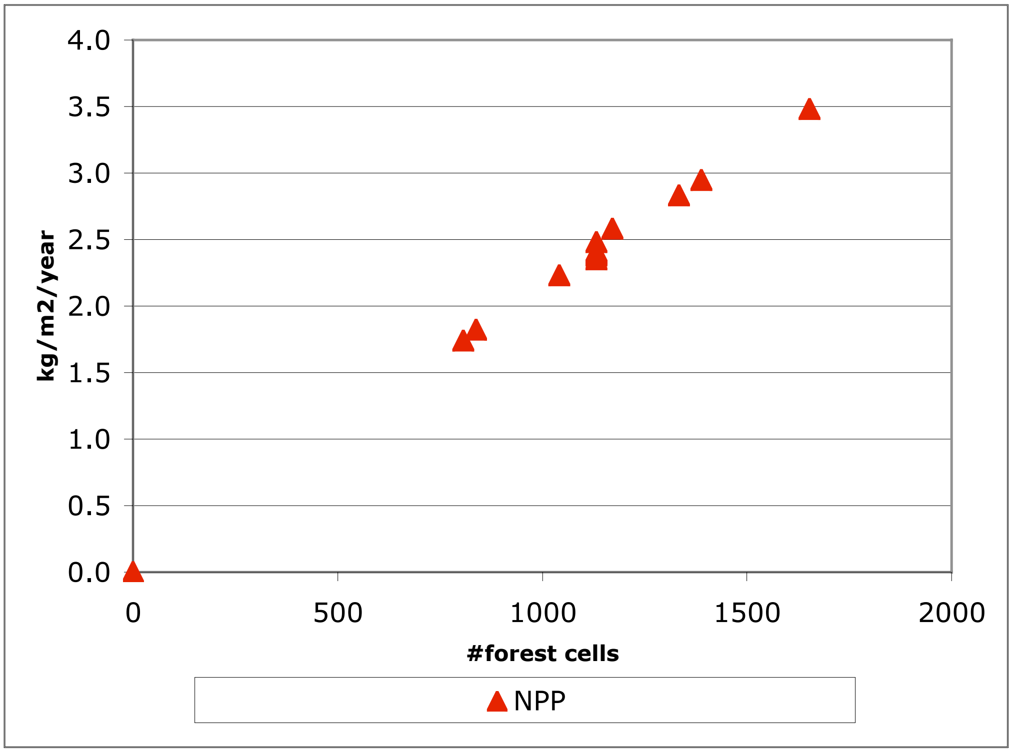


Figure 10: Total NPP as a function of forested cells in the watershed.

We can conclude from this that in terms of NPP, the precise spatial patterns are not very important. There might be more spatial variance if the changes in spatial allocation resulted in larger changes in the suitability of the landscape for plant growth, in which case water or nutrient limitations might result in more dramatic variations in the NPP index.

Nutrient Loading

The next indicator we tracked is nutrient runoff as a function of the spatial distribution of various land use types. This indicator serves as a measure of the quantity and quality of an ecosystem's water regulation services.

For scenarios that vary only the number of cells that are forested, we obtained a response that is very close to linear (Figure 11). In other words, the more forested cells in the watershed, the lower the amount of nutrients (nitrogen in this case) delivered to the estuary. If the spatial distribution of cells is random each time, the response is again almost exactly linear. However, if there are non-random patterns in the arrangement of cells of a particular type, such as what we see for the existing land use pattern (LU90), or in some of the special cases considered below, we see some deviations from the linear relationship (see the outlier point in Figure 11).

These deviations become more obvious if we run the model through the group of scenarios that have the spatial pattern of forests changed as shown in Figure 9. In this case we observe quite substantial (almost 50%) variations in the water regulation services provided, even though the overall proportions of various land use types in the watershed remain constant (Figure 12A). It should be noted here that we have used the same number (1,132) of forested cells in all of these particular model runs, and it is only how we distributed those forested cells across the landscape that was changed.

Figure 12B presents the same spatial changes but reports results for the gauging station that is located in the middle of the stream in the model watershed and mainly covers the upper left (northwest) corner of the watershed. The variations are quite substantial and do not relate well to the changes that we see in Figure 12A; different patterns of land use have different effects on the watershed as a whole and on the sub-watersheds. In other words, there is significant spatial heterogeneity in terms of the water regulation services provided.

The difference in results between Figures 12A and 12B highlight the relevance of policy and regulatory objectives to ecosystem analysis. If we are interested only in the water quality in the estuary zone, then the entire watershed can be treated as a single unit and we need not be concerned about the variations of forest distribution among the different parts of the basin. However, if we are concerned about stream health throughout the watershed, then the spatial gradients in nutrient levels become highly important, and we have to take into account the fact that land use change in one area will impact adjacent areas downstream. In other words, the estuary at the bottom (southern) end of the watershed may experience a very different level of disturbance from upstream portions of the river due to various factors, e.g., dilution of nutrients as they flow downstream.

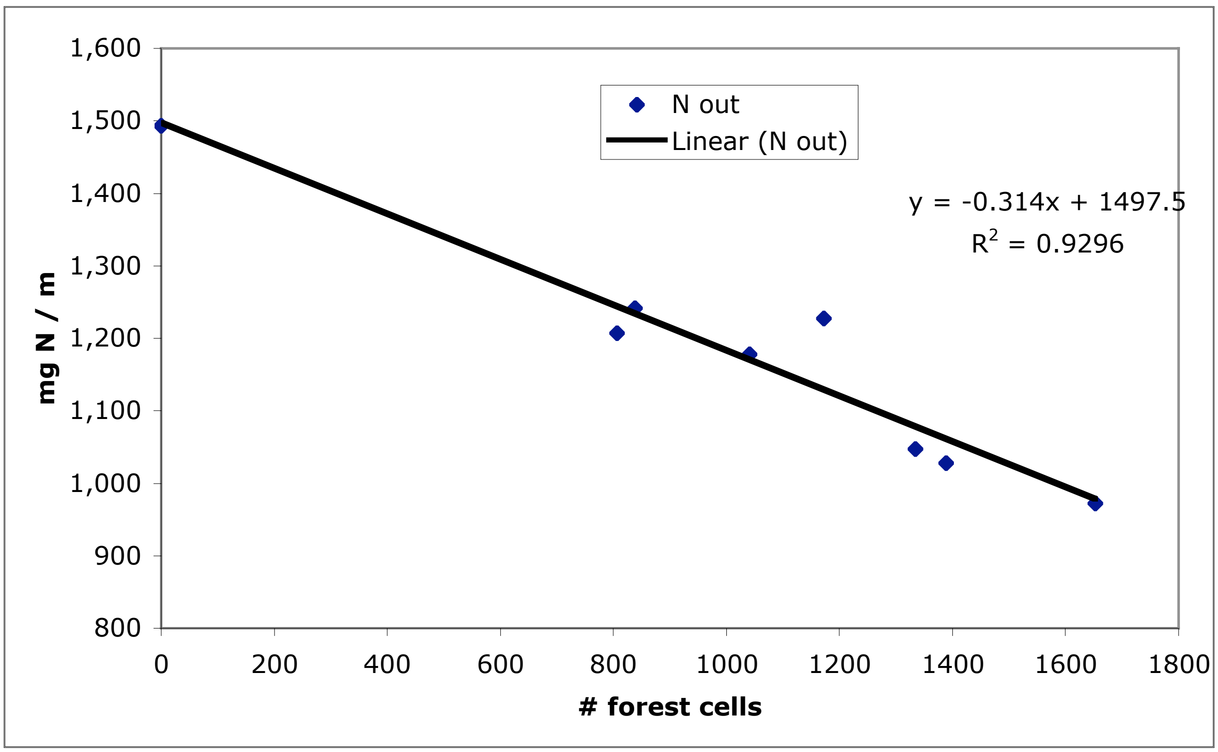
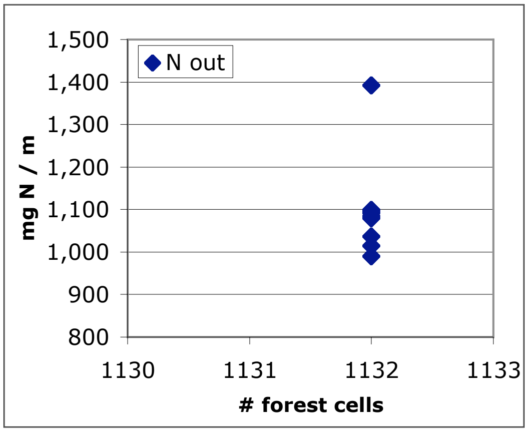
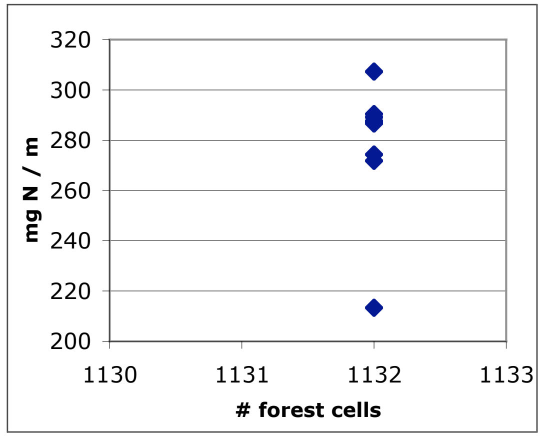


Figure 11: Response of total nitrogen in estuary to the number of forested cells on the watershed.





A. Estuary zone B. Gauging station at mid-watershed

Figure 12. Response of total nitrogen amounts to changes in pattern of forests in the watershed (Number of forested cells is 1,132 in both A and B.)

Although we did not create any scenarios that would specifically target the sub-watershed above the mid-watershed gauging station, we still get a response that is close to linear in terms of the total number of forested cells in the subwatershed (Figure 13). In this Figure we are looking at output from the same 17 scenarios described above, where the spatial variations were formulated for the whole watershed, making the subwatershed variations less clear in terms of buffer size and forest allocation. The deviations here are somewhat larger than in the previous case, when we were looking at the watershed as a whole (Figure 13). Local conditions tend to be more vulnerable to change than larger tracts of land.

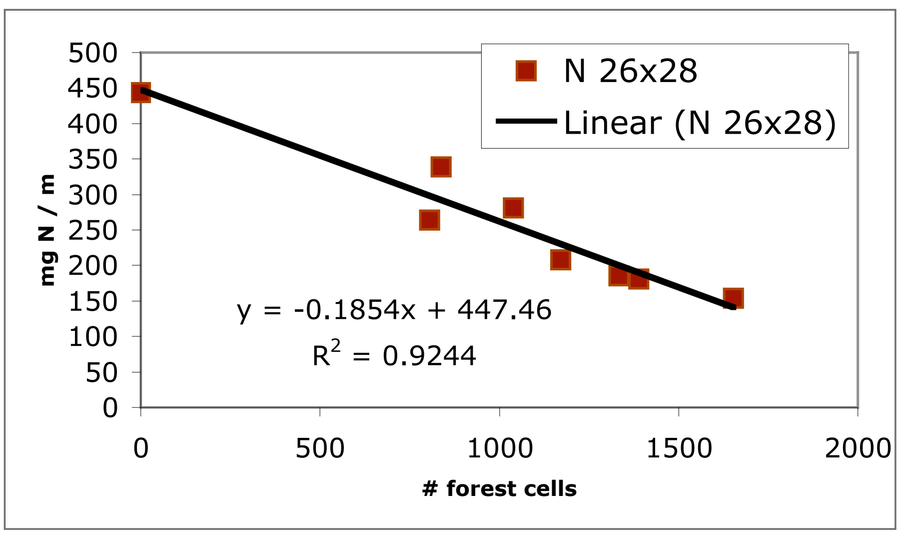


Figure 13: Relationship between water quality indicator at mid-watershed gauging station and overall land use patterns in the Hunting Creek watershed.

Conclusions

The results from these basic scenarios show, perhaps unsurprisingly, that the more forest is converted to agriculture, the poorer the quality of water in the estuary and the lower the NPP index. More generally, even this limited analysis shows that different land use allocations and patterns affect the level of ecosystem services generated in a given landscape; for the water quality index this difference can be as large as 40%.[12] Location is critical for some ecoservices; for example, forests located close to the estuary zone play a more important role in terms of estuary water quality than forests located far away. Ecosystem size is also important both by itself and as it interactions with location. For example, small river buffers have only a minor impact on water quality: the riparian buffers need to be large enough to be of use in maintaining water regulation services.

There is still a great deal of uncertainty in the estimated magnitudes of these effects. Different ecosystem services may be impacted differently by the same patterns and allocations. For example, while small forest patches appear to be better than large forest clusters from the viewpoint of water quality, a biodiversity index is very likely to favor larger patches. Much more detailed and comprehensive studies are required to take into account the whole range of ecosystem services and to account properly for all of the significant spatial heterogeneities and interactions.

The New Jersey landscape, like those in other places, is not homogeneous. Land uses appear in different patterns in different parts of the state, and these patterns may matter for specific ecosystem functions and the services that ecosystems produce. Spatial models such as the one described here can translate spatial land use allocations and patterns into indicators of the quantity and quality of ecosystem functions or services, enabling us to compare the impact of alternative landscape "design" or development patterns on overall ecosystem performance. Future studies could also include optimization experiments that would result in spatial land use allocations for New Jersey that would maximize the value of ecosystem services in defined geographic areas.

While the analyses reported here cannot yield quantitative ecosystem values for New Jersey, they clearly illustrate some of the ways in which factors external to an ecosystem can affect its functioning, and they also indicate one way in which those relationships can be modeled quantitatively. The analyses also highlight the importance of local land use planning and regulation in preserving and enhancing—or diminishing—the value of ecosystem services.

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[12] This does not necessarily mean that the economic value associated with forest in the proximity of the estuary should be 40% higher than for upstream forest, since it is the specific combination of landscape conditions and spatial patterns that determines ecoservice levels.

Discussion

Natural Capital and Ecosystem Services

If we think of ecosystem services as a stream of annual "income," then the ecosystems that provide those services can be thought of as part of New Jersey's total *natural capital*. To quantify the value of that capital, we must convert the stream of benefits from the future flows of ecosystem services into a net present value (NPV). This conversion requires some form of discounting. Discounting of the flow of services from natural assets is somewhat controversial (Azar and Sterner, 1996). The simplest case involves assuming a constant flow of services into the indefinite future and a constant discount rate. Under these special conditions, the NPV of the asset is the value of the annual flow divided by the discount rate.

The discount rate one chooses here is a matter of debate. In previous work (i.e. Costanza et al., 1989), we have displayed results using a range of discount rates and shown that a major source of uncertainty in the analysis is the choice of discount rate. But beyond this, there is some debate over whether one should use a zero discount rate or whether one should even assume a constant discount rate over time. A constant rate assumes "exponential" discounting, but "decreasing," "logistic," "intergenerational," and other forms of discoursing have also been proposed (i.e. Azar and Sterner, 1996, Sumaila and Walters, 2005, Weitzman 1998, Newell and Pizer 2003, 2004).

Table 16 shows the results using a range of constant discount rates along with other approaches to discounting, including using a decreasing discount rate, intergenerational discounting, and 0% discounting using a limited time frame. The general form for calculating the NPV is:

$$NPV = \sum_{t=0}^{\Sigma} V_t W_t \qquad (3)$$

Where:

V_t = the value of the service at time t

W_t = the weight used to discount the service at time t

For standard exponential discounting, W_t is exponentially decreasing into the future at the discount rate, r.

$$W_t = \left| \frac{1}{1+r} \right|^t \qquad (4)$$

Applying this formula to the annual ecosystem service flow estimates of \$10 Billion and \$15 Billion per year for a range of discount rates (r) from 0% to 8% yields the first two rows of estimates in Table 16. Note that for a 0% discount rate, the value of equation 1 would be infinite, so one needs to put a time limit on the summation. In Table 17, we assumed a 100 year time frame for this purpose, but one can easily see the effects of extending this time frame. An annual ecosystem service value of \$11 Billion for 100 years at a 0% discount rate yields an NPV of \$1.1 trillion while an annual ecosystem service value of \$19 Billion for 100 years at a 0% discount rate yields an NPV of \$1.9 trillion. These estimates turn out to be identical to the NPV calculated using a 1% discount rate and an infinite time frame. As the discount rate increases, the NPV decreases. As shown in Table 16, at an 8% discount rate an annual flow of \$11 billion translates to an NPV of \$138 billion and an annual flow of \$19 billion translates to an NPV of \$238 billion.

Another general approach to discounting argues that discount rates should not be constant, but should decline over time. There are two lines of argument supporting this conclusion. The first, due to Weitzman (1998) and Newell and Pizer (2003, 2004) argues that discount rates are uncertain and because of this, their average value should be declining over time. As Newell and Pizer (2003, pp. 55) put it: “future rates decline in our model because of dynamic uncertainty about future events, not static disagreement over the correct rate, nor an underlying belief or preference for deterministic declines in the discount rate.” A second line of reasoning for declining rates is due to Azar and Sterner (1996), who first decompose the discount rate into a “pure time preference” component and an “economic growth” component. Those authors argue that, in terms of social policy, the pure time preference component should be set to 0%. The economic growth component is then set equal to the overall rate of growth of the economy, under the assumption that in more rapidly growing economies there will be more in the future and its impact on welfare will be marginally less, due to the assumption of decreasing marginal returns to income in a wealthier future society. If the economy is assumed to be growing at a constant rate into the indefinite future, this reduces to the standard approach to discounting, using the growth rate for r. If, however, one assumes that there are fundamental limits to economic growth, or if one simply wishes to incorporate uncertainty and be more conservative about this assumption, one can allow the assumed growth rate (and discount rate) to decline in the future.

Table 16: Net present value (NPV) of annual flows of ecosystem services using various discount rates and discounting techniques.

Annual Flow Value (Billion$/yr)	0%, 100 yrs	1%	3%	5%	8%
	Standard constant discount rate				
$11	$1,100	$1,100	$367	$220	$138
$19	$1,900	$1,900	$633	$380	$238
	Declining discount rate (300 yr time frame)				
$11		$1,809	$640	$299	$151
$19		$3,124	$1,106	$516	$261
	Intergenerational Discounting				
$11		$5,542	$870	$405	$212
$19		$9,572	$1,503	$699	$366

As an example, (following Newell and Pizer 2003, who based their rates of decline on historical trends in the discount rate), we let the discount rate approach 0 as time approaches 300 years into the future. We do this by multiplying r by e^{-kt}, where k for this example was set to .00007. Since this function levels out at a discount rate of 0%, W_t eventually starts to increase again. We therefore forced W_t to level out at its minimum value. Also, carrying this calculation to infinity would also lead to an infinite NPV. For this example, the summation was carried out for 300 years (which is the time frame used by Newell and Pizer (2003). As one can see from inspection of Table 16, in general, assuming a decreasing discount rate leads to significantly higher NPV values than assuming a constant discount rate.

Finally, we applied a recently developed technique called “intergenerational discounting” (Sumaila and Walters, 2005). This approach includes conventional exponential discounting for the current generation, but it also includes conventional exponential discounting for future generations. Future generations can then be assigned separate discount rates that may differ from those assumed for the current generation. For the simplest case where the discount rates for current and future generations are the same, this reduces to the following formula (Sumaila and Walters, 2005, pp. 139):

$$W_t = d^t + \frac{d * d^{t-1} * t}{G} \qquad (5)$$

Where:

$$d = \frac{1}{1+r} \qquad (6)$$

G = the generation time in years (25 for this example)

One can see that this method leads to significantly larger estimates of NPV than standard constant exponential discounting, especially at lower discount rates. At 1% the NPV's are 5 times as much, while at 3% they are more than double.

There is no clear and unambiguous reason for choosing one of the three methods over the others, or for choosing a particular discount rate. Newell and Pizer (2003) argue for a 4% discount rate, declining to approximately 0% in 300 years, based on historical data. One could argue that for ecosystem services, the starting rate should be lower. If we use 3% and focus on the two alternative methods, this would place the NPV of New Jersey's natural capital assets at somewhere between \$0.6 and \$1.5 trillion.

Reliability and Possible Sources of Error

Transferred value analysis estimates the economic value of a given ecosystem (e.g., wetlands) from prior studies of that ecosystem, most likely studies that were conducted in geographic areas other than the area being analyzed. Some have objected to this approach on the grounds that:

1. Every ecosystem is unique, and per-acre values derived from elsewhere in the world may not be relevant to the ecosystems being studied.
2. Even within a single ecosystem, the value per acre depends on the size of the ecosystem; in most cases, as the size decreases, the per-acre value would be expected to increase and vice versa. (In technical terms, the marginal cost per acre is generally expected to increase as the quantity supplied decreases, and a single average value is not the same thing as a range of marginal values). This issue was partly addressed in the spatial modelling component of this project, but this remains an important issue.
3. There is no way for us to obtain all of the data we would need to address these problems, and therefore we have no way of knowing the "true" value of all of the wetlands, forests, pastureland, etc. in a large geographic area and hence no way of knowing whether our estimated value is accurate or not and, if not, whether it is even high or low. In technical terms, we have far too few data points to construct a realistic demand curve or estimate a demand function.
4. To value all (or a large proportion) of the ecosystems in a large geographic area is questionable in terms of the standard definition of "exchange" value because we cannot conceive of a transaction in which all or most of a large area's ecosystems would be bought and sold. This emphasizes the point that the value estimates for large areas (as opposed to the unit values per acre) are more comparable to national income accounts aggregates and not exchange values (Howarth and Farber 2002). These aggregates (i.e. GDP) routinely impute values to public goods for which no conceivable market transaction is possible and it is just these kinds of aggregates that the value of ecosystem services of large geographic areas is comparable to (see below).

Unfortunately, the alternative recommended by those who advance the above arguments amounts to limiting valuation to a single ecosystem in a single location and using only data developed expressly for the unique ecosystem being studied, with no attempt to generalize to other ecosystems in other locations. For a state with the size and landscape complexity of New Jersey, this approach would preclude any valuation at the state-wide level.

The above objections to transferred value analysis have been responded to in detail elsewhere (Costanza et al 1998, Howarth and Farber 2002); the responses can be summarized as follows:

1. While every wetland, forest, etc. is obviously unique in some way, ecosystems of a given type

also by definition have many things in common. The use of average values in ecosystem valuation is no more and no less justified than their use in other "macroeconomic" contexts, e.g., developing economic statistics such as Gross State Product. This study's estimate of the aggregate value of New Jersey's ecosystem services is a valid and useful (albeit imperfect, as are all economic aggregates) basis for assessing and comparing these services with conventional economic goods and services.

2. The results of the spatial modeling analysis described later in this report do not support an across-the-board claim that the per-acre value of forest or agricultural land depends across-the-board on the size of the parcel. While the claim does appear to hold for nutrient cycling and probably other services, the opposite position holds up fairly well for what ecologists call "net primary productivity" or NPP, a major indicator of ecosystem health (and by implication of services tied to NPP), where each acre makes about the same contribution to the whole regardless of whether it is part of, e.g., a large forest patch or a small one. This area of inquiry certainly needs further research, but for the most part the assumption (that average value is a reasonable proxy for marginal value) seems appropriate as a first approximation.

3. As employed here, the prior studies we analyzed (most of which were peer-reviewed) encompass a wide variety of time periods, geographic areas, investigators, and analytic methods, and many of them provide a range of estimated values rather than single point estimates. The present study preserves this variance; no studies were removed from the database because their estimated values were thought to be "too high" or "too low" and limited sensitivity analyses were performed. The approach is similar to defining an asking price for a piece of land based on the prices for "comparable" parcels; even though the property being sold is unique, realtors and lenders feel justified in following this procedure, even to the extent of publicizing a single asking price rather than a price range.

4. The objection as to the absence of even an imaginary exchange transaction was made in response to the study by Costanza et al. (1997) of the value of *all* of the world's ecosystems. Leaving that debate aside, one can in fact conceive of an exchange transaction in which all or a large portion of, e.g., New Jersey's wetlands was sold for development, so that the basic technical requirement that economic value reflect exchange value could in principle be satisfied. But even this is not necessary if one recognizes the different purpose of valuation at this scale – a purpose more analogous to national income accounting than to estimating exchange values (cf. Howarth and Farber 2002)

In the last analysis, this report takes the position that "the proof is in the pudding", i.e., the possibility of plausibly estimating the value of an entire state's ecosystem services is best demonstrated by presenting the results of an attempt to do so. In this report we have tried to display our results in a way that allows one to appreciate the range of values and their distribution (see, e.g., Tables 4 and 5). It is clear from inspection of these tables that the final estimates are not extremely precise. However, they are much better estimates than the alternative of assuming that ecosystem services have zero value, or, alternatively, of assuming they have infinite value. Pragmatically, in estimating the value of ecosystem services it seems better to be approximately right than precisely wrong.[13]

In terms of more specific concerns, the value transfer methodology introduces an unknown level of error, because we usually do not know how well the original study site approximates conditions in New Jersey. Other potential sources of error in this type of analysis have been identified (Costanza et al.

[13] The estimated value of the world's ecosystems presented in Costanza et al. (1997) has been criticized as both (1) "a serious underestimate of infinity" and (2) impossibly exceeding the entire Gross World Product. These objections seem difficult to reconcile.

1997) as follows:

1. Incomplete coverage is perhaps the most serious issue. Not all ecosystems have been well studied and some have not been studied at all as is evident from the gap analysis presented below. More complete coverage would almost certainly increase the values shown in this report, since no known valuation studies have reported estimated values of less than zero.
2. Distortions in current prices used to estimate ecoservice values are carried through the analysis. These prices do not reflect environmental externalities and are therefore again likely to be underestimates of "true" values.
3. Most estimates are based on current willingness-to-pay or proxies, which are limited by people's perceptions and knowledge base. Improving people's knowledge base about the contributions of ecosystem services to their welfare would almost certainly increase the values based on willingness-to-pay, as people would realize that ecosystems provided more services than they had previously been aware of.
4. The valuations probably underestimate shifts in the relevant demand curves as the sources of ecoservices become more limited. If New Jersey's ecosystem services are scarcer than assumed here, their value has been underestimated in this study. Such reductions in "supply" appear likely as land conversion and development proceed; climate change may also adversely affect New Jersey's ecosystems, although the precise impacts are harder to predict.
5. The valuations assume smooth responses to changes in ecosystem quantity with no thresholds or discontinuities. Assuming (as seems likely) that such gaps or jumps in the demand curve would move demand to higher levels than a smooth curve, the presence of thresholds or discontinuities would likely produce higher values for affected services (Limburg et al., 2002).
6. As noted above, the method used here assumes spatial homogeneity of services within ecosystems. The spatial modeling component of the project was intended to address this issue and showed that, indeed, the physical quantities of some services vary significantly with spatial patterns of land use and land cover. Whether this fact would increase or decrease valuations is unclear, and depends on the specific spatial patterns and services involved.
7. Our analysis uses a static, partial equilibrium framework that ignores interdependencies and dynamics. More elaborate systems dynamics studies of ecosystem services have shown that including interdependencies and dynamics leads to significantly higher values (Boumans et al., 2002), as changes in ecosystem service levels ripple throughout the economy.
8. The value estimates are not necessarily based on sustainable use levels. Limiting use to sustainable levels would imply higher values for ecosystem services as the effective supply of such services is reduced.
9. The approach does not fully include the "infrastructure" or "existence" value of ecosystems. It is well known that people value the "existence" of certain ecosystems, even if they never plan to use or benefit from them in any direct way. But estimates of existence value are rare. Including this service would obviously increase the total values.
10. On a global level, there are great difficulties and imprecision in making inter-country comparisons. This problem was of limited relevance to the current project, since the majority of value transfer estimates were from the US or other developed countries.
11. In the few cases where we needed to convert from stock values to annual flow values, the amortization procedure also creates significant uncertainty, both as to the method chosen and the specific amortization rate used. (In this context, amortization is the converse of discounting.)
12. All of these valuation methods use static snapshots of ecosystems with no dynamic interactions.

The effect of this omission on valuations is difficult to assess.

13. Because the transferred value method is based on average rather than marginal cost, it cannot provide estimates consumer surplus. However, this means that valuations based on averages are more likely to underestimate total value.

If these problems and limitations could be addressed, the result would most likely be significantly higher values. Unfortunately, it is impossible to know how much higher the values would be if these limitations were addressed. One example may be worth mentioning, however. Boumans et al. (2002) produced a dynamic global simulation model that estimated the value of global ecosystem services in a general equilibrium framework and estimate their value to be roughly twice that estimated by Costanza et al. (1997), which used a static, partial equilibrium analysis. Whether a similar result would obtain for New Jersey is impossible to say, but it does give an indication of the potential range of values.

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Appendix A: Literature Review

Ecosystem services are the benefits people obtain from ecosystems (Costanza et al. 1997, Daily 1997, de Groot et al. 2002). These include provisioning services such as food and water; regulating services such as regulation of floods, drought, land degradation, and disease; supporting services such as soil formation and nutrient cycling; and cultural services such as recreational, spiritual, religious and other nonmaterial benefits (Millennium Ecosystem Assessment 2003).

Ecosystem services are becoming more scarce. On the supply side, ecosystems are experiencing serious degradation in regard to their capability of providing services. At the same time, the demand for ecosystem services is increasing rapidly as populations and standards of living increase (Millennium Ecosystem Assessment 2005)

Value, Valuation and Social Goals

In discussing values, we first need to clarify some underlying concepts and definitions. The following definitions are based on Farber et al. (2002).

"Value systems" refer to intrapsychic constellations of norms and precepts that guide human judgment and action. They refer to the normative and moral frameworks people use to assign importance and necessity to their beliefs and actions. Because "value systems" frame how people assign importance to things and activities, they also imply internal objectives. Value systems are thus internal to individuals, but are the result of complex patterns of acculturation and may be externally manipulated through, for example, advertising.

"Value" refers to the contribution of an object or action to specific goals, objectives or conditions (Costanza 2000). The value of an object or action may be tightly coupled with an individual's value system, because the latter determines the relative importance to the individual of an action or object relative to other actions or objects within the perceived world. But people's perceptions are limited, they do not have perfect information, and they have limited capacity to process the information they do have. An object or activity may therefore contribute to meeting an individual's goals without the individual being fully (or even vaguely) aware of the connection. The value of an object or action therefore needs to be assessed both from the "subjective" point of view of individuals and their internal value systems, and also from the "objective" point of view of what we may know from other sources about the connection.

"Valuation" is then the process of assessing the contribution of a particular object or action to meeting a particular goal, whether or not that contribution is fully perceived by the individual. A baseball player is valuable to the extent he contributes to the goal of the team's winning. In evolutionary biology, a gene is valuable to the extent it contributes to the survival of the individuals possessing it and their progeny. In conventional economics, a commodity is valuable to the extent it contributes to the goal of individual welfare as assessed by willingness to pay. The point is that one cannot state a value without stating the goal being served (Costanza 2000).

"Intrinsic value" refers more to the goal or basis for valuation itself and the protection of the "rights" of these goals to exist. For example, if one says that nature has "intrinsic value" one is really claiming that protecting nature is an important goal in itself. "Values" (as defined above) are based on the contribution that something makes to achieving goals (directly or indirectly). One could thus talk about the value of an object or action in terms of its contribution to the goal of preserving nature, but not about the "intrinsic value" of nature. So "intrinsic value" is a confusing term. Since intrinsic value is a goal, one cannot estimate or measure the intrinsic value of something and compare it with the intrinsic value of something else. One should therefore more accurately refer to the "intrinsic rights" of nature to qualify as a goal against which to assess value, in addition to the more conventional economic goals.

ESV is thus the process of assessing the contribution of ecosystem services to meeting a particular goal or goals. Traditionally, this goal is efficient allocation, that is, to allocate scarce ecosystem services among competing uses such as development and conservation. But other goals, and thus other values, are possible.

There are at least three broad goals that have been identified as important to managing economic systems within the context of the planet's ecological life support system (Daly 1992):

1. assessing and insuring that the scale or magnitude of human activities within the biosphere are ecologically sustainable;
2. distributing resources and property rights fairly, both within the current generation of humans and between this and future generations, and also between humans and other species; and
3. efficiently allocating resources as constrained and defined by 1 and 2 above, and including both market and non-market resources, especially ecosystem services.

Because of these multiple goals, one must do valuation from multiple perspectives, using multiple methods (including both subjective and objective), against multiple goals (Costanza 2000). Furthermore, it is important to recognize that the three goals are not ''either–or'' alternatives. Whereas they are in some sense independent multiple criteria (Arrow and Raynaud 1986), which must all be satisfied in an integrated fashion to allow human life to continue in a desirable way.

However, basing valuation on current individual preferences and utility maximization alone does not necessarily lead to ecological sustainability or social fairness (Bishop 1993), or to economic efficiency for that matter, given the severe market imperfections involved. ESV provides a tool that enhances the ability of decision-makers to evaluate trade-offs between alternative ecosystem management regimes to meet a set of goals, namely, sustainable scale, fair distribution, and efficient allocation (Costanza and Folke 1997). Different goals may become a source of conflict during policy-making debates over management of ecosystem services. How are such conflicts to be resolved? ESV provides one approach to at least better inform these discussions.

Framework for ESV

Figure 1 shows one integrated framework developed for ESV (de Groot et al. 2002). It shows how ecosystem goods and services form a pivotal link between human and ecological systems. Ecosystem structures and processes are influenced by 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 that support human welfare. Through laws, land use management and policy decisions, individuals and social groups make tradeoffs. In turn, these land use decisions directly modify the ecological structures and processes by engineering and construction activities and/or indirectly by modifying the physical, biological and chemical structures and processes of the landscape.

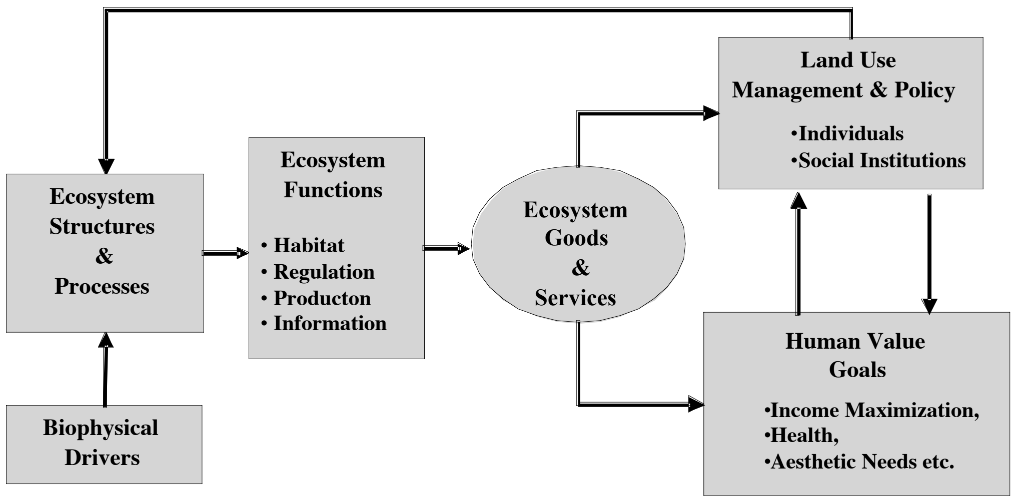

Figure 1: Framework for Integrated Assessment and Valuation of Ecosystem Goods and Services

Methodology for ESV

While measuring exchange values simply requires monitoring market data for observable trades, non-market values of goods and services are much more difficult to measure. Indeed, it is these values that have captured the attention of environmental and resource economists who have developed a number of techniques for valuing ecosystem goods and services (Freeman 2003, Bingham et al. 1995, Farber et. al. 2002, deGroot et al. 2002). When there are no explicit markets for services, more indirect means of assessing economic values must be used. A spectrum of economic valuation techniques commonly used to establish values when market values do not exist are identified in Table 1.

Table 1: Economic Valuation Techniques

Avoided Cost (AC): services allow society to avoid costs that would have been incurred in the absence of those services. For example, flood control provided by barrier islands avoids property damages along the coast.
Replacement Cost (RC): services could be replaced with man-made systems. For example, waste treatment can be replaced with costly treatment systems.
Net Factor Income (NFI): services provide for the enhancement of incomes; For example, water quality improvements may increase commercial fisheries catch and incomes of fishermen.
Travel Cost (TC): service demand may require travel, whose costs can reflect the implied value of the service. For example, recreation areas attract distant visitors whose value placed on that area must be at least what they were willing to pay to travel to it.
Hedonic Pricing (HP): service demand may be reflected in the prices people will pay for associated goods: For example, housing prices along the coastline tend to exceed the prices of inland homes.
Contingent Valuation (CV): service demand may be elicited by posing hypothetical scenarios in surveys that involve some valuation of land use alternatives. For example, many people would be willing to pay for increased preservation of wildlife.
Marginal Product Estimation (MP): Service demand is generated in a dynamic modeling environment using a production function (i.e., Cobb-Douglas) to estimate value of output in response to corresponding material input.
Group Valuation (GV): This approach is based on principles of deliberative democracy and the assumption that public decision making should result, not from the aggregation of separately measured individual preferences, but from *open public debate.*

As the descriptions in table 1 suggest, each valuation methodology has its own limitations, often limiting its use to a select range of ecosystem services. For example, the economic value generated by a naturally functioning ecological system can be estimated using the Replacement Cost (RC) method which is based on the price of the cheapest alternative way of obtaining that service, e.g., the value of a wetland in the treatment of wastewater might be estimated using the cost of chemical or mechanical alternatives. A related method, Avoided Cost (AC), can be used to estimate economic value based on the cost of damages due to lost services. Travel Cost (TC) is primarily used for estimating recreation values while Hedonic Pricing (HP) for estimating property values associated with aesthetic qualities of natural ecosystems. On the other hand, Contingent Valuation (CV) surveys are often employed in the absence of actual environmental use to estimate the economic value of less tangible services like critical wildlife habitat or amenity values. Marginal Product Estimation (MP) has generally been used in a dynamic modeling context and represents a helpful way to examine how ecosystem service values change over time. Finally, group valuation (GV) is a more recent addition to the valuation literature and directly addresses the need to measure social values directly in a group context. In many applications, the full suite of ecosystem valuation techniques will be required to account for the economic value of goods and services provided by a natural landscape.

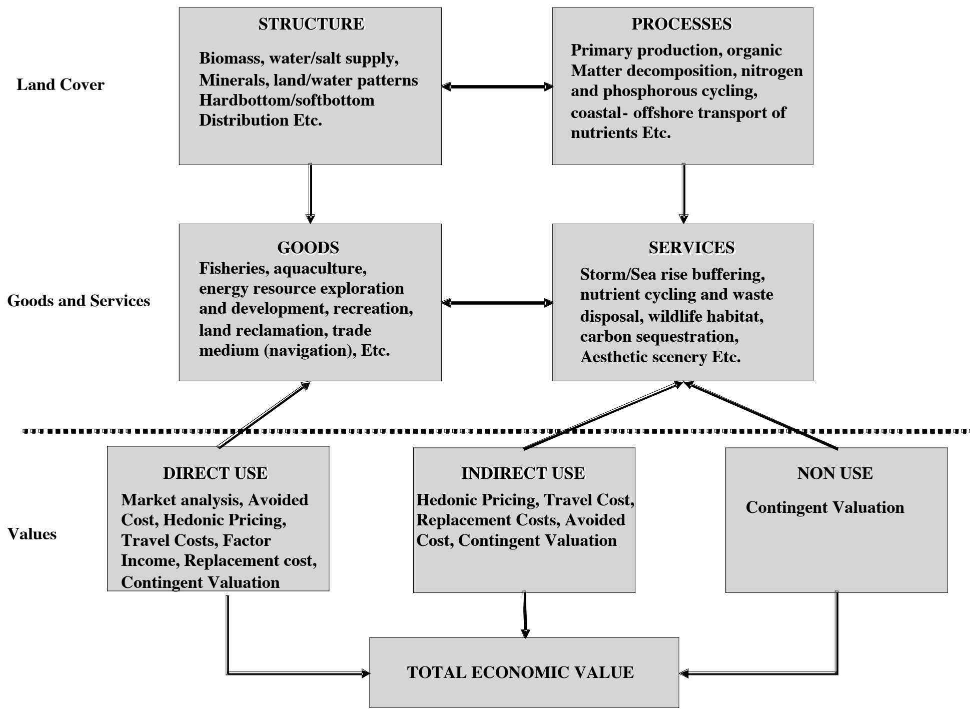

Figure 2: Total Economic Value of Ecosystem Functions, Goods and Services

Figure 2 depicts how the total value of a given landscape might be estimated by linking different ecosystem structures and processes with the output of specific goods and services, which can then be assigned monetary values using the range of valuation techniques described above. Key linkages are made between the diverse structures and processes associated with the landscape and habitat features that created them and the goods and services that result. Once delineated, values for these goods and services can then be assessed by measuring the contribution they make to supporting human welfare. In economic terms, the natural assets of the landscape can thus yield direct (fishing) and indirect (nutrient regulation) use values as well as non-use (preservation) values of the system. Once accounted for, these economic values can then be aggregated to estimate the total value of the landscape (i.e. Total Economic Value or TEV as shown in Figure 2).

History of ESV Research

This section provides a historical perspective on ESV research. For the purpose of this paper, the story opens with the emergence of environmentalism in the 1960s. However, this is not to say that the foundations of ESV were not present prior to this. For instance, Hotelling's (1949) discussion of the value of parks implied by travel costs signaled the start of the travel cost valuation era. Similarly suggestions by Ciriacy-Wantrup (1947) in the late 1940s led to the use of stated preference techniques such as contingent valuation.

Our approach to the history of advances in ESV will not be a method by method literature review[14]. Rather, we focus on how people faced the challenge presented by the transdisciplinary nature of

[14] Several reviews of the published ESV literature have been developed elsewhere. These review, including Smith

ESV research. In the 1960s, for instance, there was relatively little work that transcended disciplinary boundaries on ecosystem services. In later years this situation has gradually improved. Truly *transdisciplinary* approachs are required for ESV in which practitioners accept that disciplinary boundaries are academic constructs largely irrelevant outside of the university, and allow the problem being studied to determine the appropriate set of tools, rather than vice versa.

We frequently see ESV research in which teams of researchers trained in different disciplines separately tackle a single problem and then strive to combine their results. This is known as *multidisciplinary* research, but the result is much like the blind men who examine an elephant, each describing the elephant according to the single body part they touch. The difference is that the blind men can readily pool their information, while different academic disciplines lack even a common language with which their practitioners can communicate (e.g. see Bingham and others 1995). *Interdisciplinary* research, in which researchers from different disciplines work together from the start to jointly tackle a problem and reduce the language barrier as they go, is a step in the right direction toward the transdisciplinary path.

For convenience, we arbitrarily divide the last 45 years (1960 to present) into four periods. Influential contributions during each period are marked as milestones in figure 3 and they are placed above the timeline, while below the line is a chronology of social events that may have triggered the development of ESV[15]. The chart is meant to be illustrative, not comprehensive, as space prohibits showing all important contributions and milestones.

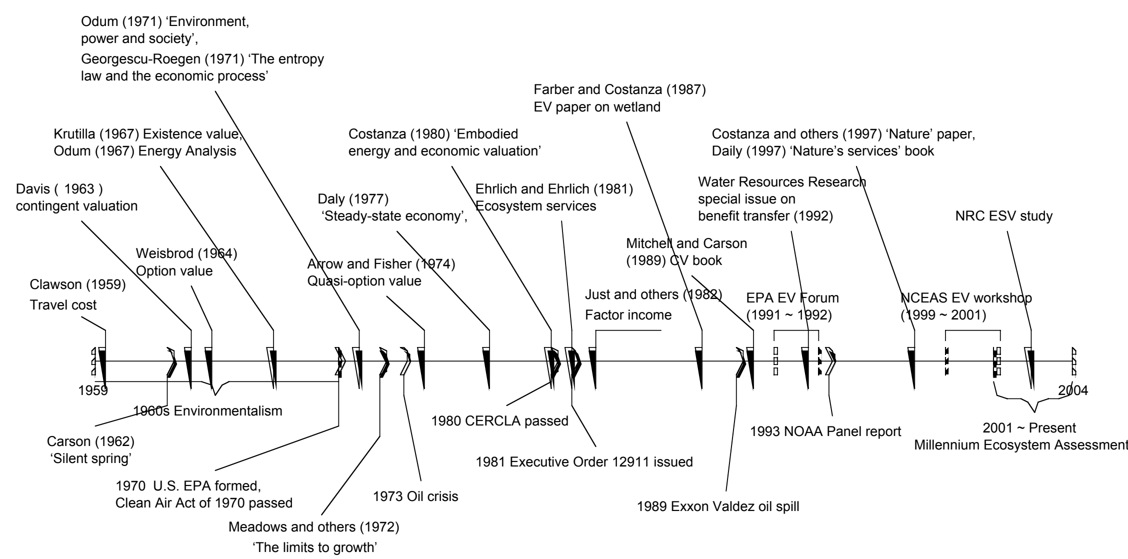

Figure 3. A historical overview of Ecosystem Valuation research

(1993, 2000), Carson (2000), Cropper (2000), Freeman (2003), Chapters in van den Bergh (1999), and Bateman and Willis (1999), provided much more detailed examination of ESV methods.

15 In general we expect a time lag between the social events and relevant academic publications. For instance, Fisher and Ward (2000) assumed two years as the lag in the writing and publication process for their 'breakpoint analysis".

1960s—Common challenge, separate answers

The 1960s are remembered as the decade of early environmentalism. Main social events include publication of Rachel Carson's *Silent Spring* in 1962, passage of the 1970 Clean Air Act, and formation of the U.S. Environmental Protection Agency in that same year.

In response to increasing public interest in environmental problems (mainly pollution and dramatic population increase[16] at the time), economists began rethinking the role of environment in their production models and identified new types of surplus for inclusion in their welfare measure (Crocker 1999).

Economist Kenneth Boulding compared the "cowboy economy" model which views the environment as a limitless resource with the "spaceship economy" view of the environment's essential limits (Boulding 1966). His work included recognition of the ecosystem service of waste assimilation to the production model, where before ecosystems had mainly been regarded as a source of provisioning services.

Consideration of cultural services in an economic analysis began with Krutilla's (1967) seminal observation that many people value natural wonders simply for their existence. Krutilla argued that these people obtain utility through vicarious enjoyment of natural areas and, as a result, had a positive WTP for the government to exercise good stewardship of the land.

In addition to existence value, other types of value were also being considered. These include option value, or the value of avoiding commitments that are costly to reverse (Weisbrod 1964). There is also quasi-option value, or the value of maintaining opportunities to learn about the costs and benefits of avoiding possibly irreversible future states (Arrow and Fisher 1974).

In most cases WTPs for these newly-recognized values could not be derived via market transactions, because most of the ecosystem services in question are not traded in actual markets. Thus, new valuation methods were also proposed, including travel cost (Clawson 1959), contingent valuation (Davis 1963) and hedonic pricing (Ridker and Henning 1967).

In the meantime, ecologists also proposed their own valuation methods. For example, "energy analysis" is based on thermodynamic principles where solar energy is considered to be the only primary input to the global ecosystem (Odum 1967). This biophysical method differs from WTP-based ones in that it does not assume that value is completely determined by individual preferences, but rather attempts a more "objective" assessment of ecosystem contributions to human welfare.

1970s—breaking the disciplinary boundary

The existence of "limits to growth" was the main message in the environmental literature during the 1970s (Meadows et al. 1972). The Arab oil embargo in 1973 emphasized this message.

"*Steady-state economics*" as an answer to the growth limit was proposed by economist Herman Daly (1977), who emphasized that the economy is only a sub-system of the finite global ecosystem. Thus the economy cannot grow forever and ultimately a sustainable steady state is desired. Daly was inspired by his mentor in graduate school, Nicholas Georgescu-Roegen. In *The Entropy Law and the Economic Process*, Georgescu-Roggen elaborates extensively on the implications of the entropy law for economic processes and how economic theory could be grounded in biophysical reality (Georgescu-Roegen 1971).

Georgescu-Roegen was not the only scientist to break the disciplinary boundary in the 1970s. Ecologist H.T. Odum published his influential book *Environment, Power, and Society* in 1971, where he

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[16] The population issue was brought to the forefront by Paul Ehrlich in the provocative book *the Population Bomb* (1968). As a biologist, he had an inclination to perceive human beings as a species and deeply questioned the sufficiency of food production when the number of individuals form a species increases dramatically.

summarized his insights from studying the energetics of ecological systems and applying them to social issues (Odum 1971).

Along with these early efforts, a rather heated debate between ecologists and economists also highlighted their differences regarding concepts of value. Economists of that day objected strenuously to the energetic approach. They contended that value and price were determined solely by people's ''willingness to pay'' and not by the amount of energy required to produce a service. H. T. Odum and his brother E. P. Odum and economists Lenard Shabman and Sandra Batie engaged in a point–counterpoint discussion of this difference in the pages of the *Coastal Zone Management Journal* (Shabman and Batie 1978, EP Odum 1979, HT Odum 1979).

Though unrealized at the time, a new method called *Factor Income* (or the Productivity-based method) became one way to bring together the views of ecologists and economists. This method is used to estimate the economic value of ecosystem services that contribute to the production of marketed goods. It is applied in cases where ecosystem services are used, along with other inputs, to produce a marketed good.

Early contributions in the area include works from Anderson (1976), Schmalensee (1976), and Just and Hueth (1979). Just and his colleagues (1982) provided a rigorous analysis of how to measure changes in welfare due to price distortions in factor and product markets. These models provide a basis for analyzing the effects of productivity-induced changes in product and factor prices[17].

The field of environmental and resource economics grew rapidly from the beginning of the 1970s. The field became institutionalized in 1974 with the establishment of the *Journal of Environmental Economics and Management* (JEEM). The objects of analysis of natural resource economists have typically been such resources as forests, ore deposits, and fish species that provided provisioning services to the economy. In the meantime, the environment has been viewed as the *medium* through which the externalities associated with air, noise, and water pollution have flowed, as well as the source of amenities. However, in later years this distinction between natural resources and the environment has been challenged as artificial and thus no longer meaningful or useful (Freeman 2003).

1980s—moving beyond multidisciplinary ESV research

In the 1980s, two government regulations created a tremendous demand for valuation research. The first was the 1980 *Comprehensive, Environmental Responses, Compensation and Liability Act* (CERCLA), commonly known as *Superfund*, which established liability for damages to natural resources from toxic releases. In promulgating its rules for such Natural Resource Damage Assessments (NRDA), the US Department of Interior interpreted these damages and the required compensation within a welfare-economics paradigm, measuring damages as lost consumer surplus. The regulations also describe protocols that are based on various economic valuation methods (Hanemann 1992).

The role of ecosystem valuation increased in importance in the United States with President Reagan's Executive Order 12911, issued in 1981, requiring that all new major regulations be subject to a Cost Benefit Analysis (CBA) (Smith 1984).

As shown in Figure 4, the 1980s witnessed the dramatic increases in the number of publications, including peer-reviewed papers, book chapters, governmental reports and thesis, on the topic of ecosystem valuation[18]. This result is based on a search in the Environmental Valuation Reference

[17] Recent progress in the area includes Barbier (1994) , Barbier and Strand (1998), Barbier (2000), Knowler et al. (2003),

[18] The drop of the total number of publications since late 1990s is probably due to artificial effect, i.e. EVRI™ has not incorporated all the papers in recent years. According to a similar analysis by Adamowicz (2004), the number of peer-reviewed literature in environmental valuation has increased over time and did not decrease after 1995. In addition, the same paper showed the growth in valuation publication is not solely the result of a larger number of

Inventory ™ (EVRI™), the largest valuation database. The search was conducted for four general types of entities relevant to ecosystem services including ecological functions, extractive uses, non-extractive uses and passive uses. We excluded valuation publications on human health and built environment from EVRI™ because they are not relevant to ESV.

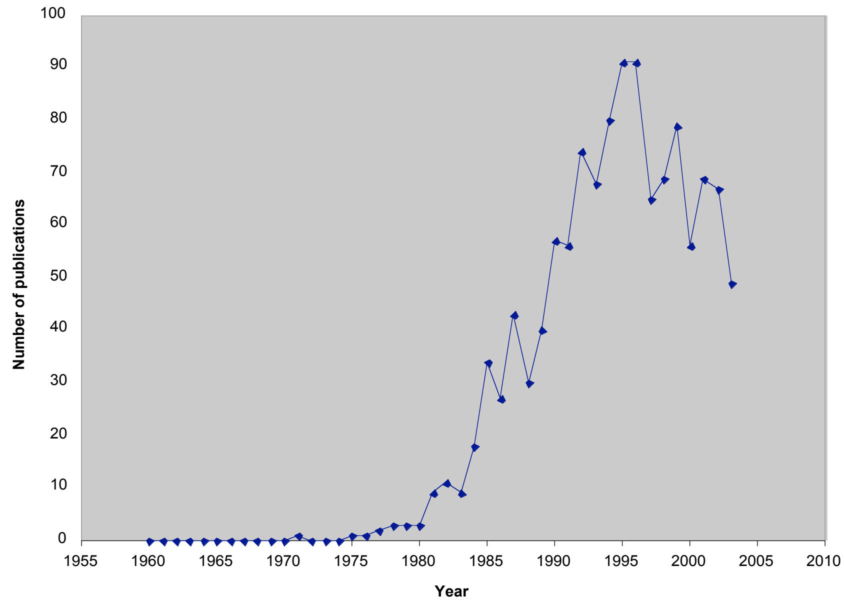

Figure 4. Number of ESV publications in EVRI over time.

The 1989 *Exxon Valdez* oil spill was the first case where non-use value estimated by contingent valuation was considered in a quantitative assessment of damages. In March of that year, the *Exxon Valdez* accidentally spilled eleven million gallons of oil in Alaska's pristine Prince William Sound. Four months later, the District of Columbia Circuit of the US Court of Appeals held that non-use value should be part of the economic damages due to releases of oil or hazardous substances that injure natural resources. Moreover, the decision found that CV was a reliable method for undertaking such estimates. Prior to the spill, CV was not a well developed area of research. After the widely publicized oil spill, the attention given to the conceptual underpinnings and estimation techniques for non-use value changed rather abruptly (Carson et al. 2003). In the same year, two leading researchers published their start-of-the-art work on CV (Mitchell and Carson 1989).

At the same time, ecologists began to compare their results based on energy analysis to economic values. For example, Costanza (1980) and Costanza and Herendeen (1984) used an 87-sector input-output model of the US economy for 1963, 1967, and 1973, modified to include households and governments as endogenous sectors, to investigate the relationship between direct and indirect energy consumption (embodied energy[19]) and the dollar value of output by sector. They found that the dollar value of sector output was highly correlated with embodied energy, though not with direct energy

total publications.

[19] The energy embodied in a good or service is defined as the total direct energy used in the production process plus all the indirect energy used in all the upstream production processes used to produce the other inputs to the process. For example, auto manufacturing uses energy directly, but it also uses energy indirectly to produce the steel, rubber, plastic, labor, and other inputs needed to produce the car.

consumption or with embodied energy calculated excluding labor and government energy costs.

Differences of opinion between ecologists and economists still existed in the 1980s in terms of the relationship between energy inputs, prices and values (Ropke 2004). But the decade also witnessed the first paper co-authored by an ecologist and an economist on ecosystem valuation (Farber and Costanza 1987). Though the idea of the paper was simply to compare the results from two separate studies using different methods, the paper also represented the first instance of an ecologist and economist overcoming their disciplinary differences and working together.

The term *Ecosystem Services*, first appeared in Ehrlich and Ehrlich's work (1981). The concept of ecosystem services represents an attempt to build a common language for discussing linked ecological and economic systems. Using "ecosystem services" as a key word (in both singular and plural forms), we did a search in the ISI Web of Knowledge. Figure 5 shows the total number of papers published and the number of disciplinary categories in which they occur over time. For example, the curves show that by the year 2003, close to 70 papers per year were being published on ecosystem services - in more than 40 subdisciplines[20]. The two exponential curves show the increasing use of the term over time and the fact that it has been embraced quickly by many different disciplines, including those which appear at first glance to be not so relevant, such as computer science, pharmacy, business, law and demography.

The concept of ecosystem services (and the related concept of "natural capital[21]" which first appeared in Costanza and Daly (1982)) have proven useful for landscape management and decision making for two fundamental reasons. First, they help synthesize essential ecological and economic concepts, allowing researchers and managers to link human and ecological systems in a viable and policy relevant manner. Second, scientists and policy makers can use the concepts to evaluate economic and political tradeoffs between landscape development and conservation alternatives.

1990s ~ present: Moving toward trandisciplinary ESV research

Not only attention but also controversy was drawn to the CV approach after its application to the *Exxon Valdez* case, when it became known that a major component of the legal claims for damages was likely to be based on CV estimates of lost nonuse or existence value. The concerns about the reliability of the CV approach led the National Oceanic and Atmospheric Administration (NOAA) to convene a panel of eminent experts co-chaired by Nobel Prize winners *Kenneth Arrow* and *Robert Solow* to examine the issue. In January 1993, the panel issued a report which concluded that "CV studies can produce estimates reliable enough to be the starting point for judicial or administrative determination of natural resource damages—including lost passive-use value (i.e. non-use value)" (Arrow et al. 1993).

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[20] This number is almost for sure an under-estimate because similar terms such as "ecological service(s)" and environmental service(s)' were not included.

[21] Natural capital is defined as the stock of ecosystem structure that produces the flow of ecosystem goods and services.

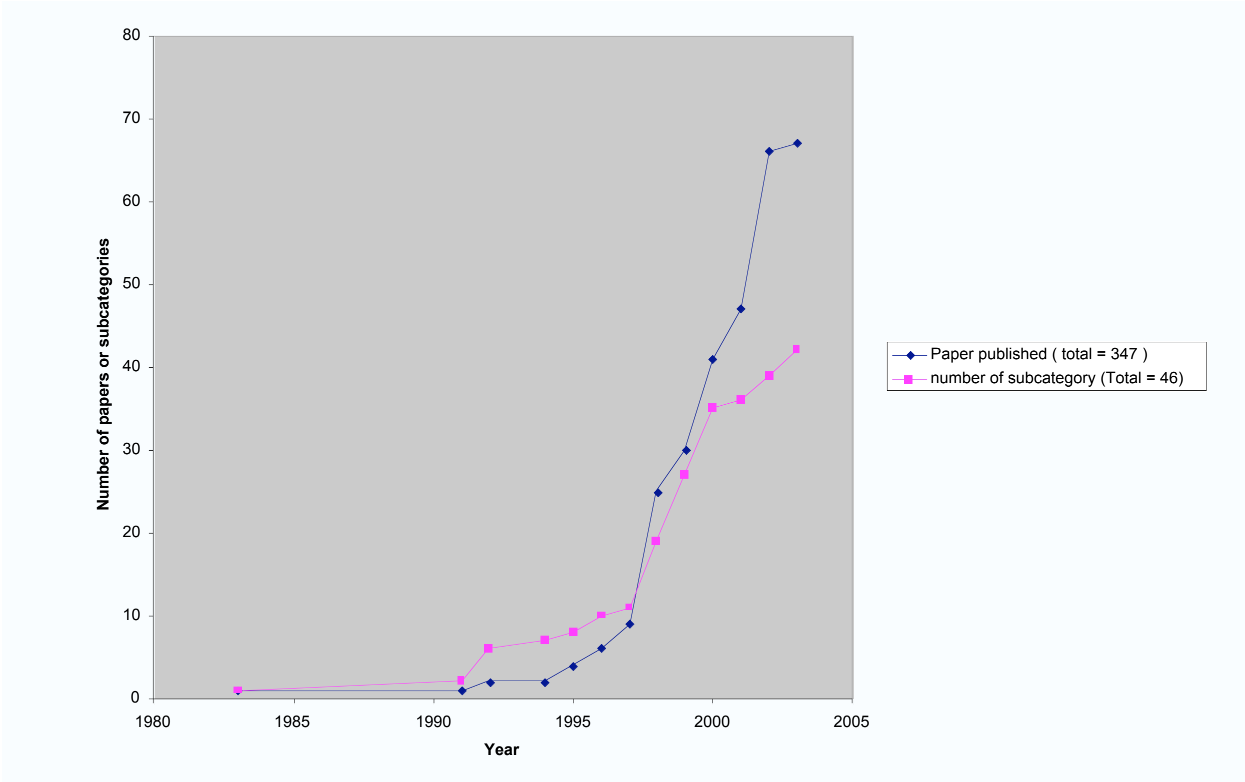

Figure 5. Number of peer-reviewed ecosystem service papers and their related sub-categories over time listed in the ISI Web of Science.

At the same time, the controversy about CV also stimulated a substantial body of transdisciplinary ESV research. Highlights include conjoint analysis, Meta-Analysis (MA), group valuation, and Multiple Criterion Decision Analysis (MCDA), each of which is discussed below.

Insights from psychology have proven fruitful in structuring and interpreting contingent valuation studies (e.g. Kahneman and Knetsch 1992). A new approach gained its popularity in the 1990s was *conjoint analysis* (e.g. Mackenzie 1992, Adamowicz et al. 1994, Boxall et al. 1996, Hanley 1998). This technique allowed researchers to identify the marginal value of changes in the *characteristics* of environmental resources, as opposed to asking direct CV questions. Respondents are asked to choose the most preferred alternative (or, to rank the alternatives in order of preference, or to rate them on some scale) among a given set of hypothetical alternatives, each depicting a different bundle of environmental attributes. Responses to these questions can then be analyzed to determine the marginal rates of substitution between any pair of attributes that differentiate the alternatives. If one of characteristics has a monetary price, then it is possible to compute the respondent's willingness to pay for other attribute.

While subject to the same concern as CV regarding the hypothetical nature of valuation, the conjoint analysis approach offers some advantages (Farber and Griner 2000). For example, it creates the opportunity to determine tradeoffs in environmental conditions through its emphasis on discovering whole preference *structures* and not just monetary valuation. This may be especially important when valuing ecosystems, which provide a multitude of joint goods and services. In addition it more reasonably reflects multi-attribute choice than the typical one-dimensional CV.

A well-developed approach in psychological, educational, and ecological research*, meta-analysis* (MA) was introduced to the ESV field by Walsh and colleagues in the late 1980s and early 1990s (Walsh et al. 1989, Walsh et al. 1992, Smith and Karou 1990). MA is a technique that is increasingly being used to understand the influence of methodological and study-specific factors on research outcomes and to synthesize past research. Recent applications include meta-analyses of air quality (Smith and Huang 1995), endangered species (Loomis and White 1996), and wetlands (Brouwer et al. 1997, Woodward and Wui). A more recent use of meta-analysis is the systematic utilization of the existing value estimates from source literature for the purpose of value transfer (Rosenberger and Loomis 2000, Shrestha and Loomis 2003).

Mainly derived from political theory, *discourse-based valuation* is founded on the principles of deliberative democracy and the assumption that public decision-making should result, not from the aggregation of separately measure individual preferences but from a process of open public debate (Jacobs 1997, Coote and Lenaghan 1997). This method is extremely useful in ESV addressing the fairness goal we mentioned earlier because ecosystem services are very often public goods (e.g. global climate regulation, biodiversity) that are shared by social groups (Wilson and Howarth 2002).

MCDA techniques originated over three decades ago in the fields of mathematics and operations research and are well-developed and well-documented (Hwang and Yoon, 1981). They provide a structured framework for decision analysis which involves definition of goals and objectives, identification of the set of decision options, selection of criteria for measuring performance relative to objectives, determination of weights for the various criteria, and application of procedures and mathematical algorithms for ranking options. The method is well-suited to both eliciting values and preferences and evaluating stakeholder interests.

Traditional MCDA assumes that there is a single decision-maker so that clear, unambiguous, non-conflicting objectives can be identified from a single perspective. Furthermore, it is assumed that the relevant criteria are well-defined, independent of each other, and measurable with certainty (Stewart 1995). In order to extend MCDA to group decision situations where there are conflicting objectives and to incorporate uncertainty into the decision-making process, MCDA needs to be used in conjunction with discursive participatory methods and with ecosystem modeling.

Fernandes et al. (1999) provide an example of MCDA in a participatory setting for coral reef management in Saba Marine Park, an island in the Netherlands Antilles. The process provided a forum for tabling, discussing and documenting the community's concerns and allowed the unexpected degree of general agreement to become apparent. In this sense, it facilitated social discourse, value formation and learning about the interactions of the social, economic and ecological systems.

The emergence of these new interdisciplinary methods can be attributed in part to two workshops in 1990s that brought together ESV researchers from different disciplines (EPA 1991 and NCEAS 1999, summarized in special issues of *Ecological Economics* in 1995 and 1998 respectively). The organizers of the first workshop believed that "the challenge of improving ecosystem valuation methods presents an opportunity for partnership—partnership between ecologists, economists, and other social scientists and policy communities. Interdisciplinary dialogue is essential to the task of developing improved methods for valuing ecosystem attributes" (Bingham et al. 1995). In a paper comparing economics and ecological concepts for valuing ecosystem services, participants from the second workshop concluded that "there is clearly not one 'correct' set of concepts or techniques. Rather there is a need for conceptual pluralism and thinking 'outside the box'" (Farber et al. 2002).

This call for cross-disciplinary research is echoed by a recent National Research Council (NRC) study on assessing and valuing the ecosystem services of aquatic and related terrestrial ecosystems. In their final report a team composed of 11 experts from the field of ecology, economics, and philosophy offered guidelines for ESV, among which "Economists and ecologists should work together from the very beginning to ensure the output from ecological model is in a form that can be used as input for economic model" (Water Science and Technology Board 2004). Their prepublication version of the report titled "*Valuing ecosystem services: toward better environmental decision-making"* is available online at http://books.nap.edu/books/030909318X/html

Two interdisciplinary publications drew widespread attention to ecosystem service valuation and stimulated a continuing controversy between ecological economists and traditional “neoclassical” economists. Costanza and his colleagues (ecologists and economists) published an often-cited paper on valuing the services provided by global ecosystems in *Nature*. They estimated that the annual value of 17 ecosystem services for the entire biosphere was US$33 trillion (Costanza et al. 1997). The journal of *Ecological Economics* contributed a special issue in 1998, which included a series of 13 commentaries on the *Nature* paper.

The first book dedicated to ecosystem services was also published in 1997 (Daily et al. 1997). *Nature's Services* brings together world-renowned scientists from a variety of disciplines to examine the character and value of ecosystem services, the damage that has been done to them, and the consequent implications for human society. Contributors including Paul R. Ehrlich, Donald Kennedy, Pamela A. Matson, Robert Costanza, Gary Paul Nabhan, Jane Lubchenco, Sandra Postel, and Norman Myers present a detailed synthesis of the latest understanding of a suite of ecosystem services and a preliminary assessment of their economic value.

State-of-the-art ESV- Millennium Ecosystem Assessment

Starting in April 2001, more than 2,000 experts have been involved in a four-year effort to survey the health of the world's ecosystems and the threats posed by human activities. Instead of evaluating how ecosystems respond to just one environmental concern, such as climate change, the experts will attempt to provide a complete “planetary health check”, that identifies and where possible quantifies the impacts of changes in land use, loss of biodiversity, the application of agricultural fertilizers, and many other factors. The synthesis report now is available for review at http://www.millennium assessment.org/en/index.aspx.

ESV in Practice

In the ESV area most of the final demand comes from policy makers and public agencies[22]. To what extent, however, is ESV actually used to make real environmental decisions?

The answer to this question is contingent on the specific area of environmental policy making that is of concern. There are a few areas in which ESV is well established. They include Natural Resource Damage Assessment (NRDA) cases in the USA, CBA of water resource planning, and planning for forest resource use (Adamowicz 2004). In other areas, however, there have been relatively few applications of ESV where it was used as the sole or even the principal justification for environmental decisions, and this is especially true in the natural resources planning area.

A number of factors have limited the use of ESV as a major justification for environmental decisions. These include methodological problems that affect the credibility of the valuation estimates, legislative standards that preclude consideration of cost-benefit criteria, and lack of consensus about the role that efficiency and other criteria should play in the design of environment regulations (see later section for details on debates on ESV). However, while environmental decisions may not always be made solely or mainly on the basis of net benefits, ESV has a strong influence in stimulating awareness of the costs and gains stemming from environmental decisions, and often plays a major role in influencing the choice among competing regulatory alternatives (Froehlich et al. 1991).

In Europe, the history of both research and applied work in ESV is much shorter than in the U.S.A. Usually, environmental effects are not valued in monetary terms within the European Union. In a number of European countries CBA has been used as a decision tool in public work schemes, especially in road construction (Navrud and Prukner 1997). In earlier years, environmental policy at the European

[22] Reviews of the use of ESV in policy include Navrud and Pruckner (1997), Bonnieuz and Rainelli (1999), Loomis (1999), Pearce and Seccombe-Hett (2000), Silva and Pagiola (2003), and Adamowicz (2004).

Union level was not informed by environmental appraisal procedures, where appraisal is taken to mean a formal assessment of policy costs and effectiveness using *any* established technique including ESV. But this picture has changed in recent years, and the use of ESV is now accelerating as procedures for assessing costs and benefits are introduced in light of changes to the Treaty of Union (Pearce and Seccombe-Hett, 2000).

A recent report from the World Bank provides a positive view of the use of ESV in the form of CBA in World Bank projects (Silva and Pagiola 2003). Their results show that the use of CBA has increased substantially in the last decade. Ten years ago, one project in 162 used CBA. In comparison, as many as one third of the projects in the environmental portfolio did so in recent years[23]. While this represents a substantial improvement, the authors predicted "there remains considerable scope for growth" (p1).

At the Macro-economic level, ESV has been used in setting up carbon taxes and calculating 'Green" GDP[24] (Pearce 1993). For the purpose of this paper, we will focus on ESV's micro-level roles in (1) Natural Resource Damage Assessments (NRDA), (2) CBA/CEA (Cost Effectiveness Analysis), (3) value transfer, and (4) GIS and ecosystem modeling. Since there are no specific mechanisms that track when research is used for policy, we have to rely on examples.

ESV in NRDA

NRDA is the process of collecting, compiling, and analyzing information to determine the extent of injuries to natural resources from hazardous substance releases or oil discharges and to determine appropriate ways of restoring the damaged resources and compensating for those injuries (see Department of Interior (DOI) Natural Resource Damage Assessments 1980 and Department of Commerce Natural Resource Damage Assessments 1990). Two environmental statutes provide the principle sources of federal authority over natural resource damages: the *Comprehensive Environmental Response, Compensation, and Liability Act* (CERCLA) and the *Oil Pollution Act* (OPA). Although other examples of federal legislation addressing natural resource damages exist, these two statutes are the most generally applicable and provide a consistent framework in which to discuss natural resource damage litigation.

Under the DOI regulations, valuation methodologies are used to calculate "compensable values" for interim lost public uses. Valuation methodologies include both market-based methods (*e.g.,* market price and/or appraisal) and non-market methodologies (*e.g.,* factor income, travel cost, hedonic pricing, and contingent valuation). Under the OPA trustees for natural resources base damages for interim lost use on the cost of "compensatory restoration" actions. Trustees can determine the scale of these actions through methodologies that measure the loss of services over time or through valuation methodologies.

Although statutory authorities existed prior to the 1989 *Exxon Valdez* oil spill, the spill was a signal event in the development of trustee NRDA programs. In the years following the spill, NRDA has been on the frontier of ESV use in litigation. The prospect of extensive use of non-market methods in NRDA has generated extensive controversy, particularly among potentially responsible parties (see Hanemann, 1994, and Diamond and Hausman, 1994, for differing viewpoints on the reliability of the use of contingent valuation in NRDA as well as in CBA in general).

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[23] An examination of the types of valuation methods used in these World Bank studies shows that market based methods such as avoided costs and changes in productivity are far more common than are contingent valuation, hedonic price, or other ESV methodologies (Silva and Pagiola 2003).

[24] Demands that the accounts measure a green GDP reflect a desire to include more of the final non-market services in measures of national income. At the mean time, measure a green GDP could also mean including damage and/or degradation of ecosystem services (CBO 1994)

In the Exxon Valdez case, a team of CV researchers was hired by the State of Alaska to conduct a study of the lost "passive use value" caused by the spill, and the team produced a conservative assessment of 2.8 billion dollars (Carson 1992). Exxon's own consultants published a contrasting critical account of CV arguing that the method cannot be used to estimate passive-use values. Their criticism mainly focused on situations where respondents have little experience using the ecosystem service that is to be altered and when the source of the economic value is not the result of some in site use (Hausman 1993)[25].

This argument led to the previously mentioned NOAA panel, which after a lengthy public hearing and review of numerous written submissions issued a report that cautiously accepted the reliability of CV (Arrow et al. 1993).

In the context of the wide-ranging public debate that continued after the Exxon Valdez case, NOAA reframed the interim lost value component from a monetary compensation measure (*how much money does the public require to make it whole?*) to a resource compensation measure (*how much compensatory restoration does the public require to make it whole?*). By recovering the costs of compensatory restoration actions (costs of resource compensation) rather than the value of the interim losses (monetary compensation), the revised format deflects some of the public controversy about economic methods (Jones and Pease 1997). However, some researchers argue, for instance, that money cannot be removed from NRDA for the simple reason that failure to consider money leaves trustees unable to judge the adequacy of compensating restoration (Flores and Thacher 2004).

ESV in a CBA-CEA framework

CBA is characterized by a fairly strict decision-making structure that includes defining the project, identifying impacts which are economically relevant, physically quantifying impacts as benefits or costs, and then calculating a summary monetary valuation (Hanley and Spash 1993). CEA has a rather similar structure, although only the costs of alternative means of achieving a previously defined set of objectives are analyzed. CBA provides an answer to "whether to do", and CEA answers "how to do".

When the Reagan administration came to power, it attempted to change the role of government in the private affairs of households and firms. Regulatory reform was a prominent component of its platform. President Reagan's Executive Order No. 12291 requiring a CBA for all new major regulations whose annual impact on the economy was estimated to exceed $100 million (Smith 1984). The aim of this Executive Order was to develop more effective and less costly regulation. It is believed that the impact of EO 12291 fell disproportionately on environmental regulation (Navrud and Pruckner 1997).

President Bush used the same Executive Order. President Clinton issued Executive Order 12866, which is similar to Reagan's order but changes some requirements. The order requires agencies to promulgate regulations if the benefits "justify" the costs. This language is generally perceived as more flexible than Reagan's order, which required the benefits to "outweigh' the costs. Clinton's order also places greater emphasis on distributional concerns (Hahn 2000).

CBA analysis for environmental rule making under the George W. Bush administration remains controversial. At the core of the controversy is the growing influence of the White House office with responsibility for cost-benefit review: the Office of Information and Regulatory Affairs (OIRA), within the Office of Management and Budget (OMB). Traditionally, OIRA has had fairly minimal interactions with submitting agencies as they prepare cost-benefit analyses. But under its current administrator, John Graham, OIRA has become intimately involved in all aspects of the cost-benefit process. During the eight years of the Clinton administration, OIRA sent 16 rules back to agencies for rewriting. Graham sent back 19 rules (not all of which were environmental) during his first year alone.

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[25] Much of this debate could be reconciled if the critiques distinguished concerns about the CV itself from a belief that CV estimates do not measure economic values because they are not the result of an economic choice (Smith 2000).

Originally, CBAs reflected mainly market benefits such as job creation and added retail sales. More recently, attempts have been made to incorporate the environmental impacts of projects/policies within CBA to improve the quality of government decision-making. The use of ESV allows CBA to be more comprehensive in scope by incorporating environmental values and putting them on the same footing as traditional economic values.

EPA's National Center for Environmental Economics' online library is a good source for all CBAs of that agency's regulations conducted over the years. The most common ESV application by the EPA involves analyses of the benefits of specific regulations as part of Regulatory Impact Analyses (RIAs). Although RIAs—and hence ESV—have been performed for numerous rules, the scope and quality of the ESV in these RIAs has varied widely. A review of 15 RIAs performed by the EPA between 1981 and 1986 (EPA and OPA 1987) found that only six of the 15 RIAs addressed by the study presented a complete analysis of monetized benefits and net benefits. The 1987 study notes that many rule makings were improved by the analysis of benefits and costs, even where benefits were not monetized and net benefits were not calculated.

One famous example of the use of CEA is the 1996 New York Catskills Mountains Watershed case where New York City administrators decided that investment in restoring the ecological integrity of the watershed would be less costly in the long-run than constructing a new water filtration plant. New York City invested between $1 billion and $1.5 billion in restoratory activities in the expectation of realizing cost savings of $6 billion–$8 billion over 10 years, giving an internal rate of return of 90–170% and a payback period of 4–7 years. This return is an order of magnitude higher than is usually available, particularly on relatively risk-free investments (Chichilnsky and Heal 1998).

ESV in value transfer

V*alue transfer* (or benefit transfer) is defined as the adaptation of existing ESV information or data to new policy contexts that have little or no data. The transfer method involves obtaining an estimate for the value of ecosystem services through the analysis of a single study, or group of studies, that have been previously carried out to value "similar" goods or services in "similar" locations. The transfer itself refers to the application of derived values and other information from the original 'study site' to a 'policy site' which can vary across geographic space and/or time (Brookshire and Neill 1992, Desvouges et al. 1992). For example, an estimate of the benefit obtained by tourists viewing wildlife in one park (study site) might be used to estimate the benefit obtained from viewing wildlife in a different park (policy site).

Over time, the transfer method has become a practical way of making informed decisions when primary data collection is not feasible due to budget and time constraints (Moran 1999). Primary valuation research is always a "first-best" strategy in which information is gathered that is specific to the location and action being evaluated. However, when primary research is not possible or plausible, then value transfer, as a "second-best" strategy, is important to evaluating management and policy impacts. For instance, EPA's regulation development process almost always involves value transfer. Although it is explicitly recognized in the EPA's *Guidelines for Preparing Economic Analyses (2000)* that this is not the optimal situation, but conducting an original study for anything but the largest regulation is almost impossible. This is due to the fact that any primary research must be peer-reviewed if it is to be accepted for regulation development, which requires both time and money (Griffiths 2002).

However, many original valuation studies are not designed for application purpose in the comparative framework that is inherent to the value transfer method, making the identification and recovery of suitable empirical studies for transfer difficult. In fact, in many cases valuation estimates are generated as a by-product of efforts to clarify research methods (McConnell 1992). This has resulted in a somewhat paradoxical situation in the peer-reviewed economic valuation literature that when a methodology is well understood and achieves reasonably high levels of professional acceptance, the attention of editors and readers shifts to new issues. As a result, peer-reviewed publications often serve merely as a vehicle for illustrating the most recent valuation method. Little interest is expressed in replication of studies or in new applications of previously developed methods, the very things which are required for developing policy for sites and actions not explicitly involved in the original study (Smith 1992).

This problem could be partly solved by constructing databases that collect ESV information for the purpose of value transfer[26]. Recognizing the widespread need for a non-market valuation library, Environment Canada, in collaboration with the U.S. Environmental Protection Agency and leading North American experts, has developed a value transfer database: the Environmental Valuation Reference Inventory ™ (EVRI™) {De Civita, 1998 #92}. Other similar efforts include the EnValue database sponsored by New South Wales Environmental Protection Authority in Australia (http://www.epa.nsw.gov.au/envalue/) and the ocean-related ESV database of National Ocean Economic Program (http://essp.csumb.edu/noep/index.html). As acknowledged by these websites, care must be taken in transferring database values to other sites, and there is neither a generally accepted verdict on the utility of these efforts to date or on a value transfer protocol in general.

Integration with GIS and Modeling

Geographical Information Systems (GIS) have been used to increase the context specificity of value transfer (e.g. Eade and Moran 1996, Wilson et al. 2004). In doing so, the value transfer process is augmented with set of spatially explicit factors, so that geographical similarities between the policy site and the study site are more easily detected. In addition, the ability to present and calibrate economic valuation data in map form offers a powerful means for expressing environmental and economic information at multiple scales to stakeholders.

Thanks to the increased ease of using Geographic Information Systems (GIS) and the public availability of land cover data sets derived from satellite images, geographic information can more easily be attributed with ecosystem service values. In simplified terms, the technique involves combining one land cover layer with another layer representing the geography by which ecosystem services are aggregated - i.e. watershed, town or park. ESV is made spatially explicit by disaggregating landscapes into their constituent land cover elements and ecosystem service types (Wilson et al. 2004). Spatial disaggregation increases the potential management applications for ecosystem service valuation by allowing users to visualize the explicit location of ecologically important landscape elements and overlay them with other relevant themes for analysis. Disaggregation is also important for descriptive purposes, for the pattern of variation is often much more telling than any aggregate statistic.

In order for stakeholders to evaluate the change in ecosystem services, they must be able to query ecosystem service values for a specific and well-defined area of land that is related to an issue pertinent to them. For this reason, several types of spatially-explicit boundary data can be linked to land cover and valuation data within a GIS. The aggregation units used for ecosystem service mapping efforts should be driven by the intended policy or management application, keeping in mind that there are tradeoffs to reducing the resolution too much. For example, a local program targeted at altering land management for individual large property owners might want to use individual land parcel boundaries as the aggregation unit. However, such a mapping level would yield far too much information for national-level application. A state agency whose programs affect all lands in the state (e.g. a water resources agency) might use watersheds as units or a state agency managing state parks might be better off using the park boundaries, or park district boundaries as units.

For example, The EcoValue Project (Wilson et al. 2003) draws from recent developments in ecosystem service valuation, database design, internet technology, and spatial analysis techniques to create a web-accessible, GIS decision support system. The site uses empirical studies from the published literature that

[26] In addition, development of more transferable value measures and further development of value transfer techniques is also very important.

are then used to estimate the economic value of ecosystem services (see http://ecovalue.uvm.edu). Using watersheds as the primary unit of spatial aggregation the project provides ecosystem service value estimates for the State of Maryland and the four state Northern Forest region including New York, Vermont, New Hampshire and Maine. The end result is a GIS value-transfer platform that provides the best available valuation data to researchers, decision-makers, and public stakeholders working in throughout the world.

In a study of the Massachusetts landscape using a similar technique, Wilson and colleagues (Wilson et al. 2004), found that the annual non-market ecosystem service value was over $6.3 billion annually for the state. As in many areas, most development in Massachusetts has come at the expense of forest and agricultural land. Based on the net forest and agricultural land lost to all forms of development between 1985 and 1999, an *ex post* study showed that the state lost over $200 million *annually* in ecosystem service value during the period, based on 2001 US dollars. Had the same amount of development occurred in a way that impacted less forest and agricultural land through denser "in-fill" development and more brownfield development, the state could have enjoyed the economic benefits of both development and ecosystem services (Massachusetts Audubon Society 2003).

Recognizing the value of ecosystem services, decision-makers have started to adopt *ex ante* ESV research linked with computer modeling. An example of this was an integrated modeling and valuation study of fynbos ecosystems in South Africa (Higgins et al. 1997). In this example, a cross-section of stakeholders concerned about the invasion of fynbos ecosystems by European pine trees worked together to produce a simulation model of the dynamics and value of the ecosystem services provided by the system. The model allowed the user to vary assumptions and values for each of the services and observe the resulting behavior and value of the ecosystem services from the system. This model was subsequently used by park managers to design (and justify) containment and removal efforts for the pine trees.

In a more recent example, the city of Portland's Watershed Management Program recently sponsored a Comparative Valuation of Ecosystem Services (CVES) analysis in order to understand the tradeoffs between different flood control plans. Integrated with ecosystem modeling, an ESV study under CVES showed that a proposed flood abatement project in Lent area could provide more than $30,000,000 in benefits (net presented value) to the public over a 100-year timeframe. Five ecosystem services would increase productivity as a result of floodplain function improvements and riparian restoration (David Evans and Associates Inc. and EcoNorthwest 2004).

Modeling has also been combined with GIS to understand and value the spatial dynamics of ecosystem services. An example of this application was a study of the 2,352 km^2 Patuxent river watershed in Maryland (Bockstael et al. 1995, Costanza et al. 2002). This model was used to addresses the effects of both the magnitude and spatial patterns of human settlements and agricultural practices on hydrology, plant productivity, and nutrient cycling in the landscape, and the value of ecosystem services related to these ecosystem functions. Several historical and future scenarios of development patterns were evaluated in terms of their effects on both the biophysical dynamics of ecosystem services and the value of those services.

Debate on the use of ESV

There are multiple policy purposes and uses of ESV. These uses include:

1. to provide for comparisons of contributions of natural capital to human welfare with those of physical and human capital.
2. to monitor the quantity and quality of natural capital over time with respect to its contribution to human welfare
3. to provide for evaluation of projects that propose to change (enhance or degrade) natural capital.

Much of the debate about the use of ESV has to do with not appreciating this range of purposes.

In addition there are a range of other obstacles and objections to the use of ESV. In summarizing experiences in terms of ESV use from six countries, Barde and Pearce (1991) mentioned three main categories of obstacles: (1) ethical and philosophical, (2) political, and (3) methodological and technical. Below we discuss each of these in greater detail.

Ethical and philosophical debate

Ethical and philosophical obstacles proceed from a criticism of the conventional welfare economics foundations of ESV. In particular, "monetary reductionism", illustrated by the willingness-to-pay criterion, is strongly rejected in "deep ecology" circles or by those who claim that ecosystems are not economic assets and that it is therefore immoral to measure them in monetary terms (e.g. Norgaard et al. 1998). As a one-dimensional concept, based exclusively on individual's preferences, the principle of maximizing expected utility is judged to be inadequate and too reductionist a basis on which to make decisions involving environmental assets, irreversibility and future generations (Vatn and Bromley 1994, Matinez-Alier et al. 1998).

Practitioners of ESV argue the ESV concept is much more complex and nuanced than these objections acknowledge. Monetization is simply a convenient means of expressing the relative values that society places on different ecosystem services. If these values are presented solely in physical terms—so much less provision of clean water, perhaps, and so much more production of crops—then the classic problem of comparing apples and oranges applies. The purpose of monetary valuation is to make the disparate services provided by ecosystems comparable to each other, using a common metric. Alternative common metrics exist (including energy units and land units i.e. the "ecological footprint") but in the end, the choice of metric is not critical since, given appropriate conversion factors, one could always translate results of the underlying trade-offs from one metric to another.

The key issue here comes down to trade-offs. *If* one does not have to make tradeoffs between ecosystem services and other things, *then* valuation is not an issue. *If* however, one does have to make such tradeoffs, *then* valuation will occur, whether it is explicitly recognized or not (Costanza et al. 1997). Given this, it seems better that the trade-offs be made explicit.

Their usefulness lies in the fact that they use easily understood and accepted rules to reduce complex clusters of effects and phenomena to single-valued commensurate magnitudes, that is, to dollars. The value of the benefit-cost framework lies in its ability to organize and simplify certain types of information into commensurate measures (Arrow et al. 1996, science).

While we believe that there is a strong case in favor of monetary valuation as a decision aid to help make trade-offs more explicit, we also recognize that there are limits to its use. Expanding ESV towards sustainability and fairness goals (on top of the traditional efficiency goal) will help expand the boundaries of those limits (Costanza and Folke 1997). A multiple attribute decision making (MADM) system that incorporates the triple goals might appear to alleviate the limitations of monetary valuation, but in fact it does not. If there are real trade-offs in the system, those trade-offs with have to be evaluated one way or the other. A MADM facilitates greater public participation and collaborative decision making, and allows consideration of multiple attributes (Prato 1999) but it does not eliminate the need to assess trade-offs, and, as we have said, conversion to monetary units is only one way of expressing these trade-offs.

Political debate

The very objective and virtue of ESV is to make policy objectives and decision criteria explicit, e.g. what are the actual benefits of a given course of action? What is the best alternative? Is the government making an efficient use of environmental resources and public funds? Introducing a public debate on such issues is often unattractive to technical experts and decision makers and may significantly reduce their margin of action and decision autonomy. Therefore, there may be some reluctance to introduce ESV into political or regulatory debates[27].

Notwithstanding this, humans have to make choices and trade-offs concerning ecosystem services, and, as mentioned above, this implies and requires "valuation" because any choice between competing alternatives implies that the one chosen was more highly "valued." Practitioners of ESV argue that society can make better choices about ecosystems if the valuation issue is made as explicit as possible. This means taking advantage of the best information we can muster, making the uncertainties in that information explicit, and developing new and better ways to make good decisions in the face of these uncertainties. Ultimately, it means being explicit about our goals as a society, both in the short term and in the long term, and understanding the complex relationships between current activities and policies and their ability to achieve these goals (Costanza 2000).

As Arrow and colleagues (1996, science) argued, it should be considered as a framework and a set of procedures to help organize available information. Viewed in this light, benefit-cost analysis does not dictate choices; nor does it replace the ultimate authority and responsibility of decisonmakers. It is simply a tool for organizing and expressing certain kinds of information on the range of alternative courses of action. The usefulness of value estimates must be assessed in the context of this framework for arraying information (Freeman 2003).

The more open decisionmakers are about the problems of making choices and the values involved and the more information they have about the implications of their choices, the better their choices are likely to be (Freeman 2003)

Methodological and technical debate

ESV has been also been criticized on methodological and technical grounds. There are a range of issues here which are covered in detail elsewhere (cf. Costanza et al. 1997b, Costanza 1998, Costanza et al. 1998, Pearce 1998, Bockstael et al. 2000, Costanza and Farber 2002). For the purposes of this discussion, we will focus on two major issues that seem to underlie much of the debate: purpose and accuracy.

One line of criticism has been that ESV can only be used to evaluate *changes* in ecosystem service values. For example, Bockstael et al. (2000) contend that assessing the total value of global, national, or state level ecosystem services is meaningless because it does not relate to *changes* in services and one would not really consider the possibility of eliminating the entire ecosystem at these scales. But, as mentioned earlier, there are at least three possible purposes for ESV, and this critique has to do with confusing purpose #3 (assessing changes) with purpose #1 (comparing the contributions of natural capital to human welfare with those of physical and human capital).

[27] This requires ESV researchers to do more than simply develop good ideas to influence policy. They need to understand how the political process affects outcomes, and actively market the use of appropriate and feasible methodologies for promoting environmental policy. In other words, ESV research has to become more problem-driven rather than tool-driven (Hahn 2000).

To better understand this distinction, the following diagram is helpful:

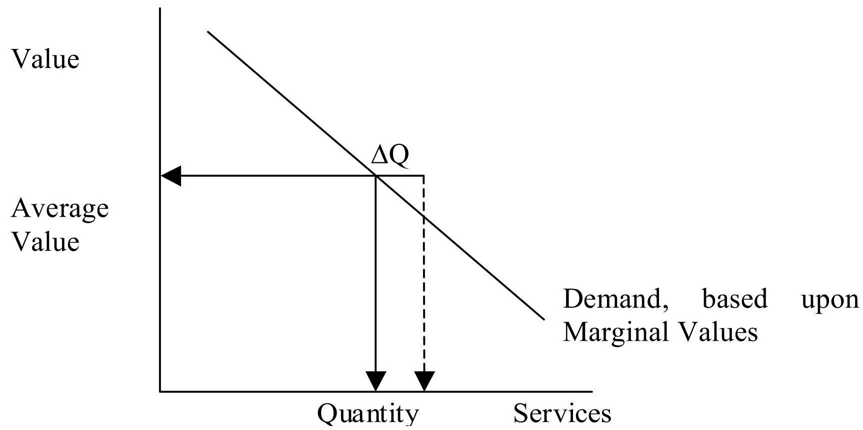

Figure 6. A model of Ecosystem Service Valuation

The Demand for Services reflects the Marginal Valuations of increasing service levels. The Quantity of Services available determines the Average Valuation of that service over its entire range. Consequently, Average Value x Quantity, would represent a "Quasi-Market Valuation" of that service level. In a restricted sense, if there were a market for the service, this would be the revenue obtained from the service; comparable to an indicator like the sales volume of the retail sector. It would be directly comparable and analogous to the valuation of income flows from physical capital, and could be capitalized to reflect the market value of natural capital and compared to similarly capitalized values for physical investment. Furthermore, changes in the volume or value of this service could be capitalized to reflect the value of new natural capital investment/disinvestment, just as we measure new investment and depreciation in physical capital at the macro level (Howarth and Farber 2002)

This "Quasi-market value" has a restricted meaning. Of course, it does not reflect the "Full Value" to human welfare of the service, since full value is the sum of marginal values; i.e., the area under the Demand curve. However, the more substitutes there are available for the service, the less the difference between "Full Value" and this Quasi-market value. In addition, this quasi-market value is more directly comparable with the quasi-market value of the physical and human capital contributors to human welfare as measured in aggregate indicators like GDP. So, if one's purpose is to compare contributions of natural capital to human welfare with those of physical and human capital (as estimated in GDP, for example) then this is an appropriate (albeit not perfect) measure.

Furthermore, if there really were a market for the service, and economies actually had to pay for it, the entire economics of many markets directly or indirectly impacted by the service would be altered (Costanza et al. 1998). For example, electricity would become more costly, altering its use and the use of energy sources, in turn altering the costs and prices of energy using goods and services. The changes in economic markets would likely feedback on the Demand for the Service, increasing or decreasing it, depending on the service and its economic implications. The "true market value" could only be determined through full scale ecologic-economic modeling. While modeling of this type is underway (cf. Boumans et al. 2002), it is costly and difficult to do, and meanwhile decisions must be made. The "Quasi-market value" is thus a reasonable first order approximation for policy and public discourse purposes if we want to compare the contributions of natural capital to the contributions of other forms of capital to human welfare.

ESV can also be used to assess the impacts of specific changes or projects. Balmford et. al. (2002) is a recent example of this use of ESV at the global scale. In this study, the costs and benefits of expanding the global nature reserve network to encompass 15% of the terrestrial biosphere and 30% of the marine biosphere were evaluated, concluding that the benefit-cost ratio of this investment was approximately 100:1. In these circumstances, Average Value x ΔQ, is likely to be a reasonable measure of the economic value of the change in services; an overestimate of benefits for service increases, and an underestimate of costs for service decreases. The degree of over- or under-estimate depends again on the replaceability of the service being gained or lost.

Beyond the purpose confusion, the *accuracy* of ESV is also sometimes questioned. Diamond and Hausman (1994), for instance, asked the question, "[In] *contingent valuation--is some number better than no numbers?*"

In our view, the answer to this question also depends on the intended use of the ESV result and the corresponding accuracy required (Brookshire and Neill 1992, Desvousges et al. 1992). As Figure 7 shows we can think of accuracy as existing along a continuum whereby the minimum degree of accuracy needed is related to the cost of making a wrong decision based on the ESV result.

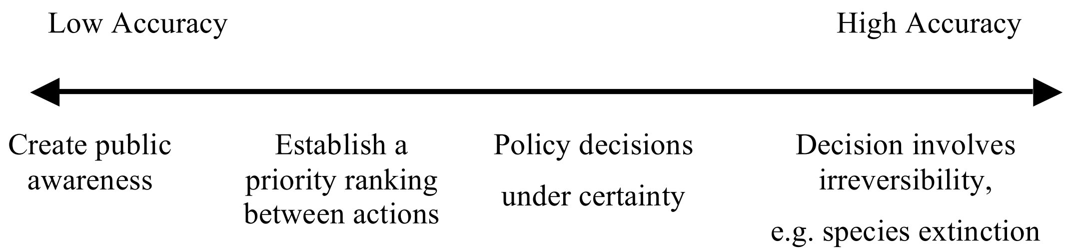

Figure 7. Accuracy Continuum for the ESV (adapted from Desvousges and Johnson 1998)

For example, using ESV to assist an environmental policy decision-maker in setting broad priorities for assessment and possibly action may require a moderate level of accuracy. In this regard, any detriment resulting from minor inaccuracies is adequately offset by the potential gains. This use of ESV represent a gain in knowledge that costs society relatively little if the ESV results are later found to be inaccurate. As Figure 6 also shows, however, if ESV is used as a basis for a management decision that involves irreversibility, the costs to society of a wrong decision can be quite high. In this case, it can be argued that the accuracy of a value transfer should be very high.

Findings and directions for the future

ESV in research—the need for a transdisciplinary approach

ESV is often complex, multi-faceted, socially contentious and fraught with uncertainty. In contrast, traditional ESV research involves the work of experts from separate disciplines, and these studies often turn out to be overly simple, uni-dimensional and "value-free". Our survey of the literature has shown that over time, there has been movement toward a more transdisciplinary approach to ESV research that is more consistent with the nature of the problems being addressed.

The truly *transdisciplinary* approach ultimately required for ESV is one in which practitioners accept that disciplinary boundaries are academic constructs that are irrelevant outside of the university and allow the problem being studied to determine the appropriate set of tools, rather than vice versa.

What is needed are ESV studies that encompass all the components mentioned in Figure 1 earlier, including ecological structures and processes, ecological functions, ecosystem services, human welfare, land use decisions and the dynamic feedbacks between them. To our knowledge, there have been few such studies to date (Boumans et al. 2002 is one example). But it is just this type of study that is of greatest relevance to decision makers (Turner et al. 2003) and looks to be the way forward.

ESV in practice—moving beyond the efficiency goal

We attempted to quantify ESV's contribution to environmental policy-making by answering questions like "to what extent is ESV actually used to make real decisions?" However, we soon realized that this goal was too ambitious. Instead, along with other reviewers (e.g. Pearce and Seccombe-Hett 2000, Adamowicz 2004), we found that the contribution of ESV to ecosystem management has not been as large as hoped or as clear as imagined, although it is widely used in micro-level studies, including NRDA, CBA-CEA, value transfer analysis, and studies integrating ESV with GIS and/or ecosystem modeling.

We discussed the three types of obstacles to the use of ESV in policy making. While there is a strong case in favor of monetary valuation as a decision aid, we also recognize that there are limits to its use. These limitations are due to the complexity of both ecological systems and values, which could be more adequately incorporated by the triple-goal ESV system. Valuing ecosystem services with not only efficiency, but also fairness and sustainability as goals, is the next step needed to promote the use of ESV in ecosystem management and environmental policy making. This new system can be well supported by current transdisciplinary methodologies, such as participatory assessment (Campell and Luckert 2002), group valuation (Jacobs 1997, Wilson and Howarth 2002), and the practice of integrating ESV with GIS and ecosystem modeling (Bockstael et al. 1995, Costanza et al. 2002, Boumans et al. 2002, Wilson et al. 2004).

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Appendix C. Value Transfer Detailed Reports

New Jersey Value-Transfer Detailed Report (Type A)

Land Cover		Author(s)	Method	Min	Max	Single Value	Mean	Median
				2004 dollars per acre/year				
Beach								
	Disturbance prevention							
		Pompe, J. J. and Rinehart, J. R.-1995	HP			$33,738	$33,738	$33,738
		Parsons, G. R. and Powell, M.-2001-2001	HP			$20,814	$20,814	$20,814
						Disturbance prevention	**$27,276**	**$27,276**
	Aesthetic & Recreational							
		Taylor, L. O. and Smith, V. K.-2000	HP	$392	$1,058		$725	$725
		Silberman, J., Gerlowski, D. A. and Williams, N. A.1992	CV			$20,680	$20,680	$20,680
		Kline, J. D. and Swallow, S. K.-1998	CV	$33,051	$42,654		$37,853	$37,853
		Edwards, S. F. and Gable, F. J.-1991	HP			$131	$131	$131
						Aesthetic & Recreational	**$14,847**	**$10,703**
	Cultural & Spiritual							
		Taylor, L. O. and Smith, V. K.-2000	HP			$24	$24	$24
						Cultural & Spiritual	**$24**	**$24**
						Beach Total	**$42,147**	**$38,002**

Land Cover		Author(s)	Method	Min	Max	Single Value	Mean	Median
				2004 dollars per acre/year				
Cropland								
	Pollination							
		Southwick, E. E. and Southwick, L.-1992	DM	$2	$8		$5	$5
		Robinson, W. S., Nowogrodzki, R. and Morse, R. A.-1989	AC			$11	$11	$11
						Pollination	**$8**	**$8**
	Aesthetic & Recreational							
		Bergstrom, J., Dillman, B. L. and Stoll, J. R.-1985	CV			$26	$26	$26
		Alvarez-Farizo, B., Hanley, N., Wright, R. E. and MacMillan, D.	CV			$4	$4	$4
						Aesthetic & Recreational	**$15**	**$15**
						Cropland Total	**$23**	**$23**
Estuary								
	Water supply							
		Whitehead, J. C., Hoban, T. L. and Clifford, W. B.-1997	CV	$6	$21		$13	$13
		Leggett, C. G. and Bockstael, N. E.-2000	HP			$40	$40	$40
		Bocksteal, N. E., McConnell, K. E. and Strand, I. E.1989	CV	$67	$120		$94	$94
						Water supply	**$49**	**$40**
	Refugium function							
		Johnston, R. J. et. al.-2002	MP			$412	$412	$412
		Johnston, R. J. et. al.-2002	MP			$1,298	$1,298	$1,298

Land Cover		Author(s)	Method	Min	Max	Single Value	Mean	Median
				2004 dollars per acre/year				
Estuary, cont.		Johnston, R. J. et. al.-2002	MP			$82	$82	$82
	.	Farber, S. and Costanza, R.-1987	MP			$15	$15	$15
		Farber, S. and Costanza, R.-1987	MP			$11	$11	$11
						Refugium function	**$364**	**$82**
	Aesthetic & Recreational							
		Whitehead, J. C., Hoban, T. L. and Clifford, W. B.-1997	CV	$1	$5		$3	$3
		Whitehead, J. C., Hoban, T. L. and Clifford, W. B.-1997	CV	$9	$81		$45	$45
		Morey, E. R., Shaw, W. D. and Rowe, R. D.	TC			$68	$68	$68
		Johnston, R. J. et. al.-2002	TC			$148	$148	$148
		Johnston, R. J. et. al.-2002	TC			$289	$289	$289
		Johnston, R. J. et. al.-2002	TC			$333	$333	$333
		Johnston, R. J. et. al.-2002	TC			$158	$158	$158
		Johnston, R. J. et. al.-2002	TC			$219	$219	$219
		Johnston, R. J., Opaluch, J. J., Grigalunas, T. A. and Mazzotta, M. J.	CV			$1,462	$1,462	$1,462
						Aesthetic & Recreational	**$303**	**$158**
						Estuary Total	**$715**	**$281**

Land Cover		Author(s)	Method	Min	Max	Single Value	Mean	Median
				2004 dollars per acre/year				
Forest								
	Gas & Climate regulation							
		Pimentel, D.-1998	AC			$13	$13	$13
		Tol, R. S. J.	MP			$57	$57	$57
		Tol, R. S. J.	MP			$302	$302	$302
		Schauer, M. J.	MP			$318	$318	$318
		Schauer, M. J.	MP			$23	$23	$23
		Roughgarden, T. and Schneider, S. H.	MP		$184	$39	$39	$39
		Reilly, J. M. and Richards, K. R.	MP			$49	$49	$49
		Reilly, J. M. and Richards, K. R.	MP			$42	$42	$42
		Reilly, J. M. and Richards, K. R.	MP			$20	$20	$20
		Reilly, J. M. and Richards, K. R.	MP			$14	$14	$14
		Plambeck, E. L. and Hope, C.	MP	$371	$933	$419	$419	$419
		Plambeck, E. L. and Hope, C.	MP	$10	$46	$20	$20	$20
		Nordhaus, W. D. and Popp, D.	MP	$0.04	$32	$11	$11	$11
		Nordhaus, W. D. and Popp, D.	MP	$1	$42	$6	$6	$6
		Nordhaus, W. D. and Yang, Z. L.	MP			$0.23	$0.23	$0.23
		Nordhaus, W. D. and Yang, Z. L.	MP			$6	$6	$6
		Nordhaus, W. D.	MP			$5	$5	$5
		Nordhaus, W. D.	MP	$2	$15	$7	$7	$7
		Nordhaus, W. D.	MP	$0.31	$2	$1	$1	$1
		Nordhaus, W. D.	MP	$8	$66	$31	$31	$31

Land Cover	Author(s)	Method	Min	Max	Single Value	Mean	Median
			2004 dollars per acre/year				
Forest, cont.	Newell, R. G. and Pizer, W. A.	MP	$7	$23		$15	$15
	Newell, R. G. and Pizer, W. A.	MP	$10	$34		$22	$22
	Maddison, D.	MP			$16	$16	$16
	Hope, C. and Maul, P.	MP	$11	$43	$28	$28	$28
	Fankhauser, S.	MP	$23	$66	$40	$40	$40
	Fankhauser, S.	MP	$5	$37	$17	$17	$17
	Fankhauser, S.	MP	$6	$43	$19	$19	$19
	Azar, C. and Sterner, T.	MP			$66	$66	$66
	Azar, C. and Sterner, T.	MP			$10	$10	$10
	Azar, C. and Sterner, T.	MP			$202	$202	$202
	Azar, C. and Sterner, T.	MP			$30	$30	$30
			Gas & Climate regulation			**$60**	**$20**
Water supply							
	Loomis, J. B.	TC	$9	$9		$9	$9
					Water supply	**$9**	**$9**
Pollination							
	Hougner, C.	RC	$59	$265		$162	$162
					Pollination	**$162**	**$162**
Refugium function and Wildlife conservation							
	Shafer, E. L. et. al.-1993	CV			$3	$3	$3
	Kenyon, W. and Nevin, C.-2001	CV			$426	$426	$426

Land Cover	Author(s)	Method	Min	Max	Single Value	Mean	Median
			2004 dollars per acre/year				
	Haener, M. K. and Adamowicz, W. L.-2000	CV	$1	$7		$4	$4
	Amigues, J. P., et. al.-2002	CV	$55	$208		$132	$132
	Amigues, J. P., et. al.-2002	CV	$1,140	$2,158		$1,649	$1,649
	Garrod, G. D. and Willis, K. G.	CV			$15	$15	$15
	Garrod, G. D. and Willis, K. G.	CV	$3,101	$3,383		$3,242	$3,242
	Garrod, G. D. and Willis, K. G.	CV	$1,817	$2,003		$1,910	$1,910
				Refugium function		**$923**	**$279**
Aesthetic & Recreational							
	Willis, K. G.-1991	TC	$89	$162		$126	$126
	Willis, K. G.-1991	TC	$20	$35		$28	$28
	Willis, K. G.-1991	TC	$8	$15		$12	$12
	Willis, K. G.-1991	TC	$5	$5		$5	$5
	Willis, K. G.-1991	TC	$0	$1		$1	$1
	Willis, K. G. and Garrod, G. D.-1991	TC			$4	$4	$4
	Shafer, E. L., et. al.-1993	CV			$459	$459	$459
	Prince, R. and Ahmed, E.-1989	CV	$1	$2		$1	$1
	Maxwell, S.-1994	CV			$10	$10	$10
.	Haener, M. K. and Adamowicz, W. L.2000	CV			$0	$0	$0
	Boxall, P. C., McFarlane, B. L. and Gartrell, M.-1996	TC			$0	$0	$0
	Bishop, K.-1992	CV			$543	$543	$543
	Bishop, K.-1992	CV			$485	$485	$485

Land Cover	Author(s)	Method	Min	Max	Single Value	Mean	Median
					2004 dollars per acre/year		
Forest, cont.	Bennett, R., et. al.-1995	CV			$144	$144	$144
					Aesthetic & Recreational	**$130**	**$11**
					Forest Total	**$1,283**	**$481**
Freshwater Wetland							
Water regulation							
	Thibodeau, F. R. and Ostro, B. D.-1981	AV			$5,957	$5,957	$5,957
					Water regulation	**$5,957**	**$5,957**
Water supply							
	Pate, J. and Loomis, J.-1997	CV			$3,066	$3,066	$3,066
	Lant, C. L. and Roberts, R. S.-1990	CV	$0	$0		$0	$0
	Lant, C. L. and Tobin, G.-1989	CV			$170	$170	$170
	Lant, C. L. and Tobin, G.-1989	CV			$1,868	$1,868	$1,868
	Hayes, K. M., Tyrrell, T. J. and Anderson, G.-1992	CV	$1,097	$1,706		$1,401	$1,401
	Creel, M. and Loomis, J.-1992	TC			$462	$462	$462
.					***Water supply***	**$1,161**	**$932**
Refugium function and Wildlife conservation							
	Vankooten, G. C. and Schmitz, A.-1992	CV			$5	$5	$5
					Refugium function	**$5**	**$5**

Land Cover		Author(s)	Method	Min	Max	Single Value	Mean	Median
						2004 dollars per acre/year		
Freshwater wetland, cont.	*Aesthetic & Recreational*							
		Whitehead, J. C.-1990	CV	$890	$1,790		$1,340	$1,340
		Thibodeau, F. R. and Ostro, B. D.-1981	CV			$559	$559	$559
		Thibodeau, F. R. and Ostro, B. D.-1981	TC	$27	$86		$56	$56
		Mahan, B. L., Polasky, S. and Adams, R. M.-2000	TC			$30	$30	$30
		Hayes, K. M., Tyrrell, T. J. and Anderson, G.-1992	CV	$1,033	$1,975		$1,504	$1,504
		Doss, C. R. and Taff, S. J.-1996	TC			$3,942	$3,942	$3,942
		Doss, C. R. and Taff, S. J.-1996	TC			$3,568	$3,568	$3,568
						Aesthetic & Recreational	**$1,571**	**$1,340**
						Freshwater Wetland Total	**$8,695**	**$8,234**
Open Fresh Water								
	Water supply							
		Ribaudo, M. and Epp, D. J.-1984	TC	$567	$719		$643	$643
		Piper, S.-1997	CV			$28	$28	$28
		Henry, R., Ley, R. and Welle, P.1998	CV			$366	$366	$366
		Croke, K., Fabian, R. and Brenniman, G.-1986	CV			$482	$482	$482
		Bouwes, N. W. and Scheider, R.-1979	TC			$526	$526	$526
						Water supply	**$409**	**$482**

Land Cover		Author(s)	Method	Min	Max	Single Value	Mean	Median
				2004 dollars per acre/year				
Open freshwater, cont.	*Aesthetic & Recreational*							
		Young, C. E. and Shortle, J. S.	HP			$70	$70	$70
		Ward, F. A., Roach, B. A. and Henderson, J. E.-1996	TC	$17	$1,635		$826	$826
		Shafer, E. L. et. al. -1993	CV			$83	$83	$83
		Shafer, E. L. et. al. -1993	TC			$470	$470	$470
		Shafer, E. L. et. al. -1993	TC			$938	$938	$938
		Piper, S.-1997	TC			$205	$205	$205
		Patrick, R.,et. al. -1991	TC	$1	$22		$12	$12
		Kreutzwiser, R.-1981	TC			$154	$154	$154
		Kealy, M. J. and Bishop, R. C.-1986	TC			$11	$11	$11
		Cordell, H. K. and Bergstrom, J. C.-1993	CV	$162	$679		$420	$420
		Cordell, H. K. and Bergstrom, J. C.-1993	CV	$115	$242		$179	$179
		Cordell, H. K. and Bergstrom, J. C.-1993	CV	$241	$682		$462	$462
		Cordell, H. K. and Bergstrom, J. C.-1993	CV	$326	$1,210		$768	$768
		Burt, O. R. and Brewer, D.-1971	TC			$393	$393	$393
				Aesthetic & Recreational			**$356**	**$299**
				Open Fresh Water Total			**$765**	**$781**

Land Cover		Author(s)	Method	Min	Max	Single Value	Mean	Median
				2004 dollars per acre/year				
Pasture								
	Gas & Climate regulation							
		Sala, O. E. and Paruelo, F. M.	MP	$4	$10	$5	$5	$5
				Gas & Climate regulation			**$5**	**$5**
	Soil formation							
		Pimentel, D.-1998	DM			$6	$6	$6
				Soil formation			**$6**	**$6**
	Aesthetic & Recreational							
		Boxall, P. C.-1995	TC			$0.03	$0.03	$0.03
		Alvarez-Farizo, B., Hanley, N., Wright, R. E. and MacMillan, D.				$1	$1	$1
				Aesthetic & Recreational			**$1**	**$1**
				Pasture Total			**$12**	**$12**
Riparian Buffer								
	Disturbance prevention							
		Rein, F. A.-1999	TC	$45	$201		$123	$123
		Rein, F. A.-1999	TC	$6	$99		$53	$53
				Disturbance prevention			**$88**	**$88**
	Water supply							
		Rich, P. R. and Moffitt, L. J.-1982	HP			$4	$4	$4
		Rein, F. A.-1999	AC	$36	$158		$97	$97

Land Cover		Author(s)	Method	Min	Max	Single Value	Mean	Median
				2004 dollars per acre/year				
Riparian buffer, cont.		Oster, S.-1977	CV			$13	$13	$13
		Mathews, L. G., Homans, F. R. and Easter, K. W.-2002	CRS			$11,089	$11,089	$11,089
		Kahn, J. R. and Buerger, R. B.	TC	$0.15	$0.77		$0.46	$0.46
		Kahn, J. R. and Buerger, R. B.	TC	$3	$3		$6	$6
		Gramlich, F. W.-1977	CV			$188	$188	$188
		Danielson, L., et. al.-1995	CV			$4,095	$4,095	$4,095
		Berrens, R. P., Ganderton, P. and Silva, C. L.-1996	CV			$1,794	$1,794	$1,794
						Water supply	**$1,921**	**$97**
	Aesthetic & Recreational							
		Sanders, L. D., Walsh, R. G. and Loomis, J. B.-1990	CV			$1,957	$1,957	$1,957
		Rein, F. A.-1999	DM	$26	$113		$69	$69
		Mullen, J. K. and Menz, F. C.-1985	TC			$328	$328	$328
		Kulshreshtha, S. N. and Gillies, J. A.-1993	HP			$43	$43	$43
		Greenley, D., Walsh, R. G. and Young, R. A.-1981	CV			$7	$7	$7
		Duffield, J. W., Neher, C. J. and Brown, T. C.-1992	CV			$1,256	$1,256	$1,256
		Duffield, J. W., Neher, C. J. and Brown, T. C.-1992	CV			$889	$889	$889
		Bowker, J. M., English, D. and Donovan, J.-1996	TC	$3,766	$9,052		$6,409	
						Aesthetic & Recreational	**$1,370**	**$608**

Land Cover		Author(s)	Method	Min	Max	Single Value	Mean	Median
				2004 dollars per acre/year				
Riparian buffer, cont.	*Cultural & Spiritual*							
		Greenley, D., Walsh, R. G. and Young, R. A.-1981	CV			$4	$4	$4
						Cultural & Spiritual	**$4**	**$4**
						Riparian Buffer Total	**$3,382**	**$797**
Saltwater Wetland or Salt Marsh								
	Disturbance prevention							
		Farber, S.-1987	AC	$1	$1		$1	$1
		Farber, S. and Costanza, R.-1987	AC			$1	$1	$1
						Disturbance prevention	**$1**	**$1**
	Waste treatment							
		Breaux, A., Farber, S. and Day, J.-1995	AC	$1,256	$1,942		$1,599	$1,599
		Breaux, A., Farber, S. and Day, J.-1995	AC	$103	$116		$109	$109
		Breaux, A., Farber, S. and Day, J.-1995	AC			$16,560	$16,560	$16,560
						Waste treatment	**$6,090**	**$1,599**
	Refugium function & Wildlife conservation							
		Lynne, G. D., Conroy, P. and Prochaska, F. J.-1981	ME			$1	$1	$1
		Farber, S. and Costanza, R.-1987	ME			$1	$1	$1
		Bell, F. W.-1997	FI	$144	$953		$549	$549

Land Cover	Author(s)	Method	Min	Max	Single Value	Mean	Median
			2004 dollars per acre/year				
Saltwater wetland, cont.	Batie, S. S. and Wilson, J. R.-1978	ME	$6	$735		$370	$370
					Refugium function	**$230**	**$186**
Aesthetic & Recreational							
	Farber, S.-1988	TC	$5	$14		$9	$9
	Bergstrom, J. C., et. al. -1990	CV			$14	$14	$14
	Anderson, G. D. and Edwards, S. F.-1986	HP	$20	$91		$55	$55
					Aesthetic & Recreational	**$26**	**$14**
Cultural & Spiritual							
	Anderson, G. D. and Edwards, S. F.-1986	CV	$120	$240		$180	$180
					Cultural & Spiritual	**$180**	**$180**
					Saltwater Wetland or Salt Marsh Total	**$6,527**	**$1,980**
Urban Green Space							
Gas & Climate regulation							
	McPherson, E. G., Scott, K. I. and Simpson, J. R.-1998	DM			$25	$25	$25
	McPherson, E. G.-1992	AC			$820	$820	$820
	McPherson, E. G.-1992	AC			$164	$164	$164
					Gas & Climate regulation	**$336**	**$164**

Land Cover		Author(s)	Method	Min	Max	Single Value	Mean	Median
				2004 dollars per acre/year				
Urban greenspace, cont.	*Water regulation*							
		McPherson, E. G.-1992	AC			$6	$6	$6
						Water regulation	**$6**	**$6**
	Aesthetic & Recreation							
		Tyrvainen, L.-2001	CV			$3,465	$3,465	$3,465
		Tyrvainen, L.-2001	CV			$1,182	$1,182	$1,182
		Tyrvainen, L.-2001	CV			$1,745	$1,745	$1,745
						Aesthetic & Recreation	**$2,131**	**$1,745**
						Urban Green Space Total	**$2,473**	**$1,915**

Code	**SubType**
DM	Direct market valuation
AC	Avoided Cost
RC	Replacement Cost
FI	Factor Income
TC	Travel Cost
HP	Hedonic Pricing
CV	Contingent Valuation
GV	Group Valuation
MD	Multiattribute Decision Analysis
EA	Energy Analysis
MP	Marginal Product Estimation
CRS	Combined Revealed and Stated Preference
MA	Meta-anlaysis
VT	Value Transfer

New Jersey Value-Transfer Detailed Report (Type A-C)

Land Cover	Ecosystem Service	Author(s)	Method	Min	Max	Single Value	Mean	Median
				2004 dollars per acre/year				
Beach								
	Disturbance prevention							
		Pompe, J. J. and Rinehart, J. R.-1995	HP			$33,738	$33,738	$33,738
		Parsons, G. R. and Powell, M.-2001	HP			$20,814	$20,814	$20,814
						Disturbance prevention	**$27,276**	**$27,276**
	Aesthetic & Recreational	Taylor, L. O. and Smith, V. K.-2000	HP	$392	$1,058		$725	$725
		Silberman, J., Gerlowski, D. A. and Williams, N. A.-1992	CV			$20,680	$20,680	$20,680
		Kline, J. D. and Swallow, S. K.-1998	TC	$33,051	$42,654		$37,853	$37,853
		Edwards, S. F. and Gable, F. J.-1991	HP			$131	$131	$131
						Aesthetic & Recreational	**$14,847**	**$10,703**
	Cultural & Spiritual	Taylor, L. O. and Smith, V. K.-2000	HP			$24	$24	$24
						Cultural & Spiritual	**$24**	**$24**
						Beach Total	**$42,147**	**$38,003**
Coastal Shelf								
	Water supply							
		Soderqvist, T. and Scharin, H.	CV	$243	$404		$323	$323
		Nunes, P and Van den Bergh, J.	CV			$517	$517	$517

Land Cover	Ecosystem Service	Author(s)	Method	Min	Max	Single Value	Mean	Median
				2004 dollars per acre/year				
Coastal shelf, cont.		Hanley, N., Bell, D. and Alvarez-Farizo, B.	CRS			$723	$724	$724
						Water supply	**$521**	**$517**
	Biological Control	Costanza, R. et. al.-1997	VT			$20	$20	$20
						Biological control	**$20**	**$20**
	Nutrient regulation	Costanza, R. et. al.-1997	VT			$723	$723	$723
						Nutrient regulation	**$723**	**$723**
	Cultural & Spiritual	Costanza, R. et. al.-1997	VT			$35	$35	$35
						Gas & Climate regulation	**$35**	**$35**
						Coastal Shelf Total	**$1,299**	**$1,295**
Cropland								
	Pollination	Southwick, E. E. and Southwick, L.-1992	DM	$2	$8		$5	$5
		Robinson, W. S., Nowogrodzki, R. and Morse, R. A.-1989	AC			$11	$11	$11
						Pollination	**$8**	**$8**
	Biological Control	Costanza, R. et al.	VT	$12	$12		$12	$12
						Biological control	**$12**	**$12**
	Refugium function & Wildlife conservation							
		Christie, M., Hanley, N, Warren, J., et al.	CV			$1,242	$1,242	$1,242

Land Cover	Ecosystem Service	Author(s)	Method	Min	Max	Single Value	Mean	Median
						2004 dollars per acre/year		
Cropland, cont.		Christie, M., Hanley, N, Warren, J., et al.	CV			$419	$419	$419
						Refugium function	**$831**	**$831**
	Aesthetic & Recreational	Bergstrom, J., Dillman, B. L. and Stoll, J. R.-1985	CV			$26	$26	$26
		Alvarez-Farizo, B., Hanley, N., Wright, R. E. et al.	CV			$4	$4	$4
						Aesthetic & Recreational	**$15**	**$15**
						Cropland Total	**$866**	**$865**
Estuary								
	Disturbance prevention	Costanza, R. et. al.-1997	VT	$286	$286		$286	$286
						Disturbance prevention	**$286**	**$286**
	Water supply	Whitehead, J. C., Hoban, T. L. and Clifford, W. B.-1997	CV	$6	$21		$13	$13
		Leggett, C. G. and Bockstael, N. E.-2000	HP			$40	$40	$40
		Bocksteal, N. E., McConnell, K. E. and Strand, I. E.-1989	CV	$67	$120		$94	$94
						Water supply	**$49**	**$40**
	Nutrient regulation	Costanza, R. et. al.-1997	VT	$10,658	$10,658		$10,658	$10,658
						Nutrient regulation	**$10,658**	**$10,658**

Land Cover	Ecosystem Service	Author(s)	Method	2004 dollars per acre/year Min	Max	Single Value	Mean	Median
Estuary, cont.	*Biological Control*	Costanza, R. et. al.-1997	VT	$39	$39		$39	
						Biological Control	**$39**	**$39**
	Refugium function	Johnston, R. J. et. al.-2002	MP			$1,298	$1,298	$1,298
		Johnston, R. J. et. al.-2002	MP			$82	$82	$82
		Johnston, R. J. et. al.-2002	MP			$412	$412	$412
		Farber, S. and Costanza, R.-1987	MP			$11	$11	$11
		Farber, S. and Costanza, R.-1987	MP			$15	$15	$15
		Costanza, R. et. al.-1997	VT	$66	$66		$66	$66
						Refugium function	**$314**	**$74**
	Aesthetic & Recreational	Whitehead, J. C., Hoban, T. L. and Clifford, W. B.-1997	CV	$1	$5		$3	$3
		Whitehead, J. C., Hoban, T. L. and Clifford, W. B.-1997	CV	$9	$81		$45	$45
		Morey, E. R., Shaw, W. D., and Rowe, R. D.	TC			$68	$68	$68
		Johnston, R. J. et. al.-2002	TC			$148	$148	$148
		Johnston, R. J. et. al.-2002	TC			$289	$289	$289
		Johnston, R. J. et. al.-2002	TC			$158	$158	$158
		Johnston, R. J. et. al.-2002	TC			$219	$219	$219
		Johnston, R. J. et. al.-2002	TC			$333	$333	$333

				2004 dollars per acre/year				
Land Cover	Ecosystem Service	Author(s)	Method	Min	Max	Single Value	Mean	Median
Estuary, cont.		Johnston, R. J. et. al.-2002	CV			$1,462	$1,462	$1,462
	.	Costanza, R. et. al.-1997	VT	$192	$192		$192	$192
				Aesthetic & Recreational			**$292**	**$175**
	Cultural & Spiritual	Costanza, R. et. al.-1997	VT	$15	$15		$15	$15
				Cultural & Spiritual			**$15**	**$15**
				Estuary Total			**$11,653**	**$11,289**
Forest								
	Gas & Climate regulation	Reyes, J. and Mates, W.-2004	VT			$11	$11	$11
		Pimentel, D.-1998	AC			$13	$13	$13
		Tol, R. S. J.	MP			$57	$57	$57
		Tol, R. S. J.	MP			$302	$302	$302
		Tol, R. S. J. and Downing, T. E.	MP			$26	$26	$26
		Tol, R. S. J. and Downing, T. E.	MP			$16	$16	$16
		Tol, R. S. J. and Downing, T. E.	MP			$74	$74	$74
		Tol, R. S. J. and Downing, T. E.	MP			$20	$20	$20
		Tol, R. S. J. and Downing, T. E.	MP			$78	$78	$78
		Tol, R. S. J. and Downing, T. E.	MP			$1	$1	$1
		Schauer, M. J.	MP			$23	$23	$23
		Schauer, M. J.	MP			$318	$318	$318
		Roughgarden, T. & Schneider, S.	MP		$184	$39	$39	$39

Land Cover	Ecosystem Service	Author(s)	Method	2004 dollars per acre/year Min	Max	Single Value	Mean	Median
Forest, cont.		Reilly, J. M. and Richards, K. R.	MP			$49	$49	$49
		Reilly, J. M. and Richards, K. R	MP			$42	$42	$42
		Reilly, J. M. and Richards, K. R	MP			$20	$20	$20
		Reilly, J. M. and Richards, K. R	MP			$14	$14	$14
		Plambeck, E. L.	MP	$10	$46	$20	$20	$20
		Plambeck, E. L.	MP	$371	$933	$419	$419	$419
		Nordhaus, W. D. and Popp, D.	MP	$0.04	$32	$11	$11	$11
		Nordhaus, W. D. and Popp, D.	MP	$1	$42	$6	$6	$6
		Nordhaus, W. D. and Yang, Z. L.	MP			$0.23	$0.23	$0.23
		Nordhaus, W. D. and Yang, Z. L.	MP			$6	$6	$6
		Nordhaus, W. D.	MP			$5	$5	$5
		Nordhaus, W. D.	MP	$8	$66	$33	$33	$33
		Nordhaus, W. D.	MP	$2	$15	$7	$7	$7
		Nordhaus, W. D.	MP	$0.31	$2	$1	$1	$1
		Newell, R. G. and Pizer, W. A.	MP	$10	$34		$22	$22
		Newell, R. G. and Pizer, W. A.	MP	$7	$23		$15	$15
		Maddison, D.	MP			$16	$16	$16
		Hope, C. and Maul, P.	MP	$11	$43	$28	$28	$28
		Fankhauser, S.	MP	$6	$43	$19	$19	$19
		Fankhauser, S.	MP	$23	$66	$40	$40	$40

Land Cover	Ecosystem Service	Author(s)	Method	2004 dollars per acre/year Min	Max	Single Value	Mean	Median
Forest, cont.		Fankhauser, S.	MP	$5	$37	$17	$17	$17
		Costanza, R., et al.	MP	$44	$44		$44	$44
		Azar, C. and Sterner, T.	MP			$202	$202	$202
		Azar, C. and Sterner, T.	MP			$10	$10	$10
		Azar, C. and Sterner, T.	MP			$30	$30	$30
		Azar, C. and Sterner, T.	MP			$66	$66	$66
				Gas & Climate regulation			**$12**	**$12**
	Soil formation	Costanza, R. et. al.-1997	VT	$5	$5		$5	$5
						Soil formation	**$5**	**$5**
	Waste treatment	Costanza, R. et. al.-1997	VT	$44	$44		$44	$44
						Waste treatment	**$44**	**$44**
	Pollination	Hougner, C.	RC	$59	$265		$162	$162
						Pollination	**$162**	**$162**
	Biological Control	Costanza, R. et. al.-1997	VT	$2	$2		$2	$2
						Biological Control	**$2**	**$2**
	Refugium function	Shafer, E. L. et. al.-1993	CV			$3	$3	$3
		Kenyon, W. and Nevin, C.-2001	CV			$426	$426	$426
	.	Haener, M. K. and Adamowicz, W. L.-2000	CV	$1	$7		$4	$4

Land Cover	Ecosystem Service	Author(s)	Method	2004 dollars per acre/year Min	Max	Single Value	Mean	Median
Forest, cont.		Garrod, G., D. and Willis K. G.	CV	$3,101	$3,383		$3,242	$3,242
		Garrod, G. D. and Willis. K. G.	CV			$15	$15	$15
		Garrod, G. D. and Willis K. G.	CV	$1,817	$2,003		$1,910	$1,910
		Amigues, J. P., et. al.-2002	CV	$55	$208		$132	$132
		Amigues, J. P., et. al.-2002	CV	$1,140	$2,158		$1,649	$1,649
					Refugium function		**$923**	**$279**
	Aesthetic & Recreational	Willis, K. G.-1991	TC	$0	$1		$1	$1
		Willis, K. G.-1991	TC	$20	$35		$28	$28
		Willis, K. G.-1991	TC	$8	$15		$12	$12
		Willis, K. G.-1991	TC	$5	$5		$5	$5
		Willis, K. G.-1991	TC	$89	$162		$126	$126
		Willis, K. G. and Garrod, G. D.-1991	TC			$4	$4	$4
		Shafer, E. L., et. al.-1993	CV			$459	$459	$459
		Prince, R. and Ahmed, E.-1989	CV	$1	$2		$1	$1
		Maxwell, S.-1994	CV			$10	$10	$10
		Haener, M. K. and Adamowicz, W. L.2000	CV			$0	$0	$0
		Costanza, R. et. al.-1997	VT	$18	$18		$18	$18
		Boxall, P. C., McFarlane, B. L. and Gartrell, M.-1996	TC			$0	$0	$0

				2004 dollars per acre/year				
Land Cover	**Ecosystem Service**	**Author(s)**	**Method**	**Min**	**Max**	**Single Value**	**Mean**	**Median**
Forest, cont.		Bishop, K.-1992	CV			$543	$543	$543
		Bishop, K.-1992	CV			$485	$485	$485
	.	Bennett, R., et. al.-1995	CV			$144	$144	$144
						Aesthetic & Recreational	**$122**	**$12**
	Cultural & Spiritual	Costanza, R. et. al.-1997	VT	$1	$1		$1	$1
						Cultural & Spiritual	**$1**	**$1**
	Water supply	NJEPA et al.-2005	RC	$247	$385		$316	$316
		Loomis, J. B.	TC	$9	$9		$9	$9
						Water Supply	**$163**	**$163**
						Forest Total	**$1,476**	**$688**
Freshwater Wetland								
	Gas & Climate regulation	Costanza, R. et. al.-1997	VT	$134	$134		$134	$134
						Gas & Climate regulation	**$134**	**$134**
	Disturbance prevention	Costanza, R. et. al.-1997	VT	$3,657	$3,657		$3,657	$3,657
						Disturbance prevention	**$3,657**	**$3,657**
	Water regulation	Thibodeau, F. R. and Ostro, B. D.-1981	AC			$5,957	$5,957	$5,957
		Costanza, R. et. al.-1997	VT	$15	$15		$15	$15

Land Cover	Ecosystem Service	Author(s)	Method	Min	Max	Single Value	Mean	Median
				2004 dollars per acre/year				
Freshwater wetland, cont						***Water regulation***	**$2,986**	**$2,986**
	Water supply	Pate, J. and Loomis, J.-1997	CV			$3,066	$3,066	$3,066
		Lant, C. L. and Roberts, R. S.-1990	CV	$0	$0		$0	$0
		Lant, C. L. and Tobin, G.-1989	CV			$170	$170	$170
		Lant, C. L. and Tobin, G.-1989	CV			$1,868	$1,868	$1,868
		Hayes, K. M., Tyrrell, T. J. and Anderson, G.-1992	CV	$1,097	$1,706		$1,401	$1,401
		Creel, M. and Loomis, J.-1992	TC			$462	$462	$462
		Costanza, R. et. al.-1997	VT	$3,839	$3,839		$3,839	$3,839
						Water supply	**$1,544**	**$1,401**
	Waste treatment	Costanza, R. et. al.-1997	VT	$838	$838		$838	$838
						Waste treatment	**$838**	**$838**
	Refugium function	Vankooten, G. C. and Schmitz, A.-1992	CV			$5	$5	$5
		Costanza, R. et. al.-1997	VT	$222	$222		$222	$222
						Refugium function	**$113**	**$113**
	Aesthetic & Recreational	Whitehead, J. C.-1990	CV	$890	$1,790		$1,340	$1,340
		Thibodeau, F. R. and Ostro, B. D.-1981	CV			$559	$559	$559

Land Cover	Ecosystem Service	Author(s)	Method	Min	Max	Single Value	Mean	Median
				2004 dollars per acre/year				
Freshwater wetland, cont.		Thibodeau, F. R. and Ostro, B. D.-1981	TC	$27	$86		$56	$56
		Mahan, B. L., Polasky, S. and Adams, R. M.-2000	TC			$30	$30	$30
		Hayes, K. M., Tyrrell, T. J. and Anderson, G.-1992	CV	$1,033	$1,975		$1,504	$1,504
		Doss, C. R. and Taff, S. J.-1996	TC			$3,942	$3,942	$3,942
		Doss, C. R. and Taff, S. J.-1996	TC			$3,568	$3,568	$3,568
		Costanza, R. et. al.-1997	VT	$248	$248		$248	$248
						Aesthetic & Recreational	**$1,406**	**$950**
	Cultural & Spiritual	Costanza, R. et. al.-1997	VT	$890	$890		$890	$890
						Cultural & Spiritual	**$890**	**$890**
						Freshwater Wetland Total	**$11,568**	**$10,969**
Open Fresh Water								
	Water supply	Ribaudo, M. and Epp, D. J.-1984	TC	$567	$719		$643	$643
		Piper, S.-1997	CV			$28	$28	$28
		Henry, R., Ley, R. and Welle, P.-1988	CV			$366	$366	$366
		Croke, K., Fabian, R. and Brenniman, G.-1986	CV			$482	$482	$482
		Bouwes, N. W. and Scheider, R.-1979	TC			$526	$526	$526
						Water supply	**$409**	**$482**

Land Cover	Ecosystem Service	Author(s)	Method	Min	Max	Single Value	Mean	Median
					2004 dollars per acre/year			
Open freshwater, cont.	*Aesthetic & Recreational*							
		Young, C. E. and Shortle, J. S.-1989	HP			$70	$70	$70
		Ward, F. A., Roach, B. A. and Henderson, J. E.-1996	TC	$17	$1,635		$826	$826
		Shafer, E. L. et. al. -1993	TC			$938	$938	$938
		Shafer, E. L. et. al. -1993	TC			$470	$470	$470
		Shafer, E. L. et. al. -1993	CV			$83	$83	$83
		Piper, S.-1997	TC			$205	$205	$205
		Patrick, R.,et. al. -1991	TC	$1	$22		$12	$12
		Kreutzwiser, R.-1981	TC			$154	$154	$154
		Kealy, M. J. and Bishop, R. C.-1986	TC			$11	$11	$11
	.	Cordell, H. K. and Bergstrom, J. C.-1993	CV	$115	$242		$179	$179
		Cordell, H. K. and Bergstrom, J. C.-1993	CV	$162	$679		$420	$420
		Cordell, H. K. and Bergstrom, J. C.-1993	CV	$241	$682		$462	$462
		Cordell, H. K. and Bergstrom, J. C.-1993	CV	$326	$1,210		$768	$768
		Burt, O. R. and Brewer, D.-1971	TC			$393	$393	$393
				Aesthetic & Recreational			**$356**	**$299**

Land Cover	Ecosystem Service	Author(s)	Method	Min	Max	Single Value	Mean	Median
				2004 dollars per acre/year				
Open freshwater, cont.				**Open Fresh Water Total**			**$765**	**$781**
Pasture								
	Gas & Climate regulation	Costanza, R. et. al.-1997	VT	$4	$4		$4	$4
		Costanza, R. et. al.-1997	VT	$0	$0		$0 $0	
		Sala, O. E. and Paruelo, F. M.	MP	$4	$10	$5	$5	$5
				Gas & Climate regulation			**$3**	**$4**
	Water regulation	Costanza, R. et. al.-1997	VT	$2	$2		$2	$2
				Water regulation			**$2**	**$2**
	Soil formation	Pimentel, D.-1998	DM			$6	$6	$6
		Costanza, R. et. al.-1997	VT	$1	$1		$1	
				Soil formation			**$3**	**$3**
	Waste treatment	Costanza, R. et. al.-1997	VT	$44	$44		$44	$44
				Waste treatment			**$44**	**$44**
	Pollination	Costanza, R. et. al.-1997	VT	$13	$13		$13	$13
				Pollination			**$13**	**$13**
	Biological Control	Costanza, R. et. al.-1997	VT	$12	$12		$12	$12

Land Cover	Ecosystem Service	Author(s)	Method	Min	Max	Single Value	Mean	Median
						2004 dollars per acre/year		
Pasture, cont.						***Biological Control***	**$12**	**$12**
	Aesthetic & Recreational	Costanza, R. et. al.-1997	VT			$1	$1	$1
		Boxall, P. C.-1995	TC			$0.03	$0.03	$0.03
		Alvarez-Farizo, B., Hanley, N., Wright, R. E. et al.				$1	$1	$1
						Aesthetic & Recreational	**$1**	**$1**
						Pasture Total	**$77**	**$77**
Riparian Buffer								
	Disturbance prevention	Rein, F. A.-1999	AC	$6	$99		$53	$53
		Rein, F. A.-1999	AC	$45	$201		$123	$123
						Disturbance prevention	**$88**	**$88**
	Water supply	Rich, P. R. and Moffitt, L. J.-1982	HP			$4	$4	$4
		Rein, F. A.-1999	AC	$36	$158		$97	$97
	.	Oster, S.-1977	CV			$13	$13	$13
		Mathews, L. G., Homans, F. R. and Easter, K. W.-2002	CRS			$11,089	$11,089	$11,089
		Gramlich, F. W.-1977	CV			$188	$188	$188
		Danielson, L., et. al.-1995	CV			$4,095	$4,095	$4,095

				2004 dollars per acre/year				
Land Cover	Ecosystem Service	Author(s)	Method	Min	Max	Single Value	Mean	Median
Riparian buffer, cont.		Berrens, R. P., Ganderton, P. and Silva, C. L.-1996	CV			$1,794	$1,794	$1,794
		Kahn, J. R. and Buerger, R. B.-1994	TC	$3	$9		$6	$6
		Kahn, J. R. and Buerger, R. B.-1994	TC	$0.15	$1		$0.46	$0.46
						Water supply	**$1,921**	**$97**
	Aesthetic & Recreational	Sanders, L. D., Walsh, R. G. and Loomis, J. B.-1990	CV			$1,957	$1,957	$1,957
		Rein, F. A.-1999	DM	$26	$113		$69	$69
		Mullen, J. K. and Menz, F. C.-1985	TC			$328	$328	$328
		Kulshreshtha, S. N. and Gillies, J. A.-1993	HP			$43	$43	$43
		Greenley, D., Walsh, R. G. and Young, R. A.-1981	CV			$7	$7	$7
		Duffield, J. W., Neher, C. J. and Brown, T. C.-1992	CV			$1,256	$1,256	$1,256
		Duffield, J. W., Neher, C. J. and Brown, T. C.-1992	CV			$889	$889	$889
	.	Bowker, J. M., English, D. and Donovan, J.-1996	TC	$3,766	$9,052		$6,409	$6,409
						Aesthetic & Recreational	**$1,370**	**$608**
	Cultural & Spiritual	Greenley, D., Walsh, R. G. and Young, R. A.-1981	CV			$4	$4	$4
						Cultural & Spiritual	**$4**	**$4**
						Riparian Buffer Total	**$3,382**	**$797**

				2004 dollars per acre/year				
Land Cover	**Ecosystem Service**	**Author(s)**	**Method**	**Min**	**Max**	**Single Value**	**Mean**	**Median**
Saltwater Wetland								
	Disturbance prevention	Farber, S.-1987	AC	$1	$1		$1	$1
		Farber, S. and Costanza, R.-1987	AC			$1	$1	$1
		Costanza, R. et. al.-1997	VT	$929	$929		$929	$1
						Disturbance prevention	**$310**	**$1**
	Waste treatment	Costanza, R. et. al.-1997	VT	$3,382	$3,382		$3,382	$3,382
		Breaux, A., Farber, S. and Day, J.-1995	AC			$16,560	$16,560	$16,560
		Breaux, A., Farber, S. and Day, J.-1995	AC	$103	$116		$109	$109
		Breaux, A., Farber, S. and Day, J.-1995	AC	$1,256	$1,942		$1,599	$2,491
						Waste treatment	**$5,413**	**$2,491**
	Refugium function	Lynne, G. D., Conroy, P. and Prochaska, F. J.-1981	ME			$1	$1	$1
		Farber, S. and Costanza, R.-1987	ME			$1	$1	$1
		Costanza, R. et. al.-1997	VT	$85	$85		$85	$85
		Bell, F. W.-1997	FI	$144	$953		$549	$549
		Batie, S. S. and Wilson, J. R.-1978	ME	$6	$735		$370	$370
						Refugium function	**$201**	**$85**

Land Cover	Ecosystem Service	Author(s)	Method	Min	Max	Single Value	Mean	Median
				2004 dollars per acre/year				
Saltwater wetland, cont.	*Aesthetic & Recreational*	Farber, S.-1988	TC	$5	$14		$9	$9
		Bergstrom, J. C., et. al. -1990	CV			$14	$14	$14
		Anderson, G. D. and Edwards, S. F.-1986	HP	$20	$91		$55	$55
						Aesthetic & Recreational	**$26**	**$14**
	Cultural & Spiritual	Anderson, G. D. and Edwards, S. F.-1986	CV	$120	$240		$180	$180
						Cultural & Spiritual	**$180**	**$180**
						Saltwater Wetland or Salt Marsh Total	**$6,131**	**$2,771**
Urban Green Space								
	Gas & Climate regulation	McPherson, E. G., Scott, K. I. and Simpson, J. R.-1998	DM			$25	$25	$25
		McPherson, E. G.-1992	AC			$164	$164	$164
		McPherson, E. G.-1992	AC			$820	$820	$820
						Gas & Climate regulation	**$336**	**$164**
	Water regulation	McPherson, E. G.-1992	AC			$6	$6	6
						Water regulation	**$6**	**$6**
	Aesthetic & Recreational	Tyrvainen, L.-2001	CV			$3,465	$3,465	$3,465
		Tyrvainen, L.-2001	CV			$1,182	$1,182	$1,182

Land Cover	Ecosystem Service	Author(s)	Method	Min	Max	Single Value	Mean	Median
				2004 dollars per acre/year				
Urban Green Space, cont.		Tyrvainen, L.-2001	CV			$1,745	$1,745	$1,745
				Aesthetic & Recreational			**$2,131**	**$1,745**
				Urban Green Space Total			**$2,473**	**$1,916**

Code	**SubType**
DM	Direct market valuation
AC	Avoided Cost
RC	Replacement Cost
FI	Factor Income
TC	Travel Cost
HP	Hedonic Pricing
CV	Contingent Valuation
GV	Group Valuation
MD	Multiattribute Decision Analysis
EA	Energy Analysis
MP	Marginal Product Estimation
CRS	Combined Revealed and Stated Preference
MA	Meta-anlaysis
VT	Value Transfer

Appendix D. Technical Appendix

Hedonic Model Specifications

Any regression equation is based on an assumed functional form, e.g., linear, quadratic, exponential, etc. Each of these functional forms implies a different type of relationship between independent question and home price. For instance, in regards to a variable for number of bedrooms: the sale price could increase in proportion to number of bedrooms, it could increase exponentially "without limit", it could increase but at a decreasing rate so that it "levels off" after five or six bedrooms, implying that the first few bedrooms are worth more on the margin, etc. Specifying the correct functional form not only can help avoid erroneously finding no relationship when one really exists or *vice versa*, but it can also help better characterize how a marginal change in an amenity affects price at various levels of that amenity.

The following are the functional forms used most commonly in hedonic analysis:

1. In a *linear* model, variables are expressed in terms of their absolute magnitudes, e.g., distance to park. In such an equation, a given coefficient can be thought of as the marginal change in price (measured in dollars) due to a one-unit change in that predictor variable, holding all else constant. (A similar interpretation holds for the less commonly used *quadratic* form where the variable might be, for example, the square of distance to park.)
2. In the commonly used *semi-log* model, the dependent variable is the logarithm of the sale price rather than the price itself. In this case, the coefficient of a predictor variable can be interpreted as the percentage change in the sale price due to a unit change in the predictor, e.g., the percentage by which the sale price changes as a result of being one unit distance closer to a beach or other environmental amenity. In this case the marginal implicit price of an amenity varies with the magnitude of sales price. For example, being 500 feet closer to a park may have a different percentage impact on the sale price of a million-dollar home than on the sale price of a $200,000 home. Likewise, having a fifth bathroom will add a different amount to two respectively priced
3. In a *log-log* or *trans-log* model, both the sale price and the predictor variables are expressed as logarithms ("logged"). Here the coefficient on a logged predictor variable can be interpreted as an "elasticity", that is, the percentage change in the sale price due to a one percent change in the predictor. In this case the marginal implicit price of an amenity varies with the magnitude of sales price and with the magnitude of the amenity. For example, a fifty foot change in a home's distance from a protected wetland may affect sale price differently if the change is from 50 to 150 fifty feet versus 500 to 550 feet or the addition of fifth bathroom may affect price differently than addition of a second bathroom; and in either of these cases, the percentage change in price may be different for more and less expensive homes.

The functional form and included variables of our hedonic equations were slightly different for each submarket. While each equation utilized the log-transformed dependent variable, the extent to which independent variables were transformed varied. The transformed dependent variable was chosen based on both the hedonic literature and on analyses of residual versus fit plots, which indicated nonlinearity in the relationships, and by the significant increase in R-squared due to transformation. Logging the dependent variable means that the coefficients of all linear independent variables can be interpreted as the percent change in the dependent variable due to a 1% increase in the independent variable. The coefficients of logged independent variables can be interpreted as elasticities.

The decision of which independent variables to transform—as well as which to include—was based on multi-model inferential statistical procedures {Burnham, 2002 #719}. This approach shows that minimization of the Akaike Information Criterion (AIC) can help select the "order" of likelihood of a set of nested or non-nested models. The commonly used measure of model fit, R-squared, is often not appropriate for comparison because it will always show the more complex model to be superior.

However, complexity comes at the tradeoff of parsimony, and therefore it is commonly accepted that a better model is one that increases fit relative to the number of parameters. AIC, on the other hand, penalizes models that are less parsimonious. By accounting for the tradeoff between model fit and complexity, it can show us which models best compromise between the two. The AIC is given by the equation is:

$$AIC = -2\log L(M) + 2k$$

Where:

k = the number of parameters plus one

log*L(M)* = the maximized log likelihood for the fitted mode

By comparing AIC scores of models including different independent variable combinations and transformations, we were able to derive a set of well fitting but parsimonious models. In general, many of the structural control variables, including lot area, living area, and improvement value were frequently log-transformed, while only a few of the distance control variables were.

Second-Stage Hedonic Analysis

The second stage seeks to estimate homeowners' demand curve for environmental amenities based on the hedonic price schedule derived from the regressions just mentioned. This function is based on consumer willingness to pay (WTP) for an attribute, which is not directly revealed. However, assuming individuals are price takers in equilibrium, a WTP function can be estimated from the marginal implicit attribute price (or "shadow price") derived in the first stage. Shadow prices are estimated by taking the partial derivative of price with respect to that amenity. The resulting equation describes how WTP for a marginal change in the amenity varies with quantity of or distance to the amenity. This is then solved for all distances or quantities observed. The resulting shadow price estimates are then regressed against distance/quantity.

Second stage hedonic analysis suffers from several major problems that are frequently cited in the literature. The most important is an econometric identification problem. This stems from the fact that the dependent variable in the second stage is not directly observed but is estimated from the hedonic price function, which is to say that both dependent and explanatory variables come from the same data source. This in fact can lead to getting the same parameters as in the first stage, in some cases (Mendelsohn, 1987). The identification problem also stems from the fact that price and quantity are chosen simultaneously by individuals.

One approach that has been used to deal with this problem is adding to the regression so-called "demand shifters," which are exogenous independent variables that at least partially correct for simultaneity (Mendelsohn, 1984). Frequently used demand shifters include socio-economic variables such as income and education levels. A more robust approach is the use of segmented housing markets to control for the identification problem (Freeman, 2003). This approach is superior because consumers in different markets with the same demand shifter characteristics (e.g. income) will face different marginal implicit attribute prices. Under this approach, separate hedonic equations are estimated for each market in the first stage (as we did for this study), yielding marginal implicit price estimates for each individual in each market, and in the second stage these values are regressed against the quantity of the attribute and some demand shifter.

Assuming a partial equilibrium analysis, where the magnitude of change in the resource quantity is small enough not to affect prices, and the time frame is relatively short run, the welfare value of a nonmarginal change in a resource can be determined for an individual by integrating under the WTP curve. In cases where the bounds of the non marginal quantity being assessed are large enough to affect price (e.g. the value of all wetlands in North America, where the two possible conditions are either all or none), a full equilibrium approach must be taken, which accounts for the endogeneity of price. Because potential non-marginal changes in the case of New Jersey are relatively small we assume that prices remain constant. The sum of the areas under the curve for all affected households then represent a lower bound of the welfare estimate (Bartik, 1988).

Landscape Modeling Framework

` The Landscape Modeling Framework (LMF) was designed to serve as a tool in integrated analysis of the interactions among physical and biological dynamics in a watershed, conditioned on socioeconomic behavior in the region. To account for ecological and economic processes in the same modeling framework we need to provide free exchange of information between the ecological and economic components. That immediately translates into the requirement that the scale and resolution of the spatial, temporal and structural interpretations are adequate to represent both of them. In particular, the spatial representation should be matched so that land use or land cover transformations in one component can be communicated to the other one. For such purposes it may be difficult to employ the more conventional approach based on spatial aggregation to larger units, called elementary landscapes, elementary watersheds, elementary areas of pollution or hillslopes (Beven and Kirby, 1979; Krysanova et al., 1989; Band et al., 1991; Sasowsky et al., 1991). These units are considered homogeneous and form the basis for the hydrologic flow network. The boundaries between spatial units are fixed and cannot be modified during the course of the simulation, which may be somewhat restrictive, if we are to consider scenarios of land use change, generated by the economic considerations, which were not envisioned in the design of the elementary spatial units.

A more mechanistic approach seems to be better suited to keep track of landuse changes and how they affect environmental conditions. We may present the landscape as a grid of relatively small homogeneous cells and run simulations for each cell with relatively simple rules for material fluxing among neighboring cells (Sklar et al., 1985; Burke et al., 1990; Costanza et al., 1990; Engel et al., 1993; Maxwell, 1995). This fairly straightforward approach requires extensive spatial data sets and high computational capabilities in terms of both data storage and calculation speed. However, it provides for quasi-continuous modifications of the landscape, where habitat boundaries may change in response to socioeconomic transformations. The LMF approach may be considered as an outgrowth of the approach first developed in the Coastal Ecosystem Landscape Spatial Simulation (CELSS) model (Sklar et al., 1985; Costanza et al., 1990), and later applied to a series of wetland areas, the Everglades clearly being the most sophisticated example (Fitz, in pressA; Fitz, in pressB).

The two main components of the LMF are the Spatial Modeling Environment (SME) and the Library of Hydro-Ecological Modules (LHEM). While SME is the computational engine that takes care of all input-output, data processing and number crunching, the LHEM provides the essential models and modules that actually describe the watershed and the ecological processes that occur there. The modular design of the LMF provides essential flexibility and transparency in model design and analysis.

We have used the LMF to construct the Hunting Creek Model (HCM) that we used in this study. The local dynamics in the HCM were similar to those developed in the Patuxent Landscape Model (Voinov et al., 1999), but the spatial implementation, defined by the Study Area, and the spatial resolution were different. By focusing on a relatively small watershed, we could make many more model runs, better calibrate the model, and refine our understanding of some of the crucial ecological processes and spatial flows in the ecosystem. The HCM became one of the most thoroughly calibrated and studied implementations under the LMF paradigm, and seems to be well-suited for the sensitivity experiments that we intend to undertake to understand how spatial allocation and processes in the watershed can influence ecosystem services and functions.

Model structure

The modeled landscape is partitioned into a spatial grid of unit cells. The model is hierarchical in structure, incorporating the ecosystem-level unit model for local, vertical dynamics that is replicated in each of the unit cells representing the landscape (Figure E1). With this approach, the model builds on the format of a raster-based geographic information system (GIS), which is used to store all the spatially referenced data included in the model. Thus, the model can be considered an extension of the analytical function of a GIS, adding dynamics and knowledge of ecological processes to the static snapshots stored in a GIS.

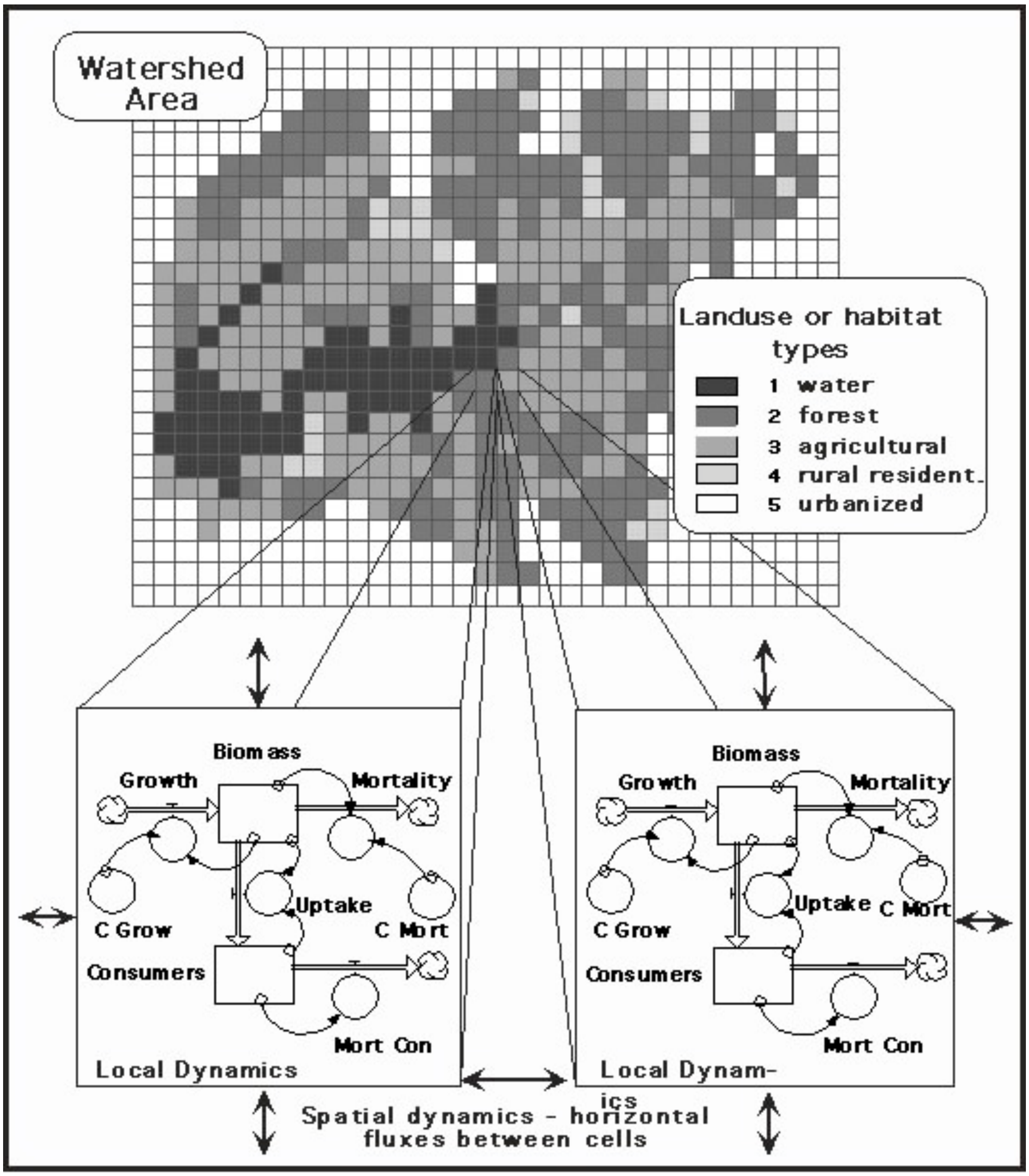

Figure E1: Spatial organization of the watershed model. Each cell is represented by a unit model.

Although the same local unit model runs in each cell, individual models are parameterized according to habitat type and geo-referenced information for a particular cell. The habitat dependent information is stored in a parameter database that includes initial conditions, rate parameters, stoichiometric ratios, etc. The habitat type and other location-dependent characteristics are referenced through links to GIS files. In this sense, the HCM is one of several site-specific ecological models that are process-based and are designed to apply to a range of habitats. The unit model in the HCM aims for an intermediate level of complexity so that it is flexible enough to be applied to a range of ecosystems but is not so cumbersome that it requires a supercomputer.

The unit models in each cell exchange matter and information across space. The horizontal fluxes that join the unit models together are defined by surface and subsurface hydrology. Alternative horizontal fluxes could be movement of air, animals, and energy such as fire and tidal waves although at this stage the HCM fluxes only water and entrained material. The spatial hydrology module calculates the amount of water fluxed over the surface and in the saturated sediment. The fluxes are driven by cell-to-cell head differences of surface water and saturated sediment water, respectively. Water fluxes between cells carry dissolved and suspended material. At each time step, first the unit model updates the stocks within each cell due to vertical fluxing and then cells communicate to flux matter horizontally, simulating flows and determining ecological condition across the landscape.

Figure E2 shows how the various modeled events are distributed in time when simulated in the HCM. The model employs a time-step of 1 day, so most of the ecological variables are updated daily. However, certain processes can be run at longer or shorter time intervals. For example some spatial hydrologic functions may need an hourly time step, whereas certain external forcing functions are updated on a monthly or yearly basis.

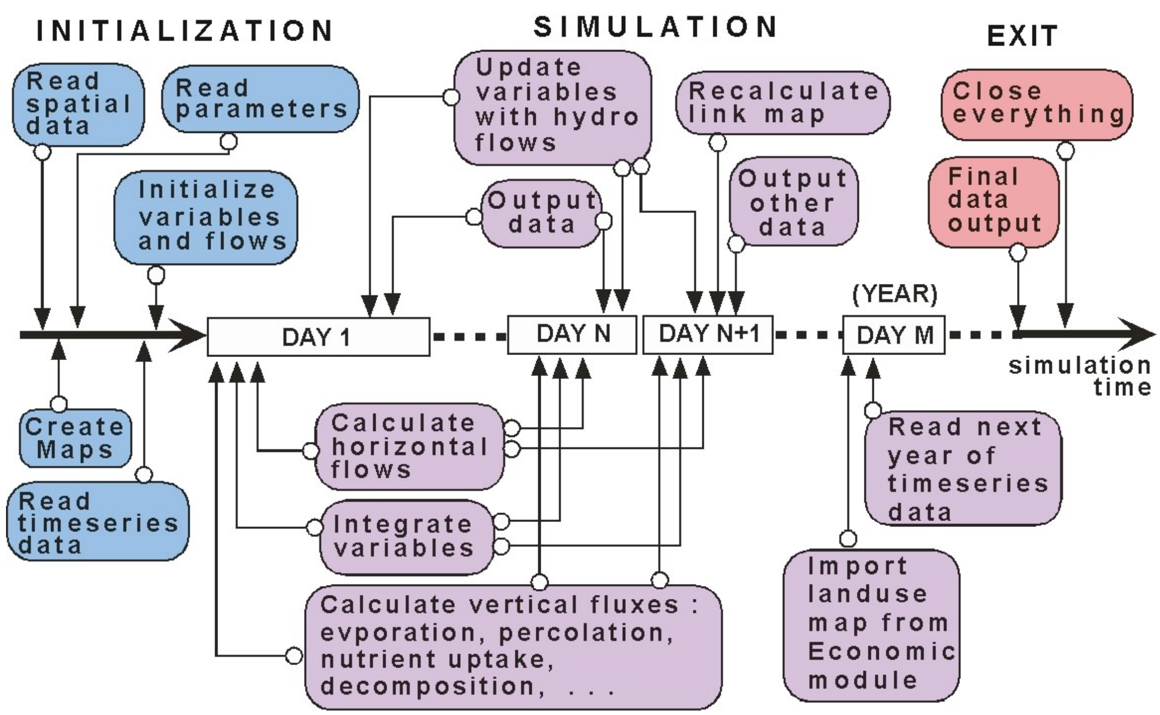

Figure E2: During simulation in HCM, model events are distributed in time.

The LHEM was used as a source of local (run in each cell) and spatial modules (run over many cells to present horizontal movement of material). Modules were picked from the Library to represent hydrology, nutrient movement and cycling, terrestrial primary productivity, and dynamics of organic decomposition (Figure E3). The hydrology module of the unit model is fundamental to modeled processes since it links the climatic forcing functions to chemical and biotic processes, and allows feedbacks between sectors. Phosphorus and nitrogen are cycled through plant uptake and organic matter decomposition, with the latter simulated in the sector that describes the sediment/soil dynamics. The module for plants includes growth response to various environmental constraints (including water and nutrient availability), changes in leaf canopy structure (influencing water transpiration), mortality, and other basic plant dynamics. Feedbacks among the biological, chemical and physical model components, influence ecosystem response to changing conditions. For further details on LMF go to the web site at http://giee.uvm.edu/IDEAS.

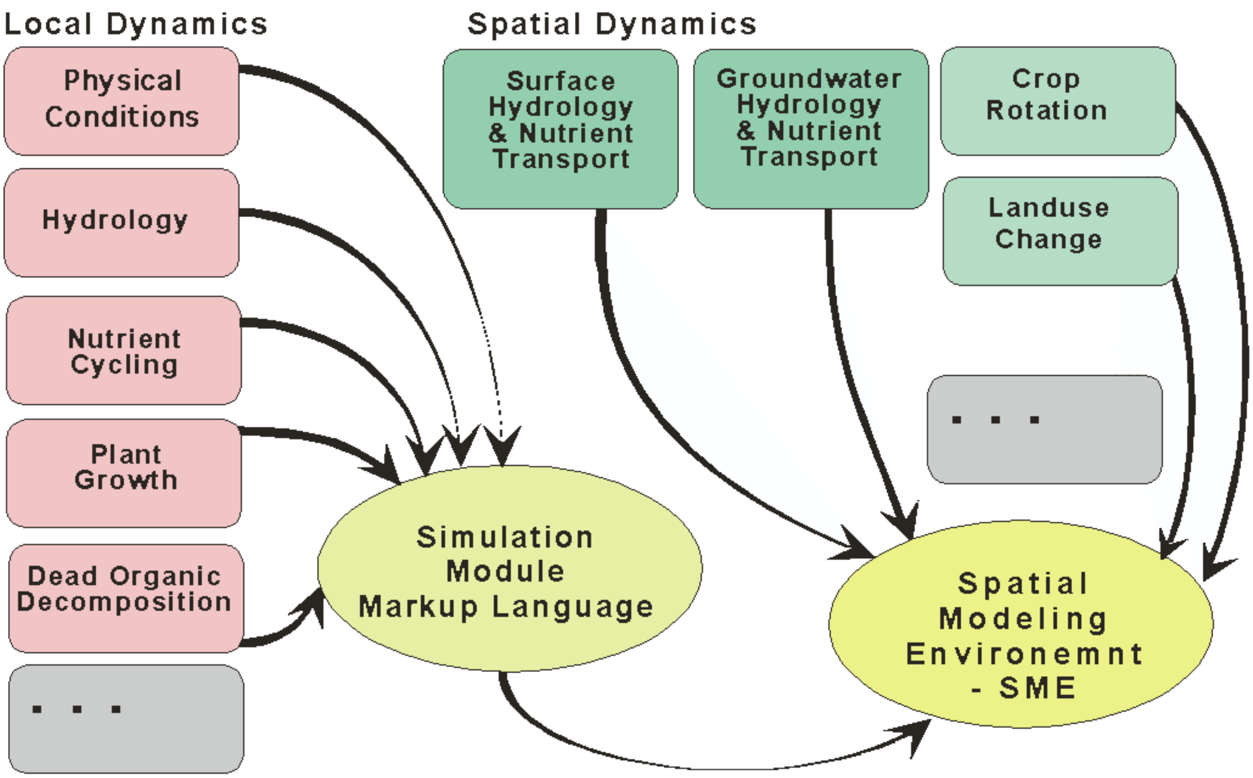

Figure E3: Flow diagram of model.

Hydrology

The traditional scheme of vertical water movement (Novotny and Olem, 1994), assumes that water is fluxed along the following 4-phase pathway: rainfall -> surface water -> water in the unsaturated layer -> water in the saturated zone. Snow is another storage that is important to mimic the delayed response caused by certain climatic conditions. In each of the stages, some portions of water are diverted due to physical (evaporation, runoff) and biological (transpiration) processes, but in the vertical dimension the flow is controlled by the exchange between these 4 major phases. Taking into account the temporal (1 day) and spatial (200 m) resolution of the HCM formalization and of the available input data, we can simplify this model as follows.

At a daily time step, the model cannot attempt to mimic the behavior of shorter-term events such as the fast dynamics of a wetting front, when rainwater infiltrates into soil and then travels through the unsaturated zone towards the saturated groundwater. During a rapid rainfall event, surface water may accumulate in pools and litter-fall but in a catchment such as the Hunting Creek watershed, over the period of a day, most of this water will either infiltrate, evaporate, or be removed by horizontal runoff. Infiltration rates based on soil type within the Patuxent and Hunting Creek watersheds range from 0.15 to

6.2 m/day (Maryland Department of State Planning, 1973), potentially accommodating all but the most intense rainfall events in vegetated areas. The intensity of rainfall events can strongly influence runoff generation, but climatic data are rarely available for shorter than daily time steps. Also, if the model is intended to run over large areas for many years, the diel rainfall data become inappropriate and difficult to project for scenario runs. Therefore, a certain amount of detail must be forfeited to facilitate regional model implementation.

With these limitations in mind, we assume that rainfall infiltrates immediately to the unsaturated layer and only accumulates as surface water if the unsaturated layer becomes saturated or if the daily infiltration rate is exceeded. Ice and snow may still accumulate. Surface water may be present in cells only if it is in rivers, creeks, lakes, and ponds. Sheet surface water is removed by horizontal runoff or evaporation. Within the daily time step, surface water flux will also account for the shallow subsurface fluxes that bring the water distributed over the landscape into the micro channels and eventually to the river. Thus, the surface water transport takes into account the shallow subsurface flow that may occur during rainfall, allowing the model to account for the significantly different nutrient transport capabilities between shallow and deep subsurface flow.

Conceptually this is close to the slow and quick flow separation (Jakeman et al., 1993; Post and Jakeman, 1996) assumed in empirical models of runoff. In our case the surface water variable accounts for the quick runoff, while the saturated storage performs as the slow runoff, defining the base-flow rate between rainfall events.

Nutrients

In LHEM, the nutrients considered are nitrogen and phosphorus. Various nitrogen forms, N02-, N03- and NH4+ are aggregated into one variable representing all forms of nitrogen that are directly available for plant uptake. Available inorganic phosphorus is simulated as orthophosphate. The distinction between N and P cycles appears in conceptualizing nutrients on the surface, since in the model they are no longer associated with surface water and therefore need not be in the dissolved form. On the contrary, since most of the time most of the cells have no surface water, N_S (P_S) represents the dry deposition of nitrogen (phosphorus) on the surface. Over dry periods N_S (P_S) continues to accumulate with incoming fluxes from air deposition or mineralization of organic material. When rainfall occurs, a certain proportion of the accumulated N_S (P_S) becomes dissolved and therefore is made available for horizontal fluxing and infiltration.

Further modification of the nutrient dynamics was required to accommodate the aggregation of surface and shallow subsurface flows in the hydrologic sector. In the PLM a proportion of nitrogen and phosphorus stored in the upper soil layer is made available for fast horizontal fluxing along with nutrients on the land surface. We have assumed this layer to be 10 cm thick, following a similar formalization in the CNS model (Haith et al., 1984), where this upper soil layer was also assumed to be exposed to direct surface runoff.

In addition to N_S (P_S), mineral N (or P) on the surface, and N_{SD} (P_{SD}), mineral N (or P) in the sediment, the phosphorus cycle features another variable P_{SS}, which is the phosphorus deposited in the sediment in particulate form, no longer available for plants uptake, and effectively removed from the phosphorus cycle. At higher concentrations the dissolved PO, becomes absorbed by the organic material and metal ions in the soil. Therefore the rate of sorption is also controlled by the amount of organic material in the soil, which in this case mostly consists of soil microorganisms (microbes). At lower concentrations of soluble PO_4 in the sediment, P_{SS} becomes available again and returns to the cycle.

Plants

The LHEM plants module includes dynamics in carbon-to-nutrient ratios that are important to woody and perennial plant communities (Vitousek et al., 1988) and introduces important differences between evergreen and deciduous plant communities. Additional fluxes were added to allow for human intervention through fertilizing, planting and harvesting of crops and trees. The newly revised macrophyte sector can now simulate the nutrient storage of a forest ecosystem in multiple year simulations and allow scenarios for Best Management Practices (BMP's) in agriculture and urban lawns.

Plants are represented by two state variables for photosynthetic and non-photosynthetic plant matter. The carbon to nutrient ratios (C:N:P ratios) for both state variables link to different steps in the N and P nutrient cycles. The C:N:P ratio in the photosynthetic part of the nutrient cycles is instrumental in controlling uptake and the resulting accumulation of organic nitrogen and phosphorous. The C:N:P ratio in the non-photosynthetic biomass is used to estimate the rates of decomposition and the extent of nutrient mineralization. The C:N:P ratios tend to increase as woody biomass low in nutrient content accumulates in aging forests. Our strategy still assigns fixed C:N:P ratios to the photosynthetic biomass, but relates changes in the non-photosynthetic biomass C:N:P ratios to changes in woody biomass, bringing estimated nutrient storages closer to measured values.

Some concepts were redefined in the new model to represent a greater variety of habitats. The terms evergreen and deciduous are broadly interpreted to encompass not only trees but other plant communities as well. Most of the agricultural crops and annual herbs are considered deciduous, while wetlands, grasslands and lawns are considered evergreen. The main difference between the deciduous and non-deciduous plant communities is that a fall hormonal trigger mechanism causes the deciduous plants to shed the photosynthetic part of the plant, while recovering some of the biomass for the non-photosynthetic tissues. No recovery of biomass occurs from leaf mortality. It is during this fall period when seeds and tubers are formed and photosynthetic products are stored in tree root systems. In the spring deciduous plants experience accelerated growth in addition to a seasonal growth also experienced in the evergreen community.

Allocation of photosynthetic products to leafy or woody tissues is controlled by the maximum in the ratio of photosynthetic to non-photosynthetic materials (*Max-ph:nph*). An accelerated spring growth, simulating sap flow in trees and seed germination, was introduced for the deciduous portion of the plant community. Labile carbon stored in non-photosynthetic tissues (roots, stems and branches) is translocated to produce photosynthetic tissue (leaves) in an attempt to reach a community-specific *Max-ph:nph*. Translocation from the non-photosynthetic tissue to the photosynthetic tissue comes to a halt when all labile carbon is used from storage, or the *Max-ph:nph* ratio is reached, or hormonal activity ceases. New photosynthetic products are created in the leaves, under the various environmental restrictions. These newly available products can be allocated to additional leaf growth if *Max-ph:nph* is not yet reached, or can be translocated back to the non-photosynthetic parts for growth of woody matter or storage. Growth in woody matter offsets the photosynthetic to non-photosynthetic ratio from *Max-ph:nph* and allows for additional growth in leafy material.

Detritus

At present this module serves predominantly to close the nutrient and material cycles in the system, it does not go into all the details of the multi-scale and complex processes of leaching, bacterial decomposition, etc. As biomass dies off, a part of it turns into Stable Detritus, D_S, whereas the rest becomes Labile Detritus, D_L. The proportions between the two are driven by the lignin content, which is relatively low for the PH biomass and is quite high for NPH biomass. Labile detritus is decomposed directly, and stable detritus is decomposed either to labile detritus, or becomes Deposited Organic Material (DOM), D_{DOM}.

Avoiding many of the complexities, we assume that the decomposition process is linear for the decay of Stable Detritus as follows:

$$F_{DS} = d_0 \cdot D_S + d_1 \cdot L_{DT} \cdot D_S,$$

where d_0 is the flow rate of stable detritus transformation into D_{DOM} and d_1 is the flow rate between stable and labile detritus. The latter flow is modified by the Vant-Hoff temperature limitation function $L_{DT} = 2^{(T-20)/10}$, where T is the ambient air temperature (^oC). The decomposition of Labile Detritus and DOM is described similarly as linear functions modified by the Vant-Hoff temperature function.

Spatial implementation

Once the local ecological processes were described, we needed to decide on the algorithms that put the local dynamics within a spatial context. For watersheds in general and for Hunting Creek in particular, hydrologic fluxes seem to be the most important mechanism linking the cells together and delivering the suspended and dissolved matter across the landscape.

The importance of hydrologic transport has been long recognized and considerable effort has been put into creating adequate models for various landscapes (Beven and Kirby, 1979; Beasley and Huggins, 1980; Grayson et al., 1992). Nevertheless there are no off-the-shelf universal models that can be easily adapted for a wide range of applications. As part of a more complicated modeling structure, the hydrologic module is required to be simple enough to run within the framework of the integrated physical-ecological model yet sufficiently detailed to incorporate locally important processes. As a result, some hydrologic details need to be sacrificed to make the whole task more feasible, and these details may differ from one application to another, depending upon the size of the study area, the physical characteristics of the slope and surface, and the goals and priorities of the modeling effort.

To simplify hydrologic calculations, we merge process-based and quasi-empirical algorithms (Voinov et al., 1998). First, given the cell size within the model (200 m), every cell is assumed to have a stream or depression where surface water can accumulate. Therefore the whole area becomes a linked network of channels, where each cell contains a channel reach which discharges into a single adjacent channel reach along the elevation gradient. An algorithm generates the channel network from a link map, which connects each cell with its one downstream neighbor chosen from the eight possible nearest neighbors.

Second, since most of the landscape is characterized by an elevation gradient, the flow is assumed to be unidirectional, fluxing water down the gradient. In the simplified algorithm, a portion of water is taken out of a cell and added to the next one linked to it downstream. To comply with the Courant condition (Chow et al., 1988), this operation is reiterated many (10-20) times a day, effectively generating a smaller time step to allow faster runoff. The number of these iterations was calibrated so that the water flow rates match gage data.

This procedure was further simplified by allowing the water to flow through more than one cell over one iteration and then generalized by assuming a variable number cells in the downstream link, as a function of the amount of water in the donor cell. This was adopted to allow for a faster flow when more water is available on the surface (Voinov et al., 1999). It increased flexibility in describing individual hydrographs and in generalizing them over longer time periods and over larger watershed areas.

For groundwater movement we used a linear Darcy approximation that moves water among adjacent cells in proportion to a conductivity coefficient and the head difference. The groundwater movement provides the slow water flow that generates the river base-flow. Surface water runoff is the major determinant of the peak flow observed.

Hunting Creek data

Spatial hydrologic modeling requires extensive data sets. Most of the spatial coverages for the HCM were derived from the data sets previously assembled for the whole Patuxent watershed. In Fig. 6 we present the basic spatial coverages that have been employed in our modeling effort and some of the derived layers that were also essential for the hydrologic module. Spatial fluxes of surface water in watershed models are predominantly driven by the elevation gradient. In this study we used the United States Geological Survey's (USGS) Digital Elevation Model (DEM) data that are available for downloading from the Internet (USGS, 1995).

USGS offers elevation data in 1 degree grid coverages for the 4 map quadrangles covering the Patuxent watershed. DEM grids are based on 1:250,000 USGS maps with 3-arc second grid spacing. Grids constructed from USGS I-degree DEMs are not immediately suitable for the analysis of such topographic features as volume, slope, or accurate visibility, because they measure the x, y (planar) locations as latitude and longitude, while the z value (elevation height) is measured in meters. Consequently, the actual distance on the ground represented by one ground unit is not constant, and the ground distance units and the surface elevation units are not the same. To make this surface model compatible with other layers of information and suitable for analysis, the ground units in the I-degree USGS DEM have been projected into non-angular units of measure such as the LTTM coordinates. After reprojection, the grid was rescaled to the 200 m resolution, which is the highest resolution currently used in the PLM. The vertical resolution of the DEM maps is 1 m.

Using a GIS the DEM data have been preprocessed to create several other raster maps needed for the hydrologic model. Watershed Boundary (Study Area map), Slopes (Fig.7) and Aspects layers have been calculated by the Watershed Basin Analysis Program in GRASS - Geographic Resources Analysis Support System (USACERL, 1993).

The River Network coverage (Figure E4) has been acquired from the TIGER/LINE database (USCB, 1996) in a vector format. The database contained numerous errors: streams that were not continuous, missing channels (improperly digitized or missing on the original maps or photos because they may have been dry at the time the photos/maps were interpreted). The hydrologic analysis tools in the ARC/INFO GRID module (ESRI, 1994) were applied to correct the digitized stream network. Using the digital elevation model as an input we delineated the drainage system and then quantified its characteristics. For any location in the grid, those tools also gave us the upslope area contributing to that point and the downslope path water would follow. A "hydrologically proper" surface, without any artificial pits or hills, was produced and flow directions and flow accumulations were determined. Water channels were identified for different threshold amounts of water accumulation (product of the number of cells draining into a target cell and the size of the precipitation event). These water channels were used as a background coverage to manually correct stream discontinuities for the digitized River Network. The corrected River Network was converted into a raster (cell -based) format in order to comply with other data layers. This River Network map produced from the elevation data turned out to be more consistent, than the original vector map.

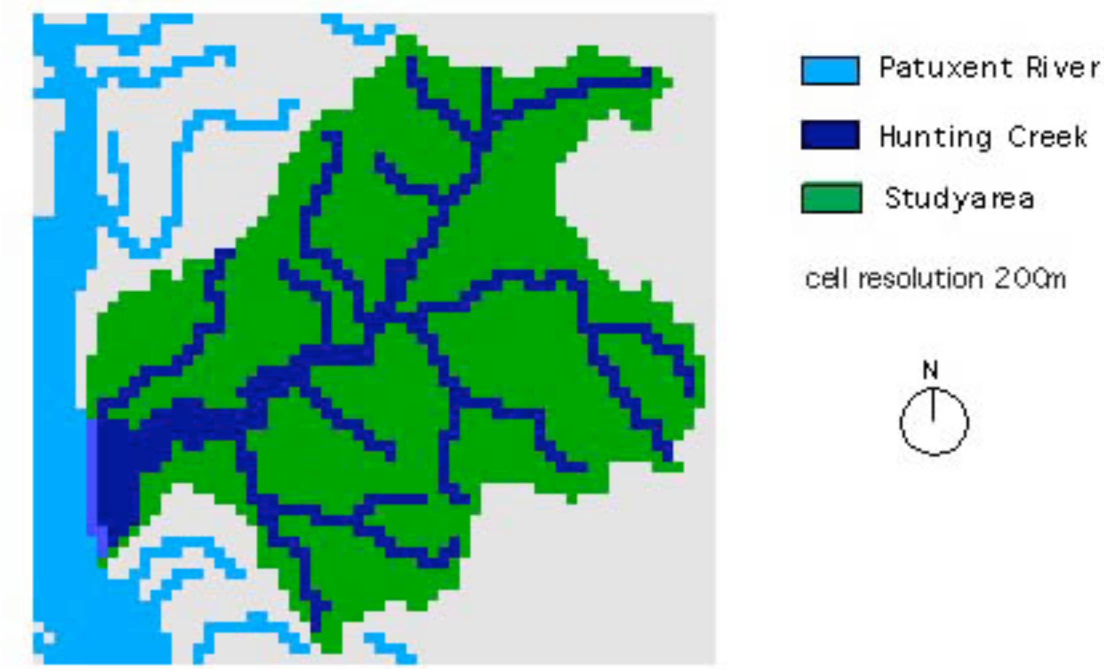

Figure E4: River network for Hunting Creek watershed based on TIGER database.

data.

The Soils layer was originally imported from the State Soil Geographic (STATSGO) data base (NRCS USDA, 1997) which has been compiled using a USGS 1:250,000 scale, 1 by 2 degree quadrangle series as a map base. The STATSGO Data Base was downloaded in GRASS format and reprojected from the Albers Equal Area Projection to the needed LTTM projection. Every map unit on a STATSGO coverage contains up to 21 components (segments) for which there are attribute data. One of the disadvantages of this data set is that these components cannot be spatially identified, which reduces the STATSGO application to the coarse regional scale.

After we analyzed the tabular information it was clear that aggregation criteria did not include hydrological properties, because one map unit could contain soils from very different hydrological groups. Therefore we could use only some general hydrological parameters from STATSGO, but most of the spatially explicit soil data was taken from the Patuxent Watershed Counties Soils map (Figure E5) available from the Maryland Office of Planning (MOP) (Maryland Department of State Planning, 1973). The Groundwater Table Map, required as an initial condition for the model, was approximated from a series of spatial and point data sets using the GRASS overlay and interpolation techniques. The reference points were taken from:

- MOP Soils map and the unsaturated depth data that was provided by the Maryland Department of State Planning;
- the elevation and river network coverages, along which the groundwater table was assumed to reach the surface;
- 15 well measurements of the groundwater level over the watershed area (James, et al., 1990).

The groundwater depth data were interpolated over the whole watershed with these data sets as reference points. After that the model was run for 100 days, the Groundwater Table Map was regenerated, saved and then fed back into the model for subsequent runs as the initial condition for the depth of the water table. This improved the performance of the Hydrological Module by significantly decreasing the initial adjustment period in the model runs.

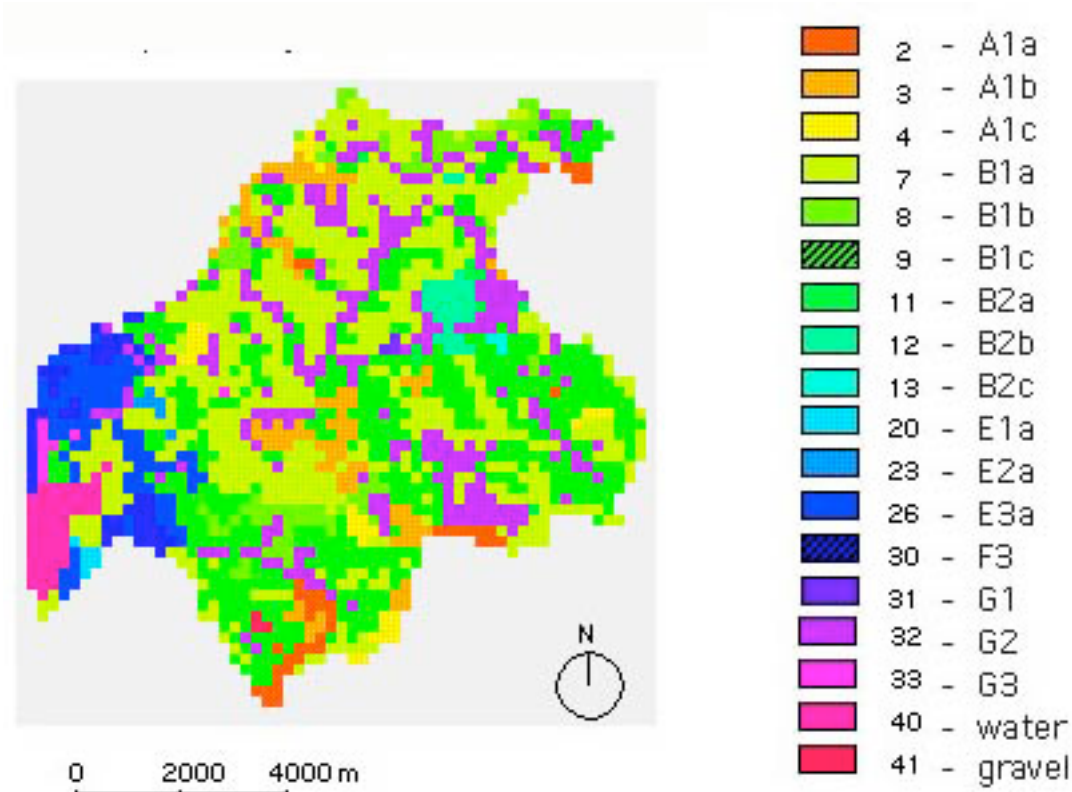

Figure E5: Soils for the Hunting Creek watershed based on Natural Soil Groups of Maryland (Table D1).

Table 1. Estimated physical and chemical properties of Natural Soils Grounp of Maryland (Maryland DePartment of state Planning, 1973)

GROUP	DEPSED	DEPWAT	DEPSOL	EROK	HYDGRP	IRRMAX	PERMAX	PERC	AWC	PH	TEXTUR
110 - 113	72+	4+	0 - 60	0.17	1	1	>6.0	<45	.02-.06	4.0 - 5.0	Lmy sd, sd sdy Lm
120	72+	1 - 10	0 - 60	0.17	1	N/A	>6.0	<45	<.06	3.0 - 8.0	Sand
210 - 213	72+	3+	0 - 60	0.32	2	0.4 - 0.6	0.60 - 2.0	45 - 60	.12 - .24	4.5 - 6.5	St lm, Lm, fine sdy Lm, sdy Lm, sty cy Lm, cy Lm, sty cy, cy
220 - 223	72+	4+	0 - 60	0.43	3	0.3 - 0.4	0.20 - 0.60	>60	.12 - .24	4.5 - 7.3	Silt loam, Loam, gravelty Loam, clay Loam, silty clay Loam
230	72+	5+	0 - 60	0.37	3	0.3	<.60	>60	.06 - .24	4.0 - 5.0	Clay, silty clay, silt Loam, Loam, Loamy sand
310 - 313	20 - 40	In Bedrock	0 - 40	0.22	3	0.3	0.60 - 6.0	<60	.12 - .24	4.0 - 7.3	St Lm, Lm, sly sty lm, sly Lm, chy Loam, chy st Lm, sdy Loam
320	20 - 40	3+	0 - 40	0.37	3	0.3	<0.60	>60	.12 - .24	5.0 - 7.5	Silty clam Loam, silty clay, clay
410 - 413	<20	In Bedrock	0 - 20	0.28	3 - 4	0.3	0.60 - 6.0	<45 - >60	.18 - .24	4.0 - 7.3	Shaly silt Loam, shaly Loam, silty clay Loam, silty clay
510 - 512	72+	1.5 - 2.5	0 - 60	0.28	3	0.4 - 0.6	0.60 - 6.0	<60	.12 - .24	4.0 - 5.0	Sandy Loam, sandy clay, Loam, Loamy sand, sand
520 - 522	72+	1 - 3	0 - 60	0.43	3	0.3 - 0.4	<.60	>60	.12 - .24	4.0 - 6.5	Silt Loam, Loam, silty clay Lm, fine sandy Loam, sdy clay Loam
530 - 532	72+	1.5 - 2.5	0 - 60	0.37	3	0.4	0.20 - 0.60	>60	.18 - .24	4.5 - 5.5	Silt Loam, Loam, silty clay Loam
610	72+	0 - 1	0 - 60	N/A	4	1	>6.0	<45	<0.06	3.5 - 5.0	Loamy sand, sand
620	72+	0 - 1	0 - 60	0.28	4	0.4 - 0.6	0.60 - 2.0	<60	.12 - .24	4.0 - 5.0	Sdy Loam, fine sdy Loam, sandy clay Loam, Loam, Loamy sand
630	72+	0 - 1	0 - 60	0.43	4	0.3	<0.60	>60	.18 - .24	4.0 - 7.8	Silty clay Loam, silty clay, clay, Loam, silt Loam
710 - 711	72+	3+	0 - 60	N/A	2 - 3	0.5 - 0.7	0.20 - 2.0	<45 - >60	.12 - .24	4.0 - 7.3	Silt Lm, Lm, fine sdy Lm, sdy Lm, sandy Loam, silty clay Loam
720	72+	0 - 1	0 - 60	N/A	4	0.5	0.60 - 6.0	<45 - >60	.18 - .24	4.0 - 7.3	St Lm, sty cy Lm, sty cy, fine sdy Lm, sandy Loam, Loam, muck
730	72+	0	0 - 60	N/A	N/A	N/A	Var	Var	Var	3.5 - 9.0	variable
810 - 813	Too variable to rate. Determine the specific soil series name from the detailed soil map and use the information for the group that the series is in.										
820 - 823	Too variable to rate. Determine the specific soil series name from the detailed soil map and use the information for the group that the series is in.										

Explanation

GROUP Natural Soil Group Code
DEPBED = Depth to bedrock (in.) -- distance from the surface of the soil downward to the surface of the rock layers. Soils were observed only to a depth of 6 feet; greater depths are specified as 72+ in.
DEPWAT = Depth of water table (ft.) -- distance from the surface of the soil downward to the highest level reached in most years by ground water.
DEPSOL = Soil depth (in.) -- this does not imply that the soils are only 60 in. deep, but rather that the estimates in the table are for th 0 - 60 in. depth and not below.
EROK = Erodibility (K factor) -- a measure of the susceptibility of the bare soil to erosion and the same K factor as that used in the Universal Soil Loss Equation (Wischmeier and Smith, 1965).
HYDGRP = Hydrologic Soil Group -- a measure of the runoff potential of soils when fully saturated. Group "A" soils have the lowest potential and "D" soils the highest.
IRRMAX = Maximum irrigation rate (in/hr) maximum rate of irrigation water applied by sprinklers.
PERMAX = Permeability (in/hr) -- rate at which soil transmits water while saturated. Permeability rates shown are based on the least permeable section of soil.
PERC = Percolation (min/hr) -- rate at which water can move through a soil with moisture at field capacity.
AWC = Available water Capacity (in/in) -- the difference between the amount of water in the soil at field capacity and the amount in the soil at the wilting point of most crops
PH = Reaction (pH) -- the degree of acidity or alkalinity of a soil group, expressed in pH units.
TEXTUR = Dominant texture -- relative percents of sand, silt, and clay in a soil sample. If the soil contains gravel or other particles coarser than sand, then a modifier is added.
Abbreviations from TEXTUR column: sd = sand, sdy = sandy, st = silt, sty = silty, cy = clay, lm = loam, chy = channery, shy = shaly,

Land Use 1990 Anderson II classification coverages (Figure E6) have been acquired from the Maryland Office of Planning in a vector format and then rasterized for the required cell resolution. In order to simplify the model and match the available sets of ecological parameters, the landuse was aggregated to 5 types. The aggregated version of the land use data (Figure E7) was developed using the algorithm described in Figure E8.

The climatic data series were taken from the EarthInfo Inc. NCDC Summary of the Day database (EARTHINFO, 1993). The point time series for Precipitation, Temperature, Humidity and Wind were then interpolated across the study area to create spatial climatic coverages. The calibration procedures were mostly based on USGS gaging data also available for downloading from the Web (USGS, 1995a). Most of the calibration runs were based on the gaging station located on Hunting Creek under the bridge on MD Route 263 approximately 2.4 miles South of Huntingtown. For this station we have data for the time period that matches the one defined by the climatic data series, that is 1990-1996.

The Calvert County Department of Planning and Zoning has provided the necessary zoning maps (Figure E9) that were important for generating the scenarios of land use change in the area. In addition the sewer planning maps (Figure E10) and maps of dwelling units densities (Figures D11 and D12) were provided by the same source.

Nitrogen fertilizer application for the farmlands of Calvert County (Table D2) has been calculated based on:

A. Natural Soils Group information (MOP),

B. Soil surveys for Calvert County;

C. MD's agronomical soil capability assessment program (defining yield expectations)

D. Plant nutrient recommendations based on soil tests and yield goals.

A nitrogen fertilizer application map has been developed using GIS techniques on the basis of soils and 1990 land use coverages (Figure E13) or on the basis of soils and projected land use scenarios (Figure E14).

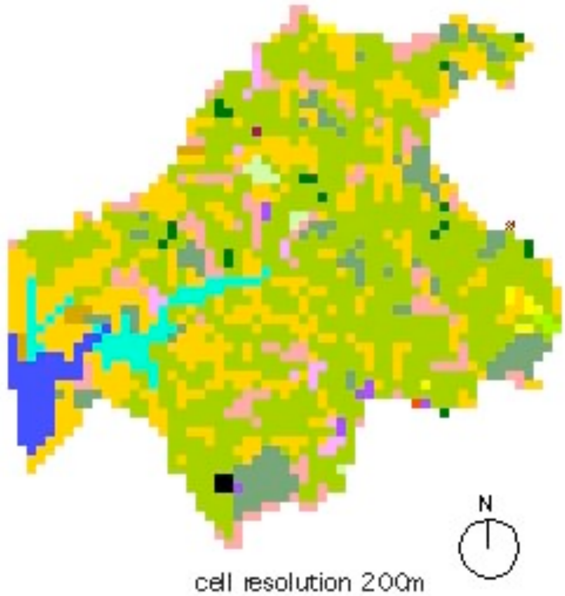

Figure E6: Landuse 1990 based on Maryland Office of planning data

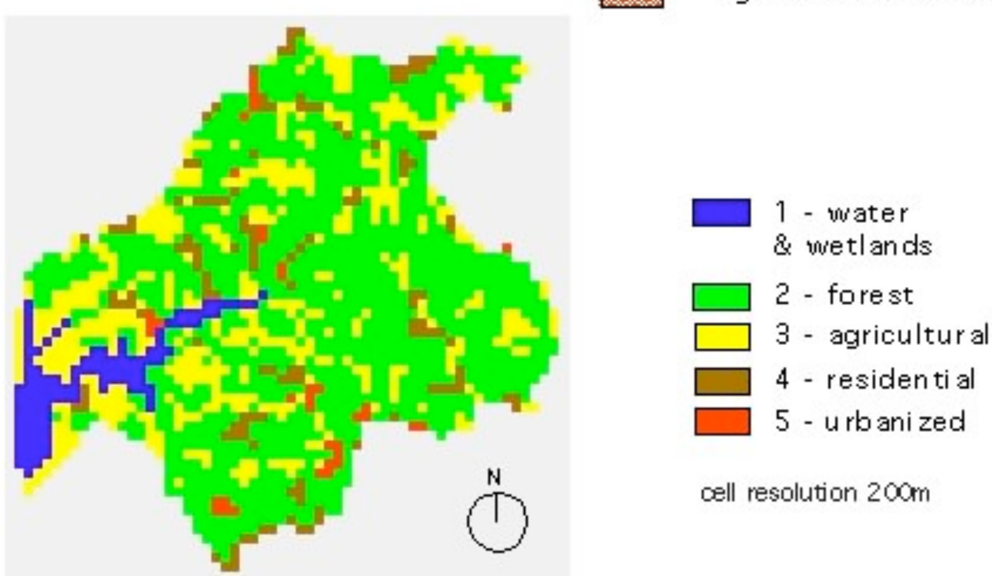

Figure E7: Aggregation level II of landuse 1990

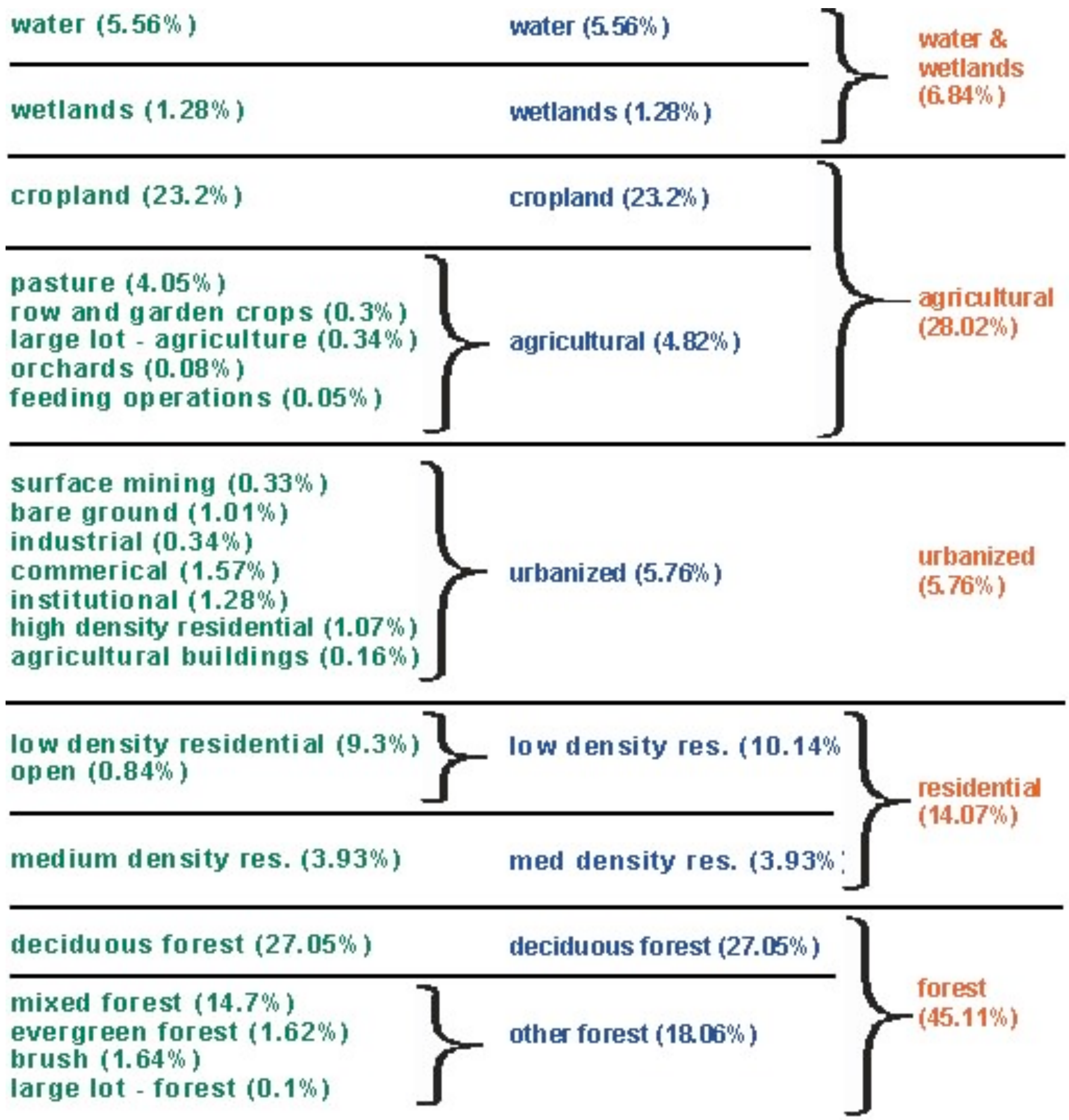

Figure E8: Aggregation of landuses assumed in the model.

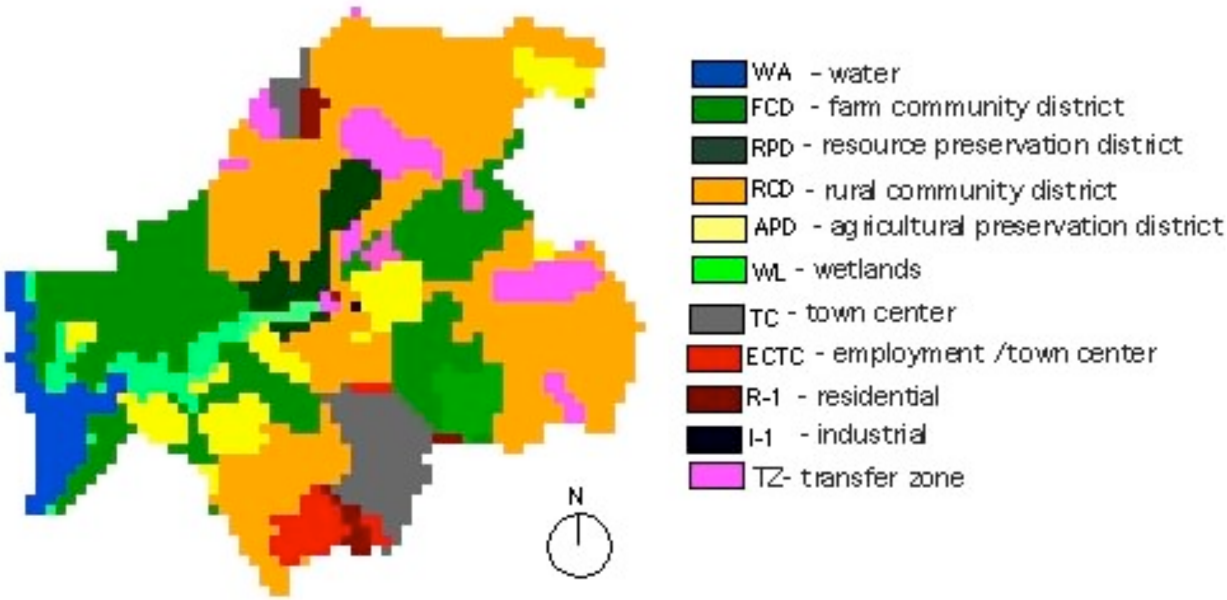

Figure E9. Zoning for Hunting Creek watershed based on data from Calvert County Department of Planning and Zoning.

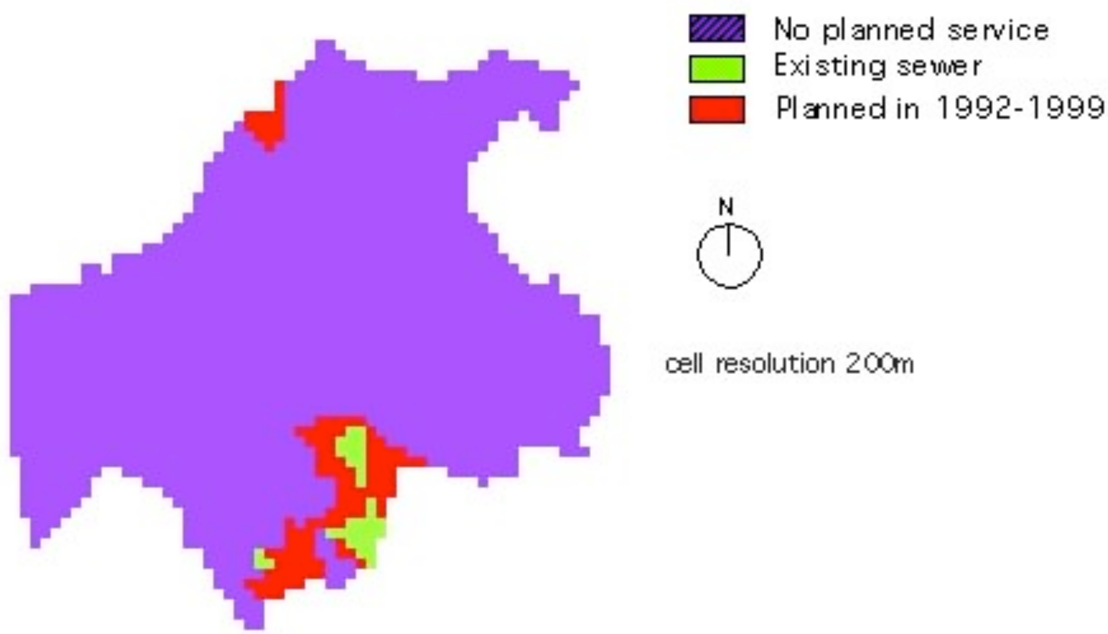

Figure E10. Zoning for Hunting Creek watershed based on data from Calvert County Department of Planning and Zoning.

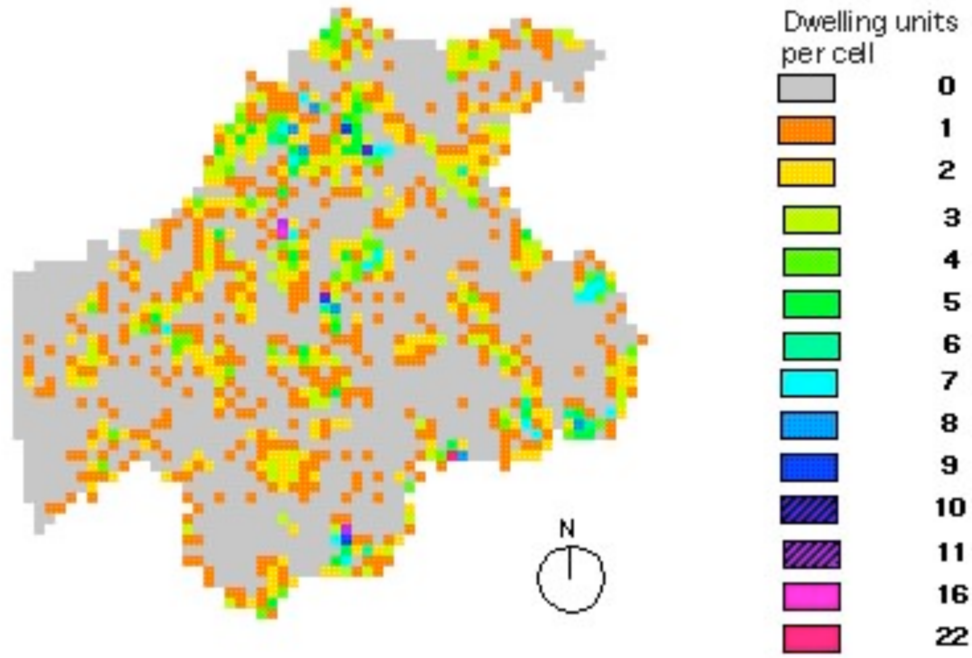

Figure E11: Density per cell (10 acres) of existing dwelling units for Hunting Creek watershed based on Calvery County Planning and Zoning Department Information.

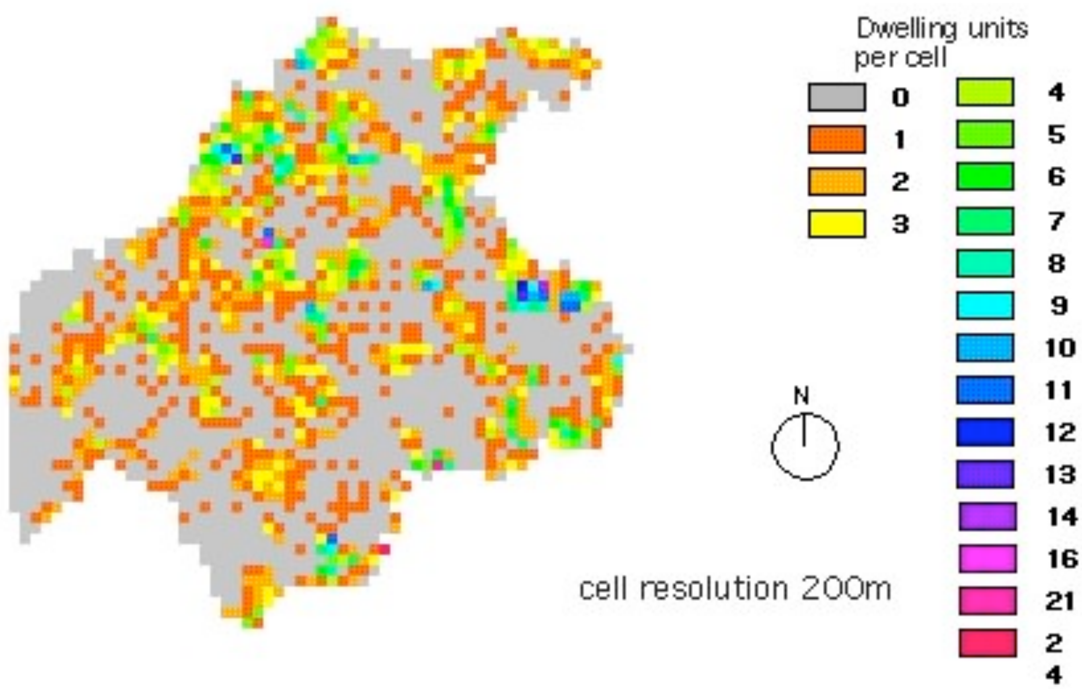

Figure E12: Density per cell (10 acres) of improved and unimproved dwelling lots for Hunting Creek watershed based on Calvert County Planning and Zoning Department Information.

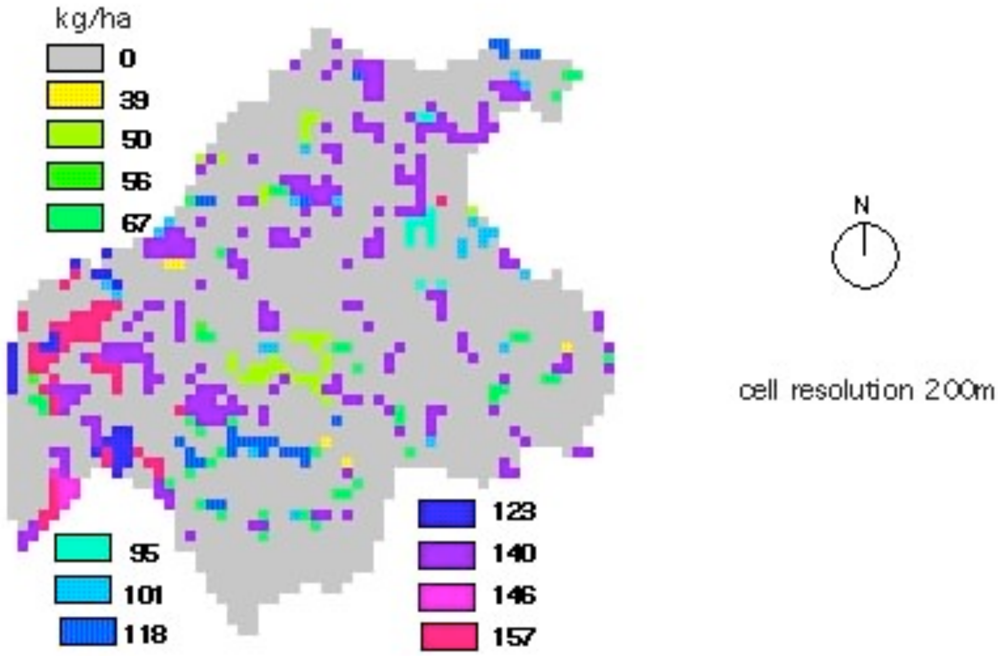

Figure E13: Estimated Nitrogen fertilizers applications (Table D2) based on Landuse 90 (Figure E7), Natural Soil Groups classification, corn yield expectation and plant nutrient recommendation.

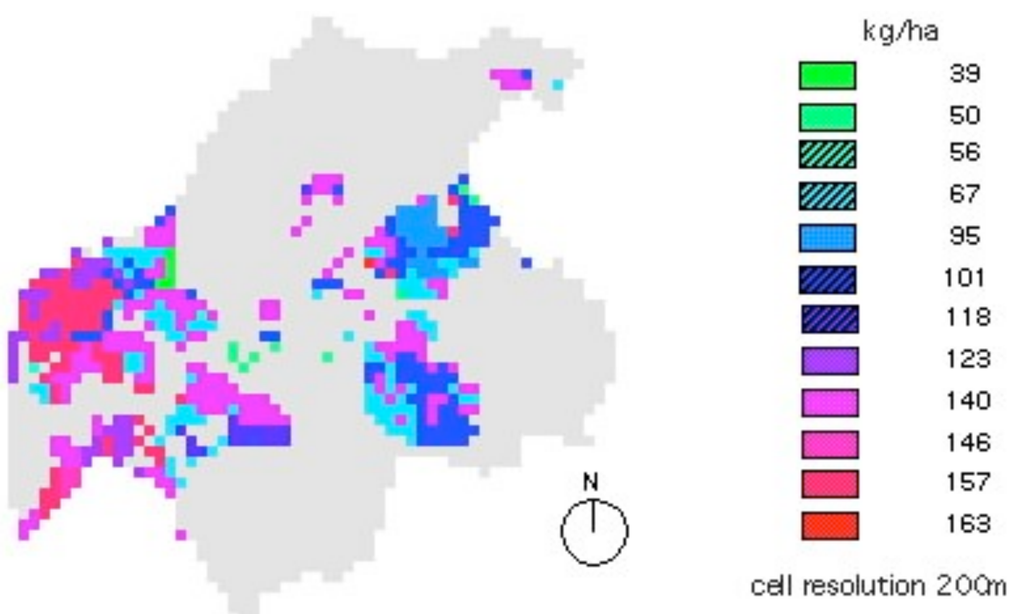

Figure E14: Estimated Nitrogen fertilizers application (Table D2) based on scenarios 1-6 Landuse, Natural Soils Groups classification, corn yield expectation and plant nutrient recommendatioin.

Table 2. Natural soil groups (NSG), yield goals and N application for Calvert County portion of Patuxent watershed

arc/info codes	NSG codes	N application (*) (kg/ha)	(lbs/a)	Corn yield(**) goal (bu/a)	number of cells	MD SCS soil types classification
2112	A1b	50	45	45	35	ReD(Rumford-Evesboro)
2113	A1c	39	35	35	32	EvE(Evesboro)
2211	B1a	140	125	125	19	ShA(Sassafras), ShC2, M1B2(Marr), M1C3, MnC2(Matapeake), MnB2
2212	B1b	118	105	105	4	WaD3(Westphalia)
2213	B1c	67	60	60	18	ErE(Eroded land, steep)
2221	B2a	157	140	140		HoB2 (Howell)
2222	B2b	95	85	85		HyD2(Howell)
2223	B2c	95	85	85		HwE2(Howell)
2511	E1	146	130	130		WoB (Woodstown)
2521	E2	140	125	125		KpB2(Keyport), BlB2(Beltsville)
2531	E3	157	140	140	12	MuA(Mattapex), MuB2
7631	F3	123	110	110	6	OtA(Otello)
7711	G1	163	145	145	1	OcB(Ochlockonee)
7721	G2	101	90	90	1	My(Mixed alluvial)
7731	G3	56	50	50	3	Tm(Tidal marsh)

References: Natural soil groups of Maryland (1973), MD Dep. of State Planning
Soil surveys by counties(1971), USDA, MD Agricultural Experiment Station
Bandel V.A., Heger E,A. MASCAP - MD's agronomic soil capability assessment program (1994) Agronomy Dep.Coop.Ext,Service, UMD, College Park
Plant nutrient recomendations based on soil tests and yield goals Agronomy MIMEO (1995), Agronomy Dep.Coop.Ext,Service, UMD, College Park

*- when corn yield was calculated, weighted avrg. was used
*- Total N recommended is 100 lbsN/a when yield goal is 100 bu/a

Calibration

When calibrating and running a model of this level of complexity and resolution, a step-wise approach is most appropriate. The HCM covers a relatively small area and could be run at a fine 200 x 200 m resolution.

We first staged a set of experiments to test the sensitivity of the hydrologic module. It has been established that there are 3 crucial parameters that control the surface water flow in the model. These were the infiltration rate, the horizontal conductivity, and the number of iterations in the hydrologic algorithms, which effectively controlled how far water could move horizontally over one day. The infiltration rate effectively controlled the height of peaks in the river water flow. The conductivity determined the amount of flow in the low period, and by changing the number of iterations we could modify the length of the peaks and the delivery rate downstream.

Calibration of the hydrologic module was conducted against the USGS data for the one gaging station on the watershed. First the model was calibrated for the 1990 data, and then it was run for 7 consecutive years (1990-1996). Figure E15 displays the annual dynamics of rainfall for 1990-1996, which shows that this period gives a good sample of various rainfall conditions that may be observed on the watershed, 1994 being the wettest year and 1991 the driest year. The results displayed in Figure E16 are in fairly good agreement with the data and may be considered as model verification, because none of the parameters were changed after the initial calibration stage for 1990.

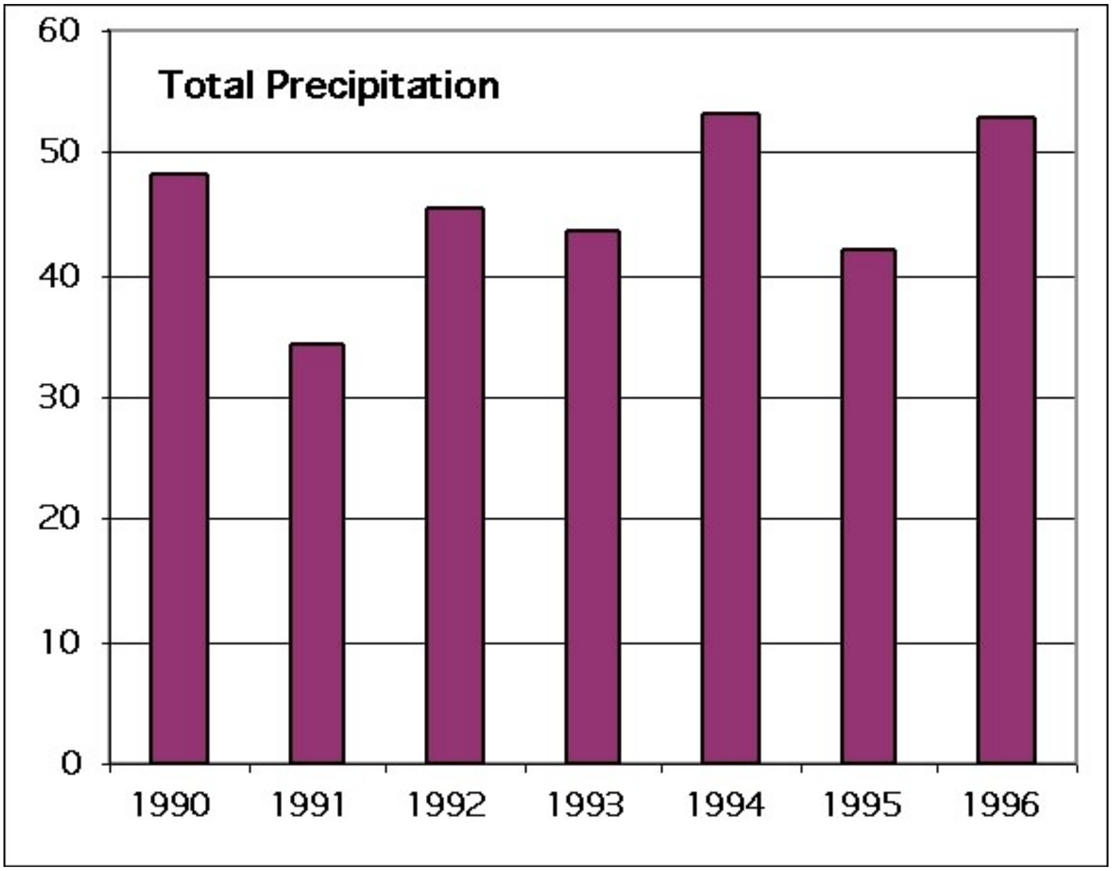

Figure E15: Annual precipitation in Hunting Creek (inches).

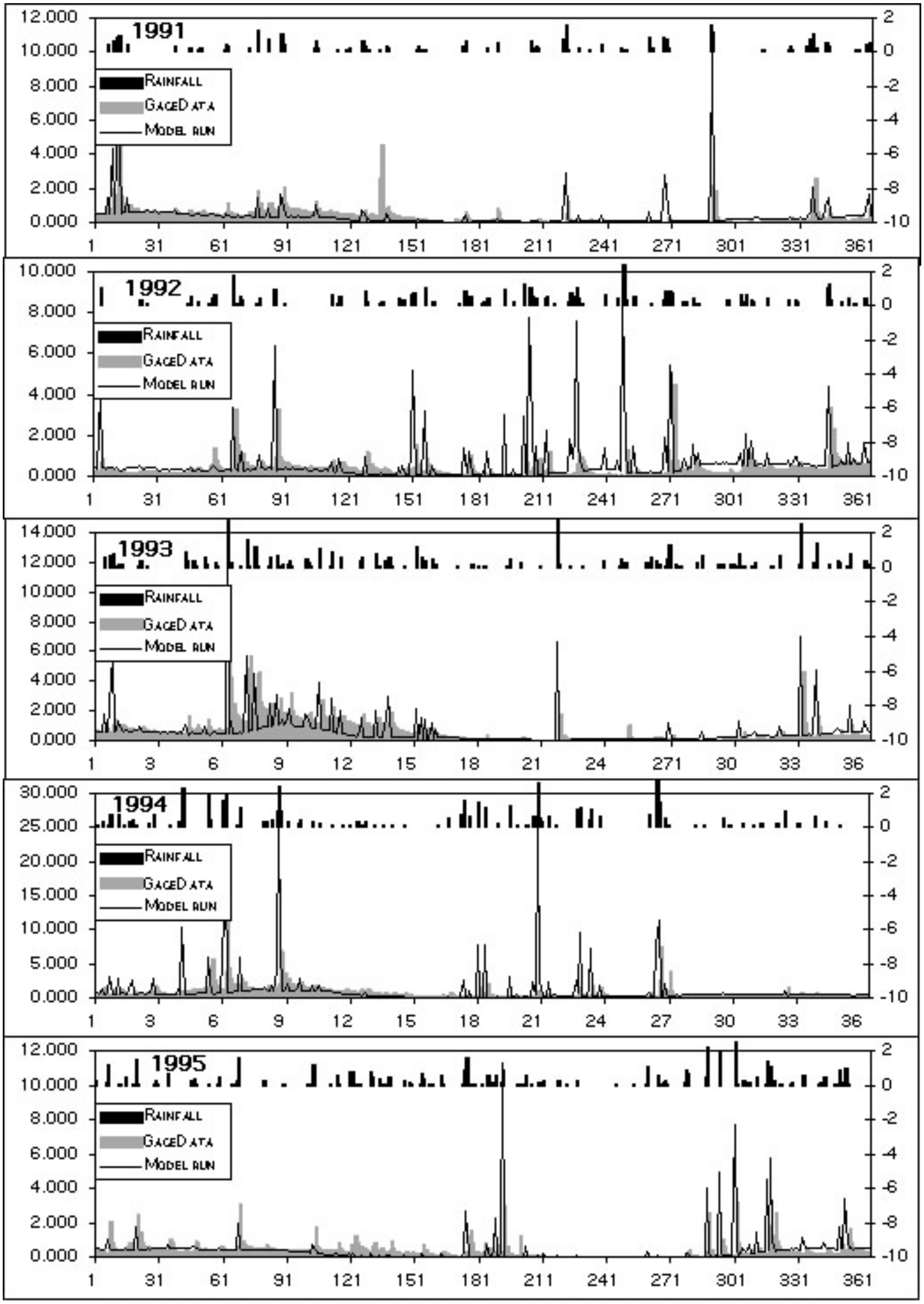

Figure E16: Calibration of the hydrologic module. Rainfall data scale on the right, flow scale on the left.

Several sources of potential error can be identified:

- Daily total precipitation is used in the model. Therefore we cannot distinguish between a downpour and a drizzle if the total amount of rainfall delivered over one day is the same. The runoff associated with these events can in fact be quite different.
- There is no climatic station located directly on the watershed. Therefore we use interpolated data from two stations nearby. However some rainfall events can be very local and therefore will not be properly simulated. The sensitivity analysis showed that the overall annual flows are highly sensitive to particular climatic time series and to the spatial patterns of climatic data.
- We also cannot exclude the chance of errors in the input data.

Nevertheless the general hydrologic trends seem to be well captured by the model. We did not have any reliable data to calibrate the spatial dynamics of ground water. However we examined the simulated total amount of water in saturated and unsaturated storage to make sure that the model is in quasi-steady state with respect to groundwater. The dynamics of these integrated values were in good agreement with the total amount of rainfall received by the watershed, responding with a lower level of the groundwater table in dry years and a rising water table during wet periods.

The comparison of flows at gaging stations is instrumental to analyze model output, calibrate and evaluate model performance. It integrates a wealth of 2-dimensional spatial information in a normalized one-dimensional fashion. For example, such spatial characteristics as infiltration rates, soil porosity, hydrologic conductivity are spatial and usually associated with a particular soil type. They define spatial flow over the landscape. Based on the elevation and link map coverages these flows are accumulated in the river network. We do not have spatial data for flow across the whole landscape, however the results observed at particular gaging stations are defined by the waterfall from all the watershed, taking into account the available spatially explicit information. Another way to view the output of a spatial model, which is especially important to localize potential accumulations of water and other spatial inconsistencies, is to output the model variables as a series of maps that can then be compiled into graphic animations. The format of a report such as this is not well suited for displaying this kind of output; further model output in map form is presented at http://giie.uvm.edu/PLM/HUNT.

Once the watershed hydrology was mimicked with sufficient accuracy, the calibration of the water quality component could be started. The nitrogen module was put into play, and the simulated nitrogen concentrations in the Hunting Creek were compared to the data observed at the USGS gaging station. It should be noted that unfortunately the station is located fairly high [does this mean upstream or vertical elevation?] on the watershed, so that it actually accounts only for a relatively small portion of the watershed. However since there is no better information available, we had to confine our calibration to this data set.

There are four major sources of nutrient loading in the watershed:

- Atmospheric deposition (data in mg/L were downloaded from the National Atmospheric Deposition Program web site (NADP, 2000)
- Discharge from sewage treatment plants (this input has been considered negligible, since in this watershed all sewage undergoes tertiary treatment (land application); however the indirect flows of nitrogen from these sources are worth further consideration in the future);
- Discharge from septic tanks (calculated as a function of discharge per individual tank multiplied by number of dwelling units multiplied by 2.9, the average number of people per dwelling unit in Maryland);
- Application of fertilizers in agricultural and residential habitats (estimated based on the

yield and soils map available from MOP);

- Mineralization of dead organic material.

The relative contribution of each of these sources is presented in Figure E17. Currently it appears that the fertilizers and the atmospheric deposition represent the major sources of nitrogen pollution on the watershed, delivering almost 80% of total nitrogen to the area. However the fate of nitrogen from different sources may be different, and one of the main uses for the simulation model is to track the pathways of nutrients from different sources to the estuary.

The model was able to reproduce the trends of nitrogen concentration at the gaging station (Figure E18). It should be noted that the water quality data are quite patchy, and a considerable time period remains unaccounted for by the observations. In addition, it may be fairly easy to miss a peak water flow while obtaining the samples, which is important because the nutrient concentrations tend to be the highest during peak flows. Therefore, the water quality data are likely to represent the baseflow concentration, and consequently they usually underestimate the true long-term nutrient dynamics.

In addition to the daily nitrogen dynamics we obtained a fairly good fit for the annual average concentration (Figure E19). This increases our confidence in the model performance, since it shows that the model does a good job of predicting the integral fluxes of nutrients over the watershed. This type of analysis is especially important when comparing the various scenarios of development in the region.

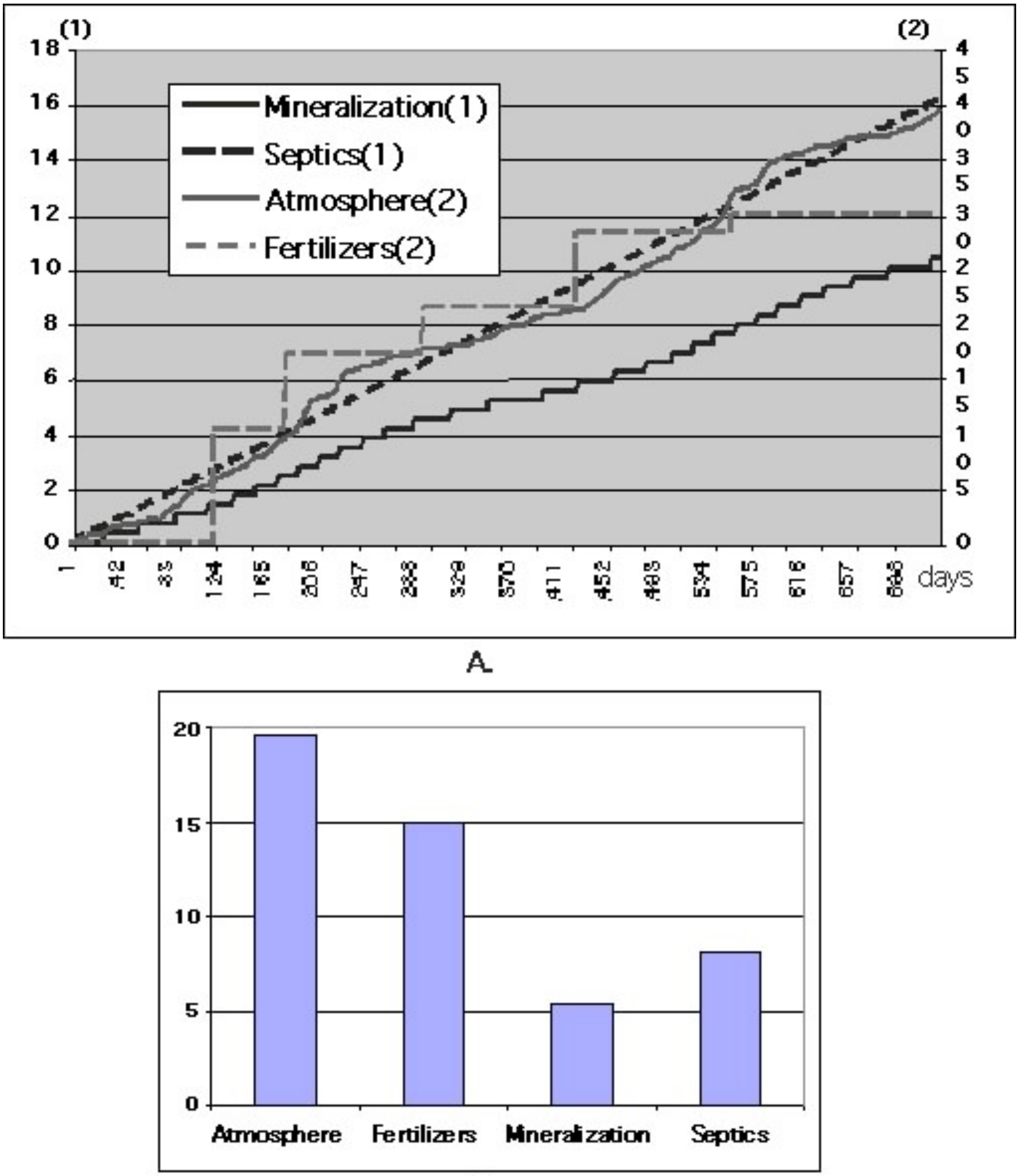

Figure E17: Nitrogen loading for the Hunting Creek watershed. A. Annual dynamics of total nitrogen loading (N kg/ha). B. Total annual nitrogen loading (N kg/ha).

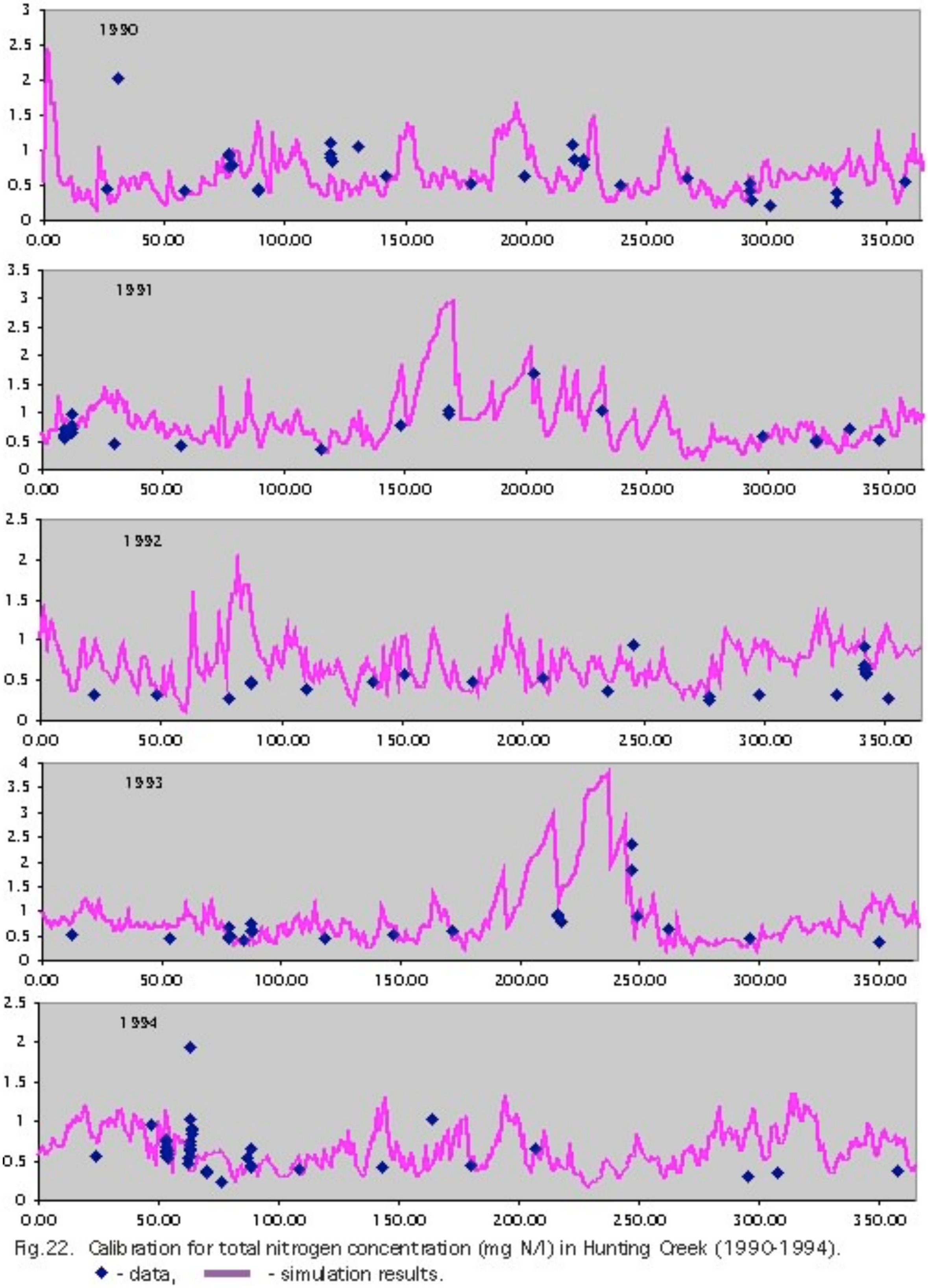

Figure E18: Calibration for total nitrogen concentraion (mg N/l) in Hunting Creek (1990-1994).

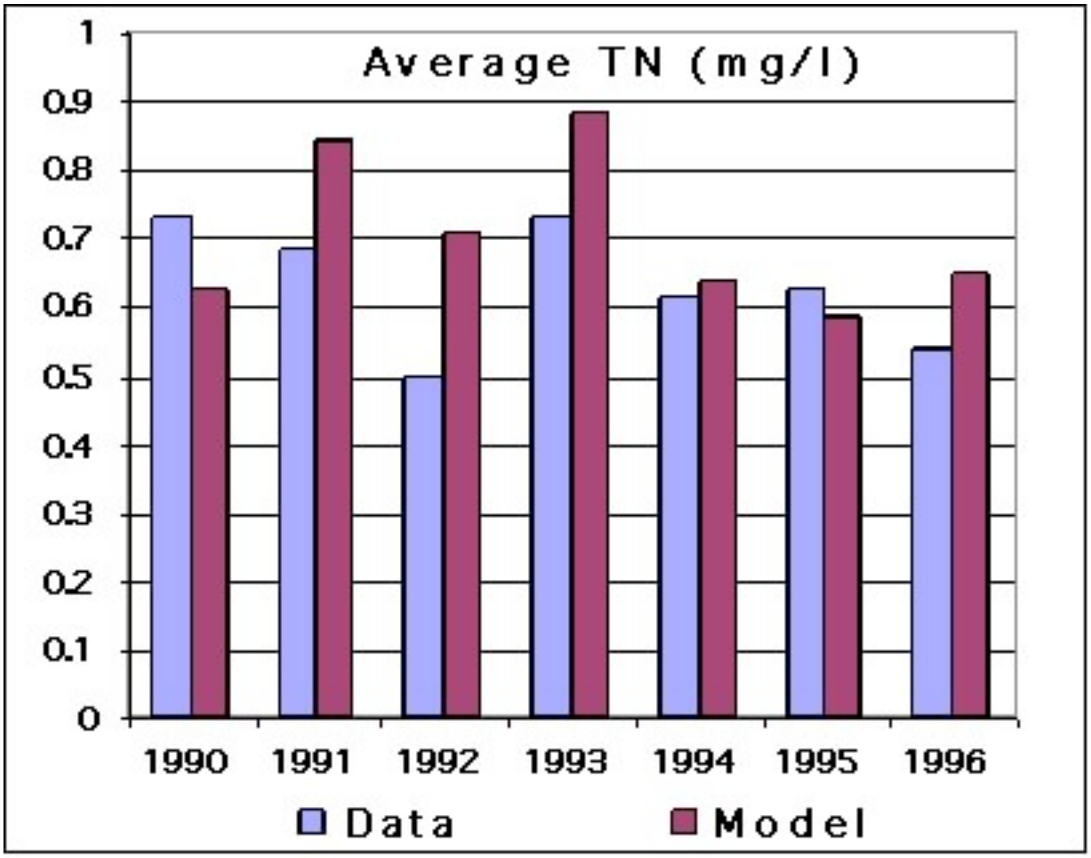

Figure E19: Comparison of average annual concentrations of total nitrogen in the model and in the USGS data.

Appendix E. Complete Hedonic Model Results

Note: For all tables, * designates significance at the 99% confidence level, ** at the 95% confidence level and * at the 90% confidence level.**

Princeton

	Value	t-value	Significance
(Intercept)	5.841795	22.628620	***
log(Liv.Area)	0.120660	2.980930	***
PropTax	0.000023	7.616288	***
log(Imp.Val)	0.492173	15.525403	***
log(LotAcres)	0.056711	7.088482	***
D2AIRPRT	-0.000003	-2.632035	***
D2TERMNL	-0.000005	-5.268763	***
D2BEACH	-0.000002	-2.059370	**
log(D2URBAN)	0.005666	3.545321	***
log(D2WATER)	0.029099	2.909319	***
D2SPARK	-0.000001	-0.452113	
D2MPARK	-0.000006	-2.670469	***
D2LPARK	-0.000004	-2.291483	**
septic	-0.033873	-1.210663	
MED.HH.INC	0.000002	6.075908	***
YRS.OLD	0.003429	4.192200	***
X2004	0.221439	4.569923	***
X2003	0.121811	4.218379	***
X2002	-0.046085	-1.864297	*

Residual standard error: 0.212356157 on 904 degrees of freedom

Multiple R-Squared: 0.86804643

F-statistic: 330.383032 on 18 and 904 degrees of freedom, the p-value is 0

New Brunswick

	Value	t-value	Significance
(Intercept)	3.862272117	7.784	***
log(Liv.Area)	0.044267533	1.978	**
log(PropTax)	0.740824135	24.658	***
log(Imp.Val)	0.060514694	2.992	***
log(LotAcres)	0.030204035	4.671	***
D2URBAN	-0.0000034	-2.788	***
D2WATER	0.000003037	1.553	
log(D2SPARK)	-0.032390188	-4.626	***
D2MPARK	0.00000328	2.073	**
log(D2LPARK)	0.018523277	3.065	***
D2BEACH	0.118599398	0.652	
log(MED.HH.INC)	-0.060697449	-1.423	
X2004	-0.00000181	-5.006	***
X2003	0.108584843	6.094	***
X2002	0.059706562	1.136	
two.story	0.084119989	4.381	***
log(D2CONTAM)	-0.038084012	-2.035	**

Residual standard error: 0.179703539 on 1636 degrees of freedom
Multiple R-Squared: 0.746015737
F-statistic: 300.333998 on 16 and 1636 degrees of freedom, the p-value is 0

Freehold

	Value	t-value	Significance
(Intercept)	6.864103484	52.017	***
log(Liv.Area)	0.153810913	10.230	***
PropTax	0.0000224	11.060	***
log(Imp.Val)	0.379310069	26.862	***
log(LotAcres)	0.076947841	14.298	***
D2AIRPRT	-0.000003805	-6.254	***
D2URBAN	0.000000522	1.442	***
URBAN	-0.000001529	-3.870	***
D2HIX	-0.054165729	-2.906	***
water100	-0.000001564	-1.717	*
CAFRA	0.12283769	1.554	
D2SPARK	-0.108707096	-5.698	***
D2MPARK	-0.000002134	-2.535	**
D2LPARK	0.000003342	2.901	***
House.age	0.000005157	8.350	***
P.VAC	-0.000484706	-2.189	**
BEACH1	0.920358857	7.075	***
BEACH2	0.228835343	3.010	***
D2UN.FOR	-0.093984101	-3.324	***
MED.HH.INC	0.000001994	9.958	***
YRS.OLD	-0.000590074	-1.488	
X2004	0.21457084	10.831	***
X2003	0.069924564	5.231	***
X2002	-0.08038887	-5.834	***

Residual standard error: 0.206935735 on 3642 degrees of freedom

Multiple R-Squared: 0.816098456

F-statistic: 702.698918 on 23 and 3642 degrees of freedom, the p-value is 0

Long Branch

	Value	t-value	Significance
(Intercept)	4.328915	41.594135	***
log(Liv.Area)	0.152283	10.003516	***
log(PropTax)	0.540172	33.870147	***
log(Imp.Val)	0.198997	18.633249	***
log(LotAcres)	0.014761	3.101666	***
log(D2URBAN)	0.001645	2.035350	**
D2WATER	-0.000005	-2.521515	**
al.siding	-0.079108	-2.605319	***
water100	0.092479	2.371969	**
D2RETAIL	0.000003	5.549714	***
D2TERMNL	0.000004	4.712920	***
ENV.SENS	0.097060	4.297184	***
D2SPARK	-0.000007	-4.481393	***
D2MPARK	0.000016	12.888312	***
D2LPARK	-0.000004	-4.910191	***
D2CLUB	-0.000014	-15.154449	***
BEACH1	0.257726	7.577603	***
BEACH2	0.045963	3.441603	***
P.BLK	-0.441276	-17.430229	***
MED.HH.INC	0.000002	11.346297	***
X2004	0.210045	2.331569	**
X2003	0.094982	6.791040	***
X2002	-0.075863	-5.265047	***
NEW	-0.023541	-2.640912	***
OLD	0.035323	6.601767	***

Residual standard error: 0.286529738 on 5991 degrees of freedom

Multiple R-Squared: 0.791114432

F-statistic: 945.407298 on 24 and 5991 degrees of freedom, the p-value is 0

Toms River

	Value	t-value	Significance
(Intercept)	6.53910765	58.918	***
log(Liv.Area)	0.12264428	10.164	***
log(PropTax)	0.48033716	48.449	***
log(Imp.Val)	0.1224917	11.604	***
log(LotAcres)	0.06662789	13.869	***
D2AIRPRT	0.00000233	4.946	***
two.story	0.04504362	7.353	***
CAFRA	0.06518192	4.920	***
D2URBAN	0.00000676	12.570	***
log(D2TERMNL)	-0.04351577	-6.378	***
log(D2WATER)	-0.02441301	-8.600	***
D2HIX	0.00000274	4.417	***
FLOOD.SFHA	0.11694168	11.533	***
water100	0.09819143	4.086	***
D2SPARK	0.00000064	0.937	
D2MPARK	-0.00000145	-2.476	**
D2LPARK	0.00000348	8.156	***
log(House.age)	-0.01731101	-3.312	***
P.VAC	0.11925327	2.208	**
NEW	-0.02124044	-2.936	***
ENV.SENS	0.03576768	2.828	***
D2UN.WET	0.00000955	3.451	***
D2UN.FOR	0.00000242	12.125	***
MED.HH.INC	-0.10721191	-5.250	***
P.OWN.OCC	-0.187534	-3.347	***
P.BLK	0.16079237	13.034	***
X2004	0.05966077	4.851	***
X2003	-0.13445492	-10.394	***
X2002	0.60186646	3.588	***
BEACH1	6.53910765	58.918	***

Residual standard error: .235852405 on 10653 degrees of freedom

Multiple R-Squared: .700414343

F-statistic: 858.831454 on 29 and 10653 degrees of freedom, the p-value is 0

Toms River fringe

	Value	t-value	Significance
(Intercept)	6.731011	7.499685	***
log(Liv.Area)	0.026877	2.249284	**
log(PropTax)	0.340076	18.545340	***
log(Imp.Val)	0.437247	21.682702	***
log(LotAcres)	0.021011	4.265779	***
D2AIRPRT	0.000013	4.205505	***
CAFRA	0.065052	2.901526	***
D2URBAN	0.000007	7.251006	***
log(D2TERMNL)	-0.123247	-4.123807	***
D2HIX	-0.000009	-8.743043	***
FLOOD.SFHA	0.139489	6.850560	***
log(D2AIRPRT)	-0.153852	-2.039607	**
D2SPARK	0.000016	9.018082	***
log(D2MPARK)	0.019294	3.529258	***
log(D2LPARK)	-0.031372	-2.982611	***
House.age	0.000779	2.317747	**
P.VAC	0.132573	1.142796	
NEW	-0.041170	-4.229298	***
D2UN.WET	0.000033	4.999717	***
MED.HH.INC	0.000001	2.772275	***
X2004	0.204360	8.701728	***
X2003	0.108891	4.610720	***
X2002	-0.081881	-3.273724	***

Residual standard error: .240302666 on 3665 degrees of freedom
Multiple R-Squared: .749568464
F-statistic: 498.624471

South Coast

	Value	t-value	Significance
(Intercept)	7.58304197	13.950	***
Liv.Area	-0.00000455	-0.379	
log(PropTax)	0.60313328	22.357	***
log(Imp.Val)	0.21887201	11.994	***
LotAcres	0.29967843	3.361	***
D2URBAN	-0.00001675	-9.090	***
log(D2WATER)	-0.04492021	-5.354	***
al.siding	-0.84312141	-2.646	***
log(D2TERMNL)	-0.27611963	-5.215	***
ENV.SENS	0.19013456	7.165	
D2SPARK	-0.00002119	-3.606	**
I(D2SPARK^2)	0	3.350	***
D2MPARK	0.00002689	7.354	***
D2LPARK	0.00002245	11.790	***
BEACH1	0.23709516	4.488	***
BEACH2	0.11549023	4.774	***
log(House.age)	-0.04620058	-3.913	***
D2UN.FOR	-2.34914171	-5.356	***
P.BLK	0.00000404	5.059	***
MED.HH.INC	0.17097883	4.593	***
X2004	0.02475577	0.670	
X2003	-0.16870714	-4.286	***
X2002	0.0289379	2.228	**
OLD	7.58304197	13.950	***

Residual standard error: .312649683 on 2224 degrees of freedom

Multiple R-Squared: .738510243

F-statistic: 273.091881 on 23 and 2224 degrees of freedom, the p-value is 0

Appendix F: Quality Assurance Plan

Summary

Valuation and value transfer

The approach to this portion of the project involves using benefits transfer methodologies to assign values to land cover types based, in some cases, on their contextual surroundings. The value estimates originate from applications of a broad range of methods and span a broad quality range, and the transfer of values from their point of origin to the target New Jersey land cover also introduces error and uncertainty. To address this, the project team maintained transparent links to the primary studies on which the estimates are based and employed a "data quality grading" system, as outlined in Costanza et al. 1992. This system can deal with the full range of data quality from statistically valid estimates to informed guesses. It assigns a numerical grade to each estimate based on assessments of the: (1) quality of models used; (2) quality of data; and (3) degree of acceptance. We implemented a simplified version of this system by creating three classes of studies, A, B, and C according to their underlying data quality (see Table 2).

GIS mapping

Since the valuation approach involves using benefits transfer methods to assign values to land cover types based, in some cases, on their contextual surroundings, one of the most important issues with GIS quality assurance is the reliability, both in terms of categorical precision and accuracy, of the land cover maps used in the benefits transfer. The team used rigorous methods to insure that the process of applying value multipliers to the maps remained error free. This involved checking area calculations to ensure that units and unit conversions are consistent, ensuring the integrity of the linkages between land cover classes and value multipliers, checking the integrity of tabular joins, and conducting manual calculations for selected records to double check certain calculations conducted in batch mode.

Hedonic analysis

This refers to the statistical disaggregation of housing prices into a schedule of marginal unobserved attribute prices and is used to empirically derive valuations for environmental amenities. Among the critical issues for hedonic analysis are the accuracy and completeness of the property sales data, accuracy of the spatial data and measurements used to derive spatial attributes, sampling strategies, rules for inclusion or exclusion of problematic observations, and analytic methods. Because of the extremely technical nature of this method, a full description of all of these is beyond the scope of this document.

Dynamic modeling

The Patuxent Landscape Model, on which this part of the study was based, has been extensively calibrated, reviewed and published (Costanza et al. 2002). The team used this model to derive relationships between spatial patterns and the provision of ecosystem services addressed in the model. The quality of these estimates can be tied to the (published) quality of the underlying model.

Data Sources

Valuation and value transfer

The data sources for this component are published studies, which have been fully referenced in the report.

GIS mapping

The two most important inputs for mapping ecosystem service values are land cover and sub-watershed boundaries (by which ecosystem service values have been summarized). Both of these have been obtained from NJDEP.

Hedonic analysis

Property sales data, including address and information on structural attributes and sales price and date, were obtained in tabular form from First American Real Estate Solutions. These records were address-geocoded, and a number of spatial attributes were derived for each observation, including control variables (e.g. distance to highway on-ramps) and variables for which values are being derived (e.g. distance to nearest park or open space). To geocode and derive these spatial attributes, a number of ancillary data sets were used (source given in parentheses). Further details on each data source is available within the metadata contained for each data layer. Layers include:

- streets/ highways (Geographic Data Technology Inc., now TeleAtlas)
- locations of downtowns/employment centers/business clusters (New Jersey Department of Community Affairs, Office of Smart Growth [NJ DCA/OSG])
- flood zones (Federal Emergency Management Agency)
- water bodies/ watercourses (New Jersey DEP)
- boundaries of public protected open space (state, county, city parks and forests, etc.; New Jersey DEP)
- Census block group boundaries (US Census Bureau)
- public transit lines and stops (GDT/TeleAtlas)
- highway exits/on-ramps (GDT/TeleAtlas)
- noxious facilities/ polluters/ major industrial sites/ Superfund sites etc./ hazardous waste sites, etc. (New Jersey DEP)
- local zoning (NJ DCA/OSG)
- school district boundaries/ school district average test scores (US Census Bureau and New Jersey Department of Education)
- shopping centers (GDT/TeleAtlas)
- Digital elevation model/slope (US Geologic Survey)

After sampling these records, a subset were analyzed using multiple regression techniques.

Dynamic modeling

Data sources for this component are detailed with the published model (Costanza et al. 2002)

Proxy measures

GIS mapping

Because ecosystem services are not mapped, the team used land cover as a proxy for ecosystem services. Using its database of valuation studies, the team was able to quantify the relationship between land cover and the ecosystem services provided for a large number of land cover types.

Hedonic analysis

As described in the main text, it was determined in the course of the hedonic analysis that the addition of school quality data to the regression model did not increase the statistical validity of the results and in some model runs actually decreased the statistical validity. It appears that the reason for this is a high degree of multicollinearity between school quality and area income. For that reason, the final model runs presented in this report exclude school quality as an independent variable, which in effect makes area income a proxy for school quality.

Historical data

None necessary for the study.

Data Comparability

Valuation and value transfer

As described earlier, the team maintained transparent links to the primary studies on which the estimates are based and also employed a "data quality grading" system, as outlined in Costanza et al. (1992). This system can deal with the full range of data quality from statistically valid estimates to informed guesses. It assigns a numerical grade to each estimate based on assessments of the quality of the underlying models, the quality of the data, and the degree of scientific acceptance of the methods. Data were coded for quality, and these codings were carried through the arithmetical calculations to help assess the quality of the results.

Hedonic analysis

A large number of value estimates for a variety of environmental resources have been derived using hedonic analysis. However, few are specific to New Jersey. This part of the study valued a set of environmental amenities specifically for New Jersey. As such, it avoided the traditional pitfalls of value transfer, where a value derived in one locale may not be truly applicable elsewhere.

GIS Data Standards

Most of the data used in the project were obtained from the New Jersey Department of Environmental Protection, or other state agencies and are presumed to meet the NJDEP spatial data standards. Some original spatial layers were created, including ecosystem service values by watershed and geocoded properties, with associated attributes. In all cases, the data processing was rigorously documented and metadata were created so as to meet the NJDEP standards. While it is expected that there are some slight spatial inaccuracies in the address geocoding of the property data, doing a full accuracy assessment of the geocoding is beyond the scope of this study because of its extremely high cost and time requirements.[28]

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[28] The vendor of the particular data product used in the study, First American Real Estate Solutions, does not supply GIS data but only tabular data with addresses. Hence spatial accuracy is irrelevant from the vendor's perspective, except for errors in recording of addresses (which are difficult to assess because it would require visiting municipal offices and reviewing paper documents). Therefore, the project team address geocoded the transaction records, using the given addresses and streets data as a reference layer. The geocoding process generates a success rate, i.e., how many records were correctly geocoded and how many could not be located on a street segment. Hence, the project team can determine the percentage of records omitted, but it is very difficult to assess the accuracy of the records that were included. Unfortunately, there is little that can be done to meaningfully assess this accuracy without making expenditures that are well beyond the level of available funding for this task. To assess the accuracy of the geocoding process with the smallest degree of statistical rigor would require sampling to get representation across a wide array of geographic conditions and would be extremely expensive because the errors are not constant over space, but relate systematically to various underlying factors. For instance, geocoding mathematically interpolates the position of a given house on a street segment (i.e. block), assuming that addresses are evenly distributed along the block, which often is not the case. Hence, errors are sometimes greater for longer street segments, which tend to occur in more rural and suburban areas. In other words, a fully stratified random design would be needed to adequately assess geocoding accuracy. More importantly, assessment of geocoding accuracy would take time that would be better spent on increasing the quality of the empirical research. In the case of a hedonic analysis the gains from such an accuracy assessment simply do not justify the extremely large assessment cost. As a research method, hedonic analysis is fairly inexact in that it generally only explains about 75 to 85% of the variance in property values. Therefore, the facts that the average geocoded property location may be off by a few meters, and that perhaps 2% of the properties are off by a few dozen meters, should make little difference in the results. Moreover, to assess accuracy, the actual location of a given house must be known and determining this is very difficult without actually going in the field with an accurate GPS unit. In some cases parcel

Data Validation

Valuation and value transfer and GIS Mapping

Because ecosystem service values are not directly observable on the landscape, there is no feasible way of validating them, other than through rigorous field tests, which is beyond the scope of this study.

Hedonic Analysis

Validation of the hedonic analysis was not conducted for several reasons. First, in any regression equation, validation requires "holding aside" a validation data set that has a similar distribution of attributes to the estimation data set. Given the high price of property data and the large number of additional property observations that would have been needed, such a validation was cost-prohibitive. In other words, we had just barely enough observations to properly conduct the hedonic analysis while staying within budget. Any further parsing of the observations into a validation set would have compromised the quality of the estimation data set, which is of far greater importance. This is not a significant problem, however, as validation is rarely done for hedonic analysis. One of the reasons for this it is very difficult to generate a comparable validation data set due to the fact that many combinations of housing attributes are nearly unique. Hence, there is likely to be systematic differences in a random draw of the validation and estimation sets. Secondly, validation is not very meaningful in the case of hedonic analysis, as actual "market value," what is intended to be measured, is not directly observable, but rather is indirectly inferred from sales price. This differs from common cases where validation is used in which actual empirical measures are being validated.

Data Reduction and Reporting

Various summaries of the data were used, but NJDEP has full access to the primary data for all parts of the study. All GIS data sets have been processed and stored in a set of ArcGIS Geodatabases,with full embedded metadata and will be burned onto DVD for NJ DEP.

Sampling

Hedonic analysis

Due to its high cost, the hedonic analysis was run on a sub-sample of property transaction data for the selected study areas. Knowing that we only had budget for approximately 30,000 records, we were able to sample only a small fraction of the state. We wished to sample a relatively contained area that contained a high concentration of the natural feature types we intended to value with the hedonic analysis. The samples also needed to be contiguous, rather than dispersed around the state, so as to have sufficient statistical power to make estimates for a given housing market or neighboring housing markets, as well as to limit the amount of predictor variable data that would need to be coded. We chose to sample within Monmouth, Middlesex, and Ocean counties based on the high degree of aquatic features, parks, protected areas, wetlands, beaches, estuaries, and forests within them. Since data are sold by zip code, our initial sampling unit was zip codes. We chose to focus our analysis on Monmouth and Middlesex Counties and purchased data for all available zip codes within them (not all were available from our vendor, First American Real Estate. We also purchased somewhat less than half of the zip codes for Ocean County (08721, 08722, 08823, 08733, 08735, 08738, 08731, 08751,08752, 08753, 08755, 08757, 08759, 08527, 08533, 08701, 08723, 08724, and 08742) and a small number of zip codes bordering Middlesex or Monmouth County, in Somerset and Mercer Counties which were included because they contained important park lands (08873, 08520, 08691, 08540). We chose to sample properties in these sample zip

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maps can be used, but this would require up-to-date digital parcel layers with identifiers that link them with the property transaction data, which, from the team's experience in several states, is usually not the case.

codes with a sales price greater than $20,000, including only single family detached homes. To reach a sample of 30,000 transactions for these zip codes, we adjusted the sales date range from between January 2001 and the time at which the records were ordered (third quarter of 2004).

Analytic Methods and Statistical Tests

GIS Mapping

This part of the project involved vector geoprocessing, in which a watershed layer is unioned with a vector land use layer. Areas were then derived and summarized for each watershed (rows) by land use category (columns) using a cross-tabulation in Microsoft Access. Multipliers were then applied to each row using valuation data from the database.

Hedonic analysis

Following sampling, data were analyzed using multiple regression analysis. The appropriate functional form and model specifications were determined through analyzing goodness of fit measures and visual and quantitative analysis of residuals. Once functional form was selected, the optimal model specification was determined by using the multi-model inference approach developed by Burnham and Anderson (2002) [29], using Akaike's Information Criterion and Akaike weights (Akaike 1973; Akaike 1978) as a heuristic for selecting models that optimized the tradeoff between model fit and parsimony.

Errors and Uncertainty

Valuation and value transfer

As outlined above, the team used a data quality grading system to describe the full range of uncertainty in the results.

Hedonic Analysis

While some slight spatial inaccuracies are to be expected in the address geocoding of the property data, doing a full accuracy assessment of the geocoding is beyond the scope of this study because of its extremely high cost and time requirements. If a large number of properties are highly spatially inaccurate, this could bias the value estimates of environmental amenities. However, it is extremely unlikely that there are enough properties with consistently large enough spatial inaccuracies to cause such bias. Other errors that are common with hedonic analysis are omitted variable bias and multi-collinearity. In the former, the lack of a control variable in the model means that the observed estimated willingness-to-pay for some attribute (as represented by the coefficient) is biased because the included and omitted variables are correlated; as a result, the coefficient on the variable may be measuring the effects of both. In the latter, two independent variables in the model are highly correlated and hence the true effect of variable 1 may be accounted for in the model by variable 2. We used the multi-model inferential method (Burnham and Anderson 2002) described above in part to help weed out unnecessarily complex models that might be characterized by such correlation.

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[29] Multi-model inferential procedures have been widely used for decades, using statistics such as Akaike's Information Criterion (which has been used since the early 1970s), Bayes Information Criterion, and Mallows Cp. Burnham and Anderson are among the latest authors to articulate a specific approach under this rubric, but many others have published on this general approach. A justification of this method or a bibliography of the extensive literature using this approach are beyond the scope of this QA statement but can be furnished upon request.

Performance Monitoring

GIS Mapping and Hedonic analysis

For both these tasks, the team produced detailed metadata, using New Jersey state standards, for all newly created data layers and rigorously documented the processing steps.

Documentation and Storage

Valuation and value transfer

All sources, data, and results have been documented and will be made available by NJDEP on a publicly accessible project web site.

GIS Mapping

All final GIS data have been made available to NJDEP through electronic media (e.g. FTP or CD-ROM). A large poster map will be printed as part of the final report.

Hedonic analysis

The data set of property transactions for hedonic analysis is proprietary and hence cannot be released to the public. However, all statistical results are contained in the final report and will be made available electronically as well.

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Valuing New Jersey's Natural Capital:

An Assessment of the Economic Value of the State's Natural Resources

April 2007

State of New Jersey
New Jersey Department of Environmental Protection
Jon S. Corzine, Governor
Lisa P. Jackson, Commissioner

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PART III:

NATURAL GOODS

State of New Jersey
New Jersey Department of Environmental Protection
Jon S. Corzine, Governor
Lisa P. Jackson, Commissioner

April 2007

Table of Contents

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Timber resources	Richard Widmann and Douglas Griffith, U.S. Forest Service
Timber demand	Dr. Adam Daigneault, U.S. Environmental Protection Agency
Valuation methods	Dr. Peter Parks, Rutgers University Dr. Hilary Sigman, Rutgers University Dr. Robert Young, Colorado State University Dr. Robert Costanza, University of Vermont Dr. Steven Farber, University of Pittsburgh

This study was prepared by William Mates, Research Scientist, NJDEP. Martin Rosen of NJDEP reviewed the report in its each of its successive drafts and provided valuable comments. Jeanne Herb of NJDEP initiated the study and provided general direction and support.

Executive Summary

I. Overview and Scope

Part III of this three-part report on New Jersey's natural capital deals with the natural goods provided by New Jersey's natural assets, i.e., its living and non-living environment. The concepts of natural capital and natural assets emphasize the fact that the natural environment, like any other capital asset, provides a stream of economic benefits over an extended period of time; given maintenance of that capital and sustainable harvest levels, those benefits can in principle be generated in perpetuity. The natural goods dealt with are divided into seven categories for analytic purposes: water, minerals, farm products, non-farm animals, non-farm plants, fish, and wood. This report is careful not to double-count ecosystem services covered in Part II.

II. Determination of Economic Value

Total Economic Value (or Total Willingness to Pay) has two main components: Market Value and Consumer Surplus. Consumer Surplus is the amount that consumers would be willing to pay for a natural good but do not actually have to pay. Market Value can be obtained from official and quasi-official data for all of the natural goods discussed in this report; Consumer Surplus, however, must be estimated. Economists have developed various ways of generating such estimates, but many of those methods require data that is not readily available or involve mathematical techniques that result in implausibly high estimates of Consumer Surplus. This report uses a more conservative approach based on the assumption of a linear demand function and a point estimate of elasticity of demand; this approach allows Consumer Surplus to be estimated based solely on Market Value and elasticity.

III. Water Resources

Based on information in the 1996 Statewide Water Supply Plan**,** New Jersey's natural environment provides between 494 and 579 billion gallons of raw (unprocessed) water annually.[1] That resource has an estimated *in situ* market value of $0.394 per 1,000 gallons. In order to measure only the value of the water itself, that figure excludes the costs of treating the water and delivering it on demand to end users. Based on the methodology described in Section II and Appendix A the Total Economic Value of that water in 2004 dollars is estimated to fall between $262 and $696 million/year (central estimate = $385 million/year), including the estimated Consumer Surplus. The present value of that benefit stream is between $9 and $23 billion (central estimate = $13 billion), based on conventional discounting at 3%/year in perpetuity. These values are subject to change based on changes in land use, climate, and other factors.

IV. Mineral Resources

According to 2004 data from the United States and New Jersey Geological Surveys, New Jersey's mines and quarries provide an average of $321 million in Market Value annually in construction and industrial sand and gravel and crushed stone. (That figure excludes a significant amount of sand dredged offshore by the U.S. Army Corps of Engineers for use in beach

[1] To avoid double-counting, these figures are net of water used for agriculture (including irrigation).

replenishment.) In order to measure only the value of the minerals themselves, the $320.9M figure excludes the costs of delivering them to end users. The Total Economic Value of that annual output in 2004 dollars is estimated at between $481 million/year and $1.1 billion/year (central estimate = $587 million/year), including the related Consumer Surplus. The present value of that benefit stream is between $16 and $37 billion (central estimate = $20 billion. These values are subject to change based on changes in extraction rates, which in turn depend on the demand for these materials.

V. Agricultural Products

Based on information from the U.S. Department of Agriculture, New Jersey's farms provided plant and animal products with a total Market Value of $787 million in 2004 dollars or $108 million net of farm production costs. The Total Economic Value of that annual output in 2004 dollars is estimated to be about $6.5 billion/year ($885 million net of production costs), including the related Consumer Surplus. The present value of that benefit flow is estimated at about $216 billion ($30 billion net of production costs). These values are highly dependent on land use, climate, and other factors and may decline as farmland is converted to other uses.

VI. Non-Farm Animals

Game animals and birds and fur-bearing animals harvested in New Jersey have an annual market value of about $3 million, based on volume data from NJDEP's Division of Fish and Wildlife and prices for related meat products in the Northeastern U.S. (The retail prices provided by the U.S. Bureau of Labor Statistics were adjusted to approximate wholesale prices.) The Total Economic Value of that annual output in 2004 dollars is estimated to be about $21 million/year, including the related Consumer Surplus, and the present value of that flow of benefits is estimated at about $703 million. The maintenance of these values depends on the stability of land use patterns, hunting policies and practices, and other factors.

VII. Fish and Shellfish

New Jersey's commercial fishing vessels harvest finfish and shellfish with a total average Market Value of about $123 million/year, according to data from the National Marine Fisheries Service. Of that amount, shellfish represent about 62% by weight and 85% by value. This harvest has an estimated Total Economic Value in 2004 dollars of about $750 million/year, including the estimated Consumer Surplus. The present value of that benefit stream is estimated at about $25 billion. These values are subject to change based on changes in fish stocks, consumer demand, and other factors.

New Jersey's recreational anglers harvest saltwater and freshwater fish with a total average Market Value estimated at about $34 million/year, according to data from various sources. This harvest has an estimated Total Economic Value in 2004 dollars of about $207 million/year, including the related Consumer Surplus; the present value of that benefit stream is estimated at about $7 billion. As with commercial fisheries, these values are subject to change based on changes in fish stocks, fishing regulations, and other factors.

VIII. Non-Farm Plants

New Jersey's landscapes provide an unknown amount of useful non-farm plants, including flowers, medicinal plants, and others. The data on these products are meager, and it is not currently feasible to estimate their economic value. Methods are being developed to estimate such values (where volume data are available), but those methods are still in the developmental stage.

IX. Timber and Fuelwood

In 2003, New Jersey used about 1.6 million cords of wood and wood wastes as an energy source, primarily for electric power generation and residential heating. The share of that fuelwood originating in New Jersey cannot be determined, and this analysis assumes that 100% of it comes from in-state sources. Based on a value of $23.48/cord in 2004 dollars, 2003 consumption had a Market Value of about $39 million/year and a Total Economic Value of about $95 million/year (including Consumer Surplus), for a present value of about $3 billion.

Between 1987 and 1999, New Jersey's marketable timber resources increased by an average of 204 million board-feet/year, of which hardwoods (i.e., deciduous trees) represented about 89%. Based on wholesale prices for the various tree species, that annual growth had a Market Value of $49 million/year in 2004 dollars. Including Consumer Surplus, this represents a Total Economic Value of between $96 and $293 million/year (central estimate = $147 million/year) and a present value of between $3 and $10 billion (central estimate = $5 billion). Whether the growth rate of the 1987-1999 period continued after 1999 is not known. The maintenance of that growth rate and therefore the above value estimates depends on a variety of factors, including land use change, climate change, harvest policies, species mix, tree disease patterns, and others.

X. Summary and Limitations

The values presented above total $1.2 billion/year in terms of Market Value (range $820 million to $1.6 billion/year) and $5.9 billion/year in Total Economic Value (range $2.8-9.7 billion/year); the difference between Market Value and Total Value represents Consumer Surplus. Based on these flows of value, New Jersey's natural capital has an estimated worth of $196 billion in present value terms (range $93-322 billion). Farm products and fish command the largest shares, followed by minerals and raw water; wood (including both sawtimber and fuelwood) and non-farm animals have the lowest shares, while the value of non-farm plants was not estimated.

The value provided varies by ecosystem, depending on the types of natural goods provided, the total acreage of the ecosystem, and the average value per acre. The value provided varies by ecosystem, depending on the types of natural goods provided, the total acreage of the ecosystem, and the average value per acre. Farmland and marine ecosystems generate the highest values in terms of total value, followed by barren land (which includes mines and quarries), forests, and freshwater wetlands. In terms of value per acre, non-ecosystem land (mines and quarries) ranks first, followed by farmland, marine ecosystems, and open fresh waters.

The results of this study should be treated as first estimates and not as final definitive valuations. For various reasons, the results do not include secondary economic benefits supported by direct expenditures on natural goods, including such secondary benefits as the economic activity supported by spending by employees in agriculture, retail food distribution, commercial fishing, mining, timber and timber-using industries, etc. These omissions lead to an *understatement* of total economic value. On the other hand, the results of the study *do* include producer costs, resulting in an overstatement of *net* economic value.

Future research should focus on the following:

- All ecosystems: more current land use/land cover data.
- All ecosystems: relationships between production of services and goods.
- Water: more current data on supplies and leakage rates.
- Minerals: tonnage and market value of sand dredged offshore.
- Farm products: more recent data on the amount of farmland by type.
- Fish: prices for recreational freshwater species; role of wetlands.
- Non-farm plants: data and methods for preparing rough valuations.
- Fuelwood: share of wood harvested in-state; estimated sustainable yield.
- Timber: more current annual growth data; estimates of sustainable yield.
- All natural goods: further research on relative per-acre ecosystem productivity.
- All natural goods: further research on elasticity of demand.

A valuation study such as this one can never be regarded as a closed book, any more than a valuation analysis in business or any other sphere: as conditions change, so do values, and the process of change is continuous. Nonetheless, it is clear that New Jersey's natural capital, both living and non-living, makes a substantial contribution every year to New Jersey's economy and quality of life by providing natural goods worth several billion dollars both annually and in present value terms.

Section I: Overview and Scope

Part II of this three-part report described in detail the valuation methods applied to the services provided by New Jersey's ecosystems and presented the results of those valuations; Part III does the same for ecosystem and abiotic *goods* (together termed "natural goods"). As Table 1 (next page) shows, New Jersey's ecosystems and the state's non-living natural capital provide a variety of economically important natural goods; for purposes of analysis and presentation, these have been grouped into the seven categories shown. While each of these categories include many specific goods, the categories themselves will frequently be referred to as "natural goods".

As Table 1 indicates, all of the natural goods considered in this report are provided by more than one ecosystem, and in some cases, it is difficult to allocate the total value of natural goods among the relevant ecosystems, as these examples show:

- "Groundwater recharge areas" are not identifiable as such from aerial photographs; rather, they exhibit one of the standard land cover types, e.g., forest or meadow. However, it cannot be assumed a priori that *all* forested lands function as recharge areas. In addition, surface waters and underground aquifers are usually hydrologically connected, so that some part of "groundwater" recharge is attributable to surface waters and vice versa.

- While forests produce more fuelwood than forested wetlands, the latter probably produce *some* fuelwood; and some farms also have woodlots. There is no clear way to determine the relative contributions of each to total fuelwood production.

Because of these and other factors, this study of natural goods does not develop detailed maps of the sort presented in Part II of this report. Additional research would be needed to address such issues and plot the results. However, Part III does allocate the value of New Jersey's natural goods on a pro rata basis among the ecosystems relevant to a particular class of goods.

The next section of this report describes the approach that will be used in estimating the economic value of the various ecosystem and abiotic goods and the value of the natural capital that produces them. After that, the seven categories of natural goods will be discussed in turn; a concluding section will assemble the results for the individual types of goods into an overall statewide summary. Each section ends with a discussion of the applicable limitations.

It should be noted that this study was unable to estimate monetary values for some natural goods (e.g., non-farm plants) due to the unavailability of certain kinds of data and/or the lack of accepted valuation methods. We omitted urban greenspace from this analysis based on the assumption that the natural goods theoretically obtainable in such ecosystems (e.g., wood) would not actually be available for harvesting; and we omitted other urban areas on the assumption that such areas do not produce any economically significant and legally available natural goods.

(text continues following Table 1)

TABLE 1: ECOSYSTEM AND ABIOTIC GOODS PROVIDED BY NEW JERSEY'S NATURAL CAPITAL[2]								
New Jersey Ecosystem	**Area (Acres)**	**Water Resources**	**Mineral Resources**	**Farm Products**	**Non-Farm Animals**	**Fish and Shellfish**	**Non-Farm Plants**	**Timber & Fuelwood**
Coastal / Marine:								
Coastal shelf	299,835		x			x	x	
Beach/dune	7,837						x	
Estuary/tidal bay	455,700					x	x	
Saltwater wetland	190,520				x	x	x	
Terrestrial:								
Forest*	1,465,668	x			x		x	x
Pastureland	127,203	x		x	x		x	
Cropland	546,261	x		x	x		x	
Freshwater wetland**	814,479	x			x	x	x	x**
Open fresh water	86,232	x			x	x	x	
Riparian buffer	15,146	x			x		x	
Urban / Other:								
Urban (impervious)	1,313,946							
Urban green space	169,550	x					x	
Barren land	51,796		x					
TOTAL	5,544,173							
***Freshwater wetland:*								
-Forested	633,380	x			x	x	x	x
-Other	181,099	x			x	x	x	--
Total	814,479							

**includes wooded farmland*

[2] In Table 1, NJDEP 1995/1997 land use/land cover data have been used to allocate Freshwater Wetlands between Forested and Other and to separate out Barren land.

Several further introductory comments are warranted. First, this part of the natural capital report deals solely with natural *goods*; Part II focuses on ecosystem *services*. In comparison, the United Nations Millennium Ecosystem Assessment treats the ecosystem goods dealt with in Part III as resulting from ecosystem "provisioning" *services*, putting the subject matter of Parts II and II in a common "service" framework. The division between goods and services in the present study is based partly on the availability of market value data for the products of "provisioning services" and not on any fundamental disagreement with the MEA's theoretical framework.

The other main reason for maintaining the distinction between goods and services (or between provisioning and other services) is to avoid double-counting benefits. For example, Part II of this study excluded the value of food from its discussion of farmland because Part III addresses it. If we include provisioning services in Part II and in Part III, we would be double-counting a major part of the value provided to New Jersey by its farmland.

Next, it should be understood that the approach to valuation used in this study uses standard economic concepts and techniques as those currently exist in "mainstream" or "conventional" *environmental* economics. Some of the basic assumptions, including the focus on human-oriented, instrumental exchange value and the use of discounting (see Section II), are contested by *ecological* economists, and there are strong arguments in favor of some of those challenges. However, the development of easily-used and widely-accepted alternative valuation techniques is still in its early stages, and the current study therefore relies on approaches which can be characterized as based on "standard" environmental economics.

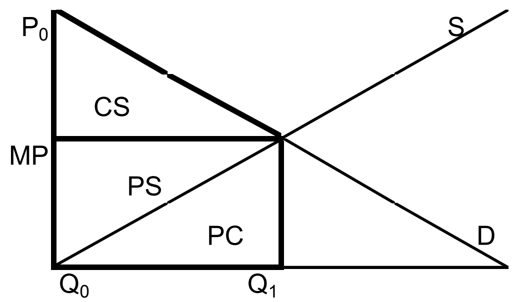
Finally, the natural capital values presented later in this report are estimates—they do not represent "the" value of any of the natural goods discussed. Estimates of the value of our natural capital will in all likelihood never be "final" because of the inherent complexity of the subject and because economic theory, empirical economic research, and "the facts on the ground" do not stand still at a given point in time. These analyses are subject to unavoidable uncertainties; and in recognition of this fact, this report presents high-end, central, and low-end estimates of the value of each natural good where the available data support this approach.

Despite these cautions, the estimated values presented in this report are supported by both data and economic theory and offer a reasonable basis both for further research and analysis and for use in policy and planning applications where it is important to have plausible estimates of the value of the many goods that nature—both living and non-living—provides to New Jersey. Together with the analyses of ecosystem services presented in Part II of this report, they give analysts, decision-makers, and the general public information that is essential for informed discussion of the values involved in environmental protection and economic development.

Section II: Economic Value of Natural Goods

This section presents a simplified summary of the approach used in this study to estimate economic value. In standard economics, the value of a good or service is the amount that consumers are willing to pay for it. Total Economic Value (TEV)[3] has two components: the amount consumers actually pay for the item, i.e., its Market Value (MV), and the additional amount they would be willing to pay for it if they had to but which they do not actually have to pay under the prevailing market conditions. The latter amount is termed Consumer Surplus (CS).[4] These components of economic value are usually illustrated as follows:

Fig. 1: Components of Economic Value



MV = PC + PS

In Fig. 1, the horizontal axis represents the quantity Q of the natural good sold by producers and bought by consumers, and the vertical axis represents the price P for that good. The upward sloping curve S represents the supply of the natural good, and the downward sloping line D represents the demand for that good. Q_1 represents 100% of the annual output of the good, and MP represents the average market price for that output. Market Value MV equals MP * Q_1.

The Market Value of the natural good in question is represented by the area inside the square box and the Consumer Surplus by the triangle lying above that box. MV in turn has two components: Producers' Cost (PC) and Producers' Surplus or profit (PS). Economic Value EV therefore equals MV + CS = (PC + PS) + CS. All of the terms defined above represent *annual* amounts.

The task of this study is to estimate the value of MV and CS for each natural good analyzed. As described in the subsequent sections of this report, estimates of MV are available from various official sources or can be calculated readily from price and quantity data provided by such sources. The challenge therefore is to estimate CS. Since we know MV, the value of CS

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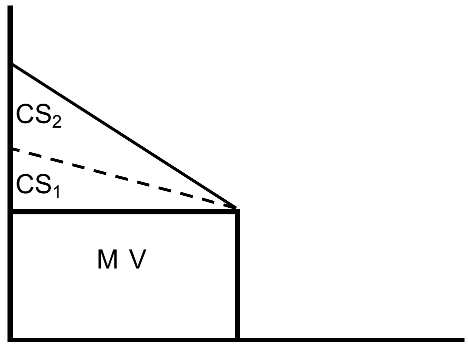
[3] Total Economic Value is also referred to as Willingness to Pay (WTP) or Total Willingness to Pay (TWP).

[4] Consumer surplus is a simplified measure of the amount by which Total Economic Value exceeds Market Value; in a more refined analysis, measures known as "compensating variation" and "equivalent variation" might be used instead.

depends entirely on the shape[5], relative steepness or slope of the demand curve, and the value of the curve close to or at the vertical axis, as Fig. 2 shows:

Fig. 2: Alternative Values for Consumer Surplus



Although we have no direct information on the shape (straight or curved), slope (steep or flat), or vertical intercept for the demand curves for the natural goods we are studying, we do have indirect information in the form of estimates for a parameter known as the "elasticity of demand" for each of these goods. Combined with certain assumptions, that information allows us to estimate the shape and slope of the demand curve for each natural good, which then allows us to estimate CS.

The mathematics involved in making these estimates is rather involved and is presented in Appendix A. The results are presented below, expressed in two ways: 1) as the ratio of Total Economic Value to Market Value, and 2) as the ratio of Consumer Surplus to Market Value, expressed as a percentage add-on. The difference between the two figures represents the Market Value itself. As can be seen, multiple estimates were developed for some goods.

Table 2: Consumer Surplus Add-Ons for Natural Goods

Class of Goods*	Ratio of Total Economic Value to Market Value	Consumer Surplus Add-On to Market Value
Fur	1.72	72%
Water	1.83 - 2.25 - 3.50	83% - 125% - 250%
Fuelwood	2.47	147%
Timber	1.96 - 3.00 - 6.00	96% - 200% - 500%
Minerals	1.50 – 1.83 - 3.50	50% - 83% - 250%
Fish	6.10	510%
Game animals	6.62	562%
Farm products	6.43 - 8.46	543% - 746%

**Comparable data are not available for non-farm plants.*

As noted above, the assumptions and formulas used to derive these figures are presented in full in Appendix A.

5 While demand "curves" are most commonly shown as straight lines, they can also have "non-linear" shapes, as discussed below.

Stock and Flow Values

Thus far we have been focusing on the value of an annual stream or flow of economic benefits. In standard economics, the value of an asset is the present value of the future benefits that it generates; this general principle applies to all types of capital assets, including natural capital. This report will present estimates of both the value of the natural goods produced by New Jersey's natural capital and the value of the natural capital itself, calculated as the present value of the recurring annual flows of natural goods.[6]

To convert future annual values to present values, it is necessary to select a discounting technique, a time horizon, and a discount rate.[7] Conventional discounting uses a single constant discount rate and assumes a finite time horizon. Under these assumptions the total present value of a benefit flow of X dollars/year for N years discounted at an annual rate of r percent equals:

$$(1) \qquad PV = X / (1+r)^1 + X / (1+r)^2 + \ldots + X / (1+r)^N$$
$$= \Sigma^N_{i=1} [X / (1+r)^i]$$

When this formula is used, the higher the discount rate, the smaller the present value of benefits received in the "distant" future. However, even at "low" discount rates, the present value of future benefits ends up being heavily discounted. For example, with a 3% discount rate, the present value of a dollar received in 50 years from now is $1 / (1.03^50) = $0.228.

The entire area of discounting is the subject of active research and debate in economics, and new discounting techniques have been developed in recent years that use multiple discount rates (with lower rates used for the more distant future) and/or completely different mathematical formulas for weighting benefits received at different times.[8] Rather than add this complexity to the report, we limit our analysis to conventional discounting of the type reflected in Equation (1). In keeping with a common practice in valuing benefits to society, we use a "social" discount rate of 3% rather than the much higher rates used in valuing private projects. See, e.g., OMB (2003).

The appropriate time horizon for valuing natural capital is also open to discussion. In principle, renewable natural capital such as a forest has a potentially infinite life if sustainably managed and if external forces do not intervene; the same is not true of non-renewable natural capital such as mineral deposits, which will eventually be exhausted regardless of the extraction

[6] Absent better information, common practice is to assume that the annual harvest and the market value of that harvest will be constant over time. Obtaining better information would require a detailed model for projecting future harvest levels and market values for each type of natural good, an effort that is beyond the scope of the current study. Moreover, even if such models could be developed, their projections of future harvests and market values would be subject to considerable uncertainty.

[7] The opposite process of converting present values to annual future ones is called amortization, and if a single rate is used, as in loan amortization, it is called the amortization rate.

[8] See, e.g., Weitzmann (2001), Newell and Pizer (2001), Newell and Pizer (2003), and Part II of this report. Some ecological economists and environmentalists argue on economic and ethical grounds against discounting future benefits, e.g., Daly and Cobb (1999); this report follows the more general practice of discounting such benefits.

rate.[9] For natural capital with a potentially infinite life, it can be shown mathematically that Equation (1) above reduces to the following over a sufficiently long time horizon:

(2) $$PV = X / r$$

In this report, present values will be converted to annual values using Equation (2), except where a relatively short time horizon is mandated by the facts applicable to a particular type of natural capital, in which case Equation (1) will be used instead. If necessary, we can also work in reverse, calculating an unknown X by amortizing the present value PV at rate r in equal annual "installments" or benefit flows:

(3) $$X = PV * r$$

This can be useful if we have an a priori estimate of PV (e.g., a price per acre for farmland) and want to estimate X (e.g., the annual rent from that land at a given amortization rate).

Inflation and Uncertainty

In looking at flows over value over time, the treatment of inflation is relevant. There are two consistent approaches in this area: 1) use real (i.e., constant dollar) values and a real discount rate, or 2) use values in current or nominal (i.e., inflated) dollars and an inflation-adjusted discount rate. For example, if the real discount rate is 3% and we assume inflation at 2%, we would inflate values by 2% each year and then discount the resulting values by a rate of about 5%.[10] However, this gives the same present value as simply ignoring inflation and discounting using the real rate of 3%, and that is the approach used in this study.

The estimates presented in this study are all subject to uncertainties of various kinds. For some natural goods, there is sufficient information to present a range of estimates; for others, there is not. In no case, however, does this study present a formal analysis of uncertainty; given the many factors whose future values are difficult or impossible to quantify, any such analysis would need to use either complex statistical techniques such as the Monte Carlo method or analysis of multiple scenarios whose individual probabilities would itself be highly uncertain. The estimates presented in this report should therefore be regarded as first-order approximations subject to change as our knowledge improves.

***In Situ* vs. Delivered Values**

As described in detail in the following section, there is an important difference between the value of natural goods and natural capital at their source (the *in situ* value) and their value at the point of final consumption (the *delivered* value). Using the terminology developed above, the former includes the cost of extracting or harvesting the natural goods; in addition, the latter also reflects processing, distribution, transportation, and marketing costs. *All* producer costs reflect value added to the raw natural goods by physical, human, and social capital; the goal of this

[9] In each case, renewability is judged on the basis of time frames relevant to society; thus, a mineral deposit that is potentially renewable given thousands of years of geological activity is classified as non-renewable in this and most other analyses.

[10] It can easily be demonstrated that the correct discount rate in this case is not 3% + 2% = 5% but rather (1.03 x 1.02) – 1 = 5.06%.

study is to estimate the value of New Jersey's *natural* capital by getting as close as possible to the *in situ* value. Table 3 summarizes the type of valuation data used for each of the natural goods discussed in this report.

TABLE 3: VALUATION DATA FOR NATURAL GOODS

Natural Good	Description of Price	Source of Price Data	Producer Costs Included in Price
Water	Contract price for raw water sold to purveyors	NJ Water Supply Authority	budgeted supplier cost and estimated return on capital
Minerals	"Free on board" price at quarry or mine site	US Geological Survey	extraction cost and profit for commercial operators
Farm products	Market value of agri-cultural products sold	US Department of Agriculture	all farm expenses (including non-cash items) and profit
Game animals	Estimated price based on selected meat prices*	US Bureau of Labor Statistics	hunter's cost and "profit"
Fur animals	Official estimate of market value	NJ Dept. of Env'l Protection	trapper's cost and "profit"
Fish	Commercial ex-vessel (dockside) price	National Marine Fisheries Svce.	harvest cost and profit for commercial fishing vessels
Fuelwood	Estimated expenditures by end-user sectors	US Energy Inform. Admin.	harvest cost and profit for commercial woodcutters
Sawtimber	Commercial sawlog price (stumpage)	Various state websites	harvest cost and profit for commercial loggers

*adjusted by deducting estimated retail margins and marketing costs.

In general, these data include the initial harvest or extraction cost and profit but not the cost of subsequent distribution, shipping, processing, etc.[11] In other words, for the most part they represent only the payments to the enterprises or individuals who first sever the natural goods from the land or water and are therefore comparable to each other and an appropriate basis for the natural capital valuations presented in this report.

[11] Some prices do reflect the cost of delivery from the harvest site to the next link in the value-added chain, e.g., delivery to dockside of commercial fish harvests.

Section III: Water Resources

Essential to life itself and to all economic activity, water is the most important of the natural goods provided by New Jersey's ecosystems and abiotic environment. Water is used as a commodity in every sector of the economy, it is widely used as a sink for pollution, and, as described in Part II, it provides a wide variety of economically and ecologically important ecosystem services.

The natural capital involved in the "production" of water resources is considered here to include all terrestrial ecosystems other than urban and barren land:

Table 4
Natural Capital for Water Resources

Ecosystem Type	Area (acres)
Forest	1,465,668
Freshwater wetland	814,479
Cropland	546,261
Urban green space	169,550
Pastureland	127,203
Open fresh water	86,232
Riparian buffer	15,146
Total	**3,224,539**

This broad definition reflects the lack of information on the specific types of land cover above New Jersey's underground aquifers, as well as the fact that wetlands also play an important role in the hydrological system. On the other hand, it is assumed here that neither impervious surfaces nor bodies of saltwater contribute to the usable water supply. These land cover assumptions can be revisited if and when more detailed information on the makeup of the hydrological system's land cover becomes available.

Valuation of New Jersey's water resources requires estimates of the quantity of water being valued and the value per unit, e.g., per thousand gallons (a common unit in water economics). In estimating the quantity of water, two general approaches are available:

- estimate the total resource "stock" contained in surface waters and aquifers and use amortization techniques to convert that stock into annual flows.

- estimate the annual "flows" of water and use discounting techniques to convert those flows into a present value i.e., a "stock value".

The stock method is very difficult to apply with any precision because we simply do not know the amount of water contained in the state's underground aquifers, and developing an estimate of that quantity would involve a major undertaking by geologists and hydrologists. The author is not aware of any water valuation studies that use this approach for a region as large and as geologically and hydrologically complex as New Jersey.[12]

This leaves us with the flow approach as a valuation method. In estimating the annual flows to be valued, we again have two major types of estimates:

- *demand* for water, i.e., the amount of water *actually withdrawn* for use.
- *supply* of water, i.e., the amount of water *potentially available* for withdrawal.

Each approach raises conceptual and data issues, as discussed below.

A. Water Demand[13]

The 1996 Statewide Water Supply Plan (Table 4.2) presented an estimate of statewide usage for 1990 of 1,499 MGD or about 547,000 MG based on average reported withdrawals for 1986-1988 for users of more than 100,000 gallons/day plus an estimate for self-supplied residential users. These figures exclude water withdrawn for power generation and storage because those uses do not involve consumptive or depletive use of the water in question.

More recent estimates of the demand for water in New Jersey were prepared by the New Jersey Geological Survey (NJGS); estimates are currently available for the period from 1990 through 1999 and are summarized below (MG = millions of gallons; per capita use in gallons). To facilitate comparison with other estimates of water demand and supply presented in this report, the table below omits water withdrawn for power generation or storage.

Table 5: Statewide Withdrawals of Fresh Water for Selected Uses (MG)
(ranked by 1999 volume; per capita figures = gallons)

Selected Use Group	1990	1999	Avg. pct. change/yr	1990-1999 Average
Potable supply	414,253	431,068	+0.4%	420,206
Agricultural/irrigation	46,775	66,240	+3.9%	58,120
Industrial/commercial	87,873	46,539	-6.8%	79,732
Mining	26,351	32,376	+2.3%	34,023
Total of selected uses	**575,272**	**576,222**	**+0.02%**	**592,082**
Total in MGD	1,576	1,579	+0.02%	1,622
NJ Population*	**7,747,750**	**8,143,412**	**+0.6%**	
Potable supply per capita	53,468	52,935	-0.1%	
Other uses per capita	20,780	17,825	-1.7%	
Total use per capita	74,248	70,759	-0.5%	

*1990 = 4/1/90 Census; 1999 = 7/1/99 estimate by US Census Bureau.

[12] According to NJGS, the next revision of the Statewide Water Supply Plan will use stream gauge records to help estimate the amount of water available for consumption.

[13] In this discussion, "demand", "use", and "withdrawals" are used as rough synonyms; despite the important distinctions among the three concepts, this usage is sufficiently precise for present purposes.

As the above table shows, use groups differ substantially in terms of their withdrawal trends. In addition, withdrawals for some uses fluctuated widely from year to year, e.g., irrigation.[14] However, considering that the 1996 Plan estimate for 1990 was based on 1986-1988 data, the agreement with the NJGS figure for actual 1990 withdrawals is quite good (547,000 MG vs. 575,000 MG).

While the figures in Table 5 represent the most recent data available on statewide water flow, using estimated withdrawals (i.e., demand) in valuing New Jersey's hydrological resources can create a serious "accounting" problem. If withdrawals exceed the level that can be sustained over time, then by definition the withdrawals must come partly from current supply and partly from depletion of (natural) capital.

Given this, discounting projected future withdrawals as though they could be maintained indefinitely would *overstate* the amount and value of our hydrological capital. Similarly, if future withdrawals were projected to fall short of what is sustainable, we could in effect be adding to our natural capital (by increasing groundwater reserves, stream and reservoir levels, etc.), in which case discounting the future withdrawals would *understate* the amount and annual value of that capital. For these reasons, estimates of water supply are arguably preferable to estimates of water demand, and the most recent supply estimates are discussed next.

B. Water Supply

The most recent estimates of the amount of water available in New Jersey are those contained in the 1996 Plan (Table 3.1) and presented below. Amounts are shown both as millions of gallons per day (MGD) and as millions of gallons per year (MGY); the latter is often referred to simply as millions of gallons (MG), the time period of a year being assumed. All figures are rounded to the nearest one thousand MGD or MG(Y).

TABLE 6: NEW JERSEY'S AVAILABLE WATER SUPPLY ACCORDING TO THE 1996 STATEWIDE WATER SUPPLY PLAN

Water Source	MGD	MG(Y)
Available surface water	853	311,000
Available ground water	903	330,000
Total available freshwater	1,756	641,000

Before we discuss these figures in detail, several caveats need to be mentioned:

[14] In evaluating these figures, it should be noted that according to NJGS staff, the most important measure of water use is not withdrawals but rather the total of consumptive (evaporative) and depletive uses, including net inter-basin transfers. On a statewide basis, about 15% of all potable supply is lost consumptively in an average year, while the other 85% is returned to the hydrological system. In some basins, such as the Passaic, such non-depletive and non-consumptive "returns" can be reused, and the reused water may represent a large part of the area's total withdrawals. The 1996 Plan discussed the significance of these factors in detail but did not include estimates of water returns in its final analysis of water availability; the updated version of the Plan will take such factors into account. Since the present study relies on the 1996 Plan for basic data, these factors are not reflected in the analysis here.

1. While the Plan is dated August 1996, the data are actually based on conditions in 1986-1988 and prior years and are therefore considerably out of date. The SWSP is currently being updated, and the new version will include more recent estimates of the state's available water supply; however, that update is not complete at this time.

2. Water for hydro and thermal power generation is not included. Leaving aside issues such as thermal pollution, water that flows through power generating equipment such as turbines is in principle available for other uses once it is discharged from the power generating facility. Therefore, the Plan omitted water used for this purpose to avoid potential double-counting.

3. Similarly, water that is diverted to storage facilities (such as reservoirs) for use in subsequent years is technically not considered to be "used" in the year in which it is diverted. Therefore, the Plan omitted stored water to avoid potential double-counting.

The sustainability or dependability of the water supply over the long-term is a key issue in this valuation analysis. In technical terms, the question is sometimes described as how to estimate the so-called "safe yield" for both surface and ground water. This question will be discussed separately for surface water and groundwater supply.

1. Surface Water Supply

The Plan defines available surface water in terms of "safe yield", i.e., the amount of surface water continuously available even during a recurrence of the worst drought on record (SWSP 1996). Surface water yield excludes water sources not backed by reservoir capacity adequate to maintain yield during a drought of that severity. Safe yield essentially represents an educated guess as to how much water it is "safe" to withdraw, based on assumptions about such variables as future precipitation, reservoir evaporation rates, stream flow needs, and other factors.

Since the severity of the worst drought of record changes whenever the record is surpassed, this factor can change over time. However, despite the severe drought of 2001, the 1963-1966 drought (often referred to as the 1960s drought) remains New Jersey's worst drought since 1895, the earliest year for which annual precipitation estimates are available.[15] Therefore, apart from changes in reservoir capacity, the SWSP estimate for surface water yield could be considered acceptable for valuation purposes. In fact, according to NJGS data, the available surface water yield given in the Plan exceeded actual withdrawals of potable surface water during the 1990s,

2. Groundwater Supply

Groundwater *recharge* is the amount of rainfall that percolates (flows) into underground aquifers (SWSP 1996). Rainfall that percolates into unconfined aquifers becomes groundwater *discharge*, i.e., water that flows out of such aquifers to streams, lakes, wetlands, and natural sub-ocean reservoirs. For groundwater, "safe yield" implies that the withdrawal rate must equal the

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[15] More precisely, the 1960s drought is the worst that New Jersey has experienced as far as potable supply and reservoir levels are concerned; however, drought impacts on agriculture and other sectors have been worse in other years.

recharge rate. That is, as consumption increases, withdrawals by public and private wells must be offset by an increase in recharge, a decrease in discharge, or both, since otherwise there will be a reduction in the amount of water stored in the aquifer.[16]

The adequacy of safe yield as a measure of sustainable supply has been questioned by some experts because it fails to take "induced recharge" into account. Induced recharge is the process whereby, at certain well pumping rates, declines in groundwater can induce water to flow out of an adjacent surface water body into the aquifer, which can in turn lead to stream flow depletion; for this reason, groundwater withdrawals are sometimes limited to help maintain streamflows and stream ecosystems. In other words, while water pumped from the aquifer initially comes from stored groundwater, its ultimate source may be induced recharge from surface water.

For this reason, unconfined aquifers and surface water together can be considered as a single resource; the concept of sustainable yield takes account of the need to look at hydrological resources as an integrated system in estimating the available water supply. As applied in the 1996 Plan, the result was that only about 15% of the total groundwater recharge was considered to be available for human use.

TABLE 7: GROUNDWATER AVAILABILITY ACCORDING TO THE 1996 STATEWIDE WATER SUPPLY PLAN

Water Source	**MGD**	**MG**
Total groundwater recharge	5,995	2,188,000
Average % available	15%	15%
Available groundwater	903	330,000

The 15% is actually a weighted average of 15% for aquifers near the Lower Delaware River, 16% for aquifers in Monmouth County, 10% for other aquifers near the coast, and 20% for aquifers in North Jersey (SWSP 1996). Each of these figures reflects expert judgment as to how much groundwater can be physically extracted in a given region without subjecting the hydrological system to "significant and unacceptable stresses", including inadequate streamflows, intrusion of saltwater into coastal aquifers, etc.

3. Projections of Water Supply

Given how out-of-date the Plan's estimates are, the question in terms of valuing New Jersey's water resources is whether the available supply is likely to have changed significantly since 1986-1988, and if so, whether there is a simple way of approximating the magnitude of the change. The most important determinant of water supply is the amount of precipitation; another possible factor is the increase in impervious surface in the state due to continued urbanization. These two factors are discussed below.

a. Precipitation Trends

Depending on the time period considered and the statistical techniques and scale used, different analysts have come to different conclusions regarding the presence or absence of a

[16] This assumes constant groundwater storage; under some circumstances, such storage can decrease.

statewide trend in precipitation in New Jersey. However, in terms of actual availability to meet human and ecological needs, the statewide precipitation totals are less important than the totals for different parts of the state, because actual water availability and the demand for water vary significantly from region to region. A given total for statewide precipitation may combine surpluses in some drainage basins and shortfalls in others; and in some cases the areas with excess available water may not be located near the areas in greatest need of that water.

Based on a detailed analysis of regional precipitation trends, Watson et al. (2005) concluded that over the last 30 years, there has been a statistically significant increase in precipitation in northern New Jersey: for the period 1895-1970, annual precipitation in that area averaged 44.6 inches, while for 1971-2001 the average was 49.8 inches, an increase of 5.2 inches or about 11.7%. For southern New Jersey, the same study found a slight but statistically insignificant increase in annual precipitation. However, the uncertainties associated with climate change make predictions based on these results subject to substantial uncertainty.

Although regional and inter-basin differences in available supply and demand are important, an analysis of economic value at the regional or basin level is beyond the scope of this study. Therefore, this analysis uses the entire state as the basic unit. A similar analysis performed at a smaller scale, e.g., HUC-11, HUC-14, WMA, or water purveyor service area could yield different results, and the differences could be material.[17] For example, while inter-basin transfers in New Jersey are significant in some areas, they impose infrastructure and other costs on society, which could affect the analysis.

b. Changes in Recharge Rates

Another factor that could affect the available water supply is the extent to which potential groundwater recharge areas have been covered with impervious surfaces such as roadways, parking lots, buildings, etc. Most water falling on impervious surfaces runs into the nearest stream or stormwater collection system and flows downstream to the ocean without recharging aquifers along the way. As development in New Jersey continues, the amount of impervious surface in the state has been increasing. Between 1986 and 1995/1997, the amount of urbanized land[18] increased by 16,545 acres annually or about 1.0%/year or much more than the 0.2%/year increase in precipitation. Even if the pace of urbanization between 1995-1997 and 2002 turns out to have slowed considerably, it seems likely to remain substantial.

Since runoff from impervious surfaces helps sustain stream flows between precipitation events, Watson et al. (2005) analyzed trends in low stream flows as a surrogate measure of changes in groundwater recharge. They found decreases in low flows at some stream gauging stations and increases in others; overall, there appeared to be no statistically significant

[17] WMAs are watershed management areas; HUC-11s and HUC-14s are smaller hydrological areas (HUC stands for hydrological unit code).

[18] In this context, the amount of urbanized land is used as a proxy for impervious surface. Most urban areas contain some green space, and many generally undeveloped areas contain some amount of paved surface, so the correspondence between land use and land cover is not exact; however, the proxy is believed to be sufficiently accurate for present purposes.

correlation between increases in impervious cover and changes in base stream flow for the period covered by the study.

Notwithstanding these results, the impact of increases in the extent of impervious surface is receiving renewed attention in the wake of the recent repeated flooding of certain reaches of the Delaware River, and the issue cannot be regarded as settled. While such flood waters inflict considerable economic damage, they move downstream too quickly to contribute significantly to New Jersey's available water supply. However, pending further research on these effects, this study make no attempt to adjust the 1996 Plan's estimates of available water supply to reflect the impacts of continued development.

C. Conclusions on Water Flow

Given the various uncertainties, there is clearly no ideal method of quantifying the amount of water that can be considered as part of New Jersey's natural capital.

- The 1996 Plan presented an estimate of statewide usage for 1990 of 1,499 MGD or about 547,000 MG based on average reported withdrawals for 1986-1988 for users of more than 100,000 gallons/day (including an estimate for self-supplied residential users but excluding water withdrawn for power generation and storage).

- Annual water withdrawals averaged 592,000 million gallons during the 1990s, again excluding power generation and stored water. This estimate represents the average for the decade; withdrawals in 1990 (the most recent year for which data are currently available) were about 3.7% *below* the average, while demand in more recent years may have increased as a result of New Jersey's continued strong population growth.

- The 1996 Plan estimates total available water supply at 641,000 million gallons/year excluding power generation and stored water. This estimate reflects allowances for maintenance of streamflow and avoidance of saltwater intrusion into coastal aquifers and is therefore arguably the best estimate of sustainable yield *based on the levels of precipitation, urbanization, etc. in 1986-1988*.

Some economists would argue that the demand figures are the most relevant ones for a valuation analysis, since water that is available but not used creates no apparent benefits for society. However, this argument ignores the fact that water not withdrawn from surface waters or aquifers can improve streamflows, increase the amount of stored (and therefore potentially available) groundwater, and provide other benefits. Therefore, the valuation analysis presented later in this section uses both the demand and supply figures to provide a range of estimated valuations.[19]

[19] It should be noted that under natural conditions, the hydrological system is in a state of approximate dynamic equilibrium. That is, over a sufficiently long period, wet years (in which recharge/supply exceeds discharge/demand) offset dry years (when the reverse is true). Within the hydrological cycle, the amount of water entering the system will always equal the amount leaving it in the long-term. Changing precipitation patterns and human activities can alter the distribution and timing of this circular flow of water, but artificial changes to the hydrologic cycle become part of that cycle.

In the context of the current study, one adjustment is needed before the above figures can be used for valuation purposes. As shown in Table 5, an average of 58 MGY or about 9.8% of the average total withdrawals of 592 MGY for the period 1990-1999 went for agriculture, including irrigation. (Comparable figures for water flow estimates derived from the 1996 Plan are not readily available.) Water is obviously an essential input for food production, but as such it is reflected in the value of the food produced in New Jersey (see Section V). Therefore, including the value of that water in this section as well would amount to double-counting. To adjust for this factor, 9.8% of the assumed annual flow is deducted in the valuation analysis below, leaving 90.2%.

In closing this discussion of the quantity of water to be valued, we note that climate projections for the mid-Atlantic states indicate that in New Jersey, global climate change could lead to increased precipitation and flooding, increased drought, or some combination of the two (e.g., flooding at certain times of the year and drought at others) (MECA 2001). The uncertainties increase when we consider the risk of more frequent and/or more intense hurricanes and other extra-tropical storms. Given these uncertainties and the lack of recent hydrological data, any estimate of the amount (and therefore the value) of New Jersey's water resources must be considered tentative. This entire analysis will need to be revisited once the NJGS withdrawal and use data and the SWSP have been updated.

D. Commercial Value of Water

The other two pieces of information needed for valuation of our water resources are estimates of the market value of water (gallons of water supplied times dollars per gallon[20]) and the elasticity of demand for water; we treat the former first. In developing an estimate of market value, we first need to avoid double counting the value of water "embodied" in goods that require water for their production. For example, food crops need water and are economically valuable; however, their value *includes* the value of the water used to produce them just as it includes the value of fertilizer, tractor fuel, farm labor, etc. (In this context, economists would call water used on crops an "intermediate" good and food a "final" good.) Counting both the water and the food represents double-counting and is to be avoided; the same applies to timber, farm animals, freshwater fish, etc.

Through the analysis on the preceding pages, we have determined the amount of water assumed to be supplied by New Jersey's natural hydrological capital. Therefore, to calculate market value, we merely need an estimate of the market value per unit, e.g., per thousand gallons (one commonly used quantity). However, valuing "raw" (i.e., untreated) water at its source presents other difficulties besides double-counting, as will appear below.

Since a number of studies of the economic value of water have used the actual price paid by consumers for water at the tap to estimate market value (see e.g. Young 2005), the most obvious source of data for this would appear to be the rates end users of water are charged by New

[20] The value of water is determined by local and regional site-specific characteristics and options for use, so in theory water value should be estimated on a regional or local basis. Such a detailed analysis is beyond the scope of this project, which focuses on the average statewide value.

Jersey's water purveyors. The New Jersey Board of Public Utilities (BPU) sets rates for water purveyors serving 1.1 million of the state's residential and commercial[21] customers or roughly a fourth to a third of that market; as of July 1, 2005, the average rate for these 1.1 million customers (weighted by the number of customers of each purveyor) was about $3.51 per 1,000 gallons (excluding meter charges), or about $3.39 in 2004 dollars.

A less obvious source of price data are the Purchased Water Adjustments Clauses (PWACs), which set the amounts included in retail rates to enable purveyors to recover the costs they incur when they themselves have to purchase water to meet end-user demand. For regulated purveyors, those amounts are also set by BPU. As part of this research, we reviewed BPU rate orders involving PWACs from 2000 forward, focusing on the seven purveyors that serve 5% or more of the 1.1 million customers whose water rates are set by BPU; as a group these seven accounted for over 87% of those 1.1 million customers. The PWACs we found established rate adjustments for purchased water ranging from $0.906 to $2.573 per thousand gallons in 2004 dollars, with an average of $1.50/1,000 gallons[22] for the orders reviewed.[23] We also reviewed data from the 2000 Community Water System Survey conducted by USEPA, a national survey with more than a thousand respondents; however, that source did not provide price data of the type needed.

While these kinds of price data are more or less readily available, they fail to distinguish between the value of raw water at its source (an aquifer or surface water body) and the value of water at the tap (Young 2005). The latter, sometimes called the "delivered price", includes the value not only of the raw water itself but also the value added to the raw water by purveyors in the form of delivery infrastructure (pipes, pumping stations), treatment facilities (plants, chemicals), labor, and so forth.

Valuing water at the delivered price thus entails valuing much more than just the water. This can be seen most easily if we break down the process that makes water available into distinct component parts and imagine that different companies are involved at each stage of the process:

- Company A pumps raw water from underground aquifers or surface water bodies and delivers it to a water treatment firm, which pays A an amount that reflects A's costs and profit margin (producer surplus).

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[21] Data for other classes of water users, e.g., industrial, is less readily available than for residential customers, and we have therefore generalized from the residential sector. Except for some industrial users that require high-quality water, quality standards are generally higher for potable (i.e., residential and commercial) water. Therefore, generalizing from the residential sector may overstate the prices actually paid for water by non-residential customers; however, the extent of that overstatement (if any) is not readily determinable.

[22] It is important to note a PWAC allocates the purveyor's cost of purchased water over the entire amount of water that the purveyor's supplies. Therefore, PWAC amounts *understate* a purveyor's actual cost per thousand gallons purchased.

[23] The PWACs of most purveyors did not come before BPU during the time period surveyed because those purveyors did not request increases in their retail rates to reflect increased costs for purchased water. The figures in the text therefore do not represent the complete universe of PWACs.

- Company B treats the raw water to conform to water quality standards and delivers it to a regional "wholesale" purveyor that pays B an amount reflecting B's costs (including the amount that B paid to A) and profit. The value added by B consists of the price at which it sells the water minus the price it paid Company A.

- Company C distributes treated water to retail purveyors that pay for it in a similar fashion. Assume for present purposes that C also temporarily stores some amount of water so that it can meet surges in demand during peak use periods. The value added by C consists of the price at which it sells the water minus the price it paid B.

- Finally,[24] D delivers treated water on demand to individual users, again paying for the water it purchases and selling it at a price that reflects its cost of purchased water and the value it adds by delivering it to end users (including D's profit margin).

In paying D for the water it uses, the end user is thus paying for the water extracted from natural sources by A, the treatment provided by B, the availability on demand provided by C and D, and the delivery services provided by D. To say that the value of the water as *natural* capital includes the value of the essential services provided by B, C and D is to attribute to nature values that are created by human and physical capital.

To further clarify this point, we could also imagine an end user (one who does not have a private well) by-passing this entire process by driving to a spring, filling a 50-gallon drum with water, bringing the drum home, adding treatment chemicals to the water, etc. While this alternative might cost less than the "normal" process of obtaining water, even including the value of the time spent by the end user, it would represent an enormous inconvenience for most people, an inconvenience that we willingly pay water purveyors to avoid. However, while convenience has clear economic value (since we willingly pay for it), it does not represent natural capital.

A final shortcoming of rate-setting information as a source of market values is the fact that rates represent administratively established prices rather than market prices.[25] Because of this, their relationship to Total Willingness to Pay is unclear. For all of the above reasons, delivered prices or rates set for purveyor-supplied water clearly have serious limitations in terms of their ability to quantify the true economic value of water and are not an appropriate basis for estimating the value of natural hydrological capital.

E. Economic Value of Water

There is another source of data that are less subject to these problems, namely the prices charged by the New Jersey Water Supply Authority (NJWSA), a public agency. In 2004, the Authority sold raw water to forty-two customers, including both purveyors and ultimate users; the Elizabethtown Water Company was the Authority's largest customer, accounting for 62.5%

[24] In this example we ignore the cost of treating and disposing of wastewater.
[25] This does *not* mean that rate-setting is an inappropriate way of establishing the prices end users must pay for water; that issue is not relevant to the present analysis.

of total 2004 contracts. In that year,[26] the Authority had contracts to supply a total of 198.562 MGD (72,475 MGY) from its Raritan and Manasquan systems at a weighted average price of $0.283 per thousand gallons.[27]

The magnitude of this price (in relation to both the retail rate and the rate adjustment for purchased water) suggests that it represents a closer approximation to the true economic value of raw water, because it clearly has much less room to include producer costs not related to natural capital than the rates discussed above. Finally, the NJWSA prices arguably represent the amount that its customers are willing to pay for raw water, since the Authority's customers include a major utility (the Elizabethtown Water Company) that purchases over half of the water contracted for by the Authority and Princeton University, a contractee that clearly does not suffer from a lack of bargaining power.

As a public agency, NJWSA sets its prices to cover its projected costs, as shown by its published rate schedules and the explanations of its rates (available at www.njwsa.org/html/publications.html). Its prices do *not* reflect what in the for-profit sector would be termed return on equity (ROE), i.e., the owners' profit or producer surplus. For 2004-2005, BPU used a standard return on *common* equity of 9.75% for regulated water utilities, representing the level determined by BPU to be needed for such utilities to earn a competitive rate of return on their common equity capital.[28] (Non-common equity would include such things as *preferred* stock.) In more recent (2006) water rate proceedings before the Board, BPU Staff recommended an increase in the return on common equity above the 9.75% level. The Board has yet to make a determination as to whether or not it will accept that recommendation, and in the absence of a Board decision, this analysis will use the 9.75% rate.

For the Authority, the equivalent to return on equity would be return on net assets. According to the NJWSA 2005 Annual Report, the Authority's net assets as of 6/30/03 were as follows:

Table 8: Net Assets of the New Jersey Water Supply Authority

Type of net asset	Value at 6/30/03
Unrestricted	$46,738,915
Invested in capital assets*	35,978,635
Subtotal	**82,717,550**
Restricted	11,721,789
Total net assets	**94,439,339**

*net of related debt

[26] The Authority operates on a June 30 fiscal year; for simplicity, FY 2004 will be taken as the relevant year for this analysis.

[27] A weighted average was used because the contract price for water supplied from the Manasquan system is much higher than the price for water from the Raritan system ($0.922 vs. $0.215 per thousand gallons).

[28] See, e.g., rate orders for New Jersey-American, Mount Holly, Gordon's Corner, Shorelands, Middlesex, Crestwood Village, and Montague Water Companies at http://www.state.nj.us/bpu/home/rincrease.shtml.

These three types of nets assets merit separate consideration in the context of determining a market rate of return to be included in the market value of raw water:

- Unrestricted net assets correspond most closely to common equity, and it is assumed here that the true 2004 market value of the raw water sold by NJWSA would include a return of 9.75% of these assets.

- While the net assets invested in capital assets are not available for other uses, it seems reasonable that those assets would be expected to earn a suitable return, and this analysis assumes that the market value of the Authority's raw water sales would also include a 9.75% return on these assets.

- Restricted net assets might be considered as the NJWSA equivalent of non-common, since such assets would not necessarily be expected to earn a market rate of return.

A return of 9.75% on the $82.7 million of unrestricted net assets and investment in capital assets equals $8,064,961; dividing this by the 72,475.13 MG of contracts in effect in 2004 gives $0.1113 per 1,000 gallons, and adding that result to the average contract price of $0.2827 per 1,000 gallons gives a total estimated for-profit equivalent *market* price (including producer surplus) of $0.3940 per 1,000 gallons.

This estimated market price is about 11.6% of the 2004 retail rate of $3.39 per 1,000 gal. for customers of regulated purveyors. This low percentage reflects the fact that, as many economists have noted, U.S. water markets treat raw (i.e., untreated and undelivered) water almost as a free good (see, e.g., Young 2005 and Tietenberg 2000), at least in the comparatively water-rich Eastern states. This implies that the only commercially important costs in those states are felt to be those for treatment and delivery.

The *potential* market value of raw water is clearly much higher than this analysis would suggest, since if prolonged drought were to become the norm as a result of climate change,[29] the price of water would presumably increase well beyond current levels. Even without prolonged drought, where underground aquifers are the source of the water used, and where the rate of withdrawal from those aquifers exceeds the recharge rate (as appears to be the case in some parts of South Jersey), the low prices currently charged reflect the partial depletion of our endowment of natural groundwater capital.

Elasticity of Demand and Leakage

The other main determinant of Total Willingness to Pay for raw water besides the quantity and value per thousand gallons is the elasticity of demand for that water. It might seem that the demand for water should be highly inelastic, since water is essential for life for most economic activities. However, empirical studies have documented the existence of some elasticity based on the fact that not all uses of water are truly essential, e.g., lawn watering and car washing. In effect, there are multiple uses of water and therefore multiple elasticities of demand.

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[29] Decreased precipitation in New Jersey has been identified as a possible consequence of global and regional climate change.

According to Young (2005, p. 269), most estimates in the literature for the price elasticity of demand for water fall into the range from -0.2 to -0.6, meaning that a 1% increase in price would lead to a decrease in demand of between 0.2% and 0.6%. Some studies have found an even wider range, e.g., -0.1 to –1.57, depending on the use, time period, etc. (WSDE 2005). This study will use the narrower range cited by Young; as in many other studies, elasticity here is assumed to be constant.

A final valuation factor not mentioned so far is the amount of water lost during delivery from the purveyor's facilities to the end user due to leaks and other causes. Water that is lost due to such causes provides no value to the end user, and Young (2005) and others state that the value of water should be reduced to reflect this. Based on the analysis of BPU data presented in Exhibit A, we estimate the loss percentage for New Jersey at between 12.8% and 26.4%, with a central estimate of 19.6%.

Calculation of Total Willingness to Pay

Based on the methodology described in Section II and Appendix A, we estimate the Total Willingness to Pay for the raw water supplied by New Jersey's hydrological capital to be as shown below; because of the range of estimates for certain key parameters, we present low-end, central, and high-end estimates.

Table 9: Total Willingness to Pay for Raw Water (2004 $)

Parameter ↓ or Estimate →	**Low-end**	**Central**	**High-end**
Key assumptions:			
Elasticity of demand	-0.6	-0.4	-0.2
Leakage rate (see Exhibit A)	26.4%	19.6%	12.8%
Total NJ supply (MGY)	547,000	592,000	641,000
% not for agriculture/irrigation[30]	90.2%	90.2%	90.2%
Adjusted total supply (MGY)	493,394	533,984	578,182
% delivered (1-leakage)	73.6%	80.4%	87.2%
Amount of water delivered (MGY)	363,138	429,323	504,175
Market value per 1,000 gal.	$0.394	$0.394	$0.394
Market value/year $MM	$143.1	$169.2	$198.6
Consumer Surplus/Market Value	83%	125%	250%
Consumer surplus/year $MM	$118.8	$211.4	$496.6
TEV/year $MM	$261.8	$380.6	$695.3
Present value at 3%/yr $Bn	$8.728	$12.686	$23.175
Natural capital (acres)	3,224,539	3,224,539	3,224,539
TEV/acre/year $	$81	$118	$216
Present value/acre $	$2,707	$3,934	$7,187

Key: CS = consumer surplus; MV = market value; TEV = total economic value

[30] As discussed earlier, the average of 9.8% of total supply used for agriculture and irrigation is deducted here to avoid double-counting the benefits of that water, since those benefits are reflected in the value of New Jersey's agricultural products (see Sec. V).

There is obviously an element of uncertainty in these estimates, but they indicate the probable order of magnitude relevant to valuation of New Jersey's water resources under current market and environmental conditions. Of course, since water is essential for life, the "true" value of water, defined as what users would be prepared to pay to obtain an adequate water supply in a severe drought, may be an order of magnitude or more *greater* than these figures suggest. If future climate change leads to reduced precipitation in New Jersey (as some climate modeling results suggest), those higher values may become more relevant than the conservative estimates presented here.

Section IV: Mineral Resources

The other major abiotic natural goods produced in New Jersey are certain non-fuel raw minerals. While New Jersey is not usually considered a major mining state, it contains deposits of commercially valuable construction and industrial sand and gravel and crushed stone.[31] Data published by the U.S. Geological Survey (USGS) indicate that for the 10-year period from 1995 to 2004 (the most recent year available), New Jersey's mining companies extracted minerals with a total market value of about $342 million in 2004 (see Table 10 and Figure 3 below).

Reflecting the fact that most quarries in New Jersey are classified as barren land, this report considers the natural capital relevant to mineral production to consist of New Jersey's 51,796 acres of barren land (see Sec. I, Table 1). This figure does not reflect the portion of the coastal shelf sites that provide sand for beach replenishment, since most of that sand is extracted by the Army Corps of Engineers for use in beach replenishment and neither the tonnage nor the value are part of the data set on which this analysis is based.

As Table 10 shows, the three mineral products for which USGS data are available have followed very different production and price trends, although in general, output and prices tended to move in opposite directions during these years.

- Production of *construction sand and gravel* generally trended upwards from 1995 to 2004. Over the same period, prices generally declined. According to NJGS staff, these figures include offshore sand dredged by a private partnership but exclude offshore sand dredged by the Army Corps of Engineers for purposes of beach nourishment. Since the valuation analysis presented below is based on the USGS figures, it therefore understates the total value of the sand-and-gravel component of New Jersey's natural capital.

- Production of *industrial sand and gravel,* a much more expensive product, fluctuated widely, declining through 2002 and rising sharply in 2003 and 2004. In contrast, prices rose steadily through 2002, then dropped sharply in 2003 and again in 2004.

- Production of *crushed stone* showed small but steady increases through 2001, plunged steeply in 2002, and recovered in 2003-2004. The price trended slowly downwards through 2001, plunged steeply in 2002, and returned to previous levels in 2003-2004.

The USGS dollar amounts represent the estimated FOB (free on board) plant prices.[32]

(text continues after table and figure)

[31] The U.S. Geological Survey defines these materials as "minerals"; an industry term used for these three materials is "aggregates". While each of the three is itself a class containing multiple related minerals, the three terms will be used here as though each of the three is a single mineral product or natural good.

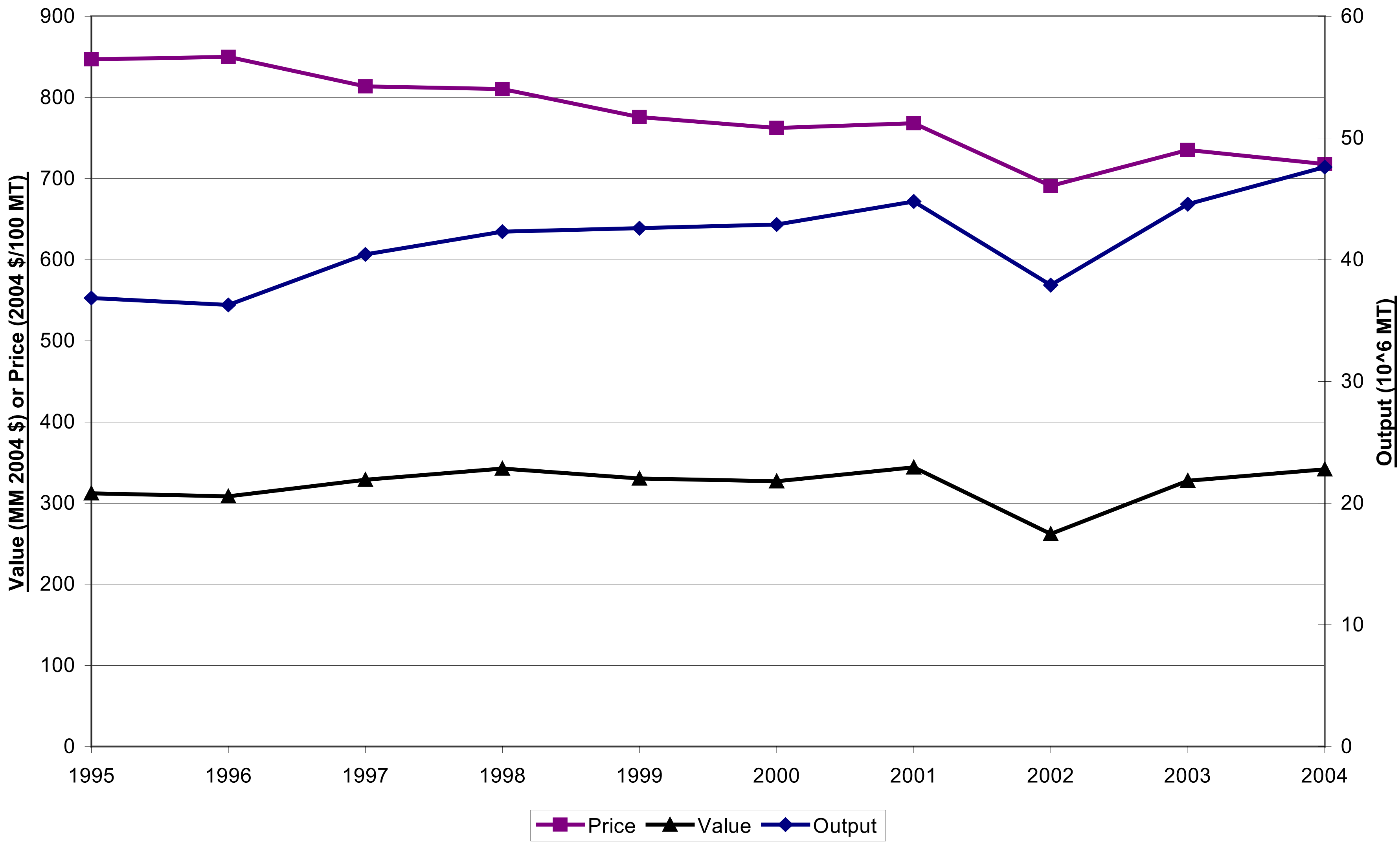
[32] FOB plant means the prices at the first point of sale or "captive" use, as reported by the production company, including all costs of mining, processing, in-plant transportation, overhead, and profit, but excluding transportation from the plant or yard to the customer.

Table 10: Nonfuel Raw Mineral Production in New Jersey (current $) (excl. $1,000/yr of gemstones; 2003 = prelim.; MT = metric tons)				
	Construction sand & gravel	**Industrial sand & gravel**	**Crushed Stone**	**Total excl. clays & misc.**
000 MT (1 MT = approximately 2,200 lb.)				
1995	14,100	1,760	21,000	36,860
1996	13,200	1,680	21,400	36,280
1997	16,100	1,530	22,800	40,430
1998	16,600	1,800	23,900	42,300
1999	16,500	1,580	24,500	42,580
2000	16,300	1,690	24,900	42,890
2001	16,800	1,580	26,400	44,780
2002	16,000	1,420	20,500	37,920
2003	18,200	1,570	24,800	44,570
2004	20,100	2,020	25,500	47,620
2004 $ per MT				
1995	$7.34	$21.98	$8.10	$8.47
1996	$6.71	$22.11	$8.53	$8.50
1997	$6.55	$22.33	$8.30	$8.14
1998	$6.56	$22.53	$8.08	$8.10
1999	$6.47	$23.47	$7.61	$7.76
2000	$5.86	$23.91	$7.67	$7.62
2001	$6.34	$23.92	$7.57	$7.68
2002	$6.38	$24.55	$6.10	$6.91
2003	$5.97	$21.47	$7.47	$7.35
2004	$5.97	$17.72	$7.29	$7.18
Value $000 (2004 $)				
1995	103,426	38,688	170,016	312,130
1996	88,634	37,148	182,555	308,336
1997	105,516	34,158	189,261	328,935
1998	108,960	40,558	193,200	342,718
1999	106,689	37,076	186,560	330,325
2000	95,540	40,412	191,080	327,032
2001	106,428	37,793	199,824	344,045
2002	102,078	34,858	125,080	262,016
2003	108,675	33,714	185,265	327,654
2004	120,000	35,800	186,000	341,800

Source: U.S. Geological Survey, Mineral Yearbook: The Mineral Industry in New Jersey, http://minerals.usgs.gov/minerals/pubs/state/nj.html and calculations by NJDEP.

Current dollars as reported by USGS converted to 2004 dollars using the US Bureau of Labor Statistics Producer Price Index for construction sand/gravel/crushed stone and for industrial sand. Available at http://data.bls.gov/PDQ/outside.jsp?survey=wp. Accessed 10/25/06.

Figure 3: Aggregate New Jersey Mineral Production



The markets for all three of New Jersey's commercially valuable minerals are strongly affected by demand in the construction industry. According to USGS, "[d]emand for industrial minerals was strong [in 2004] because of the continuing construction boom and a particularly strong housing sector. The demand for new home construction remained very strong [throughout the year], with little sign of letting up at the end of 2004" (USGS 2004). Indeed, in commenting on 2004, USGS stated that "it has become increasingly difficult to keep pace with demand" (USGS 2004). However, the 2004 figures do not reflect the subsequent slowing of the New Jersey new homes market in 2005-2006 or the slowdown in highway construction projects in the state in recent years.

As Table 10 shows, the prices for these mineral products have fluctuated widely over the period 1995-2004. However, Fig. 3 shows that despite the many fluctuations in price and output for each of the three minerals, the total market value for the three as a group has been relatively stable over the period 1995-2004, with the single exception of 2002. In that year, aggregate market value dropped by 23% from the 2001 level before increasing by 25% in 2003. In no other year (of these ten) did aggregate market value change by more than 6% in either direction. It seems reasonable, therefore, to use the average for the nine years 1995-2001 and 2003-2004 as an estimate for the annual aggregate market value. That nine-year average comes to $320.9 million in 2004 dollars.

Unlike the other natural goods considered in this report, mineral resources are not renewable[33], and in theory, therefore, future extraction volumes will depend on the time frame over which the production level implied by the $320.9 million/yr rate can be maintained. However, while there appear to be no publicly available data on New Jersey's in-ground reserves for these minerals, sand, gravel, and crushed stone are virtually ubiquitous in New Jersey, and there is no apparent reason to assume a physical limit to future extraction. As with many other minerals, estimates of reserves are driven mainly by new discoveries (probably not applicable in the New Jersey context) and by economics. That is, as a mineral's value increases, deposits previously considered not worth extracting are reclassified as "economic reserves", and vice versa.

It is true that no new mines or quarries have been opened in New Jersey in over twenty years, except for off-shore operations to extract sand for construction uses (e.g., beach replenishment).[34] In fact, as the New Jersey Geological Survey (NJGS) stated in its review of 2004, "[r]ising real estate prices, environmental concerns, and government regulations pressured the industry to close many operations" (USGS 2004). This statement suggests that future production of minerals in New Jersey may be constrained by legal and economic factors before the mines or quarries themselves are physically exhausted; USGS says much the same thing in its annual Mineral Commodity Summaries (USGS 2006).

[33] Sand used for beach replenishment may later be washed back offshore by tidal and storm activity and then re-dredged and placed on the same beach; this cycle can be viewed as a type of resource reuse.

[34] The USGS data for New Jersey reflect the extraction of sand from offshore sources by private companies.

On the other hand, it seems to be generally accepted that, barring the unforeseen, New Jersey's population will continue to increase in the decades ahead, creating fresh demand for the three mineral types being studied here. In addition, when the New Jersey Transportation Trust Fund is replenished, an increase in highway repair and reconstruction can be expected, adding to the private demand.

Therefore, although there appears to be no rigorous way to estimate reserve levels (and therefore useful economic lives) for New Jersey's three commercially valuable minerals, there is also no apparent reason for rejecting the assumption of production in perpetuity used in the other sections of this report. Even if the physical amount extracted were to decrease, it seems reasonable to assume that future demand would offset this by generating upward pressure on per-ton prices, thereby maintaining annual market value, which is the relevant factor for valuation purposes.[35]

There appear to be few published estimates of the elasticity of demand for the types of minerals found in New Jersey; this may be in part because (as noted above) the markets for such products tend to be highly localized.

- According to Poulin (1996), demand for mineral aggregates is believed to be highly inelastic in the short run, as reflected in a non-peer reviewed study in Florida (Morrell 2006) which found a demand elasticity of –0.20 for crushed stone. This value is in line with the elasticities for the other abiotic natural good considered in this report (water) and with another non-food-related good (timber).

- In contrast, an EPA analysis (USEPA 1997) under the Clean Air Act cited demand elasticities of –1.0 and –0.9 for the *cut* stone and cement industry sectors, respectively. These goods are more highly processed and value-added products than *crushed* stone and could be expected to have more elastic demands.

In the absence of other information, this report adopts these estimates and the midpoint between them of –0.6 for the three New Jersey minerals while noting that a wider literature searchmight identify other relevant elasticity estimates.

Based on these elasticity values and the methodology described in Section II and Appendix A, the Total Willingness to Pay (TWP) and Consumer Surplus (CS) for this class of natural goods are estimated to be as follows:

(see table on next page)

[35] This type of (hypothetical) increase in *real* prices should be distinguished from general inflationary increases in *nominal* prices; as discussed in Section II, only the former are relevant to this study.

Table 11: Total Willingness to Pay for New Jersey Minerals (2004 $)			
Parameter ↓ or Estimate →	**Low-end**	**Middle**	**High-end**
Elasticity of demand	-1.00	-0.60	-0.20
Market value/year $MM	$320.9	$320.9	$320.9
Consumer Surplus/Market Value	50%	83%	250%
Consumer surplus/year $MM	$160.5	$266.3	$802.3
TEV/year $MM	$481.4	$587.2	$1,123.2
Present value at 3%/yr $Bn	$16.045	$19.575	$37.438
Natural capital (acres)	51,796	51,796	51,796
TEV/acre/year $	$9,293	$11,338	$21,684
Present value/acre $	$309,773	$377,923	$722,804

Key: CS = consumer surplus; MV = market value; TEV = total economic value

In terms of future supply, a factor not considered thus far is the potential for some parts of New Jersey to meet some of their stone and gravel needs from sources outside New Jersey, e.g., from quarries in eastern Pennsylvania and southern New York.[36] However, according to NJGS staff transportation costs are a major component of the total cost of mineral aggregates, and transportation by truck[37] beyond 20-30 miles or so is not economically competitive with more local production, especially since this type of surface mining use relatively simple technology.[38]

On the demand side, the key factors driving long-term economic value will undoubtedly be the levels of residential and commercial construction and of public spending on highway projects. These factors are in turn driven by interest rates, fiscal conditions, and other factors the consideration of which lies well outside the scope of this study. While demand will probably continue to fluctuate from year to year in line with these underlying conditions, the long-term trend seems likely to be upwards for the foreseeable future.

Given the factors just described, the estimated values in Table 11 should be regarded as first-order approximations; the exclusion of offshore sand dredged for beach replenishment, probably makes them conservative. The lack of more precise data on supply sources, in-state reserves, demand and price trends, and future legal constraints precludes developing a more authoritative estimate. However, even without such information, the values presented above represent plausible first-order estimates of the substantial economic benefits provided by New Jersey's mineral-related natural capital.

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[36] The movement of *sand* would more likely be in the opposite direction, since as a coastal state, New Jersey has larger deposits of sand than inland states.

[37] According to NJGS staff, however, barge transport is economically feasible over much longer distances, with much lower per-ton shipping costs, allowing some mineral aggregates to be brought to the New York City area from quarries as far away as Quebec. Transport by rail could be even more cost-effective if an adequate freight rail network existed.

[38] CEMEX, a major Mexican cement company, has reportedly made large inroads into the U.S. cement market during the past decade, suggesting the existence of a cost-competitive long-haul distribution network for such bulk products. However, cement is a manufactured product with high value-added and few sources of supply, so its relevance to the mineral products discussed here is limited.

Section V: Agricultural Products

Farming makes a highly valued contribution to New Jersey's economy and quality of life, a contribution that figures on agricultural income do not fully reflect. In 2004, agriculture contributed an estimated $467 million of value added to the Gross State Product (excluding forestry and other non-farming activities). This figure does not include the significant ecosystem services provided by farmland (see Part II of this report), nor does it reflect the scenic and other amenities provided by agricultural open space, amenities which contribute significantly to the quality of life and frequently to the value of near-by properties.

State and Federal estimates of the amount of farmland in New Jersey are in fairly close agreement, as the following table shows (USDA = United States Department of Agriculture; UVM = University of Vermont):

Table 12: Agricultural Land in New Jersey

Land Use	USDA 2002		DEP/UVM*	
Cropland (1)		490,886		546,261
Pct. of subtotal	*81.1%*		*81.1%*	
Pastureland (2)		114,309		127,203
Pct. of subtotal	*18.9%*		*18.9%*	
Subtotal		605,194		673,464
Other Farmland (3)		66,066		allocated to above
Total**		**671,260**		**673,464**
Woodlands (4)		134,422		included in Forests
Grand Total		805,682		n/a

Notes:
* revised to reflect USDA percentage allocation of Subtotal.
** numbers include agricultural wetlands.
1. excludes cropland used as pastureland at time of survey.
2. includes cropland and woodland used as pastureland.
3. includes house lots, roads, ponds, wasteland, etc.
4. excludes woodland used as pastureland at time of survey.

The USDA figures in Table 12 were obtained from an on-ground census of farms; the UVM figures are based on a 2005-2006 UVM analysis of 1995-1997 NJDEP data obtained from aerial photographs.[39] The DEP/UVM figures for cropland and pastureland include a pro rata allocation of Other Farmland, which therefore does not appear as a separate line item in the last column. The UVM analysis classifies woodland on farms under Forests. Part II of this report presents a more detailed description of the UVM methodology, and the relevant GIS metadata are available from NJDEP.

[39] The original DEP and UVM data classify a substantial amount of grassland as pastureland even though it consists of cropland planted with row crops; the DEP/UVM Subtotal of 673,464 acres shown above has therefore been reallocated to reflect the 2002 USDA breakdown between cropland and pastureland.

Since NJDEP's updated land use/land cover estimates for 2002 will not be available until early in 2007, this study will use the UVM estimate of 673,464 acres of farmland from Part II of this report; doing so will provide consistency between Parts II and III.

Market Value of Farm Products

In valuing New Jersey's agricultural natural capital, it is important to distinguish between the value of the food and other goods produced on farms and the value of the farmland itself; only the latter can be considered natural capital. The production of food requires many kinds of inputs, e.g., land, human labor, machinery, fuel, seeds, etc., and it would not be defensible to attribute the entire market value of food products to land alone. Nature's contributions to food production are essential, but so are those of farmers and the human and physical assets they deploy.

Therefore, to get to the value of the natural capital considered by itself, we must deduct farm expenses from farm revenues, since those expenses mainly represent the cost of inputs other than land. There are two main sources of farm revenue and expense data, both of which are units of the U.S. Department of Agriculture (USDA): USDA's Economics Research Service (ERS) and its National Agricultural Statistics Services (NASS). ERS prepares annual state-level estimates of farm revenues and expenses, while NASS conducts a state and county-level Census of Agriculture every five years (the most recent census was for 2002). For 2002, the two reported the following financial data:

Table 13: New Jersey Farm Revenues and Expenses for 2002 (millions of 2002 dollars)

	NASS	ERS*
Sales of agricultural products	$749.9	$869.6
Other farm revenue	0.0	53.6
Total farm revenue	749.9	923.2
Cash expenses	$647.0	$793.2
Non-cash expenses**	43.9	67.1
Total expenses	690.9	860.3
Net farm income	**$59.0**	**$62.9**

*excluding imputed rental income and related expenses for farm dwellings.
**mainly depreciation (NASS) or capital consumption (ERS).

As Table 13 shows, the two sources show similar figures for 2002 net farm income; however, given the wide differences in revenues and expenses, the agreement may be a coincidence. ERS uses national income accounting principles, which differ substantially from the principles used in this report for other natural goods; for example, ERS includes an estimate of the imputed rental value of farm dwellings and uses a capital consumption allowance rather than the more familiar depreciation expense. In addition, the ERS revenue figures for 2002 include roughly $100 million for horse semen (i.e., stud fees), a factor that seems of questionable relevance to the current inquiry.

For these reasons, this study will use the NASS figures as a basis for analysis. Table 14 present a more detailed breakdown of the NASS data from Table 13.

Table 14: NASS Revenues and Expenses for 2002

Revenue or Expense Item	**MM 2002 $**	**MM 2004 $**
Plant products (87.68%)	$ 657.5	$ 690.4
Animal products (12.32%)	92.4	97.0
Market value of agric. products	749.9	787.4
Farm production expenses	647.2	679.6
Net farm income	102.7	107.8
Non-cash exps. (depreciation etc.)	46.9	49.2
Net *cash* farm income	149.5	157.0
Cash flow/acre/year	$222	$233

Source: USDA/NASS. Inflator of 1.05 based on CPI for all urban consumers.

NASS data are only available at five-year intervals; ERS data (available annually) show that net farm income for New Jersey plummeted in 2001-2002 from the 2000 level but rebounded sharply in 2003-2004 (with a much smaller gain in 2005). However, even 2005 was almost 15% below the 2000 level, possibly reflecting higher energy prices, further conversion of farmland to residential and commercial uses, the severe 2001 drought, or other factors. In short, 2002 data (even when translated into 2004 dollars) represent a conservative basis for estimating the value of New Jersey farm income, based on the amount of farmland shown in Table 12.

The figures in Tables 13 and 14 distinguish between cash and non-cash expenses, with depreciation of physical capital (equipment, structures, etc.) being by far the most important example of the latter (almost 94% in 2002). While some would use the Net Cash Farm Income of $157 million (in 2004 dollars) as a basis for further analysis, this study uses the more conservative Net Farm Income of about $108 million (in 2004 dollars). Maintenance and replacement of physical capital are essential for modern agricultural production, and omitting them from the analysis overstates the productivity and value of raw farmland.

Market Value of Farmland

Given an assumed annual farm income of about $108 million, the other factor needed to estimate the economic value of New Jersey's farmland is the elasticity of demand for the various farm products. The U.S. Department of Agriculture has published demand elasticities for broad food categories, e.g., meat, dairy, produce, etc.; and, using those figures we have calculated weighted average elasticities for New Jersey's farm output (see Exhibit B). The resulting elasticities are –0.067 for crops, -0.092 for animal products, and –0.069 overall.

Based on these figures, the table below shows the calculation of Total Willingness to Pay for the annual flow of farm products from New Jersey's agricultural natural capital:

Table 15: Total Willingness to Pay for New Jersey Farm Products (2004 $)			
Parameter ↓ or Sector →	**Cropland**	**Pastureland**	**Total**
Elasticity of demand	-0.067	-0.092	-0.069
Market value/year $MM	$95	$13	$108
Consumer Surplus/Market Value	746%	543%	721%
Consumer surplus/year $MM	$705	$72	$778
TEV/year $MM	$800	$85	$885
Present value at 3%/yr $Bn	$26.7	$2.8	$29.5
Natural capital (acres)	546,261	127,203	673,464
TEV/acre/year $	$1,464	$672	$1,315
Present value/acre $	$48,812	$22,394	$43,822

Key: CS = consumer surplus; MV = market value; TEV = total economic value

In this table, annual market values were allocated to cropland and pastureland based on ERS data and the overall ratio of net farm income to revenue. Because the elasticity of demand for food is much lower than the elasticity for other natural goods, Consumer Surplus makes up a relatively small portion of Total Willingness to Pay. All figures were independently rounded.

While the analysis in Table 15 presents the estimates of net benefit to society most consistent with economic theory, those estimates are not strictly comparable to the estimates for the other natural goods. The NASS data make it possible to deduct production costs from market value to obtain net farm income, which is closer than market value to the net benefit to society of agricultural natural capital. However, as Table 3 in Section II indicates, the valuation data available for the other natural goods represent the producer's sale price, which *includes* production costs. As a consequence of being more accurate, the value of farmland from Table 15 will automatically be *lower than* the estimated values for those other natural goods.

To provide figures for agricultural natural captial that are more comparable in derivation to those for the other natural goods, Table 15A presents estimates based not on net farm income but on the market value of agricultural products sold.

Table 15A: Alternate Valuation of New Jersey Farm Products (2004 $)			
Parameter ↓ or Sector →	**Cropland**	**Pastureland**	**Total**
Elasticity of demand	-0.067	-0.092	-0.069
Market value/year $MM	$690	$97	$787
Consumer Surplus/Market Value	746%	543%	721%
Consumer surplus/year $MM	$5,152	$527	$5,679
TEV/year $MM	$5,842	$624	$6,467
Present value at 3%/yr $Bn	$194.7	$20.8	$215.6
Natural capital (acres)	546,261	127,203	673,464
TEV/acre/year $	$10,695	$4,907	$9,602
Present value/acre $	$356,507	$163,559	$320,063

Key: CS = consumer surplus; MV = market value; TEV = total economic value

The foregoing analysis values New Jersey farmland based solely on its use as farmland. However, Plantinga et al. (2002) found that 82% of the value of New Jersey farmland stems from its development potential, implying that only 18% is due to the land's continued use for farming. In that regard, Appendix C presents USDA valuations for New Jersey farmland that reportedly reflect development potential as well as farming output. The data are difficult to reconcile with the above analysis, and further work in this area is clearly needed.

Uncertainties in the Analysis

The sustainable level of agricultural output depends on natural and societal forces, and an obvious question at this point is whether NFI of $222/acre/year is sustainable. Natural forces include weather, climate change, change in plant or animal diseases, etc. Projections of the impacts of climate change on New Jersey show that temperature increases are likely, but precipitation could either increase or decrease. Increased precipitation could come from fewer but more intense rainfall events, which would mean less water actually available for farming due to the rapid runoff from such storms. Seasonal patterns of precipitation could also shift so that while total rainfall increased, the amount during critical parts of the growing season might decrease. In addition, different parts of the state and different crops could experience different impacts. We are not aware of any analyses of these possibilities at a sufficiently detailed level to provide a basis for estimating the economic impact of climate change on New Jersey agriculture.

The most important societal force that will affect the future of agriculture in New Jersey is undoubtedly the conversion of farmland to residential and comercial uses, and the impacts of that force are likely to be felt sooner than those of climate change. NJDEP's land use/land cover database shows a loss of over 85,000 acres or about 11.5% of agricultural land between 1986 and 1995/97. Data on land use/land cover change through 2002 are expected to be available in the near future, but it is probable that farmland is still being lost to development and to reforestation of abandoned farms.

In theory, more intensive cultivation of the remaining farmland and/or a shift to higher-value crops might make up for such losses of farmland in terms of the dollar value of agricultural output, although such changes might also entail higher production costs. However, USDA data from previous years show that the value of New Jersey's farm output is not keeping up with inflation, which means that it is actually declining in real terms. For example, between 1997 and 2002, the market value of New Jersey's farm output rose by 6.0% in nominal terms according to the 2002 Census of Agriculture while consumer prices (as represented by the US Urban Consumer Price Index) rose by 12.1%; as a result, the real value of New Jersey's agricultural output decreased by 5.4%. (Output per farm did somewhat better, increasing by 7.3% in nominal terms, while declining by 4.2% in real terms.)

Other important societal forces affecting agriculture's future in New Jersey will include any changes in U.S. agricultural subsidy policies and levels, changes in State or Federal regulations relating to pollution from agricultural runoff, efforts to reforest farmland to sequester and store carbon dioxide as a means of combatting climate change, introduction of genetically-modified seeds, changes in consumer dietary preferences, etc.

Given the many influences (some of which could be either positive or negative), it is difficult to project the monetary value of New Jersey's future agricultural output, although if farmland continues to be converted to other uses it is probably safe to say that the total value will decrease, even if the value per acre remains the same. For purposes of this study, we assume that the value per acre will remain at $233/year (in 2004 dollars), that the acreage devoted to agriculture will remain at the estimated 2004 level of 673,464 acres, and that there will be no major adverse changes in climate or crop disease patterns or in the other factors cited above. These assumptions result in annual net farm income of $157 million in 2004 dollars, the figure used for market value in Table 15. However, the presence of so many important qualifiers makes this (and perhaps any) valuation figure an uncertain basis for extrapolation to future years, especially over an extended time horizon.

The sustainability of this flow of economic benefits from New Jersey's agricultural natural capital is perhaps more subject to future land use decisions than the benefit flows for any of the other types of natural capital discussed in this report. Farmland is often the first choice of developers for new residential and commercial projects, and it is also seen by some as a potential location for reforestation projects designed to sequester carbon dioxide, a major greenhouse gas. In addition, the usual caveats apply to the above estimates, including their vulnerability to climate change, invasive species (including plant and animal diseases), changes in consumer tastes, etc. Farmland makes an important contribution to New Jersey's wealth; but it is a contribution under constant stress and one that could well decline in coming years.

Section VI: Non-Farm Animals

In addition to farm animals, New Jersey is home to a number of game and non-game species, and the economic value of the related goods can be estimated. The most important game animals are white-tailed deer and black bears; according to NJDEP's Division of Fish and Wildlife, other game animals include rabbit, squirrel, woodchuck, raccoon, fox, coyote, and opossum. (Fish and shellfish are considered separately in Section VII below.) Game birds include pheasant, quail, chukar, crow, American woodcock, ruffled grouse, and wild turkey. New Jersey's non-game animals include a number of species classified as rare, threatened, or endangered under State or Federal law; information on these can be found in Niles et al. (2001).

Game and non-game animals and birds as a group are found in a variety of habitats (see, e.g., Niles et al. 2001 for habitat data for selected non-game species). Determining the total habitat area for each of the game species analyzed here is beyond the scope of the current report. For present purposes, the relevant natural capital is considered to include the following:

Table 16
Natural Capital for Non-Farm Animals

Ecosystem Type	Area (acres)
Forest	1,465,668
Freshwater wetland	814,479
Cropland	546,261
Saltwater wetland	190,520
Pastureland	127,203
Open fresh water	86,232
Riparian buffer	15,146
Total	**3,245,509**

Game animals (used from this point on to include game birds) are a potential source of food, and a number of ecosystems provide habitat for such animals, although hunting is legally permitted only in certain areas of the state. While comprehensive data on game harvests are not readily available, there is enough information to estimate a value for this type of ecosystem good.

Based on information from NJDEP's Division of Fish and Wildlife,[40] the total harvest of game animals in recent years has been about 3 million pounds, broken down as follows:

Table 17: Game Animal Harvests

Type of Game	Year(s) of Data	Harvest (lbs.)
Deer	1999	2,700,000
Game birds*	2003-2004	194,206
Small game*	2003-2004	99,227
Bear	2003 and 2005	69,040
Total		**3,062,473**

*Animal and bird counts were converted to weight basis assuming 1 lb./animal.

[40] Formerly the Division of Fish, Game and Wildlife.

There is obviously uncertainty in combining data for different years and in combining reported and estimated weights; in particular, a more recent estimate of the deer harvest would be helpful. Moreover, some game animals are less likely to provide food than others, e.g., coyotes. Absent such data, the above can only be viewed as a rough first approximation of the actual harvest.

The value of game animals is difficult to determine, since most such animals are taken for home consumption, and the utility derived from the hunt is part of the hunter's valuation of the hunting experience. In estimating market values, this study therefore uses retail prices for the Northeastern US for various meat products as reported by the US Bureau of Labor Statistics; since game animals tend to have less body fat than domesticated animals, we used lean beef products as a surrogate and used USDA estimates to translate retail prices into wholesale prices.

Table 18: Estimated 2004 Market Value of New Jersey Game Animals

Ground chuck, 100% beef*	$2.419
Ground chuck, lean/extra lean*	3.017
Round roast, USDA choice, boneless*	3.741
Average retail price	$3.059
Assumed farm/retail ratio**	1/3
Assumed price/lb for valuation	$1.020
Annual harvest (lb.)	3,062,473
Annual harvest value	**$3,123,722**

*average 2004 price for the Northeastern US from http://data.bls.gov, 8/16/06.
**defined here as ratio of price received by farmer to retail price; value of 1/3 based on 1997 USDA estimate for beef (ERS 2002)

As the table shows, price estimates for three related meat products were used to generate alternative estimates of the annual market value of the game animal harvest.

Trapping is not a major activity in New Jersey, but the Division of Fish and Wildlife collects data on the annual harvests of muskrat, raccoon, red and gray fox, mink, opossum, skunk, weasel, beaver, river otter, and coyote. As with game animals, a variety of ecosystems provide habitats for these species; for simplicity, the total relevant acreage is assumed to be the same as that used for game animals. The New Jersey Trapper Harvest, Recreational, and Economic Surveys for 2003-2004 and 2004-2005 provide market value estimates of $282,033 and $210,143 respectively for fur-bearing animals, with a two-year average of $246,088.

Given the heterogeneity of the game animal-fur harvest category, significant further research would be needed to determine whether species-specific elasticity of demand estimates are available; given the small number of animals for each species, the gain in accuracy from such research would probably not be significant. Since this class of natural goods is being analyzed primarily as a source of food, this study uses the US Department of Agriculture's estimated elasticity of demand for meat of –0.089 for the entire class except for fur, for which USDA's estimated elasticity of demand of –0.691 for clothing is used.

Based on these elasticities and the methods from Sec. II and App. A, Total Willingness to Pay (TWP) and Consumer Surplus (CS) for these natural goods are estimated as follows:

Table 19: Total Willingness to Pay for Game and Fur Animals (2004 $)			
Parameter ↓ or Sector →	**Game**	**Fur**	**Total**
Elasticity of demand	-0.089	-0.691	-0.134
Market value/year $MM	$3.12	$0.25	$3.37 M
Consumer Surplus/Market Value	562%	72%	524%
Consumer surplus/year $MM	$17.56	$0.18	$17.74
TEV/year $MM	$20.68	$0.42	$21.10
Present value at 3%/yr $MM	$689.23	$14.10	$703.33
Natural capital (acres)	3,245,509	3,245,509	3,245,509
TEV/acre/year $	$6.37	$0.13	$6.50
Present value/acre $	$212.36	$4.35	$216.71

Key: CS = consumer surplus; MV = market value; TEV = total economic value

As expected, these values are not especially large, since the provision of game and fur is not known as a major source of value for New Jersey's natural capital.

As with most of the natural goods discussed in Part III of this report, these estimates assume that the quantities and prices of these natural goods will continue at their 2004 levels in perpetuity. Such stability is unlikely for a number of reasons, including the following:

1. changes in land use that destroy or shrink the habitats for the animals in question,
2. changes in cultural norms regarding the ethical status of hunting and trapping,
3. changes in the legal status of individual species as rare, threatened, or endangered under State or Federal law,
4. reductions or geographic shifts in available habitat due to climate change,
5. changes in species populations and species mix due to predation, disease, changes in food supply, etc.,
6. long-term changes in consumer preferences for these natural goods,
7. other legal changes affecting the permitted extent of hunting and harvesting, e.g., the length of hunting seasons, permitted hunting methods, etc., and
8. other factors not identified.

Factors 1-4 seem more likely than not to *reduce* the sustainable harvest of these natural goods, while Factors 5-8 are indeterminate in their effects. Since deer account for almost 90% by weight of the annual game harvest, future rules regarding deer hunting are a major unknown, with public opinion apparently divided in terms of support for different methods of reducing the State's deer population. The rules regarding bear hunting also receive a great deal of public and regulatory attention, although bear account for a much smaller share by weight of the total game harvest. Given the many unknowns, the estimates presented above are necessarily subject to a large degree of uncertainty; however, they appear to represent the best estimates available given our current knowledge.

Section VII: Non-Farm Plants

As used here, “non-farm plants” includes grasses, wildflowers, herbs, medicinal plants, and other types of plants found in New Jersey, excluding trees, which are considered in Section VIII.[41] The focus here is on the plants themselves considered as ecosystem goods rather than on the pleasure many people obtain from viewing rare or aesthetically pleasing plants in their native habitats; the latter type of aesthetic and recreational benefit is treated in Part II as an ecosystem service provided by specific landscape types.

Plants obviously play an essential role in sustaining all of New Jersey’s ecosystems. However, that role is not considered separately in this study, since the ecosystems themselves are treated directly in terms of their production of economically valuable goods and services. To count this “ecosystem maintenance” role of plants as a separate source of value would be to engage in double-counting; from the standpoint of economics, this function of plant life is treated as an “input” to the production of goods and services, which are then valued directly.

Relatively little quantitative information is available on the uses of New Jersey’s non-agricultural plants (other than trees). This contrasts with the considerable attention paid to rare, threatened, and endangered animal species (see, e.g., Niles et al. 2001).[42] However, two of the values provided by plants have received attention in the economics literature: 1) the use of plants for medicinal and pharmaceutical purposes, and 2) the general importance of plants in terms of biodiversity and genetic resources. These uses are discussed briefly below.

Medicinal plants are a subject of great interest to some of the economists who work in the area of ecosystem valuation, especially those who work on tropical rainforest issues. As is well known, some of our most important medicines are derived or were first extracted from naturally occurring plants, including aspirin, cocaine, and quinine. The value of such compounds, as measured by sales, is extremely large in some cases. The problem in estimating the value of this type of natural capital is our inability to predict where, when, and whether similar discoveries will be made in the future and, if so, how valuable those discoveries will prove to be.

One study that sought to quantify this pharmaceutical value these is Simpson et al. (1996). That study attempted to determine the private *in situ* value of the marginal[43] species for use in pharmaceutical research and private value of the marginal acre of threatened habitat for pharmaceutical research. Using demand analysis for a limited sample of pharmaceutical researchers, the study obtained one-time generic values of $12,040 for the “marginal” species and $10 per acre for threatened habitat (values in 2004 $). The researchers sought to explain what they viewed as relatively low values by citing the following factors:

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[41] We can include fungi here, even thought they are no longer considered to be plants.

[42] In this regard, plant species are covered under the federal Endangered Species Act but not under current state law.

[43] In studies that ascertain values for genetic resources *in situ*, every “unit” (species or habitat area) of biodiversity is viewed as making an equal *marginal* contribution to the success of the bio-prospecting enterprise; that is, one species or one acre of habitat is about as valuable as any other.

- individual redundancy, i.e., if all representatives of a species produce a particular compound, individuals in excess of the number needed to maintain a viable population are redundant;

- species redundancy, i.e., instances in which identical drugs, or drugs with similar clinical properties, have been isolated from different species; and

- medical redundancy, where different therapeutic mechanisms may be effective in treating the same symptoms.

Given these caveats, the results of Simpson et al. (1996) at best provide indications of the order of magnitude of the benefits. Other studies have pointed to different approaches that could yield substantially different results. At this point, there is no generally accepted approach or methodology for assessing biodiversity value, and for this reason, no attempt is made here to estimate the potential pharmaceutical value of New Jersey's non-agricultural plants.

Plant species can also be considered more generally from the standpoint of biodiversity, although this takes us beyond the narrow focus on ecosystem goods.[44] Biodiversity is probably essential for habitat maintenance, since healthy ecosystems are usually characterized by containing a variety of species with population sizes sufficient to ensure long-term viability, all else being equal, e.g., climate, human development of natural lands, absence of invasive species, etc. Individual species also represent repositories of genetic data that can prove critical for ecosystem survival when habitats are subjected to stress from climate change, habitat fragmentation, entrance of invasive species (including disease-causing organisms) into the habitat, etc.

While biodiversity is unquestionably valuable, the study of the economics of biodiversity is still in its early stages, and only a few studies have attempted to quantify its value. Given the absence of data on New Jersey's endowment of plant species and the lack of a generally accepted valuation method, this study does not attempt to estimate a value for the natural capital represented by New Jersey's non-agricultural plant resources.

The conservation of biodiversity and genetic data is sometimes distinguished from the protection of rare, threatened, and endangered species. The latter has value in its own right, including the willingness of many people to pay for such protection even if they have never seen the species in question. However, the evidence for such willingness comes mainly from studies involving animals rather than plants and thus affords very little on which to base an analysis of New Jersey's plant resources. The aesthetic and recreational enjoyment that many people derive from viewing such species is considered in Part II as a service provided by the state's ecosystems.

[44] Some use the term biodiversity to mean the *number of species* in a given geographic area; others use it to mean the *population sizes* for the species in that area. These uses are not distinguished in this discussion.

Section VIII: Fish and Shellfish

Since they involve different types of data and different valuation issues, the products of commercial and recreational fishing will be treated separately below. The natural capital relevant to this class of natural goods is considered to be as follows:

- For commercial fishing, New Jersey's 299,835 acres of coastal shelf and 455,700 acres of estuaries and tidal bays, for a total of 755,535 acres.
- For recreational saltwater fishing, the same two marine ecosystems plus 190,520 acres of saltwater wetlands, for a total of 946,055 acres.
- For recreational freshwater fishing, 86,232 acres of open fresh water and 181,099 acres of unforested freshwater wetlands, for a total of 267,331 acres.

Certain wetlands are included in the above to reflect their role as fish nurseries and sources of bait fish. In effect, these wetlands are grouped in an integrated system with the waters where the fish are actually harvested, and the value of the harvest is allocated pro rata across the entire system. Forested freshwater wetlands are not included in these numbers based on the assumption that such wetlands are more important for hunting than for fishing.

Commercial Fishing

Fishing (including shellfishing) is an important industry in New Jersey. Six major fishing ports are located in the state, including Atlantic City, Barnegat Light, Belford, Cape May, Point Pleasant, and Port Norris, with a commercial fleet totaling more than 1,500 vessels and employing nearly 3,000 fishermen. The state also has 15 seafood processing plants and 81 wholesalers employing more than 2,200 workers (NJDA 2005). Recreational fishing is also significant with an estimated 806,000 participants in 2001 according to the U.S. Fish and Wildlife Service (USFWS 2003).

Fishery statistics are available from the National Marine Fisheries Service (NMFS) mainly in terms of commercial fisheries and to a certain extent marine recreational fisheries. Data on the latter are also compiled periodically by the U.S. Fish and Wildlife Service through its National Survey of Fishing, Hunting and Wildlife-Associated Recreation.

According to NMFS, over 100 species of finfish and shellfish are harvested in the waters off New Jersey. In 2004, vessels based in New Jersey ports landed over 187 million pounds of fish (finfish and shellfish), valued at almost $146 million paid to fishermen at the dock (the "ex-vessel" price) (NMFS 2005).

The two tables below present information from NMFS on the weight and value for the most important finfish and shellfish species harvested in 2004. The first table presents the 2004 finfish data, with species ranked by estimated value:

(see next page for tables)

Table 20: NMFS 2004 Finfish Landings Data for New Jersey				
Finfish Species	**Weight (lb)**	**% of Total**	**Value ($)**	**% of Total**
Flounder, Summer	2,830,565	3.9%	$ 4,430,704	20.3%
Goosefish	4,226,846	5.9%	3,496,170	16.0%
Mackerel, Atlantic	36,090,862	50.3%	3,398,195	15.6%
Sea Bass, Black	704,128	1.0%	1,293,393	5.9%
Menhaden, Atlantic	18,023,688	25.1%	1,177,226	5.4%
Scups or Porgies	1,900,801	2.7%	1,087,509	5.0%
Swordfish	404,265	0.6%	997,693	4.6%
Tilefish	721,347	1.0%	897,297	4.1%
Croaker, Atlantic	2,096,305	2.9%	850,751	3.9%
Tuna, Bigeye	219,847	0.3%	849,376	3.9%
Tuna, Yellowfin	387,305	0.5%	739,985	3.4%
All Other Finfish	4,107,526	5.7%	2,615,847	12.0%
Finfish Totals	**71,713,485**	**100.0%**	**$ 21,834,146**	**100.0%**

As this table shows, two species (Atlantic mackerel and Atlantic menhaden) accounted for 75% of total 2004 finfish landings by weight. The distribution by value was less concentrated, with the top three species accounting for about 52% of total dockside value as estimated by NMFS.

The next table presents the 2004 NMFS data for the most important shellfish species:

Table 21: NMFS 2004 Shellfish Landings Data for New Jersey				
Shellfish Species	**Weight (lb)**	**% of Total**	**Value ($)**	**% of Total**
Scallop, Sea	13,737,072	11.8%	67,497,047	54.4%
Clam, Atlantic Surf	43,521,704	37.5%	22,284,335	18.0%
Clam, Ocean Quahog	17,633,600	15.2%	9,094,961	7.3%
Clam, Quahog	1,795,538	1.5%	7,409,304	6.0%
Squid, Northern Shortfin	30,973,571	26.7%	6,742,682	5.4%
Crab, Blue	4,115,940	3.5%	4,845,982	3.9%
Lobster, American	370,536	0.3%	1,801,550	1.5%
Squid, Longfin	2,886,634	2.5%	1,780,912	1.4%
Oyster, Eastern	323,049	0.3%	1,558,136	1.3%
All other shellfish	756,144	0.7%	1,088,362	0.9%
Shellfish totals	**116,113,788**	**100.0%**	**124,103,271**	**100.0%**

As this table shows, four species accounted for over 90% of the 2004 shellfish landings by weight, while two species accounted for about 72% of the estimated dockside market value, with sea scallops alone accounting for about 54%.

A comparison of Tables 20 and 21 shows clearly that New Jersey fish landings in 2004 were heavily concentrated in terms of both weight and volume, with shellfish accounting for 62% of total landings by weight and 85% by dockside value. While this indicates that New Jersey has access to some valuable fish species (especially shellfish species), it also shows that the state's commercial fishing industry depends heavily on a few species, especially the top five shellfish species, which together accounted for over 77% of dockside value for all commercial landings.

To estimate the economic value of New Jersey's fish harvest, we first need to estimate the size of the annual harvest and its market value. Since the harvest weight varies from year to year for biological, meteorological, and other reasons, we obtained NMFS landing data for the 10-year period 1995-2004 (see Table 22 on next page).[45] Since finfish and shellfish clearly represent different classes of natural goods, the two are analyzed separately below.

Fig. 4 (follows Table 22) shows the changes in finfish landings, prices, and market value from 1995 to 2004 (the latter two expressed in 2004 dollars). The overall pattern is as follows:

- From 1995 to about 1998, finfish landings and prices moved in opposite directions, but on the whole, market value remained stable. This pattern may indicate that increased landings depress prices, that reduced prices motivate vessel owners to increase landings to cover fixed costs, or some combination of the two.
- From 1999 to 2001, landings, prices, and market value all decreased.
- From 2002 to 2004, landings and prices resumed the inverse correlation of the late 1990s, and market value again stabilized.

Based on this pattern, the years 2001-2004 appear to provide the best basis in recent years for further analysis; the annual market value of finfish landings averaged $21,527,000 in 2004 dollars, with only small variations above and below that figure.

Fig. 5 (after Fig. 4) shows the changes in shellfish landings and in prices, and market values (both in 2004 dollars) from 1995 to 2004. The overall pattern can be characterized as follows:

- From 1995 to 1998, shellfish landings and prices moved in opposite directions, but on the whole, market declined. This pattern again suggests that increased landings depress prices, that reduced prices motivate vessel owners to increase landings to cover fixed costs, or some combination of the two.
- From 1999 to 2003, landings declined, but prices market value increased.
- In 2004, prices leveled off but landings increased by 22% over the 2003 level), possibly reflecting attempts by vessel owners to take advantage of the high prices.

Based on this pattern, 2003 is the best basis in recent years for analysis, with a market value for shellfish in that year of $101,482,000 in 2004 dollars. Given the absence of any clear trend in shellfish landings from 1999 to 2003, the price trend in those years probably reflected increased demand, reduced competitive supply, or both; there is no obvious reason for a demand trend to reverse itself. Therefore, using average market value for a period of increasing prices such as 1999-2003 probably *understates* likely market value for years after 2004. On the other hand, 2004 could be an atypical year or one with inaccurate data, and it seems risky to base a value analysis on an average which reflects a sharp and possibly unsustainable increase in landings.

(text continues following table and figures)

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[45] Periods much longer than ten years could include data that is no longer relevant; periods much shorter than ten years could unduly emphasize recent departures from basic trends.

Table 22: New Jersey Commercial Fishery Landings 1995 – 2004

Year	Finfish Wt (000 lb)	Price $/100 lb.	Ex-vessel value $000	Shellfish Wt (000 lb)	Price $/100 lb.	Ex-vessel value $000	Total Wt (000 lb)	Price $/100 lb.	Ex-vessel value $000
1995	64,755	41.90	27,132	112,131	81.08	90,916	176,886	66.74	118,048
1996	79,466	34.29	27,249	103,348	83.94	86,750	182,813	62.36	113,999
1997	74,723	42.02	31,399	100,134	85.74	85,855	174,857	67.06	117,253
1998	84,221	35.00	29,477	112,922	73.69	83,212	197,143	57.16	112,689
1999	76,703	38.80	29,761	91,954	88.31	81,205	168,658	65.79	110,966
2000	70,475	35.90	25,301	101,328	91.05	92,259	171,803	68.43	117,560
2001	71,141	29.57	21,036	97,400	99.13	96,552	168,541	69.77	117,589
2002	65,046	32.20	20,945	97,093	100.32	97,404	162,139	72.99	118,348
2003	75,102	29.83	22,403	95,030	106.79	101,482	170,132	72.82	123,885
2004	71,107	30.55	21,723	116,073	106.87	124,048	187,180	77.88	145,771

Source: National Marine Fishery Service, US Dept. of Commerce

Note: prices and ex-vessel values are based on conversion of historical dollars to 2004 dollars using the US Bureau of Labor Statistics, All-Items Urban Consumer Price Index (CPI-U), 1982-1984 = 100, not seasonally adjusted.

Fig. 4: Commercial Finfish Landings, Price, and Value

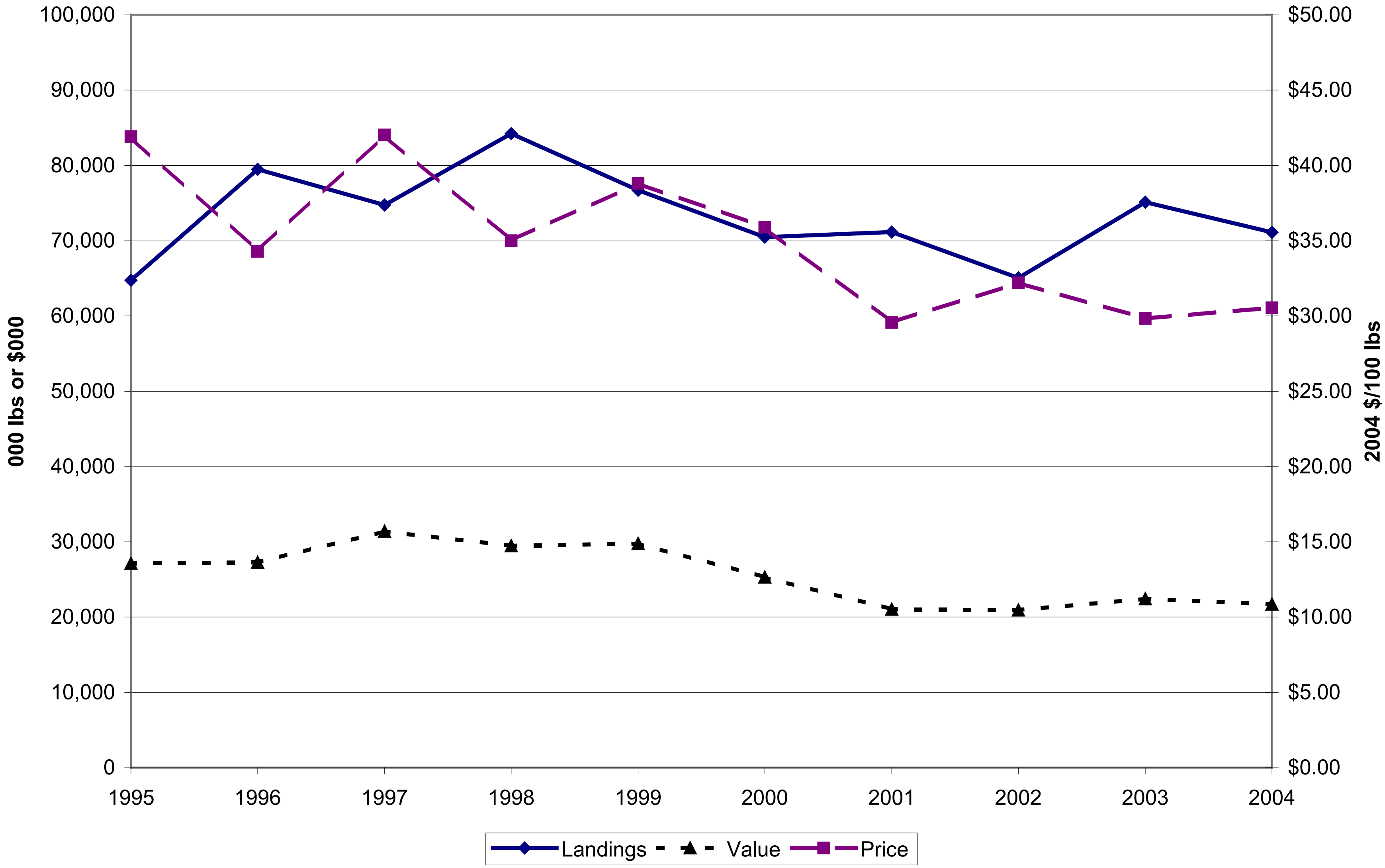
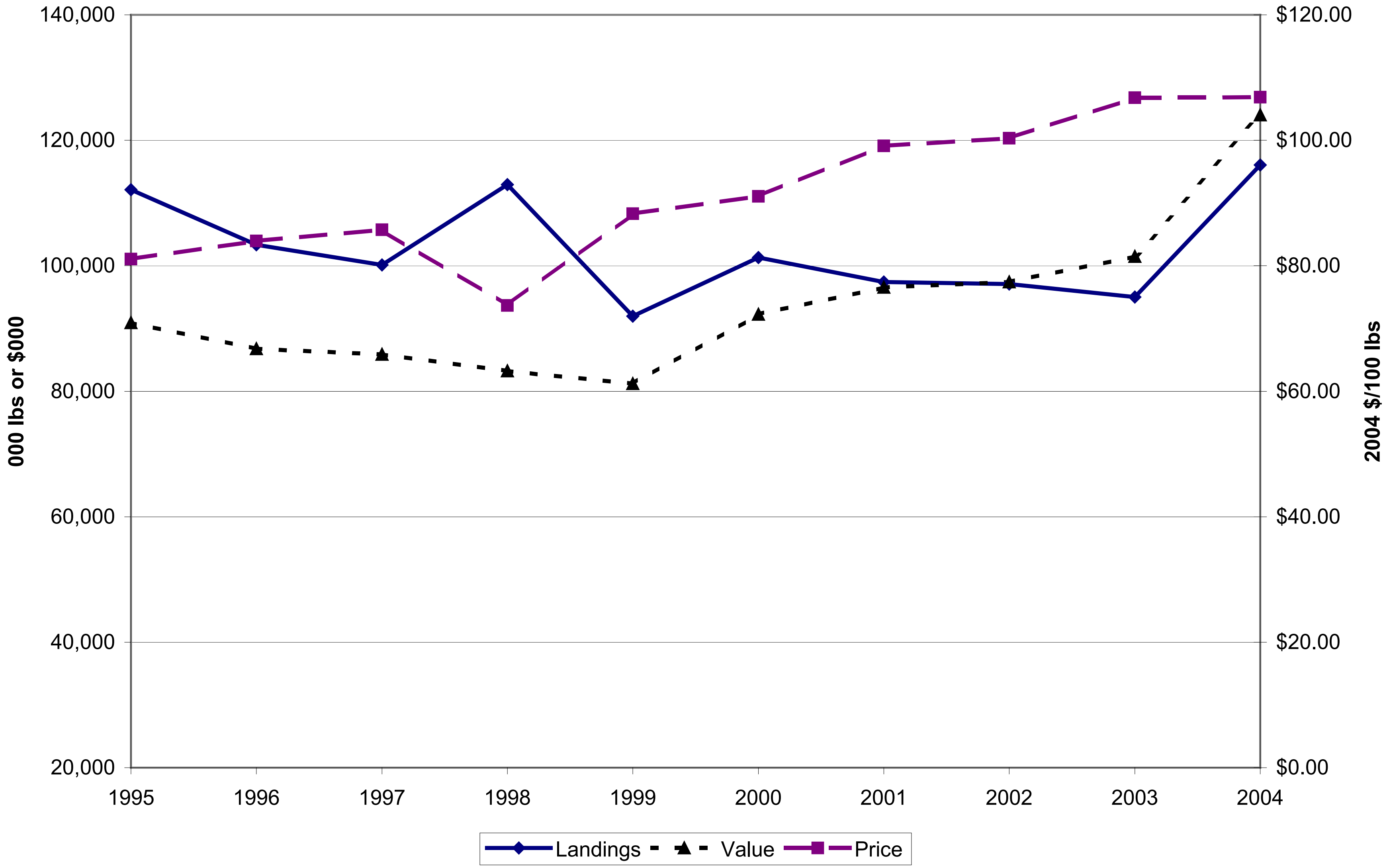


Fig. 5: Commercial Shellfish Landings, Price, and Value



To summarize, the analysis that follows assumes annual commercial landings with a market value of about $123 million, comprised of 17.5% or $21,527,000 for finfish and 82.5% or $101,482,000 for shellfish (all figures in 2004 dollars). It must be emphasized that these are not forecasts of the sustainable yield for New Jersey's commercial ocean fisheries but rather estimates based on historical data. Similarly, the prices implicit in these figures are not based on projections of future consumer demand or future alternative supplies but reflect actual historical prices calculated from NMFS data.

Given the heterogeneity of the commercial fish harvest, significant further research would be needed to determine whether species-specific elasticity of demand estimates are available; given the similarities among fish species, the gain in accuracy from such research would not necessarily be significant. For simplicity, this class of natural goods is analyzed as a single source of food, using the US Department of Agriculture's estimated elasticity of demand for fish of –0.098. Non-food uses of fish products are not addressed.

Based on that elasticity value and on the formulas described in Section II and Appendix A,[46] the Total Willingness to Pay (TWP) and Consumer Surplus (CS) for this class of natural goods are estimated to be as follows:

Table 23: Total Willingness to Pay for Commercial Fish Harvest (2004 $)

Parameter ↓ or Sector →	Finfish	Shellfish	Total
Elasticity of demand	-0.098	-0.098	-0.098
Market value/year $MM	$21.5	$101.5	$123.0
Consumer Surplus/Market Value	510%	510%	510%
Consumer surplus/year $MM	$109.7	$517.7	$627.3
TEV/year $MM	$131.2	$619.2	$750.3
Present value at 3%/yr $Bn	$4.372	$20.638	$25.010
Natural capital (acres)	755,535	755,535	755,535
TEV/acre/year $	$174	$819	$993
Present value/acre $	$5,786	$27,316	$33,102

Key: CS = consumer surplus; MV = market value; TEV = total economic value

The above discussions focuses on sales at the docks, i.e., sales from fishing boats to wholesale distributors. Subsequent sales to retail fish outlets, restaurants and ultimate consumers

[46] An alternative known as the "current rent" method has been widely employed in the construction of natural resource asset accounts by the U.S. Bureau of Economic Analysis and other researchers. The current rent from an additional fish harvested is its contribution to total revenue less the marginal cost of catching it and bringing it ashore in salable condition. Using current rents for valuing the entire fish stock essentially means estimating the current liquidation price for the stock. The method has the advantage that, under certain assumptions, only data on current market prices and costs are needed, i.e., the analyst need not attempt to forecast future market conditions. However, the method requires estimates of current stock sizes for commercially important species, which are not available for New Jersey. For some relatively well-understood fisheries, it has been proposed that bioeconomic models be used to assess likely future stocks, costs of fishing, and net rent under different management regimes. Again, as far as is known, no such models have been developed for New Jersey's commercial fish species.

will involve other costs and mark-ups, and for that reason, the estimated dockside price affords a better measure of the value to society of the fish themselves, apart from the processing and distribution chains that lead to the ultimate consumers.

Based on the assumed market value of the annual harvest, the economic value of New Jersey's commercial fisheries is clearly substantial. However, that value will be affected by changes in fish populations, species mix, consumer preferences, competition for supplies with other fishing nations, demand for fish from overseas markets, and other factors. In this regard, it is well-known that many commercially important fish species have been overfished in recent years to the point where some fisheries are no longer commercially viable. There are powerful forces working to prolong this trend, including rising incomes in many countries (making it possible to consume more expensive sources of protein such as fish), fears about the safety of other protein sources such as beef and poultry, publicity on the health benefits of fish consumption, improvements in fishing technology, increases in the scale of commercial fishing operations, etc. Increases in commercial fish farming may be a partially offsetting factor.

It is also becoming apparent that greenhouse gas-induced lake, stream and ocean warming and acidification and other pollution-related threats to fish and *their* food supplies (mainly smaller fish species) now threaten the future commercial viability of an increasing number of fisheries, although we are not aware of specific information involving New Jersey fisheries. Since it is inherently difficult for climate models to project conditions for small geographic regions such as the fishing grounds off the New Jersey coast, it may take some time before such state-specific information becomes available.

Given all of these uncertainties, the estimated values could reflect overestimates of the likely volume and value of future landings. However, in the absence of a peer-reviewed forecasting methodology for New Jersey, history appears to provide the best basis for a quantitative valuation of New Jersey's commercial fish and shellfish resources.

Recreational Fishing

Although it operates at a much smaller scale than commercial fishing, recreational fishing also provides a source of food that may be important for some households. Data on recreational fishing is available from NMFS (for saltwater fishing) and from NJDEP's Division of Fish and Wildlife (for freshwater fishing). We consider each of these in turn.

Saltwater fish. The table on the next page shows the 2004 recreational harvest of saltwater fish for New Jersey and the value of that harvest as estimated by NMFS. According to NMFS, the 2004 harvest had an aggregate weight of 13.7 million pounds and an estimated landing value of $20.5 million, for an average landing price of $1.49/lb. The many uncertainties make it difficult to project future landings with any confidence, but in the absence of a better methodology and better data, the 2004 value will be taken as a recurring market value for this sub-sector.

Table 24: 2004 New Jersey Recreational Saltwater Harvest			
AFS Species Name	**Pounds**	**Dollars**	**Price/Lb.**
Striped Bass*	4,634,160	$ 12,234,182	$ 2.64
Flounder, Summer	3,413,126	5,358,608	1.57
Bluefish	2,714,608	1,004,405	0.37
Croaker, Atlantic	909,009	372,694	0.41
Tautog	183,185	351,715	1.92
Sea Bass, Black	166,284	305,963	1.84
Weakfish	259,722	225,958	0.87
Flounder, Winter	136,339	185,421	1.36
Mackerel, King And Cero	89,641	170,318	1.90
Drum, Black	783,418	109,679	0.14
Perch, White	77,620	59,767	0.77
Scups Or Porgies	60,111	34,263	0.57
Other Tuna/Mackerel	132,525	18,554	0.14
Bonito, Atlantic	10,035	17,561	1.75
Shark, Dogfish	29,290	11,130	0.38
Sea robins	85,642	9,421	0.11
Mackerel, Spanish	2,983	5,369	1.80
Flounder, Other	959	1,112	1.16
Herring	18,503	1,110	0.06
Skates	5,893	1,061	0.18
Hake, Red	842	497	0.59
Other Saltwater Species	1,109	1,652	1.49
Total	**13,715,004**	**$ 20,480,440**	**$ 1.49**
*price based on 2004 Middle Atlantic totals = NY+DE = $2,436,062/923,034 lbs.			
Note: does not include inland freshwater harvests			
Source: NMFS website accessed 8/15/06 (www.st.nmfs.gov)			

It should be noted that the average price for the recreational saltwater finfish[47] harvest is much higher than the average for the equivalent commercial catch due to a difference in the mix of species. For example, if we limit our attention to the saltwater finfish species harvested both recreationally and commercially, the top three recreational species by weight, accounting for 78.5% of the 2004 recreational saltwater finfish harvest, are striped bass ($2.64/lb), summer flounder ($1.57/lb), and bluefish ($0.37/lb). In contrast, tuna and Atlantic mackerel, with a weighted average price of $0.14/lb, account for 78.5% of the 2004 commercial saltwater finfish harvest for the same set of species. Based on the mix of these species in the commercial harvest, the average commercial price for all species in this set is $0.35/lb.—a figure that is still well below the 2004 recreational average of $1.49/lb.[48] (all prices are in 2004 dollars).

Freshwater fish. The table on the next page shows the 2004 recreational harvest for freshwater fish, based on a 2003 survey of anglers fishing in New Jersey. An earlier 2001 study by the US Fish and Wildlife Service estimated total anglers in New Jersey at about 806,000, and the 2003 study used a sample of 0.1% of that amount or 860 anglers. The 2003 study found that

[47] The NMFS recreational harvest data do not include shellfish.

[48] The average 2004 price for saltwater finfish species harvested commercially but not recreationally was lower still at $0.21/lb.

the average angler kept 11.23 fish during the fishing season, which extrapolates to about 9 million fish over the total population of 806,000 anglers.

Table 25: New Jersey Recreational Freshwater Harvest

Species	% Sample	# Fishers*	Avg # kept	# Fish kept
brook/brown/rainbow trout	36%	310	9.85	3,050
crappie	25%	215	7.74	1,664
lake trout	17%	146	9.85	1,440
largemouth bass	65%	559	0.63	352
striped bass (freshwater)	30%	258	1.33	343
channel catfish	15%	129	1.41	182
smallmouth bass	46%	396	0.37	146
walleye	9%	77	1.34	104
pickerel	32%	275	0.25	69
northern pike	18%	155	0.36	56
striped bass (hybrid)	14%	120	0.34	41
other**	25%	215	7.45	1,602
Total or average	**100%**	**806**	**11.23**	**9,049**

*based on an 0.1% sample of NJ anglers; includes multiple responses

**bluegill, sunfish, other, or no species specified

Total # fishers	805,870
Avg # fish kept/person	11.23
Total # fish kept/yr	9,047,229
Assumed avg value/fish	$1.49
Total value/yr	**$13,480,371**

Sources: New Jersey Anglers' Participation in Fishing, Harvest Success, and Opinions on Fishing Regulations, survey conducted by Responsive Management for the New Jersey Division of Fish and Wildlife, 2003.

The 2003 study did not estimate the market value of the recreational freshwater catch, and there appears to be no official source for this information.[49] Since the recreational saltwater and freshwater data are both for finfish only, we have used the average recreational saltwater price of $1.49/lb to estimate the value of the recreational freshwater catch as $13.48 million/yr. Combining this with the saltwater harvest of $20.48 million/yr gives a total market value of about $34 million/yr.[50]

Based on the assumed continuation of these annual harvest levels, the elasticity of demand of –0.098 assumed for the commercially harvested fish, and the formulas described in Section II and Appendix A, the Total Willingness to Pay (TWP) and Consumer Surplus (CS) for this class of natural goods are estimated to be as follows:

[49] NMFS does not report this information, since freshwater fishing is not within its jurisdiction; sources such as the Fulton Fish Market in New York City report prices only for commercially harvested *saltwater* species. Retail restaurant prices for freshwater species vary widely and reflect cost and profit components whose relationship to the value of the raw fish is unknown.

[50] Because this part of the natural capital report deals solely with ecosystem and abiotic goods, these figures do not reflect the value of the recreational services provided by fishing in New Jersey; such services were dealt with in Part II of this report on an ecosystem-specific basis.

Table 26: Total Willingness to Pay for Recreational Fish Harvest (2004 $)			
Parameter ↓ or Sector →	**Saltwater**	**Freshwater**	**Total**
Elasticity of demand	-0.098	-0.098	-0.098
Market value/year $MM	$20.5	$13.5	$34.0
Consumer Surplus/Market Value	510%	510%	510%
Consumer surplus/year $MM	$104.6	$68.9	$173.4
TEV/year $MM	$125.1	$82.4	$207.4
Present value at 3%/yr $Bn	$4.168	$2.745	$6.913
Natural capital (acres)	946,055	267,331	1,213,386
TEV/acre/year $	$132	$308	$171
Present value/acre $	$4,406	$10,268	$5,697

Key: CS = consumer surplus; MV = market value; TEV = total economic value

Limitations and caveats similar to those discussed above for commercial fisheries apply to the recreational fish harvest. Given these unknowns, the estimated economic values presented above are necessarily subject to a large degree of uncertainty; however, they appear to represent the best estimates available given our current knowledge.

Section IX: Fuelwood and Sawtimber

In this section, we consider two different types of natural goods provided by New Jersey's forested lands (including forested wetlands): wood used as a *fuel*, i.e., the combustion of wood and wood wastes to produce energy for space heating, steam heating, process steam, and electricity generation, and timber used as a *material*, i.e., the use of timber for construction, manufacturing of plywood and other wood products, manufacturing of paper and paper products, production of furniture, etc. (The use of trees to stock tree nurseries is included in the analysis of agriculture above.) Fuelwood and timber present different valuation issues and are treated separately below.

The natural capital relevant to this section includes 1,465,668 acres of forest (including wooded farmland) and 633,380 acres of forested freshwater wetland, for a total of 2,129,048 acres. Urban greenspace is not considered as available for producing fuelwood or timber, and there is apparently no information on the forested portion of New Jersey's saltwater wetlands. Some riparian corridors are also forested, but even without counting that ecosystem, the total acreage essentially equals the total of 2.132 million acres reported by the U.S. Forest Service in its 1999 inventory of New Jersey's forests.

Fuelwood

All of the major energy-using sectors in New Jersey except transportation use wood and wood wastes for energy generation:

- The residential sector burns wood for direct *space heating*.
- The commercial sector uses wood for *space heating*, and wood, wood-containing municipal waste, and landfill gas from decay of wood and other substances for *steam heat and electricity generation*.
- The industrial sector uses combustible industrial by-products and wood chips for *electricity generation and process steam*.
- The electric power sector uses wood, industrial wood waste and related waste gas, and wood-containing municipal waste as *cofiring fuels or primary fuels to produce electricity*.

Wood sold or gathered for residential use is normally measured in cords; one cord equals 128 cubic feet of wood (4 x 4 x 8 ft.) according to the standard definition.[51] Wood used by other sectors is measured in a variety of units, including tons, kilowatt-hours of electricity, and others. Because of the multiplicity and varying definitions of units, wood and wood waste used as fuel are often reported in terms of the energy produced. The usual unit used for this purpose in the United States is the British Thermal Unit; one BTU equals approximately 252 calories; one million BTU is equivalent to about 293 kilowatt-hours.

[51] Non-standard cords equal to 80 or 85 cubic feet are also employed for certain purposes.

The US Energy Information Administration (EIA) of the US Department of Energy estimates the energy content of wood and wood waste used as fuel in New Jersey to be about 20 million BTU per cord.[52] Based on that value, the table below summarizes New Jersey's use of wood and wood waste as a fuel in 2003, the most recent year for which such data are available.

TABLE 27: USE OF WOOD AS A FUEL IN NEW JERSEY IN 2003			
Sector	**000 cords**	**Billion BTU**	**Share of total**
Electric power	1,025	20,500	62.6%
Residential	422	8,440	25.8%
Industrial	115	2,300	7.0%
Commercial	75	1,500	4.6%
Total*	**1,640**	**32,800**	**100.0%**

*detail does not sum to totals due to rounding.

The total of 32.8 trillion BTUs represented about 1.3 % of New Jersey's energy consumption in 2003. The underlying data is collected by EIA from a variety of sources, including the US Census, other official surveys, reports filed by electricity generators, etc. The information necessarily excludes an unknown amount of unreported gathering of fuelwood by individual homeowners and others for their own use.

The price of fuelwood depends on a variety of factors, including the quality of the wood, the area where the wood is harvested, transportation costs to the locality where the wood is sold, whether the wood is sold as logs or as wood chips, whether it is sold at wholesale or at retail, etc. In New Jersey, retail prices per cord of firewood sold to residential customers ranged from $150/cord to $230/cord in 2004 (Murray 2004). However, some quoted prices include transportation to the buyer's residence and stacking, while others do not; the prices reflect the retailer's costs, including the cost of transporting the wood from the harvest site to the sale site and possibly stacking it there.

EIA reported total New Jersey end-user purchases of wood and wood wastes in 2003 of $37.5 million which comes to $22.87/cord based on the consumption shown in Table 27 or $23.48/cord in 2004 dollars.[53] This is an *average* price; residential and commercial customers paid substantially more, while industrial and electric power users paid substantially less.[54] As described at length in the discussion of water resources in Section III, the most appropriate figure for natural capital valuation is the value at the point of harvest or *in situ value* rather than the retailer's or end user's *delivered price*. However, even EIA's reported average residential cost of

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[52] The heat content of wood actually varies from 15 to 20 million BTU per cord depending on the type of wood, moisture content, method of combustion, and other factors. Using the upper end of this range results in a lower estimate of the number of cords used in New Jersey and is therefore conservative from the standpoint of natural capital valuation.

[53] This calculation includes 1.35 million cords with an average 2003 cost of $27.80/cord and 290,000 cords of what EIA calls "uncosted" fuel with an assumed cost of zero.

[54] This may reflect in part the fact that the fuelwood used by residential and commercial customers tends to be in the form of small logs, while industrial and utility users tend to use wood chips and other wood wastes.

$44.08/cord is so far below actual New Jersey retail firewood prices that it clearly represents a value at or close to the point of harvest; therefore, EIA's overall average of $23.48/cord in 2004 dollars will be used to as the market value per cord in this analysis.

It should be noted that EIA does not publish information on the geographic source(s) of fuelwood used in New Jersey, and no other source has been found for this data. Therefore, there is no way of determining what portion (if any) of New Jersey's total fuelwood usage represents wood imported into New Jersey. In the absence of other information, the analysis below assumes that 100% of the wood used in New Jersey comes from in-state sources.

The elasticity of demand for fuelwood has been found to vary by type of end user (Skog 2003), as the next table indicates:

Table 28: New Jersey Fuelwood Consumption in 2003 (based on 20 MMBtu/cord)

Sector	000 Cords*	Shares	Elasticity	Weighted
Residential	422	25.8%	-0.87	-0.224
Commercial	75	4.6%	-0.15	-0.007
Industrial	115	7.0%	-0.39	-0.027
Electric power	1,025	62.6%	-0.13	-0.081
Total	**1,640**	**100.0%**		**-0.340**

*details do not sum to total due to rounding.

If we weight each sector's elasticity by that sector's share of total New Jersey consumption, we obtain an average elasticity of -0.340.

Based on the above, we can estimate the value of New Jersey's fuelwood as follows:

Table 29: Total Willingness to Pay for Fuelwood (2004 $)

Parameter	Value
Key assumptions:	
Pct. of fuelwood from NJ	100%
Elasticity of demand	-0.340
Total NJ supply (000 cords/year)	1,640
Market value per cord (2004 $)	$23.48
Market value/year $MM	$38.507
Consumer Surplus/Market Value	147%
Consumer surplus/year $MM	$56.606
TEV/year $MM	$95.112
Present value at 3%/yr $Bn	$3.170
Natural capital (acres)	2,129,048
TEV/acre/year $	$45
Present value/acre $	$1,489

Key: CS = consumer surplus; MV = market value; TEV = total economic value

The estimated annual value of $58.7 million is based on the assumption that future consumption will remain constant at the 2003 level reported by EIA, which in turn implies that this level is the maximum that is both ecologically sustainable and economically feasible.

As with the other goods provided by New Jersey's natural capital, the continued provision of this level of benefits depends on climate, land use patterns, energy consumption, fuel preferences among energy users, the mix of end-user sectors, etc. None of these factors can be predicted with much confidence, and the valuation presented above arguably represents the best estimate that can be derived given the available data.

Sawtimber

The other main category of wood resources in New Jersey is sawtimber, i.e., timber intended for use in furniture, home-building, etc. Sawtimber consists of trees that are larger than those harvested for fuelwood; unlike fuelwood, sawtimber does not include standing and fallen dead trees or wood wastes. Cubic foot for cubic foot, the value of wood as a construction and manufacturing material is much greater than its value as fuel.

Forests and forested wetlands cover about 2.1 million acres or 45% of New Jersey's total land area, a remarkable figure for a state that has experienced substantial population growth and economic development since World War II. About 1.9 million acres or 90% of the 2.1 million acres are classified by the United States Forest Service (USFS) as "timberland", i.e., forested land containing resources suitable for commercial timber harvesting under a regime of sustained yield management. The other 10% (referred to as Other Forestland) consists of preserved lands where timber harvesting is administratively restricted and unproductive forests where timber harvesting is economically impractical. Most Other Forestland is publicly owned.

Forests contain a wide variety of trees, including live trees of various species, ages, and sizes, standing and fallen dead trees, etc. Commercial interest focuses on live trees ("growing stock") that meet certain standards of size and wood quality ("sawtimber")[55]. At its simplest, the monetary value of the timber contained in the state's forests equals the volume of merchantable (commercially valuable) sawtimber times the price per unit volume. (Appendix D describes several other timber valuation methods.) Sawtimber volume is conventionally measured in board-feet; a sawtimber log measuring 1 foot x 1 foot x 1 inch contains 1 board-foot of wood. Since timber prices vary by tree species, the volume data used in valuation must reflect the mix of tree species or forest types in New Jersey's forests.[56]

The principal sources of detailed information on New Jersey's forest resources are the periodic inventories conducted by USFS; the most recent such inventories took place in 1987 and 1999. According to these inventories, the volume of sawtimber on New Jersey's timberland increased from 5.6 billion board-feet in 1987 to 8.1 billion in 1999, an increase of 2.4 billion or

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[55] In addition to growing stock, topwood (wood and bark of above merchantable height), cull (rotten or rough trees) and non-growing stock may also have commercial value. Due to lack of data, these values are not estimated here.

[56] A "forest type" contains multiple species found growing in close proximity; a "forest type group" include several forest types.

43.6%. The average annual increase of 204 million bd-ft/year, if continued through 2004, would result in a sawtimber inventory of 9.1 billion bd-ft in that year. Table 30 on the next page presents a detailed breakdown of the above totals.

Table 30 also shows the 2004 stumpage prices (in 2004 dollars per 1,000 board-feet) for the tree species present in New Jersey. Those prices were obtained from a variety of sources since no single source had prices for all of the species present in New Jersey; New Jersey itself apparently has no published source for stumpage prices. Where several states reported price data, preference was given to the states closest to New Jersey; as a result, about two-thirds of the prices are from Pennsylvania or other Northeastern states.

Based on the 2004 prices, Table 30 presents an estimated value for the assumed annual increase in New Jersey's sawtimber inventory of about $49 million/year. It should be emphasized that this figure does not necessarily represent the value of the *sustainable* sawtimber yield from New Jersey's timberland. The estimate is simply based on an annual yield of about 204 million-board feet, obtained by dividing the total increase in estimated sawtimber volume of 2.4 billion bd-ft from 1987 to 1999 by twelve.[57]

It can be argued that 204 million bd-ft/yr overstates the sustainable yield because of New Jersey's loss of forests and forested wetlands to development. However, such losses may be balanced in part by growth of existing trees, increases in the number of trees per acre (as occurred from 1987 to 1999), and reforestation of abandoned agricultural land. Moreover, while 204 million bd-ft represented 3.6% of the 1987 sawtimber inventory, it represents 2.5% of the 1999 inventory and only 2.2% of the projected 2004 inventory. For these reasons, this study does not include an acreage adjustment.

A number of empirical studies provide estimates of the elasticity of demand for sawtimber and related products (see Exhibit C). The estimates span a fairly wide range, reflecting the multiple uses of timber; in effect, there are multiple timber markets and multiple elasticities of demand. Therefore, Table 31 (following Table 30) uses both the first and third quartiles and the median to develop a range of estimated valuations.

(text continues after tables)

[57] According to the New Jersey Forest Service, only 4.7 million board-feet were harvested on privately-owned timberland during the period from July 2003 to June 2004, based on unaudited reports submitted by certified consulting foresters. If the figure of 4.7 million bd-ft is representative of other years, it is clear that private landowners, who owned 69% of New Jersey's timberland in 1999, have been harvesting far less than the average annual increase reported by USFS; the reasons for this difference are not obvious.

Table 30: Estimated Value of New Jersey's Sawtimber									
Tree Species	**1987 Volume MM bd-ft**	**1999 Volume MM bd-ft**	**Net Change in Volume MM bd-ft**	**Annual Change MM bd-ft/yr**	**Projected 2004 Vol. MM bd-ft**	**Stumpage Price '04 $/000 bd-ft**	**Source of Prices (state)**	**Value of Ann. Chge. MM $/yr**	**Value of '04 Stock MM $**
Atlantic White Cedar	145.1	236.2	91.1	7.6	274.2	$445	AL	$3.4	$122.0
Shortleaf Pine	72.5	36.8	-35.7	-3.0	21.9	$326	MD/DE	-$1.0	$7.1
Pitch Pine	722.9	928.9	206.0	17.2	1,014.7	$86	various	$1.5	$87.3
Virginia Pine	13.3	47.1	33.8	2.8	61.2	$86	various	$0.2	$5.3
Other Pine	89.3	41.0	-48.3	-4.0	20.9	$88	PA	-$0.4	$1.8
Eastern Red Cedar	32.3	51.2	18.9	1.6	59.1	$61	ME	$0.1	$3.6
Softwood Total	**1,075.4**	**1,341.2**	**265.8**	**22.2**	**1,452.0**			**$3.9**	**$227.1**
Red Maple	441.8	861.2	419.4	35.0	1,036.0	$199	PA	$7.0	$206.2
Sugar Maple	104.8	116.4	11.6	1.0	121.2	$508	PA	$0.5	$61.6
Hickory	119.5	254.7	135.2	11.3	311.0	$71	NY	$0.8	$22.1
Beech	121.6	163.7	42.1	3.5	181.2	$39	NY	$0.1	$7.1
Ash	406.9	553.9	147.0	12.3	615.2	$252	PA	$3.1	$155.0
Sweetgum	292.7	412.3	119.6	10.0	462.1	$84	IL	$0.8	$38.8
Yellow Poplar	646.8	1,066.4	419.6	35.0	1,241.2	$223	PA	$7.8	$276.8
Blackgum	78.5	100.6	22.1	1.8	109.8	$152	PA	$0.3	$16.7
Black Cherry	16.2	44.0	27.8	2.3	55.6	$1,143	PA	$2.6	$63.5
Select White Oaks	403.1	495.7	92.6	7.7	534.3	$270	PA	$2.1	$144.3
Select Red Oaks	524.6	836.2	311.6	26.0	966.0	$533	PA	$13.8	$514.9
Other Red Oaks	690.3	866.8	176.5	14.7	940.3	$158	IL	$2.3	$148.6
Other White Oaks	334.2	432.1	97.9	8.2	472.9	$217	various	$1.8	$102.6
Other Hardwoods	355.5	512.1	156.6	13.1	577.4	$152	PA	$2.0	$87.8
Hardwood Total	**4,536.5**	**6,716.1**	**2,179.6**	**181.6**	**7,624.3**			**$45.0**	**$1,845.8**
GRAND TOTAL	**5,611.9**	**8,057.3**	**2,445.4**	**203.8**	**9,076.2**			**$48.9**	**$2,073.0**

Source of 1987 and 1999 volume data: USDA Forest Service, 2001, Forest Statistics for New Jersey: 1987 and 1999, Northeastern Research Station Resource Bulletin NE-152. Projected 2004 volume = 1999 volume + 5 x avg. increase/yr. from 1987 to 1999.

Note 1: Sawtimber is commercial-grade timber that meets minimum size criteria for diameter at breast height (dbh); the minimums are 9 in. dbh for softwoods and 11 in. dbh for hardwoods. Breast height is defined as 4.5 ft. above ground level.

Note 2: The board-foot is a unit of lumber measurement equal to the amount of wood in a sawtimber log 1 ft. long, 1 ft. wide, and 1 in. thick.

Note 3: The stumpage price is the price landowners receive from loggers for the right to cut down standing trees. The prices are intended to serve as a general guide for the marketing of standing timber; the actual value of a specific stand of timber depends on timber quality etc.

Table 31: Total Willingness to Pay for Sawtimber (2004 $)			
Parameter ↓ or Estimate →	**Low-end**	**Central**	**High-end**
Key assumptions:			
Elasticity of demand	-0.520	-0.250	-0.100
Total annual supply (MM bd-ft)	203.783	203.783	203.783
Avg. price ($/000 bd-ft)	$240	$240	$240
Market value/year $MM	$48.9	$48.9	$48.9
Consumer Surplus/Market Value	96%	200%	500%
Consumer surplus/year $000	$46.9	$97.8	$244.5
TEV/year $000	$95.8	$146.7	$293.4
Present value at 3%/yr $Bn	$3.195	$4.890	$9.780
Natural capital (acres)	2,129,048	2,129,048	2,129,048
TEV/acre/year $	$45	$69	$138
Present value/acre $	$1,501	$2,297	$4,594

Key: CS = consumer surplus; MV = market value; TEV = total economic value

A more precise estimate of New Jersey's sustainable sawtimber yield and value would require more detailed modeling by tree species of such factors as growth of previously established trees, colonization of new acreage, deliberate tree plantings and removals, tree diseases, normal tree mortality, and other factors. Those variables are in turn affected by such things as climate change, spread of disease vectors, crowding-induced tree morbidity and mortality, etc. Such modeling would require an ecological analysis which is beyond the scope of this study.

As with all of the other natural capital value estimates presented in this report, these figures are subject to change as a result of changes in land use (e.g., conversion of forested land to residential and commercial uses and reforestation of abandoned farmland), climate, tree disease patterns, timber harvest policies, the relative prices of different tree species, and numerous other factors. The above estimates reflect a snapshot at a point in time; their future relevance will depend on a combination of human decisions and natural forces. As of 2004, however, New Jersey's forests clearly made a significant contribution to the state's collective income and wealth.

Section X: Summary and Conclusions

Table 32 below and the tables on the following pages summarize the conclusions reached in this study of New Jersey's ecosystem and abiotic natural goods. Based on those results, this report concludes that the natural goods provided by New Jersey's natural capital have economic values of about $5.9 billion on an annual basis; the natural capital that provides those goods has a present value of about $196billion.

As the various tables show, farm goods and fish have the highest shares of these totals, followed by minerals and water; wood and non-farm animals have the lowest shares, and the value of non-farm plants cannot be estimated. All of these estimates are subject to various uncertainties as described throughout this report.

The value provided varies by ecosystem, depending on the types of natural goods provided, the total acreage of the ecosystem, and the average value per acre. Farmland and marine ecosystems generate the highest values in terms of total value, followed by barren land (which includes mines and quarries), forests, and freshwater wetlands. In terms of value per acre, barren land ranks first, followed by farmland, marine ecosystems, and open fresh waters.

As emphasized in Section II, total economic value has two components: market value and consumer surplus. The relative contribution of each to TEV depends on the type of good in question, as the following table shows:

Table 32: Components of Total Economic Value (middle estimates; MM 2004 $)

Natural Good	MV	CS	TEV	Share	CS/TEV
Farm products	$448	$3,228	$3,676	62.7%	88%
Fish (total)*	157	801	958	16.3%	84%
Minerals	321	266	587	10.0%	45%
Raw water	169	211	381	6.5%	56%
Sawtimber	49	98	147	2.5%	67%
Fuelwood	39	57	95	1.6%	60%
Game/fur animals	3	18	21	0.4%	84%
Total or avg.	**$1,186**	**$4,679**	**$5,864**	**100.0%**	**80%**
Commercial fish	123	627	750	12.8%	84%
Recreational fish	34	173	207	3.5%	84%

Key: TEV = total economic value; MV = market value; CS = consumer surplus.

The final column in Table 32 gives the Consumer Surplus share of Total Economic Value. The variations among classes of goods reflects the varying estimates of elasticity of demand as obtained from prior empirical studies or official sources. For the reasons described in Appendix A (use of linear rather than constant elasticity; assignment of estimated elasticity to right end of demand curve), the above estimates of consumer surplus are more likely to be conservative (i.e., low) than aggressive.

(text continues after tables)

Table 33: Economic Value of New Jersey's Natural Goods (middle estimates; 2004 $)				
Middle Estimates	**Annual Market Value $MM**	**Annual Consumer Surplus $MM**	**Total Economic Value per year $MM**	**Present Value $Bn****
Farm products*	$448	$3,228	$3,676	$122.5
Minerals	321	266	587	19.6
Raw water	169	211	381	12.7
Sawtimber	49	98	147	4.9
Subtotal	**987**	**3,804**	**4,791**	**159.7**
Commercial fish	123	627	750	25.0
Recreational fish	34	173	207	6.9
Fuelwood	39	57	95	3.2
Game/fur animals	3	18	21	0.7
Total	**1,185**	**4,679**	**5,864**	**195.5**
Low-end totals	820	1,979	2,798	93.3
High-end totals	1,555	8,098	9,652	321.7

**middle estimate = low-end estimate + 50% of the difference between the high and low estimates (see Section V).*
***present value at 3% per year in perpetuity.*

Low-End Estimates:				
Farm products	$108	$778	$885	$29.5
Minerals	321	161	481	16.0
Raw water	143	119	262	8.7
Sawtimber	49	47	96	3.2
Total	**621**	**1,104**	**1,724**	**57.5**

High-End Estimates:				
Farm products	$787	$5,679	$6,647	$215.6
Minerals	321	802	1,123	37.4
Raw water	199	497	695	23.2
Sawtimber	49	245	293	9.8
Total	**1,356**	**7,223**	**8,579**	**285.9**

Table 34: Annual Value of New Jersey's Natural Capital by Ecosystem (2004 $MM/year) (middle estimate)											
Ecosystem	**Area (acres)**	**Farm Goods**	**Fish - All***	**Minerals - All**	**Raw Water**	**Wood - All**	**Game + Fur**	**TEV/yr $Mm**	**TEV/yr $/ac**	**PV TEV $Bn**	**PV TEV $/ac**
Farmland[1]	673,464	3,676			79			$3,760	$5,583	$125.3	$186,095
Marine[2]	755,535		850					850	1,125	28.3	37.512
Barren land	51,796			587				587	11,337	19.6	377,893
Forest land**	1,465,668				173	166	12	349	238	11.6	7,934
Freshwater wetland[3]	814,479		14		96	75	7	191	234	6.4	7,801
Open fresh water	86,232		69		10		1	79	921	2.6	30,698
Saltwater wetland	190,520		25				2	26	139	0.9	4,617
Urban[4]	1,483,496				20			20	13	0.7	450
Riparian buffer	15,146				2			2	118	0.1	3,934
Beach/dune	7,837							0	0	0.0	0
TOTAL	**5,544,173**	**3,676**	**$958**	**$587**	**$381**	**$242**	**$21**	**$5,864**	**$1,058**	**$195.5**	**$35,259**

1. Farmland:											
Cropland	546,261	3,223			64			3,291	6,025	109.7	200,828
Pasture/grassland	127,203	453			15			469	3,685	15.6	122,827
2. Marine:											
Estuary/tidal bay	455,700		513					513	1,125	17.1	37,505
Coastal shelf	299,835		338					338	1,126	11.3	37,524
3. Freshwater wetland:											
Forested	633,380				75	75	5	154	244	5.1	8,122
Other	181,099		14		21		1	36	200	1.2	6,679
4. Urban:											
Urban (impervious)	1,313,946										
Urban green space	169,550				20			20	118	0.7	3,934

*recreational saltwater fishing includes saltwater wetlands; recreational freshwater fishing includes unforested freshwater wetlands.
**includes wooded farmland.

Table 35: Annual Value of New Jersey's Natural Capital by Ecosystem (2004 $MM/year) (low and high-end estimates)									
		Low-End				**High-End**			
Ecosystem	**Area (acres)**	**TEV/yr $Mm**	**TEV/yr $/ac**	**PV TEV $Bn**	**PV TEV $/ac**	**TEV/yr $Mm**	**TEV/yr $/ac**	**PV TEV $Bn**	**PV TEV $/ac**
Farmland	673,464	$944	$1,402	$31.48	$46,746				
Marine	755,535	850	1,125	28.34	37,512	850	1,125	28.34	37,512
Barren	51,796	481	9,294	16.05	309,805	1,123	21,685	37.44	722,836
Forest	1,465,668	260	177	8.66	5,910	593	404	19.76	13,483
Freshwater wetland	814,479	145	178	4.82	5,923	316	388	10.53	12,927
Open fresh water	86,232	76	884	2.54	29,470	88	1,019	2.93	33,951
Saltwater wetland	190,520	26	139	0.88	4,617	26	139	0.88	4,617
Urban	1,483,496	14	9	0.46	309	37	25	1.22	821
Riparian buffer	15,146	1	81	0.04	2,706	3	216	0.11	7,188
Beach/dune	7,837	0	0	0.00	0	0	0	0.00	0
TOTAL	**5,544,173**	**$2,798**	**$505**	**$93.28**	**$16,824**	**$9,652**	**$1,741**	**$321.75**	**$58,033**

**TEV = total economic value*

Limitations of the Study

The future flows of these natural goods are impossible to predict with confidence because they depend heavily on "natural" factors such as climate change and on social policies such as land use conversion that are themselves impossible to project with much precision. Despite the high level of uncertainty, however, it seems likely that these factors will tend to operate over time so as to decrease the value of the goods-producing natural capital in New Jersey.

Two other limitations on the results of this study need to be mentioned. First, *total* willingness to pay (i.e., *total* economic value) differs from *net* willingness to pay (*net* economic value). The difference is the *cost* of producing the goods in question and bringing them to market, i.e., to the consumer. Even though nature (conceived of as natural capital) provides the goods we are discussing, human effort and physical capital (tools, equipment, vehicles, roads, etc.) are required for the goods to actually be used. The net benefit to society is therefore the total benefit (or total WTP) minus the costs of production and distribution.

While cost information is thus essential to determining net economic value, market prices do not clearly indicate costs. What they show is the amount actually paid for something. That amount in turn consists of the producer's or supplier's *costs* and his or her return or *profit*, termed producer surplus (see Sec. II). The net benefit to society equals consumer surplus plus producer surplus. By including producer costs, market values thus overstate the net benefits to society.

To estimate producer costs for each natural good so that we can deduct them from total economic value to obtain net economic value would require detailed investigations of each of the industries involved—mining, fishing, logging, etc.—and such investigations are beyond the scope of this report. In this respect, the estimated values of natural goods summarized above are comparable to the estimated values of ecosystem services presented in Part II in that they are "gross" (before costs) rather than net.

There is another factor, however, that offsets this overstatement to some extent. When costs are incurred to produce and distribute natural goods (or when costs are avoided because natural ecosystem services eliminate the need for investment in artificial substitutes), the expenditures made on the natural goods (or the expenditures made with the funds saved on replacing natural ecoservices) stimulate "secondary" economic activity, e.g., as when farmers purchase supplies or equipment or when employees of mining companies spend their wages on goods and services. In regional economics and macroeconomics, this stimulation of secondary activity is known as the "multiplier effect".

While secondary activities can result in economic benefits to society that may partially compensate for the fact that market values include producer costs, it is beyond the scope of this report to analyze the secondary benefits to New Jersey related to each of the industries involved in producing and distributing natural goods. As a result, the "total" economic values derived in this report thus represent only the total *direct* values and therefore understate the true value by the amount of the secondary benefits.

Directions for Future Research

Whether producer costs are completely offset by the unquantified secondary benefits is an empirical matter, and the answer may differ from industry to industry, e.g., from agriculture to logging to mining to fishing. [58] Nonetheless, given the available data and other constraints, total (direct) willingness to pay, defined as Market Value + Consumer Surplus, is a valid, albeit incomplete, first-order approximation of the true economic value of the natural goods produced in New Jersey.

Future research in the following areas could help improve the accuracy and precision of the estimates in this report:

- All ecosystems: more current land use/land cover data.
- All ecosystems: relationships between production of services and goods.
- Water: more current data on supplies and leakage rates.
- Minerals: tonnage and market value of sand dredged offshore.
- Farm products: more recent data on the amount of farmland by type.
- Fish: prices for recreational freshwater species; role of wetlands.
- Non-farm plants: data and methods for preparing rough valuations.
- Fuelwood: share of wood harvested in-state; estimated sustainable yield.
- Timber: more current annual growth data; estimates of sustainable yield.
- All natural goods: further research on relative per-acre ecosystem productivity.
- All natural goods: further research on elasticity of demand.

Within the limits imposed by nature, New Jersey has a measure of control over the future capacity of its natural capital to produce valuable natural goods. To the extent of that control, the quantities of those goods available in the future should be a matter for informed and deliberate public choice. In combination with the findings in Part II on ecosystem services, this report documents the considerable economic value provided by New Jersey's ecosystems and thereby helps provide a more scientific basis for those decisions.

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[58] In most situations, the offset is probably only partial because a dollar's worth of spending by New Jersey producers will usually generate less than a dollar of secondary activity in the state. This is so for several reasons, including the fact that some of the spending flows to out-of-state suppliers (e.g., manufacturers of farm implements and mining equipment); the same is true when employees spend their income on goods produced out-of-state. In addition, unless the suppliers were operating below capacity and unless the employees were otherwise unemployed or underemployed, the secondary activity merely displaces other New Jersey activity that would have occurred anyway. Only the net secondary effects represent real contributions to the Net Benefit to New Jersey from producing natural goods.

Appendix A: Estimation of Total Economic Value

This appendix presents the derivation of the formula used to obtain the estimates of Consumer Surplus (CS) and Total Economic Value (TEV) presented in Sections III-VIII. The derivation of the valuation formula is general and does not depend on the type of natural good being analyzed. The only required input data are the Market Value (MV) of the good when the quantity demanded equals 100% of the annual output and an estimate of the price elasticity of demand for that good obtained from the economics literature or official sources.

As suggested in Figures 1-2, Sec. II, determining CS is tantamount to estimating the total area TEV between the demand curve[59] and the horizontal axis and then subtracting MV from that total. To estimate that area, we need to know three things:

- the functional form, i.e., the general shape of the demand curve;
- the slope of the curve, i.e., its relative "steepness"; and
- the y-intercept or asymptote, i.e., the values the demand curve takes on as it approaches and reaches the y-axis (i.e., the vertical axis).

for the range from Q_0 to Q_1 (see Fig. 1 of Section II).

In general, these factors can be derived in two ways: empirically and analytically. In an empirical study, the investigator has multiple data points available, either from existing databases or from an original study, e.g. a stated preference study (in essence, a sophisticated consumer survey in which respondents state how much they would be willing to pay for a given good under various circumstances). Using various econometric (i.e., statistical) techniques, the investigator can determine the functional form that appears (with varying degrees of certainty) to fit the data most closely.

In our case, we have only one known data point, namely the point where $Q = Q_1 = 100\%$ of annual output and $P = MP$ = the average market price of that output, e.g., dollars per thousand gallons of water. (For various technical reasons, values of Q and P from prior years are not a suitable basis for this type of empirical study.) Given this lack of data, we need to turn to a more analytic approach. In developing such an approach, we will need to make use of information on the elasticity of demand for each type of natural good being considered[60], and that concept is discussed next.

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[59] In Figs. 1-2, the horizontal axis represents quantity (demand) and the vertical axis represents price, suggesting that price is being graphed as a function of quantity. In fact, the concept of elasticity on which critical parts of this analysis are based defines quantity (demand) as a function of price; however, it is standard practice in economics to show the independent variable price on the vertical axis and the dependent variable quantity on the horizontal. For convenience, we ignore these details and refer simply to the demand curve. The line defined by the demand function is traditionally termed the demand "curve" even if it is in fact a straight line.

[60] More precisely, the type of elasticity we will use is the own-price short-run price elasticity of demand. There are also "cross-price", long-run, income, and supply elasticities.

Elasticity of Demand

Elasticity of demand is the percentage change in the quantity demanded associated with a one percent change in price: $E = (\Delta Q/Q) / (\Delta P/P)$. For example, if price increases by 1% and demand falls by 0.5%, the elasticity of demand equals –0.5% / +1% = –0.5. As the example shows, elasticities are unit-less numbers because they are the ratio of two percentages; the minus sign indicates that price and demand move in opposite directions, as we would expect for typical goods like those we are considering.

Estimates of elasticity derived from prior studies are available for each of the broad classes of natural goods analyzed in this report. Those elasticities represent *point* estimates (i.e., single values) for the types of natural goods being considered, e.g., -0.098 for fish. Technically, a point estimate applies only to the relatively small portion of the demand curve covered by the original empirical study; since we are interested in the economic value represented by the *entire* area under that curve, we theoretically need separate estimates of elasticity all along the demand curve.

It is rarely if ever feasible to obtain such comprehensive information on elasticities. However, as will be demonstrated below, elasticity is a critical variable because if its value is known, a demand function can be derived, making it possible to estimate CS and TEV. In the absence of detailed information on the relevant elasticities and the appropriate demand function for a given situation, economists often make simplifying assumptions, of which the following are probably the most common (Nicholson 2002):

- One common assumption is that elasticity is constant all along the demand curve. This assumption leads to a type of non-linear demand function discussed below.

- Another common assumption is that the demand function is linear. As will be seen below, this assumption leads to varying elasticities along the demand curve, but those elasticities can easily be calculated.

These two approaches are discussed below; for reasons that will be indicated, linear demand functions were chosen for this study.

Non-Linear Demand Functions

As just noted, economists often assume for convenience that elasticity is constant at every point on the demand curve. The demand functions associated with constant elasticity are non-linear functions of the form $Q = A \times P^E$, where Q, P, and E represent respectively quantity, price, and elasticity, and A is an empirically-derived parameter. Fig. 6 shows an example of such a function, and Nicholson (2002) presents a more detailed discussion of constant elasticity demand functions. Such demand functions have been used extensively in the field of water economics, e.g., in Young (2005) and other sources cited in the References.

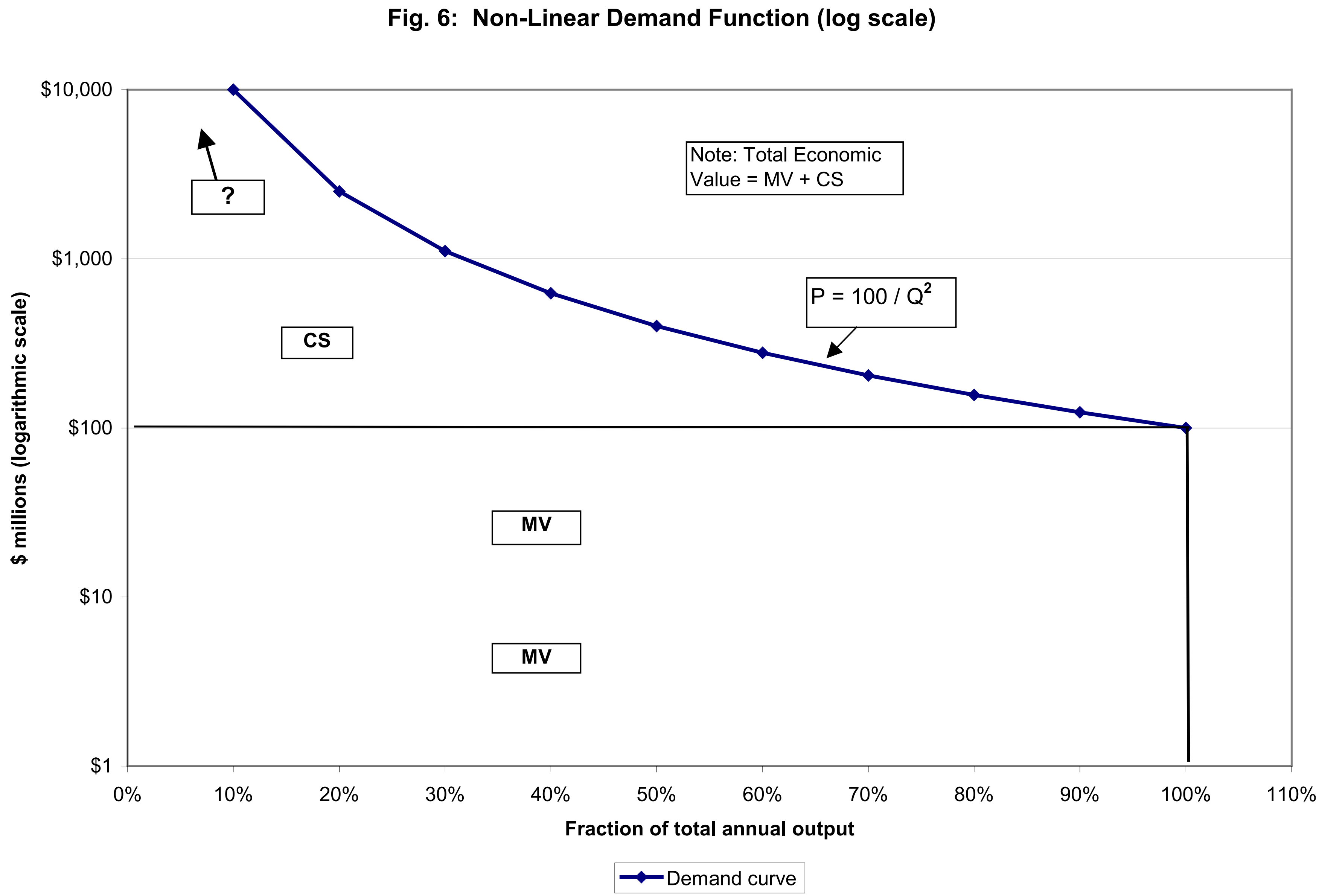


Fig. 6: Non-Linear Demand Function (log scale)
$10,000
$1,000
$100
$10
$1
$ millions (logarithmic scale)
?
Note: Total Economic Value = MV + CS
P = 100 / Q2
CS
MV
MV
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
110%
Fraction of total annual output
Demand curve

While constant elasticity functions of this type are often used by economists, there is no a priori reason that elasticity *must* be constant: isoelasticity (i.e., constant elasticity) is merely a convenient assumption made to address the absence of detailed empirical estimates of elasticities along the demand curve.[61] In fact, constant elasticity demand functions create difficult calculation problems if demand is relatively inelastic (i.e., close to zero), because as shown in Fig. 6, as the value of Q approaches zero, the area under such a demand curve increases exponentially without limit; at Q = 0, the demand function is mathematically undefined. This makes it impossible to calculate CS and TEV, because the area under the demand curve is "open-ended".

Linear Demand Functions

Given the somewhat arbitrary nature of the assumption of constant elasticity and the mathematical problems presented by non-linear demand functions, economists often use instead a linear demand function of the form Q = A x P + B, where A is the slope of the linear demand "curve" and B is the value of Q when P = 0. Fig. 7 presents an example of such a function, and Appendix B shows that while elasticity of demand is not constant with a linear demand function, it can readily be calculated for any interval along the demand curve.

The next question is how to estimate the parameters A and B. It turns out that we can develop a linear estimate of the demand function if we can determine either the y-intercept for the demand curve or the slope of that curve. The approach used here begins by determining the y-intercept. First, we define a function for Price in terms of Quantity:

1. $\boxed{\mathbf{P = P_0 - Q * (P_0 - MV)}}$

where P, Q, and MV represent respectively price, quantity, and market value, and P_0 is the y-intercept of the demand curve, i.e., the value of P when Q = 0. In Eq. 1, when Q = 1, P becomes $P_0 - 1 * (P_0 - MV) = MV$. (As noted earlier, although Eq. 1 defines P in terms of Q, it will still be referred to for simplicity as a demand function.)

Given the above, a formula for estimating P_0 can be derived as follows:

2. From the definition of elasticity, E = dQ/Q / dP/P.
3. Rearranging terms in Eq. 2, we get P = E * Q * dP/dQ.
4. Evaluating Eq. 3 at Q = 100%, we get MP (Market Price) = $E_1 * Q_1 *$ dP/dQ.[62]
5. We note next that MV = MP * Q_1 = MP * 1 = MP.
6. Since MP = MV and Q_1 = 100% = 1, Eq. 4 becomes MV = E_1 * dP/dQ.

(text continues after Fig. 7)

[61] As long ago as 1974, Fisher, Krutilla and Cicchetti concluded that "there is no theoretical argument advanced in support of nonlinearity anywhere in the [economics] literature". Cited in Bockstael and McConnell (1980), p. 60.

[62] Eq. 4 assumes that the point elasticity estimate E_1 available for a given natural good applies at point Q_1.

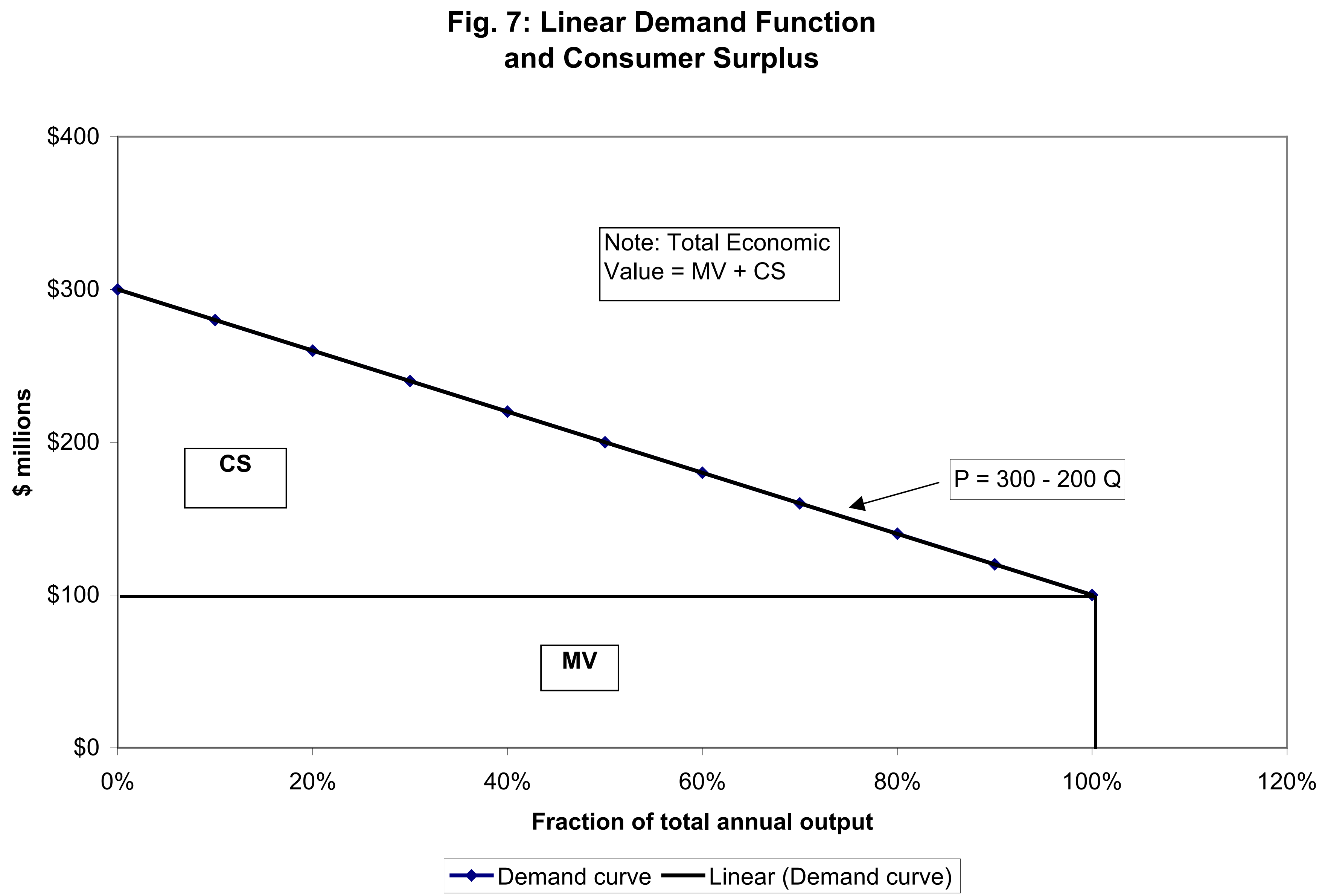


Fig. 7: Linear Demand Function
and Consumer Surplus
$400
$300
$200
$100
$0
$ millions
Note: Total Economic
Value = MV + CS
CS
MV
P = 300 - 200 Q
0%
20%
40%
60%
80%
100%
120%
Fraction of total annual output
Demand curve
Linear (Demand curve)

7. Now dP/dQ is the slope of the demand function, and for a linear function the slope is constant over any portion of the curve or indeed for the curve as a whole.
8. Therefore, $dP/dQ = \Delta P / \Delta Q = (MP - P_0) / (Q_1 - Q_0)$.
9. Substituting for MP, Q_1, and Q_0 in Eq. 8, we get $dP/dQ = (MV-P_0) / (1 - 0) = MV - P_0$.
10. Plugging Eq. 9 back into Eq. 6, we get $MV = E_1 * (MV-P_0)$.
11. Solving Eq. 10 for P_0, we obtain $\boxed{\mathbf{P_0 = MV * [(E_1 - 1) / E_1]}}$

We can now derive a linear equation for Total Economic Value TEV as follows:

12. TEV equals the rectangular area MV plus the right triangular area CS (see Fig. 2, Sec. II).
13. Area of the rectangle = height x width; area of the right triangle = ½ x height x width.
14. Substituting these formulas in Eq. 12, we obtain $TEV = (MP*Q_1) + (P_0-MV)*(Q_1-Q_0) / 2$.
15. Plugging Eq. 11 into Eq. 14 and simplifying, $TEV=MV+\{MV*[(E_1-1)/E_1]-MV\}/2$.
16. Eq. 15 then simplifies to $\boxed{\mathbf{TEV = MV * (1 - 1 / 2E)}}$

In addition to mathematical simplicity,[63] the approach described above has the advantage of providing estimated values for TEV that are more conservative (i.e., lower) than those provided by non-linear demand functions. Fig. 8 (next page) compares the demand functions in Fig. 6 and Fig. 7; to fit both demand curves on the same page, a logarithmic scale had to be used for the vertical axis.

What Figs. 6 and 8 clearly show is that TEV for a non-linear demand function increases without limit; at Q = 10%, P has already reached $10 *billion*, compared with a value at Q = 100% of only $100 *million*. Except possibly under extreme circumstances, it is unlikely that TEV would reach such high levels when Market Value equals only $100 million. The linear demand function is clearly the more conservative of the two by a wide margin.

For any natural good for which we have an elasticity value, we can compute the ratio of TEV or CS to MV using Equation 16 above. Table 36 below shows the calculations for eight types of natural goods covered in this study. As Table 36 shows, the excess of TEV over MV grows in a non-linear fashion as elasticity increases towards zero, i.e., as demand becomes less elastic (more inelastic). An increasingly inelastic demand is exactly what we would expect as the natural good becomes more of a necessity (more essential) than a luxury good. Figure 9 (following Table 36) shows this relationship graphically.

(text continues following figures and table)

[63] While the derivations presented above may appear complex, those involving non-linear functions tend to be even more complex and require calculus techniques for their solution.

Fig. 8: Linear vs. Non-Linear Demand Curves (log scale)

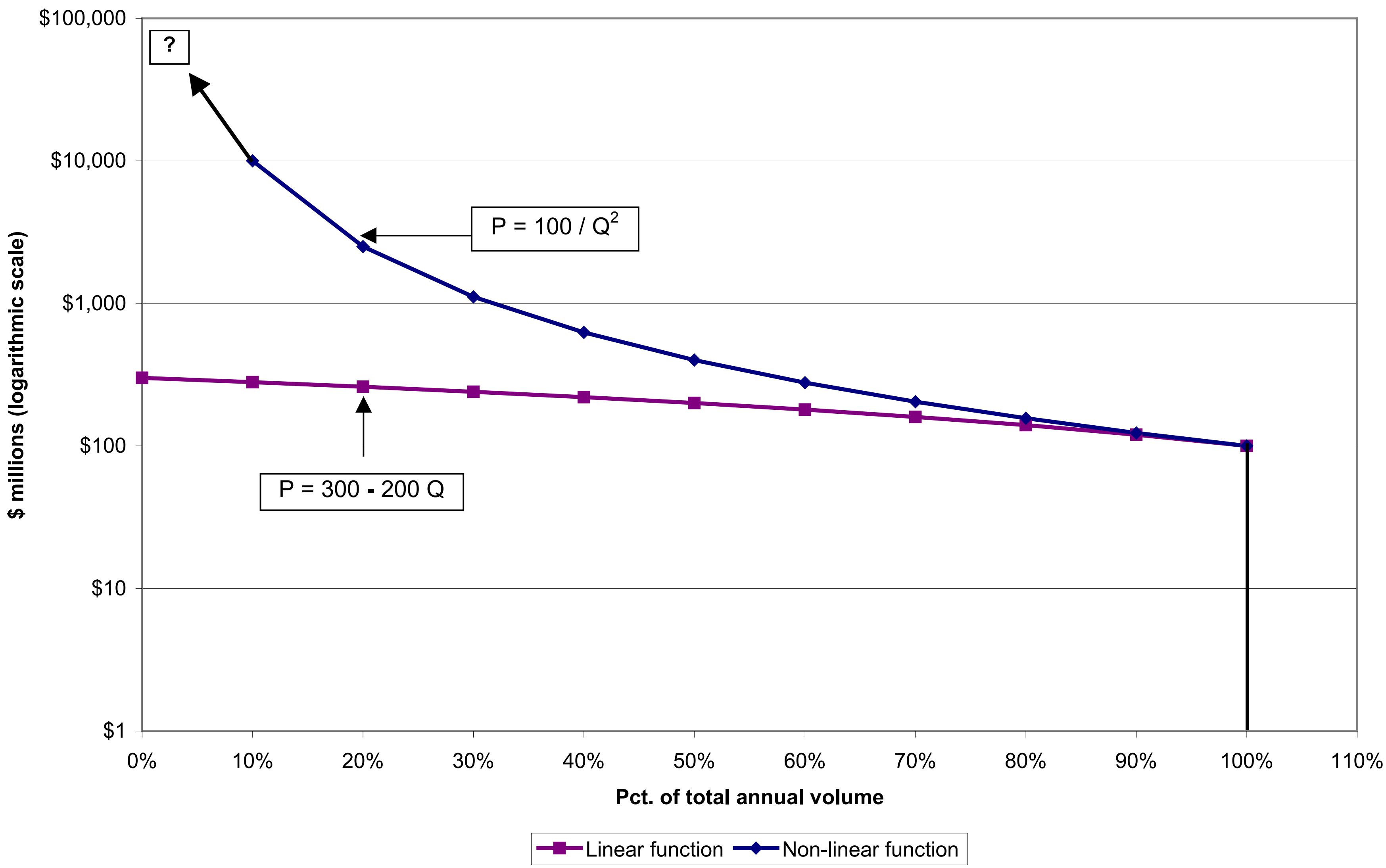


Table 36: Elasticity, Consumer Surplus, and Economic Value			
Type of Natural Good	**Elasticity***	**TEV / TMV**	**CS / TMV**
Farm products-weighted avg (1)	-0.069	8.21	721%
Game animals	-0.089	6.62	562%
Fish (finfish and shellfish)	-0.098	6.10	510%
Timber-median (2)	-0.250	3.00	200%
Fuelwood	-0.340	2.47	147%
Water-midpoint (3)	-0.400	2.25	125%
Minerals-midpoint (4)	-0.600	1.83	83%
Fur-bearing animals	-0.691	1.72	72%

**own-price short-run elasticity of demand.*

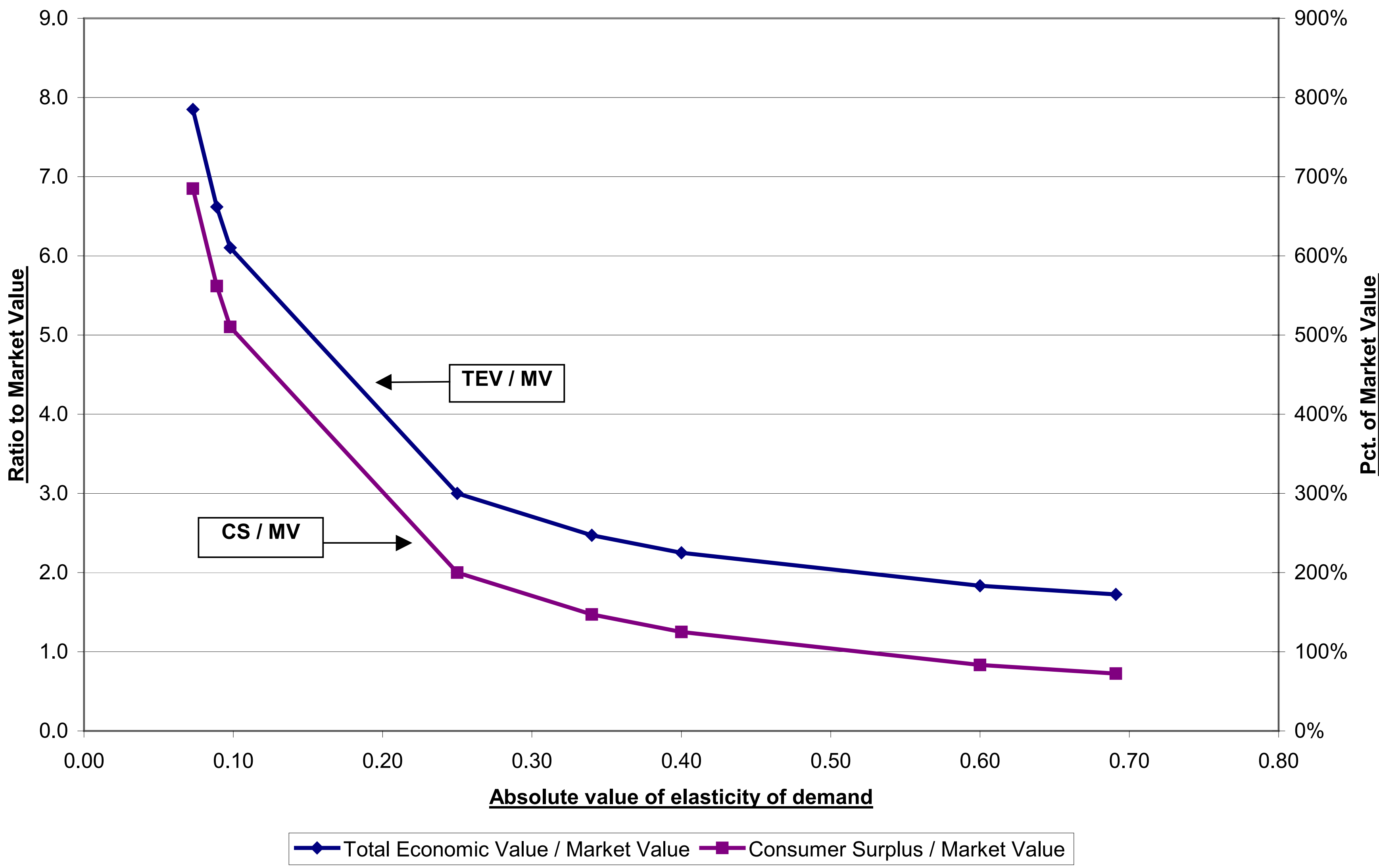
TEV = Total Economic Value = TMV + CS
TMV = Total Market Value = TEV - CS
CS = Consumer Surplus = TEV – MV

1.	Farm products-crops (87.68%)	-0.067	8.46	746%
	Farm products-animals (12.32%)	-0.092	6.43	543%
2.	Timber-1st quartile	-0.520	1.96	96%
	Timber-median	-0.250	3.00	200%
	Timber-3rd quartile	-0.100	6.00	500%
3.	Water-low end	-0.600	1.83	83%
	Water-middle	-0.400	2.25	125%
	Water-high end	-0.200	3.50	250%
4.	Minerals-low end	-1.000	1.50	50%
	Minerals-middle	-0.600	1.83	83%
	Minerals-low end	-0.200	3.50	250%

<u>Sources of elasticity estimates:</u>

Farm products	See Exhibit B
Game animals	USDA/Economics Research Service (meat)
Fish	USDA/Economics Research Service (fish)
Timber	Daigneault (2006)
Fuelwood	Skog (1993)
Water	Young (2005)
Mineral aggregates	Morrell (2006); USEPA (1997)
Fur products	USDA/ERS (clothing)

Fig. 9: Elasticity, Consumer Surplus, and Economic Value



It should be noted that the market values and the elasticity estimates used in this study come from different sources, and there is a difficult-to-quantify risk that elasticities estimated using non-New Jersey data might differ from elasticities based on New Jersey-specific data. For example, Equation 4 above assumes that our point estimates of elasticity E_1 apply at the Q_1 ends of the related demand curves, i.e., the ends where demand is *greatest*. However, Nicholson (2002) points out that a common practice in empirical work is to report estimated elasticities based on the *average* price for the good in question. This could mean that the elasticity estimates on which this study relies apply somewhere in the *middle* of the various demand curves rather than at their maximum-demand ends.

Even if it applies, however, this possibility may not pose a significant problem for our purposes. Suppose, for example, that an empirical study derived an elasticity of –0.5 based on a "price point" halfway between Q_0 and Q_1. It can easily be shown that for a linear demand curve, elasticities are lower at the Q_1 end (where the marginal percentage changes in Q are smaller and those in P larger) and higher at the Q_0 end (where the marginal percentage changes in Q are larger and those in P smaller). Therefore, the elasticities above (to the right of) the halfway point in this case should be *smaller than* –0.5. However, as Fig. 9 shows, the lower the elasticity, the greater the add-on for CS and therefore the higher the TEV. The assumption in Equation 4 that the –0.5 elasticity applies at the Q_1 end of the curve is therefore *conservative*, i.e., it results in lower estimates for CS and TEV.

If the elasticities of any of our natural goods were close to zero, we would face the problem of demand functions whose values increase exponentially without limit and become undefined when quantity equals zero. For example, if E = -0.001, the ratio of TEV to MV becomes 501, and the CS add-on becomes 50,000% of MV. There are only two natural goods "produced" in New Jersey whose elasticities might be that low, namely air and water. The above method might indeed not work well for air, and this study does not attempt to estimate a value for that "good".

As to water, most empirical studies have found elasticities ranging from –0.2 to –0.6 rather than closer to zero (Young 2005). While these findings may seem surprising for such a clearly essential good, they reflect in part the existence of multiple uses for. While the elasticity of demand for drinking water may in fact be close to zero, most uses of water are not as essential, and some, such as watering lawns and other green spaces, are *much* less essential and therefore much more likely to be influences by price changes.[64] The empirically-determined elasticity range for water may indicate that a substantial part of our use of water is in fact non-essential.

In conclusion, the approach developed in this appendix allows us to calculate reasonable and conservative first-order linear estimates of the Total Economic Values of the provisioning services delivered by New Jersey's natural capital. Sections III-IX of the main report apply the approach to specific types of natural goods.

[64] This suggests that the demand for water is not completely linear, since linear demand implies the existence of a price above which *no* water is demanded. As noted above, the assumption of linearity is a first-order approximation of the "true" demand curve.

Appendix B: Elasticity in Linear Demand Functions

As noted in Appendix A, while a linear demand function is easy to manipulate mathematically, elasticity is not constant along the demand curve, as shown in the following example based on the linear demand function shown in Fig. 7. The example uses the concept of "arc" elasticity, in which the midpoints of the Q and P intervals are used to calculate the percentage changes in Q and P respectively.

- If demand drops from 100 units to 90 units, the change is -10 units; the midpoint of the arc is (100+90)/2 = 95, and the percentage change in demand is –10/95 = -10.5%. If the price related to the demand change increases from $100 to $120, the change is +$20; the arc midpoint is (100+120)/2 = $110, and the percentage change in price is +20/110 = +18.2%. The elasticity of demand over this range is therefore –10.5% / +18.2% = **-0.58**.

- If demand drops again from 90 units to 80 units, the change equals -10 units; the midpoint is (90+80)/2 = 85, and the percentage change in demand is –10/85 = –11.8%. If the unit price increases from $120 to $140, the change is +$20; the midpoint of the arc is (120+140)/2 = $130, and the percentage change in price is +20/130 = +15.4%. The price elasticity of demand over *this* range is therefore –11.8% / +15.4% = **-0.77**.

In each case, price increases by $20 and quantity demanded decreases by 10 units; however, the significance of those changes in *percentage* terms depends on the absolute levels from which the percentage changes are measured. Constant elasticity means that the marginal elasticity is constant *everywhere* on the demand curve.

Although the linear demand function shown in Fig. 7 does not exhibit such constant elasticity, it does have the property that over larger intervals, "overall elasticity" is constant as long as the percentage changes in P and Q are measured from MP and Q_1 respectively. For example, for the same linear demand function:

- If demand drops from 100 units to 90 units, the percentage change in demand is –10/100 = -10%. If the related price change is from $100 to $120, the percentage price change is +$20/$100 = +20%. Overall elasticity for this range is –10%/+20% = **-0.5**.

- Similarly, if demand drops to 80 units, the percentage change in demand measured from Q_1 is –20/100 = -20%. If the related price increases to $140, the percentage price change measured from P_1 is +$40/$100 = +40%. Overall elasticity for this range equals –20%/+40% = **-0.5**.

It is easy to show that for the demand function in Fig. 7, overall elasticity remains at –0.5 for any value of Q between 1.0 and 0.0 as long as the percentage changes in P and Q are measured from MP and Q_1 respectively. While overall elasticity is not a recognized concept in standard economics, it does show that a weaker type of constancy exists for linear demand "elasticity".

Appendix C: Alternate Farmland Valuations

The estimates of farmland value presented in Section V are based on the land's continued use for farming and on net farm income as the metric for the annual flow of value from farming.[65] In the New Jersey real estate market, however, there are probably few sales of farmland in which a substantial portion of the sale price is not due to the land's potential as a site for commercial or residential development. That is, the market value of farmland reflects both its continued use to produce agricultural products and its development potential.

In that regard, NASS and ERS have reported different estimates for the market value of New Jersey farmland as Table 37 shows (COA = Census of Agriculture; NFI = net farm income).

Table 37: Estimated Market Value of New Jersey Farmland ($/acre)

Source	Coverage	2002	2004	Calculation
NASS Census of Agric.	Land + all bldgs.	9,137	n/a	Note A
NASS Census of Agric.	Land + all bldgs.	9,245	n/a	Note B
NASS Land Values	All farmland	8,600	9,750	Note C
NASS Land Values	Cropland	9,000	9,900	Note C
NASS Land Values	Pastureland	9,700	10,600	Note C
NASS Land Values	All farmland	9,224	10,124	Note D
ERS Balance Sheet	Land + farm bldgs.	7,615	8,487	Note E

A. As reported by NASS in the 2002 Census of Agriculture (COA); includes dwellings.
B. Market value/farm (including dwellings) / acres/farm from 2002 COA.
C. As reported by NASS in Land Values and Cash Rents 2004 Summary, August 2004.
D. NASS 2002 or 2004 cropland and pastureland values/acre x 2002 COA cropland and pastureland shares of total acreage.
E. ERS 2002 or 2003 balance sheet figure for real estate assets (excluding dwellings) / total farm acreage from 2002 COA or 2003 acreage estimate; 2003 price/acre is inflated to 2004.

The large differences between the ERS and NASS estimates may be due to the fact that NASS includes the value of farm dwellings in its farm balance sheet estimates; since dwellings constitute physical or "built" capital, ERS's figures might seem to come closer to the "pure" natural capital value we are seeking.

As stated in Section V, a 2002 study by Plantinga et al. using 1997 data concluded that 82% of the value of New Jersey farmland could be attributed to development potential. Based on that figure, we might multiply the 2004 ERS land value estimate of $8,487/acre by 18% to obtain $1,528/acre as an estimate for the market value of New Jersey farmland *as farmland*, i.e., net of

[65] Some portion of net farm income could be attributed to the cost of the owner's or operator's human and financial capital and another portion to a premium for risk-taking (Pearce 1992), i.e., to bearing the risk of loss inherent in agriculture (other than risks covered by crop insurance or similar safeguards).

both dwellings and development potential.[66] This figure is much lower than the average present value of $9,570 presented in Section V, a figure that is based solely on the value of farm output in perpetuity.

The estimated land value from farming of $1,528/acre is potentially compatible with the actual average cash flow from farming (net cash farm income) of $222/acre/year calculated in Section V. In principle, the value of land attributable to farming should equal the present value of the annual cash flows from farming. That present value depends on two factors—the discount rate and the time horizon; since we are now examining actual price data (or estimates thereof), discounting by 3%/yr in perpetuity is not the only possibility.

We can shed some light on this by using a plausible range of time horizons and discount rates to calculate the present value of the annual cash flow of $233/ac/yr (see Table 14, Section V), which in principle should equal the value of the land from farming. The results for selected discount rates are as follows (NCFI = net cash farm income):

Table 38: Net Farm Income and Agricultural Value of Farmland

Years	NCFI/ac/yr	PV rate	PV of NCFI	Assumed price
10	$233	8.50%	$1,529	$1,528
11	233	9.80%	1,527	1,528
12	233	10.80%	1,527	1,528
13	233	11.60%	1,526	1,528
14	233	12.20%	1,529	1,528
15	233	12.70%	1,529	1,528
16	233	13.15%	1,526	1,528
17	233	13.45%	1,530	1,528
18	233	13.75%	1,528	1,528
19	233	14.00%	1,526	1,528
20	233	14.15%	1,530	1,528

The values in this table represent the type of analysis that owners of farmland might engage in to estimate the present value of their land based solely on the annual flow of net income from farming, the owners' time horizons, and their projected or desired rates of return. In effect, landowners with different time horizons could in principle arrive at the same estimated value of $1,528/acre from farming if they also had different rates of return in mind.

For periods shorter than about ten years, the discount rates needed to equate the present value of the annual cash flow from farming to the estimated market price of $1,528/acre become implausibly low, meaning that owners of farmland would probably demand higher rates of return from their investment in agriculture. Similarly, as the time horizon increases, the discount rates needed to equate the present value of the annual cash flow from farming to the estimated market

[66] The resulting estimate would still include non-residential farm structures such as barns, silos, etc. and would therefore still somewhat overestimate the value of the land itself. Presumably such structures only have value if the land continues to be farmed.

price of $1,528/acre may become implausibly high, meaning that they may exceed the rates of return that such landowners could expect to realize.

This analysis suggests that USDA's estimated values for New Jersey farmland—which rely on self-reported estimates provided by farmers themselves and by other sources—are based on the assumption of a fairly short time horizon for the continuation of agricultural activities. This is probably not unreasonable in the New Jersey context, especially given that the average age of farmers was 55 according to the 2002 Census of Agriculture.[67]

The cash flow and land price methods as presented in this study can thus be made consistent if we assume that the landowner's valuation of agricultural income is based on a relatively short time horizon. However, since the focus of this study is on the value of goods provided by New Jersey's natural capital, the estimated per-acre value presented in Section V is based solely on continued use of farmland as farmland rather than on future development potential and the sale of development options.

[67] A possible implication of this assumption is that the option to sell farmland for development is valued as though it would not be exercised until the current farm owner or operator retires, which again may be a reasonable assumption in the New Jersey context.

Appendix D: Valuation of Standing Sawtimber

Forest economics recognizes two theoretical methods for valuing standing timber on forested land, both involving present value techniques. The first values the standing timber at a moment in time, assuming that no regeneration will take place as trees mature and die or are cut (harvested); in effect, harvesting of timber is assumed to be restricted to the current rotation cycle. The unit values are based on biomass growth (wood volume) as modified by economic factors such as timber price. In this case, the value of standing timber equals the timber volume (at a specific point in time) multiplied by the stumpage price multiplied by the discount factor.

The second theoretical valuation method assumes that harvesting can be sustained indefinitely, so that the value of the forest asset can be calculated as the present value of an indefinite annual stream of rent generated from harvesting the timber stock. In effect, this approach values the forest "estate" composed of timber and land combined. In this method, the value of standing timber is equal to the discounted future stumpage price for mature timber after deducting the costs of bringing the timber to maturity. The stumpage price is the price paid by the logger to the owner of the forest for the right to log standing timber. The costs include thinning (net of any receipts), other forest management costs and rent on the forestland. For natural (or non-cultivated) forests the management costs are very low or minimal. For this case**,** the value of standing timber equals the discounted future stumpage price minus the costs.

Applying either of the two present value methods to actual forests is relatively complicated and requires a great deal of data on the age structure and growth rate of the forest, forest management costs, and the rent on forest land. As a result, various simplified methods have been developed and are applied. Two such valuation approaches are the stumpage valuation and consumption value methods.

The *stumpage valuation method*, also known as the net price method, assumes that the discount rate is equal to the forest's natural growth rate. Since the two rates then cancel each other out, this assumption eliminates the need for discounting, so the value of the stock can be obtained simply by multiplying the current volumes of standing timber by the stumpage prices (neglecting costs).[68] In many applications, the value of the standing timber is based on the receipts from harvesting mature timber only, while costs are neglected. The assumption is that receipts are only realized when the timber reaches maturity. Maturity depends on physical growth but also involves economic factors in its definition. The stumpage prices are reflected in the receipts and therefore directly obtainable. The average stumpage price is calculated dividing the stumpage value by the volume of the removals.

An advantage of the stumpage value method is that it can be used to value all the items related to physical timber accounting in a simple way, including stocks, removals, natural growth, and other changes. This is not the case for other valuation methods. In the stumpage valuation method an average stumpage price is obtained and applied to the whole stock of standing timber. In its simplest formulation, no discrimination is made for the age of the timber

[68] This approach is somewhat similar to the Hotelling method except that the discounting is offset by physical growth rather than by price increases. For a further discussion, see Hotelling, J. (1931). "The Economics of Exhaustible Resources," *Journal of Political Economy,* 39, pp. 137 – 175.

at the valuation date. Other methods require data for different age or diameter classes, which complicate the calculation of the value of the timber stocks, and consequently, of other items in the physical timber accounts since the valuation of these items should be consistent with that used for stocks.

The *consumption value method* uses different stumpage prices not only for different tree species but also for different age or diameter classes. These prices are applied to the stock of timber based on information on species mix and age or diameter classes obtained from forest inventories. The consumption value method measures the value of the timber as if it were all cut now, hence its name. Which of the methods gives reasonably accurate results depends on the characteristics of the forest stock to be valued and the current and expected exploitation conditions and harvesting patterns. The stumpage valuation method gives good results when the current stock and harvesting structure can be assumed to continue in the future. The consumption value method yields good results for old growth forests, a category which generally does not include New Jersey's forests.

List of Exhibits

Exhibit A: Water Losses for Major Regulated Water Utilities in New Jersey

Utility	Loss Pct.	000 Gal. Lost	000 Gal. Demand	# Customers
Elizabethtown Water	16.80%	9,057,621	53,914,411	206,583
Gordon's Corner	7.98%	163,715	2,051,566	14,526
Middlesex Water	11.09%	1,933,924	17,438,449	58,354
Mount Holly Water	21.70%	399,977	1,843,212	16,064
New Jersey American	23.10%	9,721,539	42,084,584	361,502
Shorelands Water	3.44%	64,782	1,883,198	11,091
United Water NJ	23.10%	9,721,539	42,084,584	193,379
United Water Toms River	12.97%	599,888	4,625,197	48,557
Subtotal	**19.08%**	**31,662,985**	**165,925,201**	**910,056**
Avg. gal./customer (000)			182	
Aqua NJ:				
Northern division	23.43%	318,759	1,360,474	38,097
Central division*	10.10%	386,355	3,825,293	
Southern division	3.37%	59,320	1,760,237	
Subtotal	**11.01%**	**764,434**	**6,946,004**	**38,097**
Avg. gal./customer (000)			182	
Total or average	**18.76%**	**32,427,419**	**172,871,205**	**948,153**
NJ total per 1996 NJSWSP (based on 1,499.1 MGD)			547,171,500	
Share of above in NJ total			31.6%	
		Weighted avg.	Excluded share	
NJ avg. if excluded sources =	*10.0%*	*12.8%*	*68.4%*	
NJ avg. if excluded sources =	*20.0%*	*19.6%*	*68.4%*	
NJ avg. if excluded sources =	*30.0%*	*26.4%*	*68.4%*	
Major utilities not included (no data):				
Trenton Water				61,873
Village of Ridgewood				19,857
Wildwood Water Utility				13,197
Total customers of regulated utilities				1,118,500

* demand inferred from no. of customers and avg. demand per customer for other major utilities; loss pct. obtained by NJBPU staff from utility annual report.

Note: regulated utilities are those for which NJBPU sets rates; major utilities are those with 10,000 or more customers as of 7/1/05. Figures do not include unregulated water purveyors, self-supplied demand (e.g., private wells), etc. Loss percentages may not apply to excluded sources.

Sources: information obtained by NJBPU staff from utility annual reports and rate orders and calculations by NJDEP. N/a = not available.

Exhibit B: Market Value and Elasticity of Demand for New Jersey Agricultural Products			
Type of Agricultural Product	**2002 $000**	**Elasticity**	**Weights**
Nursery, greenhouse, floriculture, sod	$ 356,863	n/a	n/a
Vegetables, melons, potatoes	167,956	-0.070	-11,757
Fruits, tree nuts, and berries	87,148	-0.070	-6,100
Oilseed, dry beans, dry peas	20,352	-0.047	-957
Hay, holiday trees, SRWC*, other	15,643	n/a	n/a
Grains	9,533	-0.040	-381
Total crops (87.68%)	**657,494**	**-0.067**	**-19,195**
Milk / other dairy products from cows	$ 29,154	-0.095	-2,770
Poultry & eggs	26,041	-0.092	-2,396
Other livestock & animal products**	18,870	-0.089	-1,679
Horses/ponies/mules/burros/donkeys	18,314	n/a	n/a
Total animal products (12.32%)	**92,378**	**-0.092**	**-6,845**
Total current production for sale* **	**$ 749,872**	**-0.069**	**-26,040**

* SRWC = short-rotation woody crops. N/a = not available.

** includes cattle & calves; hogs & pigs; sheep, goats, & their products; aquaculture; and other animals and animal products.

*** excludes machine hire & customwork, forest products sold, other farm income, & gross imputed rental value of farm dwellings.

NASS 2002 = US Department of Agriculture, National Agricultural Statistics Service, 2002 Census of Agriculture.

Elasticities from USDA, Economics Research Service. Weights = market value x elasticity.

n/a = not available

Exhibit C: Econometric Estimates of Timber Demand Elasticity

Study	Region	Product	Elasticity*
Adams et al. (2002)	Western OR	Sawlogs	-2.00
Polyakov et al. (2004)	Alabama	Pulpwood	-1.72
Adams et al. (2002)	Western OR	Private timber	-1.58
Merrifield and Haynes (1985)	Pacific NW	Plywood	-0.85
Connaughton et al. (1988)	Montana	Stumpage	-0.65
Newman (1987)	South	Sawtimber	-0.57
Robinson (1974)	South	Softwood	**-0.52**
Abt et al. (2000)	Southeast	Timber products	-0.50
Newman (1987)	South	Pulpwood	-0.43
Carter (1992)	Texas	Pulpwood	-0.41
Adams et al. (2002)	Western OR	Timber for plywood	-0.36
Adams et al. (2002)	Western OR	Timber for lumber	-0.26
Abt (1987)	South	Lumber	-0.25
Median			***-0.25***
Robinson and Fey (1990)	South	Softwood	-0.25
Abt (1987)	West	Lumber	-0.20
Haynes et al (1981)	Pacific NW	Softwood	-0.17
Haynes et al (1981)	Pacific NW	Softwood	-0.14
Haynes et al (1981)	South Central	Softwood	-0.13
Merrifield and Singleton (1986)	Pacific NW	Plywood	-0.10
Abt and Kelly (1991)	FL and GA	Softwood	**-0.10**
Connaughton et al. (1988)	Montana	Stumpage	-0.09
Merrifield and Haynes (1985)	Pacific NW	Lumber	-0.07
Haynes et al (1981)	Southeast	Softwood	-0.05
Daniels and Hyde (1986)	N. Carolina	Hard and Soft	-0.03
Merrifield and Singleton (1986)	Pacific NW	Lumber	-0.01
Merrifield and Haynes (1985)	Pacific NW	Lumber	-0.001

*Short-run own-price elasticity of demand

Sources: compiled by A. Daigneault, USEPA, and W. Mates, NJDEP

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