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Sheri Jewhurst, U.S. Environmental Protection Agency,
Region 2, NY, NY

Marisa Mazzotta, U.S. EPA
Office of Research and Development
Atlantic Ecology Division,

US Environmental Protection Agency
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National Health and Environmental Effects Research Laboratory
Atlantic Ecology Division,
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## Notice and Disclaimer

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Cover photo by Joe Bailey

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# I. INTRODUCTION

WATERSHED MANAGERS are interested in using economics to communicate the value of estuarine resources to the wider community, determine the most cost-effective means to reduce nitrogen pollution, and evaluate the benefits of taking action to improve coastal ecosystems. We spoke to coastal watershed managers who had commissioned economic studies and found that they were largely satisfied with the information and their ability to communicate the importance of coastal ecosystems. However, while managers were able to use these studies as communication tools, methods used in some studies were inconsistent with what some economists consider best practices. In addition, many watershed managers are grappling with how to implement nitrogen management activities in a way that is both cost-effective and achieves environmental goals, while maintaining public support. These and other issues led to this project. Our primary intent is to provide information to watershed managers and others interested in watershed management – such as National Estuary Programs, local governments, or nongovernmental organizations – on economic tools for managing nitrogen in coastal watersheds. Our second intent is to inform economists and other analysts who are interested in assisting them in meeting their needs.

In order to learn more about how economics has been used by watershed managers and the purposes for conducting studies, we interviewed staff at eight coastal watershed management entities. The interviews focused on management questions related to nitrogen in estuaries and the economic analyses that have been done or could be done to assist in nitrogen management.[1] The research was conducted via one-hour structured telephone discussions. In these discussions, we asked managers about their needs with regard to nitrogen management and the use of economic analyses, and found that many estuarine watershed managers are grappling with similar questions.

[1] This project was conducted as part of the US Environmental Protection Agency's (EPA) Regional Research Partnership Program, which provides short-term training opportunities for regional technical staff to travel to Office of Research and Development (ORD) labs/centers and work with ORD scientists on projects that are top regional priorities. Under this project, Sheri Jewhurst, the Region 2 participant, conducted the interviews described here, and compiled information relevant to answering managers' questions regarding their needs for economics.

Participants in this study emphasized that using economic analysis to measure the value of coastal resources and ecosystems is an excellent means to communicate the links between these systems and communities, businesses, and the local economy. Participants also expressed interest in examining the cost-effectiveness of various nitrogen management activities, such as best management practices (BMPs), over a specific geographic area in order to achieve a predetermined goal, such as a total maximum daily load (TMDL). Further, as progress is made in reducing nitrogen and measuring the environmental improvements from pollution control investments, watershed managers are considering larger questions about the societal benefit from these investments.

This document highlights the common themes and questions identified by those participating in this study, and provides basic information on how their nitrogen management questions may be answered using economic analyses. Based on the specific needs, different economic methods may be used: cost-effectiveness analysis, economic contribution analysis, economic impact analysis, or economic benefits analysis. Each of these approaches provides different types of information, useful for different purposes. This document is not intended to provide a complete explanation of all methodologies and variables that could be used when evaluating complex decisions, but to provide an overview of common questions and the appropriate types of analyses to answer each question. For those wanting more detail, we provide references to more detailed sources of information.

In Section II, we provide a brief overview of some common economic terms that are often misunderstood by non-economists. In Section III, we present results of discussions with watershed managers, highlighting common themes. While the interview sample is not sufficient to extrapolate to all estuary management contexts, it included people from 6 of the 9 National Estuary Programs that have conducted economic analyses that we identified at the time of this research, plus two county-level organizations involved in watershed management. There are 28 National Estuary Programs nationwide. We suggest that these themes are best used as a starting point for future research. In Section IV, we discuss the specific types of economic analyses that answer the major management and policy questions watershed managers are asking, and why they are appropriate to address those issues.

Photo by Dotty Motta, NEP

# II. TERMINOLOGY REVIEW

DEMONSTRATING THAT environmental resources have value to many people is one of the major reasons watershed managers have conducted economic analyses. The terms ‘economic impact,’ ‘economic contribution,’ ‘economic value,’ ‘economic benefit,’ and ‘ecosystem services’ are sometimes used interchangeably to describe the benefits quantified by economic analyses, but these terms refer to very different things. Understanding the differences can help managers decide what type of analysis is most useful for their purposes, and can clarify how to best present the results to the public. It is important to recognize that measuring each of these requires specific types of metrics, which are often very different, and that each provides a different result with appropriate uses. In this section, we go over some of the differences between the vernacular use of words like “value” and “benefit”, and what those words mean when conducting economic analyses. For a more detailed list of definitions related to evaluating ecosystem services, see Munns et al. (2015).

## Economic Impacts and Contributions

Commonly, when people think of economics and economic values, what they are thinking of is either *economic impacts* or *economic contributions*. Both of these are measures of economic activity, or how money flows in a local or regional economy, and both economic contributions and economic impacts measure the effects of an industry, event, or policy on the local economy. Both types of measure look at business revenues in a region that can be attributed to a specific sector, such as water-dependent businesses. The difference is that economic contributions are measures of an existing proportion of the local economy, and economic impacts are measures of new revenues brought to the local economy or revenues retained in the local economy that would otherwise be lost (Watson et al., 2007). For example, currently-existing water-based businesses will contribute a certain amount to the local economy – an economic contribution. A policy to improve water quality might either prevent some of these businesses from leaving or attract new businesses to the area – an economic impact.

## Economic Value

The term "value" as used by economists does not mean the same thing as it does in regular conversation. To most people, the word "value" is synonymous with significance. Ecologists and other scientists may consider ecosystems to be valuable because they provide habitat for certain species or serve a role in biological processes. The term "*economic value*" is used by economists to refer to a measure of social welfare. It is an anthropocentric (human-centered) measure of value, defined in terms of tradeoffs that people are willing to make.

An economist would say that unless there are people who would be willing to pay a certain amount (or trade something else of value, such as time or another valued item), for an ecosystem to serve specific functions, those functions of the ecosystem do not have a measurable economic value (Lipton et al., 1995). To further illustrate how economists think about value, consider what it means to call something "a good value" in everyday conversation. This implies that you paid less for something than you thought it was worth. The difference between what you would have paid (your *willingness to pay*) and what you actually paid is how economists measure economic value (Pendleton, 2008).

People usually do not pay for most environmental resources because they are provided freely by nature. Yet, they still make decisions requiring tradeoffs between changes in ecosystems and other valued things. Economists refer to values for things that are important to people, but are not purchased or sold for money, as *non-market values*. There are several categories of non-market values for environmental resources, which capture various aspects of the environmental and economic picture. Depending on the goals of the analysis and available data, an economic analysis can include some or all of the following categories of non-market values.

> **"Direct use values** refer to ecosystem goods and services that are used directly by human beings. They include the value of *consumptive uses* such as harvesting of food products, timber for fuel or construction, and medicinal products and hunting of animals for consumption; and the value of *non-consumptive* uses such as the enjoyment of recreational and cultural activities that do not require harvesting of products. Direct use values are most often enjoyed by people visiting or residing in the ecosystem itself.
>
> **Indirect use values** are derived from ecosystem services that provide benefits outside the ecosystem itself. Examples include natural water filtration which often benefits people far downstream, the storm protection function of mangrove forests which benefits costal properties and infrastructure, and carbon sequestration which benefits the entire global community by abating climate change.
>
> **Option values** are derived from preserving the option to use in the future ecosystem goods and services that may not be used at present, either by oneself (*option value*) or by others/heirs (*bequest value*). Provisioning, regulating, and cultural services may all form part of option value to the extent that they are not used now but may be used in the future.

> **Non-use values** refer to the enjoyment people may experience simply by knowing that a resource exists even if they never expect to use that resource directly themselves. This kind of value is usually known as *existence value* (or, sometimes, *passive use value*) (The World Bank, 2004, pp. 9 – 10)."

All of these categories of value are likely to be important in evaluating the benefits of protecting watershed resources. Many watershed management analyses focus most heavily on use values because consumptive uses, such as harvesting fish or timber, or non-consumptive uses, such as recreation, are the most salient aspects of value resulting from environmental management and are seen as contributing directly to local economies. However, many people have non-use values for coastal resources, and these values can be large. Non-use values are often more difficult to estimate, requiring surveys of the public. Current state-of-the art approaches to measuring non-market values focus on Total Economic Value (TEV), which is a sum of all the types of value listed above – use values, option values, and non-use values. Determining the appropriate way to incorporate all of the important aspects of value for your needs should be discussed with a qualified economist conducting your study, contingent upon the question you are trying to address as well as the availability of quality data and information to estimate values.

## Understanding "Benefits"

Economists generally do not distinguish between the terms "*benefits*" and "*economic value*," but see them as synonymous ways of referring to the welfare an individual or society derives from a particular thing, such as clean water in an estuary (Barbier et al., 2011; Watson et al., 2007). *Willingness to pay* is the preferred measure of benefit because it theoretically assumes that individuals will use the dollars at their disposal to maximize their well-being by spending it on the things that make them happiest (or, in economic terms, maximize their *welfare* or maximize their *utility*). Monetary measures of economic benefits enable decision makers to decide how to manage resources by comparing the benefits received under different management scenarios using a common metric.

For watershed managers, it is important to know that the word "benefit" as used in an economic context is a measure of welfare that depends on an individual's willingness to pay (or trade) for something.

Economic benefits are generally aggregated for a population in order to conduct a benefit-cost analysis of the change resulting from an explicit action, such as a management action that would reduce nitrogen loading. To calculate total benefits from an action, economists would first calculate the economic benefits received by each member of the population who benefits (both consumers and producers) and then aggregate across people to derive total benefits (Pendleton, 2008).

Here's an example that shows how values, willingness to pay, and measuring benefits all fit together. It's taken from Lipton et al. (1995, p. 13):

> "*Economic Value Based on Net Willingness to Pay (WTP)*
>
> *Consider the case in which only one unit of a certain market good, oysters, is produced at a cost of $1 per dozen and sold at a price of $8. If the purchaser had been willing to pay $10, the net benefit of a dozen oysters to this consumer would be $2 ($10 less $8) — this amount is called consumer surplus. At $8 a dozen, the producer earns $7 from the sale (the selling price minus the production price), so the net benefit of the good to the producer is $7 (called producer surplus). The total economic value of a dozen oysters is thus $9 ($2 net benefit to the consumer plus $7 net benefit to the producer). If for some reason the producer was denied the opportunity to produce and sell oysters (say because of a moratorium on fishing) — and the consumer was denied the opportunity to buy and consume oysters — the total loss to these individuals would be $9."*

The nuances of how to calculate benefits in the form of economic values (social welfare) from complex environmental systems are extremely detailed. There are innumerable ecosystem functions that can provide benefits to individuals and society. Which ones to include and how to evaluate them should be determined by a qualified economist when scoping an economic analysis. For watershed managers, it is important to know that the word "benefit" as used in an economic context is a measure of welfare that depends on an individual's willingness to pay (or trade) for something. That "something" is often ecosystem services.

## Ecosystem Services

There are many different types of ecosystem services that can be evaluated in a given policy context. The term "*ecosystem services*" is often used in a way that is analogous with "benefits" (whether correctly or incorrectly) because ecosystem services are often the means by which the ecosystem provides benefits (Barbier et al., 2011). The definition of benefits as synonymous with economic value, and the definition of benefits as synonymous with ecosystem services are commonly used in research literature and in practice. It is important to clarify terminology when developing and reporting a study.

According to the US Environmental Protection Agency (2009, p. 12),

> *"Ecosystem services are the direct or indirect contributions that ecosystems make to the well-being of human populations. Ecosystem processes and functions contribute to the provision of ecosystem services, but they are not synonymous with ecosystem services. Ecosystem processes and functions describe biophysical relationships that exist whether or not humans benefit from them. These relationships generate ecosystem services only if they contribute to human well-being, defined broadly to include both physical well-being and psychological gratification. Thus, ecosystem services cannot be defined independently of human values."*

Barbier et al. (2011) provide a review of estuarine and coastal ecosystem services, ecological factors that are important in their provision, and their values.

## A Note on Intrinsic Values

Many people would agree that ecosystems have value beyond strictly anthropocentric economic values. Such values are often referred to as *intrinsic values*. People who feel strongly about intrinsic values often object to evaluating environmental decisions using monetary values (Justus et al., 2009; Maguire and Justus, 2008; Mazzotta and Kline, 1995; Reyers et al., 2012). Economists recognize that economic values may not be the sole metric for decision-making, but should be considered within a broader social discourse that includes consideration of things like equity, fairness, or precautionary principles (Arrow et al., 1996). Economic values are an explicit way to evaluate, quantify and present *the trade-offs that people are actually willing to make* to protect or clean up the environment. Ultimately, people have to pay for these actions, either individually or through government spending. Understanding what people are willing to pay for, and how much they are willing to pay, can help decision makers and managers be more effective and efficient in carrying out actions, and can inform the larger public debate about environmental regulation and management.

Economic values are an explicit way to evaluate, quantify and present *the trade-offs that people are actually willing to make* to protect or clean up the environment.

Photo by John Repoza

# III. Results of Discussions with Watershed Managers

The following information was extracted from the one-hour structured discussions with watershed managers, conducted in the summer of 2015. Those who were contacted for this research are located in estuaries that have already completed or are currently engaging in some form of economic analysis.

## Overall Context of Study Participants' Watersheds

### *Study Participants*

Of the eight organizations participating in the study, six have a coordination and facilitation role but no direct regulatory authority. Among other things, this role can include providing technical and scientific support, developing plans to address water quality impairments, facilitating consortiums for pollution management, and coordinating overall voluntary watershed management activities. Two participants have regulatory authority within an estuary and are responsible for promoting environmental protection, environmental planning, implementing public health laws, and dealing with issues of water supply and wastewater management.

### *Management Contexts*

These organizations are working within a wide range of policy contexts. In some contexts point sources dominate, while in others nonpoint sources are the main issue. Some estuaries have TMDLs and/or nutrient criteria which provide endpoints for management, while others do not.

In areas where point sources dominate, point source permits are the main regulatory driver for nitrogen reduction activities. Where nitrogen loading is point-source dominated, most watershed managers expressed that permit limits have been an effective means to address nitrogen loading.

Where nitrogen loading is nonpoint-source dominated, managers expressed interest in better understanding the relative contributions of different nonpoint sources. For example, where onsite septic systems, residential fertilizers, and agricultural fertilizers all contribute to nitrogen loading, watershed managers want to understand how much of the load is coming from each of these sources. Since nonpoint source reduction activities are largely voluntary and spread out over the watershed, this information would help to target management activities to address the most dominant sources.

### *Public Concerns*

Most participants indicated that, in their estuary, the public is most concerned about visual impacts and the overall perception that the water is "dirty." Visible impacts include algal blooms, floatables, debris, and seaweed. Other concerns include the loss of cultural and lifestyle assets, such as fishing and shellfishing. Several participants noted that those people who have lived in the watershed for many years seem to have a sense that the coastal environment has declined, and understand that there is a problem or that things "aren't what they used to be." In other areas, there have been fish kills, wildlife mortality events, and algal blooms that have called the public's attention to water quality issues.

## Economic Analyses Conducted by Participants

The following questions explore the intent, purpose, and scoping of economic analyses that have been conducted by participants. Not all of the economic analyses were conducted with specific focus on nitrogen management, therefore the information presented applies broadly to economic analyses in general.

### *What questions were watershed managers trying to answer with economic analyses?*

For many participants who have conducted economic analyses, the impetus for the analyses centered on demonstrating that the estuary provided real, tangible contributions to society, the economy, and the local community. Watershed managers wanted to use this information to inspire people to appreciate the value of the ecosystem and to promote stewardship.

There was also desire to justify the large investments being made in water quality improvement and nitrogen management. Regional management plans such as National Estuary Programs' Comprehensive Conservation and Management Plans (CCMPs) often call for very large investments by many partners. Having information that illustrates that there are economic benefits to healthy estuarine resources and that waterways contribute to the local economy could help justify some of these costs to policymakers and the public.

Economic analysis was also seen to make an abstract principle, such as nitrogen pollution, more relatable to the general public and policymakers by illustrating the connections between water quality and community assets (i.e. home value, recreational opportunities, ecotourism, etc.). Knowing "what the estuary was worth" to the local economy could also identify what sectors of the economy and community are driving that value and benefiting most from environmental improvement. This analysis could also identify what sectors of the economy and community would be most interested in possibly undertaking and financing management actions.

In other cases, watershed managers were interested in updating previous economic analyses now that conditions have changed and economic tools have improved. Note that updating old economic analyses using newer information and methodologies will not necessarily result in an accurate assessment of the increase or decrease in value resulting from water quality improvements. This is because newer calculations of value may be done in different ways and incorporate different variables, so that results may not be comparable. Please see the sections on the "total value" method and benefit-cost analysis for further information.

### *Who was the intended user of existing economic analyses?*

Participants identified policymakers, board members, National Estuary Program Management Conference participants, and the broader public as recipients for this information.

### *By whom was the analysis done, and how was the methodology chosen?*

In several cases, economic studies were conducted opportunistically based on existing data, tools, or expertise already associated with the watershed management entity in question. This had an impact on both the scope and best uses of the analyses done, as well as the selection of economic analysts and approach taken. For example, some entities had existing partners with the capability or data to do an economic analysis at a reasonable cost and took advantage of that opportunity. In other cases, economic analyses were done by piggybacking on work previously completed by similar entities, which lowered costs. It was also noted that using a methodology that had worked in another area of the country enhanced acceptance of the new analysis' results.

While it is advantageous for watershed management entities to be opportunistic and thrifty, considering the large cost of some types of economic analyses, it seems that the scope of some studies was largely dictated by what was being offered and what was currently available, rather than the explicit expressed needs of watershed managers. This is an interesting finding, as it implies that economic analyses are not necessarily being conducted through a process that begins with critical management questions in mind. This often creates a dichotomy between the economic information that watershed managers believe they need (discussed later in the document), and the economic information they are receiving from entities conducting their studies. This is not to discourage watershed managers from taking these opportunities to have economic analyses done, nor does it make the information gleaned from those studies less useful. It does highlight that there could be better coordination when commissioning economic analyses in order to ensure the analyses address the critical management questions at hand.

A lesson learned through these efforts was that local data may be available, but without a central repository for those data, the necessary information on a local scale can be difficult to find.

### *Were there adequate data to perform the analysis, and how were data gaps addressed?*

Many respondents described a need for more local economic data so that economic analyses could be accurately utilized at a local scale. A clear need across the board is localized data that could feed into improved economic analyses, such as site-specific valuations of natural resources and willingness to pay studies. In particularly data-rich analyses, there was a vast and concerted data collection effort that contacted numerous stakeholders to collect data. A lesson learned through these efforts was that local data may be available, but without a central repository for those data, the necessary information on a local scale can be difficult to find.

Available data had a large influence on the scope of the economic analyses done and the type of analyses employed. For example, in an area with rich data on the local economy and water-dependent businesses, an economic impact study was done that examines the connection between the water resources and the local environment. This type of assessment was selected because an economic impact study draws on the type of data that were available in this region; but an economic impact study does not provide the same type of information as an economic valuation for benefit-cost analysis and therefore the results cannot be compared or used interchangeably.

### *How and where were the results of the analyses presented?*

Results have been presented at internal meetings of the watershed management entity or through presentations to community members. Monetary values from the studies have also been highlighted in certain circumstances, such as when new projects or grant funding are announced. Having these values to draw upon has brought interest in the natural environment from the business community, many of whom were not interested in this subject until the economic valuation was done. The studies also have given politicians and legislators numbers to draw upon when making the case for spending on the environment.

### *Did the economic analyses meet their intended uses, and how are they now being used?*

Participants believed that the various economic analyses conducted did answer the questions they were asking, and overall were pleased with the results and their usefulness. As previously noted, one of the needs identified by watershed managers was a way to communicate that our waterways make tangible contributions to our communities and economies. All the studies discussed seemed to be successful for this purpose, but care must be taken to communicate the values only in the context for which the original study was intended. Extrapolating about the overall value to society or attempting to make benefit-cost assumptions based on economic impact or contribution studies would be inappropriate uses of the analyses.

Managers have used the analyses to talk about how environmental improvement can be compatible with, or even lead to, increased economic activity in the community, and to increase people’s level of comfort with the fact that costly environmental improvement projects are also economically important. The valuation numbers were used to introduce new bills, increase awareness of economic value, increase discussion with other funding partners, create interest in doing more specific economic studies, and get the public’s attention by demonstrating that improving water quality is not an abstract exercise. In one case, the cost per pound of nitrogen removed was factored into a ranking methodology for proposed projects. Watershed managers have also used economic information to encourage residents living along tidal creeks to make more environmentally conscious choices.

### *What are some of the barriers to using economic analyses, and what could make them more useful?*

Participants widely noted that it would be beneficial to have more local studies in order to confidently portray information at a finer scale for local decision-makers. Participants also wanted to understand how to enhance the thinking about funding mechanisms when economic analyses identified the sectors of the community that benefit the most from environmental improvement. If the data could show beneficiaries at a local scale, those groups could potentially be targeted for participation.

Other comments included having the information in a short and accessible format that could be digested by the public. Because most people are not well-versed in economics jargon, it is important to have executive summaries and other abridged results in plain language so that the information is actually usable.

### *How did managers address uncertainty in the results of the economic analyses?*

Because most studies were not intended to guide specific decisions, but rather as a communication tool, the level of uncertainty that was acceptable or not acceptable was not noted as a great concern. When the methodology and data used were presented in a transparent fashion, it seems that there was little issue with regard to uncertainty that might have limited the use of the analyses.

### *What prevents watershed managers from obtaining additional economic information they need?*

Not surprisingly, costs and availability of data are major limiting factors in obtaining the economic information that watershed managers need. Data at the local scale are generally not organized in a centralized database that allow local information to be located and used, and a complex and expensive data collection effort would be required to conduct surveys of the population for specific economic information.

Photo by John Repoza

# IV. Watershed Management Questions and Economic Analyses That Can Be Applied

This section focuses on the main questions that managers expressed as important and would like to address using economic analysis, and highlights the types of economic analysis that are most relevant to each of the questions. We group the questions by those relevant to specific types of analysis, and present details of the type of analysis relevant to each type of question. Because it is not appropriate to add up or compare different types of values estimated with different approaches, it is important for those considering an economic study to think carefully about the intended uses and outcomes. In some cases, it may be useful to conduct more than one type of study.

## The Questions:

What is the most cost-effective way to implement management practices in order to meet a TMDL or other predetermined endpoint?

What is the cost per pound of nitrogen removed for a given management practice?

Using decision support tools, how can we convert environmental and cost-effectiveness data into actionable information for decision makers and the public?

These first three questions were expressed as an explicit need most frequently during this research, and each would be addressed, at least in part, through the methods of cost-effectiveness analysis. When a predefined goal—such as a TMDL, environmental endpoint, or permit limit—is already in place, it is possible to use *cost-effectiveness analysis* to evaluate alternative ways to achieve that endpoint at least cost. Cost-effectiveness analysis does not require assessments of economic benefits to society, although considering social costs, and not just financial costs, requires analysis similar to that used to estimate economic benefits.

Cost-effectiveness information is particularly important to watershed managers in nitrogen-impaired watersheds where nonpoint sources are the major source of nitrogen. There are a wide variety of BMPs that could be implemented. Choosing an appropriate matrix that will result in achievement of loading goals and attainment of water quality standards at the least cost is a challenge. This is particularly acute as watershed managers grapple with the extremely high cost of reducing nitrogen from sources like onsite septic systems.

The first question listed above is the standard question of cost-effectiveness analysis, while the second question is actually a subsidiary question that would need to be answered as part of the analysis to answer the first question. In order to understand the most cost-effective approach, it is necessary to understand the costs of different options that might be included in implementing an overall management plan. The third question goes beyond the actual economic analysis to ask how to put the information together into a decision support tool that managers and the public can use to compare different options. This type of tool is sometimes developed by economists, but could require additional specialized expertise to develop and implement, such as Geographic Information Systems (GIS) or optimization capabilities. Since this document is focused on economics, we will not detail those additional capacity needs here.

## The Approach: Cost-effectiveness Analysis

Cost-effectiveness analysis does not compare monetary estimates of values or benefits to society but instead assumes that those benefits have been deemed worthwhile to members of society (through the public process of enacting a TMDL or similar regulatory or policy option). Therefore, cost-effectiveness analysis assesses the least cost way to achieve an already-established goal, with the objective of avoiding waste of public money. Once a regulatory driver such as a TMDL is in place, implementation of that action proceeds based on regulatory requirements rather than the results of explicit benefit-cost analysis. In essence, this approach assumes that the benefits of implementing the regulatory requirement are greater than the costs. In order to actually quantify the benefits to society of TMDL implementation vs. cost of TMDL implementation, a full benefit-cost analysis is required. Please see the section describing benefit-cost analysis for more information.

Cost-effectiveness analysis focuses on selecting either the least costly way to achieve a specified outcome, or the most beneficial way of spending a given budget (Balana et al., 2011; Halkos, 2013). Since the combination of any number of management alternatives is expected to yield the same endpoint, the most cost-effective means of achieving the outcome can be selected. While this may sound relatively simple, it requires understanding the relevant set of options, the cost of each (over the full time-span of the policy, program, or action), and the expected outcome from each feasible mix of options. In the case of nitrogen management, this means that an outcome, such as a TMDL, must be specified; and both the costs and effectiveness of the technologies or BMPs that might contribute to the outcome must be quantified (see Brown Gaddis et al., 2007; Latimer and Charpentier, 2010 for examples of nitrogen loading models).

The cost-effectiveness ratio $CE_i$ (cost effectiveness of implementation action i) is calculated using the cost of implementation, $C_i$, and effectiveness of implementation, $E_i$ (Boardman et al., 2001):

$$CE_i = C_i / E_i$$

or, for a nitrogen management scenario (adapted from Wood, 2015 ):

$CE_i$ = Estimated costs of management action, including operation and maintenance /

Nitrogen mitigation potential of management action.

In a situation where the desired effectiveness level is fixed – such as when attempting to reach a TMDL– the cost-effectiveness analysis is a cost minimization exercise. One consideration here is that this analysis supposes that we do not value additional units of effectiveness (nitrogen reductions) over and above the TMDL, even though in reality having additional nitrogen removed may be desirable. However, the nature of this optimization analysis requires this constraint to be in place (Boardman et al., 2001).

Alternatively, instead of optimizing to minimize costs of reaching a particular goal, it is also possible to maximize the effectiveness of management actions for a given cost. This would be applicable to situations where grant funding has become available, or when a policymaker has budgeted a specified amount for the management activity. The effectiveness to cost ratio can be calculated by flipping the equation to calculate the effectiveness-cost ratio ($EC_i$):

$$EC_i = E_i / C_i$$

and then running the model to maximize effectiveness per unit of cost, as opposed to minimizing cost per unit of effectiveness (Boardman et al., 2001).

Most cost-effectiveness analysis relies on mathematical programming and optimization models to select the optimal mix of technologies. These methods require specific technical skills beyond the data-gathering and formatting skills needed to understand effectiveness and costs of each option. In the case of nitrogen management, we need some very specific pieces of information that go into the cost-effectiveness equation:

1. A reliable goal or endpoint
   In the equations provided above, the goal or endpoint lets us know what constraints to place on the model used in order to minimize costs or maximize effectiveness. While TMDLs and permit limits are intended to provide an allowable nitrogen load that would theoretically meet water quality standards, additional information on the environmental response associated with reductions in nitrogen would enhance confidence that environmental goals would actually be reached. For practical purposes, watershed managers must proceed with implementation without this increased certainty or it would be impossible to move forward, so they must assume that existing TMDLs or other goals are accurate endpoints.

2. Data on the pollution reduction potential (effectiveness) of various management activities
   Each available technology, such as nitrogen removal systems for wastewater or specific agricultural BMPs like conservation tillage, must be evaluated for effectiveness. Depending on the technology or BMP, there is more or less uncertainty surrounding such effectiveness estimates. This uncertainty may be incorporated into the model to provide for a margin of safety on the choice of technologies. While effectiveness analyses have been conducted some

watersheds (for example,The Center for Watershed Protection, 2013), effectiveness data may not be directly transferrable outside the original geographic area due to differing environmental conditions impacting the efficacy of nitrogen removal. For technology-based nitrogen removal such as innovative and advanced onsite wastewater treatment systems, demonstration projects such as the Massachusetts Alternative Septic System Test Center (Barnstable County Department of Health and Environment, 2016) and the recent septic demonstration pilot program as part of the Reclaim Our Water Initiative in Suffolk County, New York (Suffolk County, 2014), can demonstrate nitrogen removal potential. Having a standardized way to transfer the nitrogen reductions demonstrated in one location to another location is highly desirable, as the demonstration sites may take many years of monitoring before an actionable reduction level is agreed upon.

3. An understanding of the costs of implementing various management practices
   The relevant costs to consider include not only the installation cost of nitrogen-removing technologies or BMPs, but also their operation and maintenance costs and average lifespan. Costs in future years must be discounted and annualized (Wood, 2015) to arrive at an estimated annual cost for each technology, which means that an appropriate discount rate must be selected (see U.S. EPA, 2010, for a discussion of discount rates ). This analysis does not necessarily include potential costs that would result from failures due to unforeseen circumstances, such as the impacts of climate change, although these may be an important additional consideration depending on the geographic area (Halkos, 2013).

A very complex but highly desirable approach (according to many watershed managers interviewed for this study) is a nitrogen management tool that would integrate the cost-effectiveness analysis with geospatial information. This would allow watershed managers to consider cost-effective locations for implementation of management actions. Developing such a tool requires a thorough understanding of the hydrologic transport of nutrients in the area and the biochemical processes that may be impacting nitrogen delivery to the estuary. In order to decide which technologies and BMPs should be considered in the cost-effectiveness analysis, watershed managers would also want to know where the nitrogen sources are and how much each source contributes. There are levels of uncertainty with regard to hydrologic and environmental modeling of nutrient transport, and any tools developed should carefully consider the modeling and environmental data feeding in to them. To develop such a tool would require expertise in a number of fields, including hydrology, GIS, and optimization. Further discussion is beyond the scope of this document (see Cools et al., 2011; Gren et al., 2000 for examples).

## The Questions:

**How do we use economic information as a communication tool to illustrate the importance of water quality improvements to a wider audience?**

This is a broad question, asked by many managers. While this is probably the most important overarching question for managers, it does not directly lead to any one type of analysis. It might be formulated in two different ways, based on the actual needs and analyses conducted by the people we interviewed, leading to very different types of analysis. The following questions are two ways to frame this more general question of communicating the importance of estuarine resources. Depending on how the question is framed, there are *several methodologies* that provide different measures and interpretations.

**How do we impress upon the local community the tangible economic values related to water quality, in the form of money circulating through the community?**

This question would be addressed using *economic impact* or *economic contribution analysis*.

**How do we evaluate the social benefits of protecting water quality in the community in a way that can be compared to other social programs or actions?**

This question would be addressed using *economic benefits analysis*.

**How do we link the benefits of water quality improvement to business revenues, jobs, and other measures that resonate with residents, the business community, and broader stakeholder groups?**

This question focuses on money flowing through the local economy, and would be addressed using either economic impact analysis or economic contribution analysis. Many economic analyses that are being used by watershed managers were intended to illustrate that estuarine resources provide real economic impacts on or contributions to the community. There are ways to do this that exclusively focus on businesses and economic transactions related to a particular sector – in our case, estuaries. These are *economic contribution analysis* and *economic impact analysis*. These studies can illustrate that the coastal environment contributes tangible values to a local economy. However, they do not measure social welfare, because dollars flowing in a local economy are dollars that do not go to other local economies, and are thus transferred from one sector or region to another.

## The Approaches: Economic Contribution Analysis and Economic Impact Analysis

### *Economic Contribution Analysis*

Economic Contribution Analysis uses current regional data to determine how much economic activity is associated with a particular industry, event, or policy. An economic “contribution analysis may provide evidence of how relatively large a sector is in the existing economy and how much economic activity is being cycled through the economy by a given industry (Watson et al., 2007, p. 143).” For example, in our case, it might add up all of the economic activity of estuary-dependent businesses, or of businesses that depend on clean water in the estuary. Or, an economic contribution analysis might be conducted to evaluate an event that occurs in the estuary to illustrate the contributions of such estuary-dependent events to the local economy.

> Economic contribution analysis and economic impact analysis enable watershed managers to demonstrate links between a watershed and the local economy without dealing with the complex world of valuation of economic benefits.

An economic contribution analysis can show the relative size of a particular sector compared to the whole economy of the state or region, and therefore demonstrate the importance of that sector. An economic contribution analysis does NOT consider the fact that, if money were not spent in that sector (for example, a waterfront restaurant) it might be spent elsewhere in the town (such as an inland restaurant with no connection to the estuary). Therefore, it doesn’t measure changes to the local economy that might occur if water quality improves. “The direct effect in a contribution analysis includes purchases by local consumers and non-local consumers and is neither a measure of changes to the regional economic base nor a measure of the value added to the region above what was paid to input suppliers (Watson et al., 2007, p.143).”

### *Economic Impact Analysis*

An economic impact analysis estimates the money flowing to a local or regional economy from other geographic areas as a result of environmental amenities such as a clean estuary. These studies focus exclusively on the revenues brought into a region, or revenues that remain in the region that would otherwise be lost absent the environmental resource (Watson et al., 2007). “This, obviously, is a much more complicated and exclusive way to perform a regional economic analysis but one that really attempts to get at the net effects of an industry, event, or policy on a region’s economic base (Watson et al., 2007, p. 143).” See Colgan (2013) for an example of an economic impact study for the America’s Cup World Series in Newport, Rhode Island.

Neither of these types of analysis measure social welfare as a result of the existence of environmental resources. These methodologies enable watershed managers to demonstrate links between a watershed and the local economy without dealing with the complex world of valuation of economic benefits. For example, the Sarasota Bay Estuary Program conducted an economic impact analysis as part of their economic valuation project (Hindsley and Morgan, 2014). For additional understandable and brief information on economic contribution analysis and economic impact analysis, refer to Watson et al. (2007).

## The Questions:

What are the benefits of nitrogen management and the associated environmental improvement, compared to the costs of implementing nitrogen management practices?

If we spend a given number of dollars for a given level of treatment, what is the return on investment and increase in benefits to society?

These questions are two different ways of framing the benefit-cost question. To answer these questions, a full benefit-cost analysis is required. This requires a great deal of expertise, and it is critically important that the individual or team leading any economic analysis is highly trained. We do not go into deep detail about how to conduct these analyses because, within the scope of this document, we can only scratch the surface of what is needed

## The Approaches: Economic Benefits Analysis and Benefit-Cost Analysis

Economic Benefits Analysis, also called economic valuation, can be used to estimate the economic value of environmental resources and ecosystem services to individuals, and individual values may be added up to calculate benefits to society at large. Valuation studies focus on determining what citizens would be willing to pay for the goods and services provided by ecosystems, and are most appropriate for evaluating the social benefits of management actions or policies. Economic benefits analysis can feed into a full benefit-cost analysis, which is used to evaluate whether people's values for the benefits of environmental protection outweigh the costs, including both monetary costs of implementation and other social costs in the form of foregone opportunities.

A benefit-cost analysis defines a baseline condition and an expected condition after a management action is taken or a policy is implemented, and evaluates the value of the difference between the two. Benefit-cost analysis is completed in many steps requiring both economic and environmental information. Here's a brief overview of what it would take to conduct a benefit-cost analysis of nitrogen management (see Barbier et al., 2011, for more detailed descriptions). Remember that in this context the word "benefits" refers to the value that human beings place on or receive from environmental quality and ecosystem services, and benefits are quantified in terms of people's willingness to pay for a change (or to avoid an unwanted change).

> The actual benefit of the management action is the value of the difference between the post-implementation conditions and the pre-implementation conditions.

1. Determine the level of environmental quality and/or ecosystem services provided by the ecosystem under current nitrogen loading conditions (establish a baseline).
2. Determine the expected nitrogen load reduction from a proposed management activity or suite of activities. This requires scientific expertise and modeling of spatial and temporal aspects of how actions lead to environmental changes over time and space within the study area.
3. Determine the environmental change (and its trajectory over time) that would result from the nitrogen load reduction as a result of the management activity.

4. Use appropriate economic valuation techniques to value the change in environmental quality or ecosystem services. The actual benefit of the management action is the value of the difference between the post-implementation conditions and the pre-implementation conditions. This is typically expressed in annual values, related to the annual stream of environmental changes. These values per year are then discounted to estimate a present value of benefits and/or an annualized stream of benefits.
5. Once benefits have been quantified, they can be compared to costs of actions, which include initial implementation costs, operation and maintenance, and also what economists refer to as "opportunity costs" – the social costs that might be incurred beyond expenses on the program itself. For example, agricultural BMPs might take some agricultural land out of cultivation, incurring a cost in the form of lost profits to farmers.

As you can see, a benefit-cost analysis of nitrogen management (or any other environmental policy) is not strictly an economic exercise, but requires significant scientific expertise input from the affected community to identify the relevant environmental quality measures or ecosystem services, their current levels of provision, and the expected trajectory over time. Additional science regarding environmental responses to nitrogen reduction measures is particularly needed. If we do not have an established environmental response relationship, it is difficult to determine the value of those improved conditions because we won't know what they are (Kline et al., 2013).

Full benefit-cost analysis for nutrient management is not common, although many locations have evaluated at least some of the benefits of nutrient reductions. On example of a place where the increased value from nitrogen reduction is being estimated using economic tools is in Cape Cod, by the Cape Cod Commission. So far, they have focused evaluating how reduced nitrogen loads may lead to an increase in property values, which resonates greatly with the local community whose greatest asset is most often their home (Ramachandran, 2015). Morgan and Owens (2001) conducted an analysis of economic benefits from water quality improvements in the Chesapeake Bay from 1972 to 1996, to evaluate the benefits to that point from the Clean Water Act.

These examples illustrate that economic analyses *can* be used to answer complex management questions, such as whether or not implementing TMDLs result in greater benefits to the community than costs, or how much reducing nitrogen will impact home values. They also illustrate that the type of analysis that economists advocate focuses on evaluating the impact of a particular action and the value of the resultant change.

### *Considerations with regard to benefit-cost analysis*

As you might imagine, evaluating the complete suite of economic benefits from a change can be quite difficult, especially for changes in environmental quality or ecosystem services that are difficult to quantify or to relate to people's willingness to pay. Therefore, benefits analyses are often incomplete, providing only a lower bound estimate of benefits. In many cases, non-use values may be larger than use values but, because it is difficult and costly to estimate non-use values (since they can only be quantified using surveys of the public), this large and important component of benefits is likely to be omitted.

Because the environmental changes in the resources that people directly use may be small relative to the baseline, if we were to implement a very costly TMDL, it is possible that the economic analysis will show that benefits do not outweigh the costs, or that benefits and costs are very close in magnitude.

Simply identifying and recognizing benefit streams may be able to meet the need of demonstrating that environmental assets produce tangible positive impacts, without all the complications of monetizing that are included in a full scale benefit-cost analysis.

That is something one might want to bear in mind before embarking on an economic analysis. As individuals who work in the environmental field, it is easy to assume that restoring our environment is always worth the cost. However, when actually doing an economic analysis, values are aggregated across the community and sometimes an economic analysis might show that environmental restoration does not result in net benefits to society at large, at least in terms of those values that can be estimated with a reasonable investment of effort. It also is important to remember that while benefit-cost analysis provides a means of assessing the economic efficiency[2] of actions, economic efficiency is not the only criterion to consider when evaluating public policy. It is simply one piece of information to include in public decision-making, along with other concerns such as equity, precaution, and the distribution of costs and benefits.

Simply identifying and recognizing benefit streams may be able to meet the need of demonstrating that environmental assets produce tangible positive impacts, without all the complications of monetizing that are included in a full scale benefit-cost analysis. Referring to the first step in the summary of benefit-cost analysis above, we see that it includes using both community input and values as well as scientific information to determine which benefits are most relevant and most likely to be impacted by a management action. Engaging with the community to identify benefit streams qualitatively could be a manageable way to demonstrate that an ecosystem provides benefits without actually monetizing them. Those identified benefit streams can be expounded upon in a full benefit-cost analysis when and if resources for such a complicated exercise become available (Schuster and Doerr, 2015; The Nature Conservancy, 2015).

## The "Total Value" Method

*(and why it makes economists crazy)*

Before we close, we have to address a major sticking point that has emerged between what is recommended by economists and some analyses that are occurring in the real world. This issue will continue to come up between economists and non-economists attempting to use economic analyses until there is mutual understanding regarding the what economists consider standard practice and how that relates to the real-world needs of watershed managers.

One of the common methodologies employed by some environmental groups is the "total value" method (not to be confused with the economic term "total economic value" or TEV). Total value studies attempt to quantify the value of an ecosystem by estimating and monetizing the total flow of goods and services from an ecosystem. This is typically done by adding up all the acres of each type of ecosystem,

[2] Also referred to as "Pareto efficiency." As measured using benefit-cost analysis, an economically efficient outcome has positive net social benefits. This means that those who are made better off could compensate those who are made worse off so that, overall, society is better off (Boardman et al. 2001).

and multiplying by a value per acre for the services provided by that type of ecosystem (see, for example, Batker et al., 2014; Costanza et al., 1997; Costanza et al., 2014). According to watershed managers we spoke to who have used this method, it has been successful in demonstrating that seemingly abstract assets in the environment actually contribute economic value to the community. Unfortunately, from a traditional economics standpoint, this method is not generally recommended by economists (Bockstael et al., 2000; Toman, 1998).

One issue that concerns economists about the total value method is that this method simply compares the value of the current state of the ecosystem to a hypothetical case of the complete disappearance of the ecosystem. Just demonstrating that an entire ecosystem is valuable in its current state does not allow us to draw any further conclusions that would enable us to weigh different management options to protect or improve that ecosystem (unless the option we're weighing is to prevent the total loss of a site). We also cannot make the case that the calculated value of the benefits of an ecosystem is equal to the dollar amount we should be spending per year on that ecosystem (Pagiola, 2008). An entire ecosystem and all its benefits and services, in all likelihood, is not going to completely disappear (The World Bank, 2004). It might be in better or worse condition, therefore providing more or less value and benefits, but these "total value" analyses do not capture the values of policy-related changes, as the following examples illustrate.

Economists' value measurement establishes a baseline of time, place, and context relative to people's quality of life, and looks at the implications of a change resulting from a management action and how willing people are to make sacrifices to accomplish this change. The total value approach omits the role of people's choices as a key to understanding value.

*Example #1:*
Knowing that wetlands contribute $1 million in total flood protection benefits to a watershed does not tell us whether converting a recreation beach to wetlands will be more or less beneficial to society than leaving the beach alone. Maybe the nearby recreation beach is the most valuable asset to community character! Or, perhaps the beach provides habitat for an endangered shorebird species, so that protecting the beach may be more critical than creating a wetland that would support other important, but less scarce, species. There is no way to make these types of tradeoff decisions simply by calculating the value of existing services.

*Example #2:*
As a scientist, would you conclude that a community of insects is a healthy community by simply observing that insects are there and counting them up? No! That would only tell you that insects exist, and how many of them there are – nothing about how they were serving (benefiting) the broader ecosystem. In order to determine whether or not that insect community is healthy (what its value is), you would need to know what a representative healthy community consists of (establishing a baseline). Then you would need to compare that baseline community and its functions with what you have at hand. Economists apply this same concept to economic data, in that you can't estimate the value and benefits of the environment without first establishing a realistic baseline to compare it to.

The issue of estimating the value of an ecosystem relative to the generally unrealistic baseline of total loss of that ecosystem is only one issue with this approach (Bockstael et al., 2000; Masood and Garwin, 1998; Toman, 1998). Other issues include: the application of values calculated for marginal changes (changes that measure the value of adding one additional unit of the resource) to large changes associated with the presumed loss of an entire ecosystem; applying per-acre values from one location to another without accounting for differences variables across locations and the people who benefit; and the fact that only a subset of all relevant values can be included due to lack of existing data and the difficulty of identifying and then valuing all of the relevant benefits an ecosystem provides. Even if we assume that the resultant total value is a reasonable estimate, despite the missing and inaccurate values, what is being compared is a situation which does not exist in reality.

Photo by Dotty Motta, NEP

# V. SUMMARY AND RECOMMENDATIONS

WATERSHED MANAGERS would benefit from better access to trained economists who understand their needs and can advise them in plain language about how to conduct valuation analyses. This document can serve as a starting point for illustrating those needs to economists who may be interested in pursuing relevant research and analysis. It also gives an overview of the types of economic analyses that are appropriate to answering different questions that watershed managers might ask, providing managers with a basis for evaluating economic proposals.

Watershed management requires balancing scientific, political, and social issues to solve environmental problems. Watershed managers expressed a need for proactive support to achieve economic data goals. Environmental economics is a broad and complicated field of study that requires a great deal of expertise to execute properly. Consultation with several trained economists who understand the watershed management needs prior to commissioning economic analysis will ensure adequate review of methods and promote more accurate results. The simple solution is better communication before, during, and after economic analyses are conducted, and a mutual understanding that both fields have to make a concerted effort to communicate what is needed and to select appropriate and feasible approaches to meet those needs.

Due to restrictions on data collection by government agencies, it is often difficult to obtain the local, primary data that is required for many of these analyses. Agencies might explore ways to facilitate better data collection on environmental economics topics so that both government and non-government users can easily locate quality data, and therefore produce better studies. Adequate funds also need to be available to conduct analyses using accepted methods, despite their great expense, so that watershed managers can get the information they require.

Photo by John Repoza

## For more information

Along with the sources referenced in the text, the following references provide additional detail on the topics we've introduced in this document.


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