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Advisory on Plans for Ecological Effects Analysis in the Analytical Plan for EPA's Second Prospective Analysis – Benefits and Costs of the Clean Air Act, 1990-2020

Advisory by the Ecological Effects Subcommittee of the Advisory Council on Clean Air Compliance Analysis

U.S. Environmental Protection Agency
Advisory Council on Clean Air Compliance Analysis
Ecological Effects Subcommittee

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1. EXECUTIVE SUMMARY

In this Advisory, the Ecological Effects Subcommittee (EES) of the Advisory Council on Clean Air Compliance Analysis (Council) provides detailed advice related to a wide range of ecological effects to be addressed in the Environmental Protection Agency's (EPA) forthcoming *Second Prospective Analysis*, the third of a series of reports from the Office of Air and Radiation on the costs and benefits of regulations issued under the Clean Air Act (CCA). The overall purpose of the Advisory is to assist the Agency in fully characterizing the science associated with health effects related to the CCA. The Council formed this Subcommittee to focus specifically on ecological effects and the questions issued from the Office of Air and Radiation pertaining to these effects.

In 2003, the EPA issued a document that describes EPA's plan for conducting the Second Prospective Study. This document, *Benefits and Costs of the Clean Air Act 1990-2020: Revised Analytical Plan for EPA's Second Prospective Analysis (Analytical Plan)*, specified three charge questions related to ecological effects (charge questions 18-20):

Charge Question 18. Does the Council support the plans in Chapter 7 for: (a) qualitative characterization of the ecological effects of Clean Air Act-related air pollutants, (b) an expanded literature review, and (c) a quantitative, ecosystem level case study of ecological service benefits? If there are particular elements of these plans which the Council does not support, are there alternative data or methods the Council recommends?

Charge Question 19. Initial plans described in Chapter 7 reflect the preliminary EPA decision to base the ecological benefits case study on Waquoit Bay in Massachusetts. Does the Council support these plans? If the Council does not support these plans, are there alternative case study designs the Council recommends?

Charge Question 20. Does the Council support the plan for a feasibility analysis for a hedonic property study for valuing the effects of nitrogen deposition/eutrophication effects in the Chesapeake Bay region, with the idea that these results might complement the Waquoit Bay analysis?

The EES strongly supports the EPA's plans for: (a) qualitative characterization of the ecological effects of CAA-related air pollutants, (b) an expanded literature review, and (c) a quantitative, ecosystem-level case study of ecological service benefits. These activities would help serve notice of the importance of ecosystem service benefits and could provide a foundation for future advances to quantify the complete benefits associated with air pollution control programs.

The EES generally supports the EPA's plans to conduct a quantitative ecological benefits case study. The EES recommends that the EPA consider conducting two case studies, one involving a coastal ecosystem, and a second involving an upland region. In this Advisory, the

EES summarizes several regions where case studies quantifying ecosystem service benefits associated with air pollution control might be conducted, including a suite of coastal and upland forest regions. The EES encourages the EPA to consider sites in different regions and with different resources at risk to help focus attention on the importance of ecosystem valuation. The EES suggests consideration of: 1) clear quantifiable ecological effects due to air pollution; 2) the degree to which a significant component of ecological effects are attributable to air pollution; 3) the responsiveness of ecosystem services to changes in air pollution; 4) the cumulative impacts of multiple air pollutants; 5) the abundance of ecological effects and economic benefit cost analysis; and 6) the visibility to the public and value of resources at risk in the selection of a site (or sites) for an ecological benefits case study.

The EES has some reservations with focusing the proposed ecological benefits case study initiative exclusively on Waquoit Bay, MA. The EES understands the advantages of studying the Waquoit Bay ecosystem, given the quality and depth of the information available on the long-term inputs of nitrogen and the resulting effects. However, there are several disadvantages associated with Waquoit Bay as a potential case study. First, the watershed is small and may not be representative of coastal ecosystems, and their associated functions and services in the U.S. Second, although atmospheric deposition is an important input of nitrogen to the Waquoit Bay watershed, it is not the largest or the source of nitrogen that is most rapidly changing the coastal zone. Hence, the EES has concerns that it would be difficult to quantify the specific contribution of regulated atmospheric nitrate deposition to changes in the Waquoit Bay ecosystem. Further, the EES believes that by conducting a case study solely on Waquoit Bay, an opportunity is lost to consider the service benefits associated with control of two or more air pollutants simultaneously, such as are currently being considered with proposed multi-pollutant legislation (i.e., sulfur dioxide, nitrogen oxides, mercury).

The EES also has some reservations concerning the proposed feasibility analysis for a hedonic property study focusing on Chesapeake Bay. The purpose of the Chesapeake Bay Property Value Feasibility Study is to investigate the possibility of using a hedonic analysis of coastal area property values to estimate the benefits of reductions in atmospheric nitrogen deposition associated with CAA regulations. The EES believes that the premise of the proposed Feasibility Study — that changes in coastal area water quality can be ascribed to fluctuations in atmospheric nitrogen deposition — is tenuous. As with most other coastal ecosystems, atmospheric nitrogen deposition derived from sources regulated under the CAA represents just a fraction of the total nitrogen loading to Chesapeake Bay. There is an absence in the environmental literature of hedonic studies dealing with water quality, largely due to the fact that homeowners do not understand or relate to many of the water quality indices used to track water quality or that they do not experience any impairment of the enjoyment derived from their waterfront homes.

To address this problem, the Feasibility Study proposal indicates that continuous near-shore chlorophyll *a* measurements, coupled with annual measurements of near-shore submerged aquatic vegetation and periodic observations of macroalgal blooms, can be used as a surrogate for nitrogen deposition. Although this approach may hold some merit, the EES is concerned that it relies too heavily on assumptions that cannot be fully substantiated. The EES recommends that the EPA not proceed with the Feasibility Study as it is currently proposed. Rather, it is recommended that alternative case studies, such as those summarized in this document, be explored that could be better correlated with atmospheric nitrogen deposition.

2. INTRODUCTION

2.1 Background on this Advisory

The purpose of this Advisory is to provide commentary and guidance on the EPA plans for developing the ecological effects analysis described in the 2003 review document, *Benefits and Costs of the Clean Air Act 1990-2020: Revised Analytical Plan for EPA's Second Prospective Analysis (Analytical Plan).* Chapter 7 of this Plan, "Characterizing the Ecological Effects of Air Pollution," is the basis for the three charge questions discussed in this Advisory.

The Ecological Effects Subcommittee (EES) of the Advisory Council on Clean Air Compliance Analysis (Council) met in a face-to-face public meeting on November 5, 2004 and held teleconferences on December 9, 2004 and December 20, 2004 to discuss the charge questions provided by the Agency related to the ecological effects analysis for the Analytical Plan. In addition to the EES members listed on Page ii of this Advisory, the Chair of the Council, Dr. Trudy Cameron, and one additional member of the Council, Ms. Lauraine Chestnut, participated in these meetings and contributed substantively to this Advisory. The EES's deliberations were also greatly aided by discussions and presentations from Mr. Jim Democker of the Office of Air and Radiation.

This Advisory serves as a sequel and supplement to the Council's Advisory issued in May 2004, *Review of the Revised Analytical Plan for EPA's Second Prospective Analysis – Benefits and Costs of the Clean Air Act 1990-2020*, which addresses the full spectrum of charge questions from the 2003 *Analytical Plan*. However, the Council declined to fully answer charge questions 18-20 until the Ecological Effects Subcommittee could be formed and respond to these three charge questions with its unique expertise. This Advisory constitutes the completion of the Council's advice on the 2003 *Analytical Plan*.

3. RESPONSES TO CHARGE QUESTIONS

3.1 Agency Charge Question 18:

Charge Question 18. Does the Council support the plans in Chapter 7 for: (a) qualitative characterization of the ecological effects of Clean Air Act-related air pollutants, (b) an expanded literature review, and (c) a quantitative, ecosystem level case study of ecological service benefits? If there are particular elements of these plans which the Council does not support, are there alternative data or methods the Council recommends?

The EES strongly supports the Council's plans for: (a) qualitative characterization of the ecological effects of Clean Air Act-related air pollutants, (b) an expanded literature review, and (c) a quantitative, ecosystem-level case study of ecological service benefits. There is increasing recognition of the value of ecosystem functions and services. The importance of some of these functions and services has been long acknowledged, such as the supply of abundant, clean water, forest biomass production, fisheries habitat and support of recreation. Other processes and phenomena, such as the regulation of trace gases or biological or landscape diversity, are more subtle and their link to human welfare is only starting to be understood.

Research over the past few decades has established that air pollutants can affect the structure and function of ecosystems, which in turn can alter ecosystem services. Many important air pollutants are regulated under the Clean Air Act, such as nitrogen oxides, sulfur dioxide and certain hazardous air pollutants (HAPS; e.g., benzene; mercury). Other air pollutants such as ammonia and carbon dioxide have clear effects on ecosystem functions and services but are not addressed in the Clean Air Act. There are many examples of significant effects of air pollution on ecosystems. Elevated emissions and atmospheric deposition of nitrogen contribute to the over-enrichment of coastal waters. This disturbance can reduce submerged aquatic vegetation and dissolved oxygen, diminishing recreational and commercial fisheries. Atmospheric deposition of sulfur and nitrogen can acidify base-poor soils and waters in high elevation forested regions. These inputs can decrease species diversity and the abundance of sensitive species in both terrestrial and aquatic ecosystems, altering recreational opportunities and possibly impacting forest productivity. Atmospheric deposition of mercury can contaminate consumable fisheries and, in part, has led to the plethora of consumption advisories on the nation's waterways.

It is difficult to quantify ecological service benefits. The EES agrees that an expanded literature review and case studies of ecological service benefits would be important undertakings. These activities, and publication of the findings, would help serve notice of the importance of ecosystem service benefits and could provide a foundation for future advances to quantify the complete benefits associated with air pollution control programs.

3.2 Agency Charge Question 19:

Charge Question 19. Initial plans described in Chapter 7 reflect preliminary EPA decision to base the ecological benefits case study on Waquoit Bay in Massachusetts. Does the Council support these plans? If the Council does not support these plans, are there alternative case study designs the Council recommends?

The EES generally supports the EPA's plans to conduct a quantitative ecological benefits case study. However, the EES has some reservations about focusing this initiative on Waquoit Bay, MA. Waquoit Bay's watershed and estuary are small and relatively homogenous, and there is a substantial knowledge base on the long-term inputs of nitrogen, its fate, and effects on the ecosystem (Section 4.1). In this regard, the EES acknowledges the benefits of conducting a quantitative case study here. However, there are some disadvantages with relying solely on this watershed as an ecological case study. Waquoit Bay is small and relatively homogenous. Thus, it is probably not representative of coastal ecosystems and their associated functions and services in the U.S. Because it is located in unconsolidated sediments of a glacial outwash plain typical of the Cape Cod region, Waquoit Bay is largely supplied by groundwater. Given the long hydraulic residence times associated with these deep groundwater flowpaths, it is anticipated that the nitrogen loading to Waquoit Bay would change slowly in response to future changes in atmospheric nitrogen deposition loadings to the region. Although atmospheric deposition is the largest input of nitrogen to the upland components of the watershed, fertilizer inputs are also important and human waste is the largest overall source of nitrogen to the Waquoit Bay estuary. In recent decades the contributions of nitrogen loading from wastewater have increased substantially, while atmospheric nitrogen deposition has remained relatively constant (Section 4.1). Thus, recent changes in the Waquoit Bay ecosystem are probably largely driven to a greater extent by changes in inputs from human wastes than by changes in air pollution. The EES is concerned that it would be very difficult to quantify the specific contribution of regulated atmospheric nitrogen deposition (e.g., nitrate originating from regulated emission sources) to the benefits of the Waquoit Bay ecosystem.

Conceivably, the EPA could consider a case study in which the ecosystem would receive large and/or changing inputs of a contaminant of interest from a source that might be used as a surrogate for an air pollutant. For example, the proposed case study on Waquoit Bay might consider nitrogen inputs to an estuary from a wastewater treatment facility, as a surrogate for inputs from air pollution. The EES urges caution in any chosen case study when using surrogate sources to quantify ecological effects of air pollutants. "New" nitrogen (or mercury)[1] derived from air pollutants is generally more bioavailable than "old" nitrogen (or mercury). Moreover, ecosystems and associated organisms respond differently to different species and sources of nitrogen (and mercury). The response of an ecosystem to changes in nitrate (say due to controls on nitrogen oxide emissions) is likely to be different from the response to an equivalent change in inputs of nitrogen from wastewater effluent or agricultural runoff (i.e., a mixture of ammonium, organic nitrogen and nitrate). For example, recent research on algal blooms on both the east and west coasts of the U.S. shows that the growth of toxic and harmful algae is stimulated specifically by urea, a nitrogen compound dominant in nitrogen inputs from

[1] "New" nitrogen (or mercury) is nitrogen (or mercury) that is derived from atmospheric deposition (and partially from anthropogenic sources) as opposed to nitrogen (or mercury) that already resides in ecosystems.

agricultural and urban runoff, over inorganic nitrogen sources such as ammonium and nitrate that are dominant in nitrogen inputs from atmospheric deposition. The EES emphasizes that the ecological effects associated with nitrogen loadings are not the same regardless of precursor source. In order to meet the EPA's goals of assessing the ecological effects of reductions in atmospheric pollutants associated with implementation of the Clean Air Act, it is important to choose case studies where atmospheric deposition itself can be distinguished from other sources contributing to the ecological effects of interest. Thus the selection of an appropriate case study should be based not only on the type of ecosystem and its geographical location, but the sources and types of air pollutants that impact it.

Further, the EES believes by conducting a case study solely on Waquoit Bay, or any other coastal ecosystem, an opportunity is lost to consider the benefits associated with control of two or more air pollutants simultaneously, such as are being currently considered with proposed multi-pollutant legislation (i.e., sulfur, nitrogen, mercury). The EPA could consider the benefits of nitrogen and mercury controls to a coastal ecosystem, such as Waquoit Bay, but the processes regulating mercury concentrations in estuarine fish are not well established.

The EES recommends that the EPA consider conducting two ecological benefits case studies, one involving a coastal ecosystem and a second involving an upland region. In this regard we have summarized below several possible regions where case studies quantifying benefits of ecosystem services associated with air pollution control might be conducted (Table 1). The EES encourages the EPA to consider sites in different regions with different resources at risk to help bring attention to the importance of ecosystem valuation. Several of these potential case study sites provide the opportunity to examine the effects of control of multiple pollutants individually or in combination. In some instances information is available to determine both the "before" and "after" impacts of atmospheric deposition, thus enhancing the scope of the particular case study.

As the EPA moves forward to select a site (or sites) for an ecological benefits case study, the EES urges consideration of the following:

- Sites with clearly quantifiable ecological effects due to air pollution;
- Sites where a significant share of the documented ecological effects is attributable to air pollution (as opposed to another input or disturbance);
- Sites that are expected to be responsive to changes in air pollution;
- Sites that are impacted by multiple air pollutants;
- Sites where considerable ecological effects and research on economic valuation has been conducted; and
- Sites that are visible to the public and have highly valued resources.

Table 1. Summary of potential sites for an ecosystem-level case study of ecological service benefits associated with reductions in air pollutants.

Ecosystem / Region	Main CAA Pollutant(s)	Percentage(s) Attributable to Atmospheric Deposition	Quantitative Ecological and Economic Information	EES Comments
Coastal				
Waquoit Bay	Nitrogen	30	Yes	Medium priority. Higher loading from non depositional sources may confound analysis.
Chesapeake Bay	Nitrogen	20 - 30	Yes	Medium priority. Loading from diverse sources, particularly agricultural, may confound analysis.
Long Island Sound	Nitrogen; Mercury	Nitrogen = 20 – 35; Mercury = ?	Yes	Medium priority. High nitrogen loading from wastewater treatment plants may confound analysis.
Everglades	Mercury	85	Ecological = yes; Economic = uncertain	Medium priority. Reductions in atmospheric deposition has already resulted in decreased mercury burdens in fish and other biota.
Lake Michigan	Mercury	86	Ecological = yes; Economic = lacking	Medium priority. Lack of quantitative economic data may restrict analysis.
Barnegat Bay	Nitrogen	30 - 50	Yes	High priority. Direct linkage of ecological effects with atmospheric deposition, quantitative economic data exist.
Tampa Bay	Nitrogen; Mercury	Nitrogen = 25	Yes	Medium priority. Examined in previous EPA efforts. Variability in loading data may confound analysis.
Gulf of Maine	Nitrogen	Low	?	Low priority. Linkage of nitrogen loadings and ecological impacts is not well established. Major source of nitrogen is open ocean influx.
Casco Bay	Nitrogen; Mercury	Nitrogen = 20 – 40; Mercury = 84 – 92	Yes	Medium priority. Good data on ecological and economic impacts are available.
Forested				
Adirondacks	Nitrogen; Sulfur; Mercury	Nearly 100	Yes	High priority. Good quantitative ecological and economic data exist. Previous studies can be augmented readily.
Catskills	Nitrogen; Sulfur	Nearly 100	Yes	Medium priority. Economic data may be lacking. Issues similar to the Adirondacks.
Southern Appalachian Mountains	Nitrogen; Sulfur	Nearly 100	Yes	Medium priority. Economic data on fisheries are available. Issues similar to the Adirondacks.
Rocky Mountains	Nitrogen	Nearly 100	Yes	Medium priority. Levels of nitrogen loading much lower than for Northeastern locations. Economic data may be lacking.

4. COASTAL ECOSYSTEMS

4.1 Waquoit Bay

Waquoit Bay is a very small watershed located on Southern Cape Cod, Massachusetts, draining an area of 52 km^2 (CCW 2004) to the Waquoit Bay estuary which encompasses an area of about 3 km^2 with a shallow average depth of about 1 m (WBNEER 2004). The region is underlain by unconsolidated sandy deposits with very high infiltration rates. Thus groundwater transports the bulk of the flow and solutes entering the estuary. In addition to the dominant contributions to the Bay from groundwater flows, fresh water enters the Bay from the Quashnet/Moonakis River, Red Brook, and the Childs River.

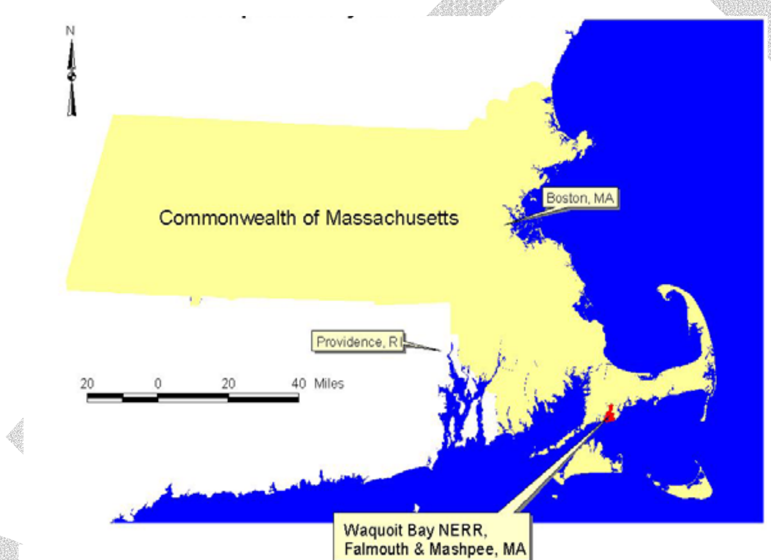

Figure 1. The Waquoit Bay watershed in southern Cape Cod, Massachusetts (WBNEER 2004).

Degradation of the estuary has been well publicized. The Waquoit Bay region was once a highly productive shellfishing area, but eutrophication has resulted in increased algae, loss of eel grass beds, depleted oxygen, and a significant decline in shellfish productivity, and increased incidences of fish kills. These ecological effects have been attributed to pollution by nitrogen, the limiting nutrient in the estuary.

Nitrogen concentrations in groundwater below areas of Cape Cod are directly linked to development and have increased as building density has increased (Valiela et al. 1992). Human waste, largely transported via groundwater flow paths, is the largest source of nitrogen to the estuary (Sham et al. 1995; Valiela and Bowen 2002). Though atmospheric deposition is the largest source of nitrogen inputs to the watershed, waste, deposition, and fertilizer are all important sources to the estuary in that order (Figure 2, Valiela and Bowen 2002). This reflects that storage and loss of nitrogen inputs occur within the watershed and highlights the importance of groundwater residence times in controlling water quality in the estuary.

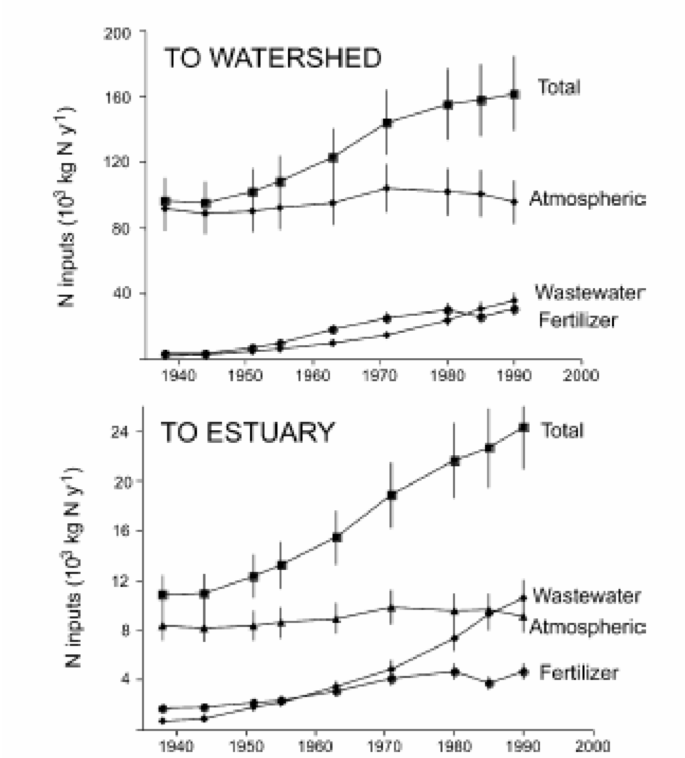

Figure 2. Nitrogen loads over time to the Waquoit Bay watershed (top) and Estuary (bottom) from the major sources: wastewater, deposition, and fertilizer. Figure taken from Valiela and Bowen 2002.

There is considerable potential in using Waquoit Bay as an ecological benefits case study. It is small and one of the best studied watershed-estuary ecosystems in the nation. The region has been the focus of extensive work by researchers, stakeholders, and community watershed groups, providing a wealth of data to be synthesized on its water quality, watershed processes, and land use change. Much of the research conducted has been directed at the impacts of nutrient loading. The Waquoit Bay is a National Estuarine Research Reserve (WBNERR) facility. Many publications and data links about the issues and effects from a host of sources can be found on their web site (http://www.waquoitbayreserve.org/resproj.htm). Further, significant information about the nitrogen issues and effects are related to Ivan Valiela's research group in the Boston University Marine Program (http://www.bu.edu/biology/Faculty_Staff/valiela.html), resulting in nutrient loading models for the estuary.

However, the EES emphasizes that there are several disadvantages in focusing on Waquoit Bay as a case study given the EPA's goals of assessing the ecological effects of reductions in atmospheric nitrogen deposition associated with the Clean Air Act. Due to its very small size and the sandy sediments of the glacial outwash plain, Waquoit Bay may not be representative of nitrogen-impacted estuaries of the eastern U.S. Nitrogen inputs to the estuary are largely due to wastewater effluent, although atmospheric deposition and fertilizer inputs are significant.

Over the past six decades atmospheric deposition inputs to the watershed have remained relatively constant while contributions of nitrogen loading from wastewater and fertilizers have increased (Figure 2, Valiela and Bowen 2002). Therefore, recent changes in the Waquoit Bay ecosystem are likely driven by changes in inputs due to human wastes and fertilizers, rather than by air pollution. The EES is concerned that it would be very difficult to quantify the specific contribution of regulated atmospheric nitrogen deposition (e.g., nitrate originating from regulated emission sources) to the ecosystem response of Waquoit Bay. Due to the relative long hydraulic residence time associated with these deep groundwater flowpaths, it is anticipated that the nitrogen loading to Waquoit Bay would change slowly in response to future changes in atmospheric nitrogen deposition loadings to the region.

Table 2. Qualitative evaluation rating for Waquoit Bay, MA.

1.	Well-documented impacts to a particular ecosystem function or service: *Yes.*
a.	impacts (specify): *Typical coastal nitrogen over-enrichment problems: eutrophication, hypoxia, shellfish declines.*
b.	level of degradation (specify severe, moderate, mild): *Moderate.*
c.	importance of atmospheric deposition source (specify % and other sources): *Atmospheric deposition is about 30% of the total nitrogen inputs to the estuary; see Figure 2. Wastewater is the dominant source of nitrogen to the estuary, and fertilizer inputs are also important.*
2.	Quantifiable physical endpoints that can be linked to atmospheric deposition of Clean Air Act pollutants
a.	ecological (specify): *Estuarine water quality. Pollution level, species health, and population statistics. From the analytical blueprint: "studied ecological endpoints that may be amenable to economic valuation include changes in percent eelgrass cover, shellfish abundance, and finfish assemblages. Further, annual landings data and recreational harvest statistics are available for certain species (e.g., winter flounder, tautog, Atlantic menhaden, scup, summer flounder, bay scallops, softshell clams, hardshell clams, and blue crabs)."*
b	economic (specify): *Not known by the committee.*
3.	Available monetary values for at least some endpoints (if available): *This is a potential case study put forth by EPA.*
4.	Take advantage of existing initiatives to maximize use of available resources, avoid redundant research, and demonstrate multiple applications of ongoing project: *Research and data are extensive and available as is a nutrient loading model for the region.*

4.2 Chesapeake Bay

The Chesapeake Bay is the largest estuary in the United States. It is about 320 km long, has a width that varies from 5 to 55 km and has an average depth of about 34 m. The Bay receives about 50% of its water volume from the Atlantic Ocean and the rest is supplied from the 166,000 km^2 watershed, which includes portions of the states of Delaware, Maryland, New York, Pennsylvania, Virginia, and West Virginia and all of the District of Columbia. There are about 150 rivers and streams in this watershed. The Susquehanna River provides about 50% of the fresh water that enters the Chesapeake Bay from the watershed. The Bay and its watershed is an incredibly complex ecosystem that supports about 3,600 species of plants, fish and animals, including 348 species of finfish, 173 species of shellfish, about 2,700 plant species and 29 species of waterfowl. The Chesapeake Bay is a valuable commercial and recreational resource for the 15 million people who live in the watershed. For example, the Bay produces about 500 million pounds of seafood each year. The Chesapeake was also the first estuary in the nation to be targeted for restoration as an integrated ecosystem.

Currently, the health of the Chesapeake Bay estuary is severely degraded (Bricker et al. 1999). For example, in the summer of 2004 approximately 35% of the water in the main stem of the Chesapeake Bay had unhealthy oxygen concentrations (< 5 mg/L). As in many previous years, the primary cause of this degradation was the large watershed inputs of nitrogen. This nitrogen fueled massive algal blooms that were decomposed by oxygen consuming bacteria, which lowered the oxygen concentrations in the water column to unhealthy concentrations. In 2004, annual nitrogen inputs were 2.5 times greater than the level needed to meet the Chesapeake 2000 Agreement (80 million Kg).

Over the past 10 years, considerable research has been devoted to determining the sources of nitrogen to the Chesapeake Bay estuary. Several studies suggest that agricultural activities are the most important source of nitrogen to the Chesapeake Bay, followed by point sources and atmospheric deposition. Most of the recent studies suggest that atmospheric deposition accounts for between 20 and 30% of the total nitrogen input. Whitall et al. (2004) suggested that realistic changes in nitrogen emissions from utility and mobile sources are not likely to produce significant reductions in the contribution made by atmospheric nitrogen to the total nitrogen inputs to the Chesapeake Bay. However, the authors also noted that changes in animal emissions could reduce the agricultural nitrogen input by approximately 50%. The EES believes there are several advantages to the Chesapeake Bay estuary as a potential ecological benefits case study. This ecosystem is highly visible to the public, perhaps the most well studied estuary in the U.S., with several long-term data sets on water quality, living resources and others. However, atmospheric nitrogen deposition is not a dominant source of nitrogen to this estuary.

Table 3. Qualitative evaluation rating for Chesapeake Bay Estuary.

1.	Well-documented impacts to a particular ecosystem function or service: *Yes.*
a.	Impacts (specify): *Eutrophication; loss of aquatic vegetation, low dissolved oxygen concentrations in main stem and possibly other locations; decrease in fish and shellfish harvest. The fishery is contaminated with mercury and other toxic chemicals.*

b.	level of degradation (specify severe, moderate, mild): *Severe.*
c.	importance of atmospheric deposition source (specify % and other sources): *About 30% of the total nitrogen inputs are from atmospheric deposition.*
2.	Quantifiable physical endpoints that can be linked to atmospheric deposition of Clean Air Act pollutants
a.	Ecological (specify): *Fisheries and shellfish declines.*
b	economic (specify): *Not known by the committee.*
3.	Available monetary values for at least some endpoints (if available): *Not known by Committee.*
4.	Take advantage of existing initiatives to maximize use of available resources, avoid redundant research, and demonstrate multiple applications of ongoing project: *Yes, there has been considerable work from federal, state, and local governments and researchers at many universities and research institutions.*

4.3 Long Island Sound

Long Island Sound (LIS) is located on the Atlantic shoreline of the states of New York and Connecticut. There are approximately 7.3 million people living in the watershed. Long Island Sound has a watershed area of 40,770 km^2 and a surface area of 3,400 km^2. The Sound has 960 km of coastline and is about 34 km across at its widest point. The estuary provides feeding, breeding, nesting and nursery areas for a diversity of plant and animal life. More than 120 species of finfish can be found in LIS, with at least 50 species that spawn in the estuary. This coastal area contributes an estimated $5.5 billion per year to the regional economy from boating, commercial and sport fishing, swimming, and sight-seeing.

There has been considerable analysis of the impacts of nitrogen and mercury to LIS. Several mass balance studies for nitrogen have been conducted. Castro et al. (2003) estimated the contribution of nitrogen from atmospheric deposition to be 23%, while Alexander et al. (2000) suggested that atmospheric inputs were 35% of total nitrogen loading. The Connecticut Department of Environmental Protection has collected long-term data on the oxygen status of LIS, and has regularly observed a large area of hypoxic water for one to two months during the summer. Due to water quality violations, the states of Connecticut and New York have conducted a total maximum daily load (TMDL) analysis for LIS. This analysis will guide future management decisions and reductions in nitrogen load, particularly from wastewater treatment facilities. Currently atmospheric nitrogen deposition is a small but significant component of the total nitrogen load to the ecosystem; the dominant source being nitrogen from wastewater treatment plants. However, with additional controls on nitrogen loading from wastewater treatment plants, it is anticipated that the contribution of atmospheric nitrogen deposition will increase in the future.

Researchers from the University of Connecticut have conducted extensive analysis of mercury inputs and transformations for LIS. Mass balance studies indicate that atmospheric deposition is a major source of mercury input to the ecosystem.

There have been several economic analyses of LIS that could help advance an ecological benefits case study (Apogee Research Inc. 1992; Altobello 1992; Yale Center for Environmental Law and Policy 1995; Carstensen et al. 2001; Kildow et al. 2004).

The EES believes that there are several advantages and disadvantages of LIS as a potential ecological benefits case study. Long Island Sound is highly visible to the public and an important resource for tourism, recreation and commercial fisheries. There is a major focus on reductions of nitrogen loading to this ecosystem, which could undoubtedly support an ecological benefits case study. In addition, there is considerable information on mercury inputs and contamination for the ecosystem. Extensive databases for these two contaminants would allow the EPA to examine the ecological benefits associated with control of multiple air pollutants. There have been several economic analyses of the LIS ecosystem. The major disadvantages of LIS as a case study are that it is a large and complex ecosystem and that atmospheric deposition is not the major source of nitrogen inputs. Note however that the contribution of atmospheric nitrogen deposition to the total nitrogen loading for the ecosystem will likely increase in the future following plans to reduce nitrogen loading from wastewater treatment plants.

Table 4. Qualitative evaluation rating for Long Island Sound.

1.	Well-documented impacts to a particular ecosystem function or service: *Yes.*
a.	impacts (specify): *Eutrophication; loss of submerged aquatic vegetation and decreases in dissolved oxygen; decreases aquatic habitat. Mercury contamination of fisheries.*
b.	level of degradation (specify severe, moderate, mild): *Moderate.*
c.	importance of atmospheric deposition source (specify % and other sources): *20-35%; major inputs from other nitrogen sources, particularly treated wastewater. Atmospheric deposition is a large component of the mercury inputs to LIS.*
2.	Quantifiable physical endpoints that can be linked to atmospheric deposition of Clean Air Act pollutants
a.	ecological (specify): *Loss of aquatic habitat. Mercury contamination in fisheries.*
b	economic (specify): *Loss of recreational and commercial fisheries.*
3.	Available monetary values for at least some endpoints (if available): *Yes, the State of Connecticut conducted a cost analysis for removing nitrogen in wastewater. There may be economic analysis associated with TMDL developed for LIS for N.*
4.	Take advantage of existing initiatives to maximize use of available resources, avoid redundant research, and demonstrate multiple applications of ongoing project: *Yes, there is considerable work going on in the States of Connecticut and New York. Researchers from the University of Connecticut have done considerable research of impacts of atmospheric mercury deposition on LIS.*

4.4 <u>Everglades</u>

The Everglades and associated Everglades National Park (ENP) is a diverse aquatic ecosystem in southern Florida covering more than 100 km^2. Despite the absence of major industrial point sources of contamination, the water, sediments and numerous biota of the ENP are known to contain elevated levels of mercury (Kang et al. 2000). One main pathway of mercury to the ENP is through atmospheric deposition, stemming from near and far-field sources such as incinerators and electrical power generating facilities. Upwards of 30 $\mu g/m^2$-yr (total Hg, wet + dry deposition) (Table 5) is estimated to fall in the ENP area (Florida Department of Environmental Protection 2003; Schuster et al. 2002), where approximately 85% results from atmospheric deposition. There are three forms or species of atmospheric mercury: elemental mercury (Hg(0)), reactive gaseous mercury (Hg(II)), and particulate mercury (Hg(p)). The sources and speciation of the mercury deposited in the ENP is shown in Table 6, and illustrated in Figure 3.

The deposition of Hg has lead to elevated levels of mercury in fish species, and reductions in some populations of piscivorous birds (Sepulveda et al. 1999). The decline in bird populations and the potential for reduced human recreational use of fish and other aquatic species impacted by mercury contamination may provide a sufficient backdrop for estimating the potential economic consequences of the contamination in this area.

Even more importantly, recent controls on emissions from point sources have resulted in concomitant reductions in body burdens of mercury in selected species; however the reduction in atmospheric deposition does not result in a linear reduction in body burdens due to the recycling of mercury inventory in the sediments and other media (Florida Department of Environmental Protection 2003). Given this relatively new information, this case may present a situation for a “before” and “after” analyses of the economic benefits that might have accrued as a result of the reduction in atmospheric deposition.

The Everglades case provides a tangible example of the array of impacts associated with atmospheric deposition of mercury in a sensitive aquatic and semi-aquatic habitat. Moreover, as noted above, there is the possibility, pending further evaluation of the literature, to conduct a before and after assessment of the economic benefits stemming from a reduction in emissions. This is predicated on obtaining quantitative economic data (e.g. tourism, recreational use, etc.) that can link directly to existing quantitative biological data collected on resident organisms within the ENP system.

Table 5. Estimates of mercury loading to the Everglades Protection Area. Taken from Florida Department of Environmental Protection (2003), based on U.S. EPA estimates in 1994-1995.

Year	Atmospheric Deposition Hg kg/ yr.
1994	238
1995	206

Table 6. Sources and speciation of mercury deposited in the Everglades. From Florida Department of Environmental Protection (2003).

Mercury Emission Source Type	% Hg(0)	%Hg(II)	%Hg(p)
Municipal Waste Combustion	20	60	20
Medical Waste Incinerators	2	73	25
Electric Utility Boilers (coal, oil, gas)	50	30	20
Commercial and Industrial Boilers	50	30	20

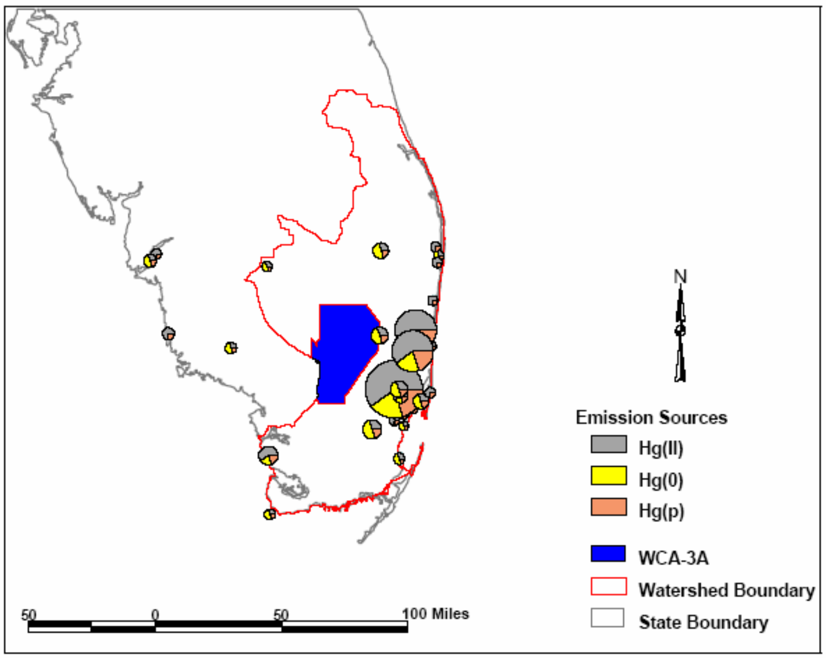

Figure 3. Illustration of the sources and species of mercury deposited in the Everglades study area. From Florida Dept. Environmental Protection (2003).

Table 7. Qualitative evaluation rating for the Florida Everglades.

1.	Well-documented impacts to a particular ecosystem function or service: *Yes.*
a.	impacts (specify): *Reduction in piscivorous, wading bird populations. Contamination of lower and upper trophic level biota.*
b.	level of degradation (specify severe, moderate, mild): *Moderate. Appears to be improving as a result of the reduction in atmospheric emissions.*
c.	importance of atmospheric deposition source (specify % and other sources): *Estimated low of 20%, estimated high of 85%. Majority of deposition results from incinerators, boilers, etc.*
2.	Quantifiable physical endpoints that can be linked to atmospheric deposition of Clean Air Act pollutants
a.	ecological (specify): *Contamination of food web with mercury; reduction in wading bird population.*
b.	economic (specify): *Potential reductions in human use and recreational opportunities; reduction in tourism.*
3.	Available monetary values for at least some endpoints (if available): *Tourism, angler fishing days/license fees, etc.*
4.	Take advantage of existing initiatives to maximize use of available resources, avoid redundant research, and demonstrate multiple applications of ongoing project: *Yes, national initiative on mercury emissions.*

4.5 <u>Lake Michigan</u>

Considerable work regarding mercury deposition has been amassed in the Great Lakes Region from studies conducted primarily from Lake Superior and Lake Michigan (Back et al. 2002; Landis and Keeler 2002; Vette et al. 2002; Back et al. 2003; Cleckner et al. 2003; Rolfhus et al. 2003; Great Lakes National Program Office 2004; McCarty et al. 2004). All of these Great Lakes studies have added considerably to the resource knowledge base regarding the sources, speciation, and impacts of mercury deposition to freshwater ecosystems. Probably one of the most comprehensive and concerted investigations conducted for any of the Great Lakes has been the EPA's Great Lakes National Program Office's (2004) Lake Michigan Mass Balance Study (LMMB Study).

Lake Michigan, the second largest Great Lake by volume with just under 4,917 cubic kilometers of water, is the only Great Lake entirely within the United States. Approximately 190 kilometers wide and 494 kilometers long, Lake Michigan has more than 2,576 kilometers of shoreline. Averaging 85 meters in depth, Lake Michigan reaches 282 meters at its deepest point. Lake Michigan's northern tier is in the colder, less developed upper Great Lakes region, while its more temperate southern basin contains the Milwaukee and Chicago metropolitan areas. Lake Michigan's drainage basin includes portions of Illinois, Indiana, Michigan, and Wisconsin. Lake Michigan, as well as the other Great Lakes, supports an important sports and commercial fishery and serves as a recreational resource for the Great Lakes Region (Fuller et al. 1995).

The LMMB Study was instituted in 1997 to measure and model the concentrations of representative pollutants within important compartments of the Lake Michigan ecosystem (Great Lakes National Program Office 2004). The goal of the LMMB Study was to develop a sound, scientific base of information to guide future toxic load reduction efforts at the federal, state, tribal, and local levels. The objectives of the study were to:

1. Estimate rates of pollutant load;
2. Establish a baseline to gauge future progress;
3. Predict the benefits associated with load reductions; and
4. Further understand ecosystem dynamics.

Mercury was among the pollutants investigated in the LMMB Study. Lake Michigan receives approximately 86% of its mercury input through direct atmospheric deposition (McCarty et al. 2004).

Global releases of mercury to the environment come from both natural and anthropogenic sources. Many of these sources are the result of releasing geologically bound mercury to the atmosphere. Once mercury enters the atmosphere, it becomes part of a global cycle of mercury among land, water, and the atmosphere. In the LMMB Study, mercury was extensively measured in atmospheric, tributary, open-lake water column, sediment, lower pelagic food web organism, and fish samples. Methylmercury, the major toxic and bioaccumulative form of mercury, also was measured in tributary samples. Extensive modeling of Lake Michigan atmospheric mercury deposition also took place in conjunction with the LMMB Study (Landis and Keeler 2002; Cohen 2004; Cohen et al. 2004).

The EES believes that there are several advantages and disadvantages to the use of the LMMB Study as a potential ecological benefits case study. Lake Michigan is a major freshwater ecosystem and an important economic and recreational resource. Considerable information regarding atmospheric mercury inputs to this freshwater ecosystem has been amassed as a result of the comprehensive LMMB Study. The disadvantage of using the LMMB Study is that economic impacts were not specially identified or evaluated since neither constituted the primary purpose for the investigation.

Table 8. Qualitative evaluation rating for Lake Michigan.

1.	Well-documented impacts to a particular ecosystem function or service: *Yes.*
a.	Impacts (specify): Generalized impacts to fish and wildlife: *Focus of information is on fish advisories dealing with Coho salmon and lake trout. In fish, mercury has been shown to cause (in high enough doses) increased mortality, decreased growth, sluggishness, poor reproduction and deformities.*
b.	Level of degradation (specify severe, moderate, mild): *Moderate.*
c.	Importance of atmospheric deposition source (specify % and other sources*): Estimated atmospheric deposition contribution 87%.*
2.	Quantifiable physical endpoints that can be linked directly (or indirectly) to atmospheric deposition of Clean Air Act pollutants.
a.	Ecological (specify): *Contamination of sediments and aquatic biota with mercury.*

b.	Commercially exploited resources (specify): *Impact to recreational and commercial fishery industry and tourism.*
3.	Quantified economic benefits estimates: *Yes, for impacts to commercial and sport fisheries.*
4.	Takes advantage of existing initiatives to maximize use of available resources, avoid redundant research, and demonstrate multiple applications of ongoing project: *Yes, part of larger Lake Michigan Mass Balance Project and Lake Michigan Lakewide Management Plan.*

4.6 Barneget Bay

The Barnegat Bay estuarine system includes Barnegat Bay, Manahawkin Bay and Little Egg Harbor. This system covers about 70 km of shoreline in Ocean County, New Jersey, supports a thriving tourist industry, and has a fishery that is a valuable recreational and commercial resource. For example, $1.71 billion tourist dollars were spent in Ocean County in 1995 (STAC 2001). The watershed of the Barnegat Bay estuarine system drains 1700 km^2, which was dominated in 1995 by forests (45.9%), wetlands (25.2%) and urban areas (19.5%). This watershed is home to about 460,000 people year-round and more than 800,000 people during the summer (STAC 2001). These people enjoy an array of recreational activities, such as boating, fishing, swimming, and hunting.

There have been several water quality studies of the Barneget Bay estuarine system. For example, STAC (2001) reported elevated concentrations of nitrogen in the water column of this system. Total nitrogen concentrations ranged from 0.3 – 1.1 mg N/L (1989-1996). Organic nitrogen was the dominant form of nitrogen, about 10 times greater than the inorganic nitrogen concentrations. Seasonal averaged (1989-1996) ammonium concentrations were 0.04 mg N/L and nitrate concentrations were 0.05 mg N/L. These high nitrogen concentrations fueled intense blooms of phytoplankton, which created low dissolved oxygen concentrations (< 5 mg/L) in the central part of this estuarine system (STAC 2001). These blooms, together with elevated sediment loads, have increased the turbidity and reduced the area of submerged aquatic vegetation. There have also been changes in fish and shellfish numbers and fisheries revenue. For example, the annual commercial value of American eel in Barnegat Bay declined from $62,857 to $17,150 from 1989 to 1994 (STAC 2001).

Atmospheric deposition is clearly the dominant source of nitrogen to this estuary ecosystem (Castro et al. 2001), primarily because point sources of wastewater are discharged offshore bypassing this estuary. Castro et al. (2001) estimated that atmospheric deposition accounted for 50% of the total nitrogen inputs to this ecosystem, followed by agricultural runoff (32%) and septic systems (16%). The Scientific and Technical Advisory Committee (STAC, 2001) estimated that direct deposition to the surface of this estuarine ecosystem accounts for 39% of the total nitrogen inputs. Similarly, Castro et al. (2001) estimate direct deposition accounted for approximately 30% of the total nitrogen inputs.

The EES believes that there are several advantages to the Barneget Bay estuarine system as a potential ecological benefits case study. This ecosystem is highly visible to the public, an important economic and recreational resource, is well studied and atmospheric deposition is the dominant nitrogen source. In addition, since this ecosystem has a relatively large direct depositional input of nitrogen, ecosystem responses due to changes in atmospheric deposition are more likely to be observed in this ecosystem compared to other ecosystems with much smaller direct deposition inputs.

Table 9. Qualitative evaluation rating for Barneget Bay ecosystem.

1.	Well-documented impacts to a particular ecosystem function or service: *Yes.*
a.	impacts (specify): *Eutrophication; loss of submerged aquatic vegetation, low dissolved oxygen in places; changes in fish and shellfish populations. Mercury and other trace metal contamination of fisheries.*
b.	level of degradation (specify severe, moderate, mild): *Moderate.*
c.	importance of atmospheric deposition source (specify % and other sources): *50 % of the total nitrogen inputs from atmospheric deposition.*
2.	Quantifiable physical endpoints that can be linked to atmospheric deposition of Clean Air Act pollutants
a.	ecological (specify): *Fisheries decline for several species.*
b	economic (specify): *Decreased revenues from commercial fisheries, diminished recreational benefits, local economic impacts.*
3.	Available monetary values for at least some endpoints (if available): *Yes, there is some data for selected fishery endpoints.*
4.	Take advantage of existing initiatives to maximize use of available resources, avoid redundant research, and demonstrate multiple applications of ongoing project: *Yes, there has been considerable work on this system for several researchers associated with the National Estuary Program and Rutgers University.*

4.7 Tampa Bay

Tampa Bay covers 1000 km^2 and has a watershed of 5700 km^2 on the west coast of Florida. More than 2 million people reside within the watershed, including the cities of Tampa and St. Petersburg. One of the fastest-growing urban regions in the U.S., its population increased 25% between 1975 and 1995, with another 20% gain expected by 2010. As of the mid-1990s, approximately 17% of the watershed was urban, and another 40% was agricultural. The major rivers draining into Tampa Bay are the Hillsborough, Alafia, Little Manatee, and Manatee Rivers. Tampa Bay provides rich habitat for diverse species of fish, invertebrates and birds in habitats ranging from mangrove, oyster reef, and seagrass bed to salt marsh and sand beach. Species of particular interest that reside in the Bay include the federally threatened piping plovers and loggerhead sea turtles, and the endangered West Indian manatee, bald eagle, shortnose sturgeon, as well as the green, hawksbill, and Kemp's Ridley sea turtles.

Water quality decreased through the first half of the 20th century associated with increases in nitrogen loading. By 1982, seagrass beds had declined to 20% of their pre-settlement area. However, the introduction of advanced wastewater treatment in Tampa, St. Petersburg, and Clearwater in the late 1970s and early 1980s reduced the loading of nitrogen from wastewater by 90%. Seagrass growth began to recover between 1982 and 1992 following reductions in nitrogen loading.

Tampa Bay has been part of the Clean Water Act's National Estuary Program since 1991 (Tampa Bay Estuaries Program, TBEP), through which multiple stakeholders are brought together in regional planning actions, including development of a Comprehensive Conservation and Management Plan, and a Nitrogen Management Consortium developed in 1996. The TBEP estimates that in the early 1990s, atmospheric deposition contributed 25-30% of the nitrogen loading to the Bay; point sources, 14%; fertilizer, 4%; and the remainder was mostly stormwater runoff (45%). These estimates were based on data sources of varying quality. Total nitrogen deposition was estimated by assuming that the rate of dry deposition amounted to twice that of wet deposition (Zarbock et al. 1996). Recent data indicate that total inorganic nitrogen deposition to the estuary during the late 1990s averaged ~8.0 kg N ha^{-1} y^{-1} (Poor 2000). Of this total, dry deposition contributed just less than half, with ammonia (a constituent not routinely measured) making up 75-85% of total dry deposition (Poor 2000). Alternative estimates of nitrogen loading to Tampa Bay (Castro et al. 2001; Alexander et al. 2001) suggest a much smaller contribution from atmospheric deposition (~8-11%), due to inclusion of fewer forms of nitrogen in deposition, and to 3-4-fold higher estimates of total loading of nitrogen from fertilizer and agriculture.

Tourism and both recreational and commercial fishing are important industries dependent on the health of the bay. Commercial harvest of shellfish is presently banned. Recreational harvest of shellfish is confined to clamming. Assessments of the economic value and impacts on these resources exist as part of the Comprehensive Conservation and Management Plan for Tampa Bay (TBNEP 1996). In addition, past workshops by the EPA Science Advisory Board (SAB) have examined four disparate approaches for examining public valuation of ecological resources, using the Tampa Bay Estuary as a case study (US EPA 2001).

The very real and direct impacts of nitrogen loading on estuarine resources, combined with an abundance of past and ongoing research, make Tampa Bay an advantageous area for further benefits study. The water quality impacts are significant, and most (but not all) lines of evidence suggest that atmospheric deposition plays a major role in nitrogen loadings.

Table 10. Qualitative evaluation rating for the Tampa Bay, FL.

1.	Well-documented impacts to a particular ecosystem function or service: *Yes.*
a.	impacts (specify): *Eutrophication; loss (and recovery) of seagrass and fisheries. Mercury contamination of fisheries*
b.	level of degradation (specify severe, moderate, mild): *Moderate and improving.*
c.	importance of atmospheric deposition source (specify % and other sources): *Recent estimates suggest ~25%; published range 8-50%. Other sources either fertilizer & agriculture or stormwater runoff.*

2.	Quantifiable physical endpoints that can be linked to atmospheric deposition of Clean Air Act pollutants
a.	ecological (specify): *Seagrass habitat impaired due to eutrophications; concerns over habitat for endangered species.*
b	economic (specify): *Loss of recreational and commercial fisheries. Adverse impact on tourism and recreation.*
3.	Available monetary values for at least some endpoints (if available): *Bay resources quantified in the TBEP Conservation & Management Plan.*
4.	Take advantage of existing initiatives to maximize use of available resources, avoid redundant research, and demonstrate multiple applications of ongoing project. *See prior 1999 EPA Prospective analysis for consideration of Tampa Bay, particularly EPA SAB workshop on public valuation of ecological resources (US EPA 2001).*

4.8 Gulf of Maine

The Gulf of Maine (GOM) watershed includes several large river basins spanning eastern New England and the Maritime provinces of Canada with a total land area of approximately 177,000 km^2. Major rivers within New England include the Merrimack, Saco and Kennebec/Androscogin systems in Massachusetts and Maine. The region is heavily forested with increasing population densities along immediate coastal areas and towards the Boston Metropolitan area to the south.

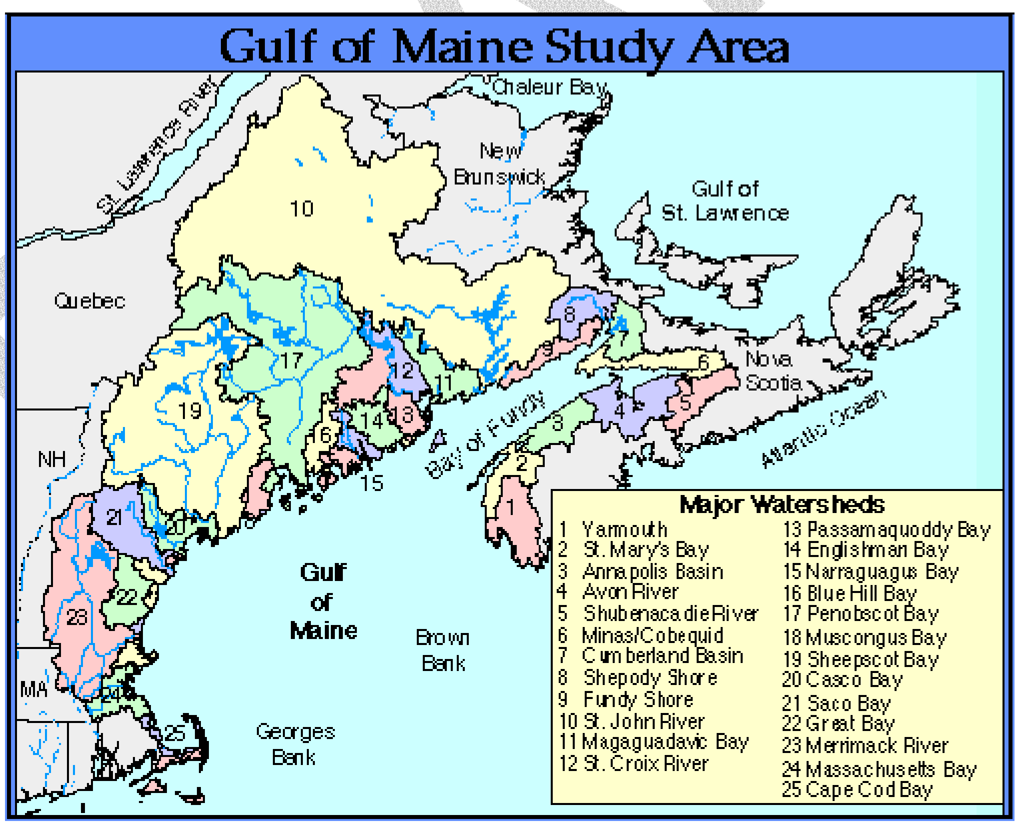

Figure 4. Watersheds in the Gulf of Maine region (from http://spo.nos.noaa.gov/projects/gomaine/gome_wtshd.html).

Links between nitrogen pollution and harmful algal blooms have been a cause for concern, particularly in southern portions of the Gulf such as Casco Bay. In addition, blooms of toxin-producing dinoflagellates (e.g., Red tide) have known adverse effects on shellfish. These toxins could also harm humans so this condition led to closure of numerous shellfish beds. What is less well understood is the underlying cause of harmful algal blooms and the degree to which nutrients derived from terrestrial runoff versus open ocean influx are responsible. Red tides in the eastern portions of the GOM, for example, are believed to be caused by oceanic nutrient influx (Townsend et al. 2001). However, coastal blooms have also been reported and terrestrial nitrogen sources likely have a greater role in these events.

For the basin as a whole, the largest single source of inorganic nitrogen is inflow from the open ocean. Based on estimates from Christensen et al. (1992) and Townsend (1998), as much as 95% of the total nitrogen load to the GOM is ocean derived. Nevertheless, the relative importance of terrestrial runoff increases towards inland bays and estuaries, where terrestrially-derived nitrogen is most concentrated and where most nutrient problems appear to exist. However, the relationships between nutrient loadings and estuarine degradation are largely anecdotal and do not appear to have been quantified.

Many organizations are presently involved in either monitoring environmental parameters relevant to GOM marine ecosystems or in distributing data from research and monitoring efforts. These include the Gulf of Maine Ocean Observing System (http://www.gomoos.org/), the Center for Coastal Ocean Observation and Analysis (http://www.cooa.sr.unh.edu/) and the WebCoast data retrieval system (http://webcoast.sr.unh.edu/home.jsp). Further, a consortium of federal, state, and local agencies has developed the Gulf of Maine Land-Based Sources Inventory, a digital database that contains information on the location, timing, and magnitude of point and nonpoint source discharges to the rivers, streams, lakes, and estuarine and coastal waters of the Gulf of Maine drainage area (http://spo.nos.noaa.gov/projects/gomaine/).

Table 11. Qualitative evaluation rating for the Gulf of Maine.

1.	Well-documented impacts to a particular ecosystem function or service:
a.	impacts (specify): *Primary impacts include algal blooms and associated declines in shellfish populations and larval stage of finfish.*
b.	level of degradation (specify severe, moderate, mild): *Moderate degradation has occurred in some areas, but specific causes are unclear.*
c.	importance of atmospheric deposition source (specify % and other sources): *Most terrestrially-derived nitrogen is from atmospheric sources, although influx from the open ocean is by far the largest source to the entire GOM (approximately 95%).*
2.	Quantifiable physical endpoints that can be linked to atmospheric deposition of Clean Air Act pollutants
a.	ecological (specify): *Declines in shellfish and larval stages of vertebrate fish.*
b.	economic (specify): *Loss of fisheries, decline in the number of shellfish beds that are open for harvesting.*
3.	Available monetary values for at least some endpoints (if available): *Monetary*

	values of species that are part of the GOM fisheries industry are available, but again, linkages with nitrogen pollution aren't well established.
4.	Take advantage of existing initiatives to maximize use of available resources, avoid redundant research, and demonstrate multiple applications of ongoing project: *A good deal of data are available on water chemistry, nitrogen loadings and populations of commercially-important species. However, the degree to which declining fisheries have been directly linked with nitrogen pollution remains unclear.*

The EES believes that there are both advantages and disadvantages to the GOM basin as an ecological benefits case study. The principal advantage is that atmospheric deposition represents the dominant source of nitrogen in runoff from the upland watershed and is an important source of nitrogen for inland estuaries. There are also several active scientific investigations encompassing terrestrial nitrogen budgets, estuarine ecosystem dynamics and oceanic chemical and biological processes, including the occurrence of harmful algal blooms and their effects on shellfish production. Two substantial disadvantages are the following: 1) for the GOM basin as a whole (i.e. including offshore waters), the largest overall source of nitrogen is influx from the open ocean, and 2) although harmful algal blooms have been anecdotally connected to nitrogen pollution, there is little hard evidence of a causal link and some researchers believe that oceanic nutrient influx is the primary controlling mechanism. The EES believes that these disadvantages probably outweigh the advantages of an entire GOM case study, although the potential for a more narrowly defined study of an individual river basin within the GOM (where open ocean processes play a smaller role) may warrant future consideration.

For example, Bliven (2001) points out that unlike other water bodies, anthropogenic deposition loadings in the Gulf of Maine do not appear to have had ecosystem-wide impacts, but rather have affected individual estuaries and embayments, due to the topographic setting and tidal flats. Rather than the Gulf region as a whole, the EES believes that the Casco Bay watershed in particular may hold potential for a case study.

The Casco Bay watershed is located entirely in the U.S. (in southern Maine), and drains an area of 2550 km^2. The Casco Bay estuary itself covers 518 km^2, and was designated an estuary of national significance in 1990. Twenty-five percent of the population of Maine (about 0.25 million people) live in the Casco Bay watershed. The estuary is home to a major port and fishery.

The contributions of nitrogen via atmospheric deposition to the Casco Bay estuary from its watershed are estimated to be 30% by Castro et al. 2001, 34% by Driscoll et al. 2003, 30-40% by Ryan et al. 2003, and 40% by the EPA in their report on the environmental effects of acid rain (http://www.epa.gov/boston/eco/acidrain/enveffects.html). The contributions of mercury via atmospheric deposition to the Casco Bay estuary are estimated to be 84 to 92% (Ryan et al. 2003). Data from the National Atmospheric Deposition Program (NADP) site at Casco Bay for 2003 (annual) indicate a pH of 4.8, nitrate deposition of 1.5 kg N/ha-yr, and sulfate deposition of 2.9 kg S/ha-yr; mercury deposition and other atmospheric monitoring data are also available.

Ecological effects of concern in Casco Bay include eutrophication, harmful algal blooms, shellfish losses and closures, and habitat loss. There is particular interest in maintaining biodiversity in the tidal flats for aquatic species and in the 758 islets for birds and plant species. The Comprehensive Conservation and Management Plan for the estuary is well underway, and there is ongoing monitoring to assess results (see weblinks specific to Casco Bay below, in addition to those described above for the entire Gulf of Maine area). Regarding resources for a case study and economic valuation, the EPA's Analytical Plan (Appendix F-G by Jim Democker 5/12/03) indicates that their Office of Water and the National Center for Environmental Economics has completed an economic profile of the estuary and determined that the health of the estuary impacts tourism and recreation. The Estuary Program highlights that many of the commercially valuable fisheries and seafood species in the New England region (e.g., lobsters, mussels, scallops) depend upon the health of Casco Bay for survival, and also points out the recreational value of the Bay and the local economic impacts of these activities.

Web resources regarding Casco Bay:
http://www.americanoceans.org/issues/pdf/casco.pdf (issues)
http://www.cascobay.usm.maine.edu/SONOMA.html (atmospheric deposition)
http://www.epa.gov/owow/estuaries/programs/cb.htm (EPA's Casco Bay activity)
http://www.gulfofmainesummit.org/docs/state_of_gulf_report_nutrients10_03.pdf (nutrients)

5. UPLAND FOREST ECOSYSTEMS

5.1 <u>Adirondacks</u>

The Adirondack region in northern New York State is a large (2,400 km^2) forested area, ranging in elevation from 30 to 1,630m. It is underlain by bedrock composed primarily of granitic gneisses and metasedimentary rocks which are generally resistant to chemical weathering. Surficial materials are primarily the result of glacial activity. Soils are generally developed from glacial till, and are shallow and acidic. There are approximately 2,800 lakes in the Adirondacks (with surface area > 0.2 ha). The region receives elevated inputs of acidic deposition of nitrate, sulfate and mercury (Table 12) and probably exhibits the most severe ecological impacts from acidic deposition of any region in the U.S. For example, in a survey of 1469 lakes during 1984-87, 27% were chronically acidic (i.e., acid neutralizing capacity (ANC) < 0 μeq/L; Baker et al. 1990). An additional 21% had summer ANC values between 0-50 μeq/L and could experience hydrologic events which decrease ANC values near or below 0 μeq/L. Decreases in pH and elevated concentrations of aluminum have reduced species diversity and abundance of aquatic life in many lakes and streams in the Adirondacks. Fish have received the most attention to date, but entire food webs are often adversely affected. There is also apparently a linkage between acidic deposition and fish mercury contamination (Driscoll et al. 1994).

Table 12. Summary of the pH of wet deposition, and wet deposition of sulfate and nitrate for long-term precipitation chemistry station in the Adirondacks (1998-2000). Data taken from the National Atmospheric Deposition Program (NADP) http://nadp.sws.uiuc.edu.

Site	pH	Sulfate (kg S/ha-yr)	Nitrate (kg N/ha-yr)
Huntington Forest	4.50	4.7	3.1
Whiteface Mountain	4.56	4.9	3.1

Effects of acidic deposition are less well documented for terrestrial ecosystems. Nevertheless it appears that acidic deposition has resulted in: 1) elevated accumulation of sulfur and nitrogen in soil, 2) depletion of available pools of nutrient cations (i.e., calcium, magnesium), and 3) the mobilization of aluminum from soil (Driscoll et al. 2001). The long-term impacts of these perturbations are not clear but recent studies suggest linkages to the decline of sensitive tree species such as red spruce and sugar maple.

Long-term monitoring and modeling studies have documented the response of the Adirondacks to recent decreases in acidic deposition (Driscoll et al. 2003) and the potential response to future reductions in sulfur dioxide and nitrogen oxides (Chen and Driscoll 2004; Chen and Driscoll 2005).

Recently Banzhaf et al. (2004) conducted a study on valuation of natural resource improvements in the Adirondacks. Based on their estimates of willingness to pay, benefits in New York State from reductions in acidic deposition in the Adirondacks range from $336 million to $1.1 billion per year. The 1999 Prospective Study considered economic impacts associated with recreational fisheries due to acidic deposition in the Adirondacks.

There have been numerous assessments of the effects of acidic deposition on the Adirondacks (Baker et al. 1990; Driscoll et al. 1991; Wigington et al. 1996; Sullivan 2000; Driscoll et al. 2001). Numerous groups continue to conduct research concerning the effects of air pollution in the Adirondack region, including the New York State Department of Environmental Conservation, the New York State Energy Research and Development Authority, the Adirondack Lakes Survey Corporation, the U.S. Geological Survey, Syracuse University, Cornell University, SUNY College of Environmental Science and Forestry and Rensselaer Polytechnic Institute.

There are several advantages to conducting an ecological benefits case study in the Adirondacks. The region receives elevated inputs of sulfur, nitrogen and mercury, and atmospheric deposition is the major source of these materials. There are well-documented effects of acidic deposition on large number of lakes and streams and associated fisheries in the region. To a lesser extent there are studies documenting air pollution impacts on trees. There have been several studies quantifying the response of Adirondack ecosystems to past and future changes in atmospheric deposition. There is considerable ongoing research on the effects of air pollution in the Adirondacks. Finally, there have been economic studies on the impacts of air pollution to the region.

Table 13. Qualitative evaluation rating for the Adirondack region of New York.

1.	Well-documented impacts to a particular ecosystem function or service: *Yes.*
a.	impacts (specify): *Soil and surface water acidification; decreases in diversity in aquatic biota; possible impacts to red spruce and sugar maple.*
b.	level of degradation (specify severe, moderate, mild): *Severe.*
c.	importance of atmospheric deposition source (specify % and other sources): *Virtually 100%; some inputs of naturally occurring organic acids.*
2.	Quantifiable physical endpoints that can be linked to atmospheric deposition of Clean Air Act pollutants
a.	ecological (specify): *Soil and surface water acidification.*
b	economic (specify): *Loss of fisheries; possible loss of tree species.*
3.	Available monetary values for at least some endpoints (if available): *Yes, from Banzhaf (2004).*
4.	Take advantage of existing initiatives to maximize use of available resources, avoid redundant research, and demonstrate multiple applications of ongoing project: *Yes, much work is going on in the Adirondacks; it would be good to take advantage of the Banzhaf (2004) study.*

5.2 <u>Catskills</u>

Covering approximately 5000 km^2 (500,000 ha) in southeast New York State, the Catskill Mountains receive some of the highest rates of acidic deposition in the nation, with a suite of impacts on forest vegetation, soils, and streams roughly comparable to those in Adirondack forests. In addition, the region supplies 90% of New York City's fresh water. Hence, water quality issues are of particular concern, although at present, phosphorus loads are of greater concern than nitrogen.

The Catskill Mountains consist of broad peaks up to ~1200 m elevation, dominated by quartz sandstone and formed as erosional remnants of an uplifted sedimentary delta. Northern hardwood forests cover most of the region, with some oak at low elevations and mixed spruce-fir at the highest elevations. Rates of atmospheric deposition are high: in the late 1990s, wet + dry sulfate-S deposition averaged 8-12 S kg/ha- y (15-27 kg SO4/ ha-y of in precipitation), and nitrogen deposition averaged 10-13 kg N/ ha-y (NADP, Lovett et al. 2000). Acidic deposition has depleted soil calcium (Lawrence et al. 1999) and contributed to stream acidification. A survey of 66 headwater streams in 1985-87 indicated that 8% were chronically acidic, and at least 16% were acidic under high-flow conditions (Stoddard and Murdoch 1991). Effects of acidification on vegetation in the region are not well documented. The Catskill region has a world-renowned trout fishery. Native brook trout occur in headwater streams and the more acid-sensitive brown trout occur farther downstream. Streams chronically or episodically acidified exhibit reduced fish diversity and biomass, and increased trout mortality (Baker et al. 1996). Twenty percent of 61 streams surveyed in the Appalachian Plateau lack any trout (Sharpe et al. 1987). Mercury advisories have been issued for fish consumption in all of the Catskill reservoirs (NYS Dept. of Health 2004).

New York City presently avoids EPA filtration requirements for drinking water, although water treatment includes addition of sodium hydroxide to increase water pH. Regulation of non-point source pollution is focused on phosphorus, with several reservoirs exceeding their Total Maximum Daily Loads (TMDL). Stream and reservoir nitrate concentrations are presently below the EPA threshold of 10 mg N/L nitrate-N: nitrate-N concentrations in drinking water from the Catskill/Delaware system average 0.19 mg N/L (range 0.10 – 0.89 mg/L) (NYC DEP 2003). Peak nitrate-N concentrations in streams in spring can exceed 1.5 mg N/L (Murdoch and Stoddard 1992). Yet, stream nitrate is likely to increase in the future in response to chronic deposition or disturbances. If forest ecosystems were not accumulating and denitrifying the nitrogen received in deposition, stream nitrate concentrations might be expected to average ~1-3 N mg/L (assuming that all nitrogen from deposition passed through the system, and 1/3 to 1/2 of precipitation is lost to evapotranspiration). Stream nitrate concentrations following disturbances can be quite high, due to continued soil nitrogen mineralization and lack of plant uptake. Following an experimental clear-cut, stream nitrate-N concentrations averaged 2-4 mg N/L and peaked at 19.6 mg N/L, or twice the EPA standard (Burns and Murdoch, in press). The particularly large response to disturbance by these forests relative to harvests elsewhere in the U.S. likely reflects the long-term accumulation of atmospheric nitrogen in these forest soils. Hence, ecosystem services help maintain stream nitrate levels below the EPA threshold; should this threshold be lowered, additional treatment could be needed to reduce stream nitrate.

The advantages of an ecological benefits case study in the Catskills are similar to those in the Adirondacks in many ways: the region receives similarly elevated inputs of sulfate, nitrogen, and mercury, with similarly documented effects on vegetation, soils, and streams. Features particular to the Catskills include the exceptional trout fishery and the importance of the NYC drinking water supply. No studies are known on the economic impact of acidic deposition on these particular resources, although efforts from the Adirondacks may be transferable. In addition, New York City depends upon the natural water-filtering ability of the Catskills. To fend off the multi-billion dollar cost of new drinking water treatment facilities, New York City in 1997 began a program of land purchases and conservation easements to maintain the water cleansing capabilities of the land and considerable information is available on NYC water treatment.

Table 14. Qualitative evaluation rating for the Catskill Mountains, NY.

1.	Well-documented impacts to a particular ecosystem function or service: *Yes.*
a.	impacts (specify): *Soil and surface water acidification; episodic acidification effects on fish; effects on vegetation poorly documented. Significant nitrogen loading to NYC drinking water reservoirs.*
b.	level of degradation (specify severe, moderate, mild): *Severe ecosystem effects; moderate fish effects; nitrate loading to important drinking water source.*
c.	importance of atmospheric deposition source (specify % and other sources): *100% to forest/stream ecosystems; a dominant contributor of nitrate to drinking water reservoirs.*
2.	Quantifiable physical endpoints that can be linked to atmospheric deposition of Clean Air Act pollutants
a.	ecological (specify): *Soil and surface water acidification.*
b.	economic (specify): *Loss of fisheries; possible loss of tree species; avoided drinking water treatment/possible treatment required should drinking water standard be lowered.*
3.	Available monetary values for at least some endpoints (if available): *None known specifically for Catskill region, although many effects transferable from Adirondacks; locally valuable fisheries; water treatment costs might be transferable from elsewhere.*
4.	Take advantage of existing initiatives to maximize use of available resources, avoid redundant research, and demonstrate multiple applications of ongoing project: *Ample work on stream acidification, fisheries, and drinking water monitoring; less known work on monetized benefits.*

Active research groups include:
U.S. Geological Survey – New York District, Watersheds Research Section, Troy, NY
Institute of Ecosystem Studies, Millbrook, NY
New York City Dept. of Environmental Protection
National Atmospheric Deposition Program: http://nadp.sws.uiuc.edu/

5.3 Southern Appalachian Mountains

The southern Appalachian region of the U.S. includes approximately 140,000 km^2 from northeastern Alabama to West Virginia and Virginia. This region receives elevated inputs of atmospheric sulfur and nitrogen deposition (Table 15). Bedrock geology of the Southeast is more variable than that of the Northeast and includes shales and metabasalts as well as granites and quartzites. Surficial deposits are much older than the glaciated Northeast. Soils in high elevation sensitive areas are typically shallow, acidic and adsorb inputs of sulfate. Acid-sensitive surface waters of the Southern Appalachian region are generally limited to low-order or headwater streams; lakes are rare.

Table 15. Summary of wet deposition at sites in the Southern Appalachian Mountain region 2003. Data are from the National Atmospheric Deposition Program (NADP) http://nadp.sws.uiuc.edu.

Site	pH	Sulfate (kg S/ha-yr)	Nitrate (kg N/ha-yr)
Parsons, WV	4.48	7.5	3.4
Coweeta, NC	4.74	6.4	2.8

The southern Appalachian region includes Class I wilderness areas, such as the Great Smoky Mountain National Park and the Shenandoah National Park. This region includes many air quality related values, such as forest ecosystems, stream ecosystems, and vistas. Air quality issues of concern from the region include visibility, acidic deposition and ground-level ozone. Ecological effects of these air quality issues include acidic deposition to forest ecosystems, ozone damage to terrestrial resources, acidic deposition to aquatic ecosystems and visibility impairment. The economy of the southern Appalachians is highly dependent on the natural resources of the region.

There have been several assessments of the effects of acidic deposition on the southern Appalachian mountain region (Cosby et al.1991; Elwood et al. 1991). An important recent initiative was the Southern Appalachian Mountain Initiative (SAMI). The objective of SAMI is to identify air pollution effects in the southern Appalachian region, particularly Class I wilderness areas, and to make recommendations to mitigate these impacts. SAMI is a multi-institution, multi-stakeholder initiative (http://www.epa.gov/region4/programs/cbep/saaa.html). As part of SAMI, an assessment of economic impacts of acidic deposition on recreational fisheries in the region was conducted (Abt Associates, 2002). This analysis suggested that emission controls would not have positive impacts on recreational fisheries because acid-impacted streams are not expected to recover substantially.

There are many groups with ongoing research activities on effects of air pollution on resources of the southern Appalachian mountains, including Oak Ridge National Laboratory, the U.S. Park Service, the U.S. Forest Service, the U.S. Geological Survey, and the University of Virginia.

There are several advantages associated with conducting an ecological benefits case study in the Southern Appalachian region. The region is highly visible to the public and a valued resource which includes Class I wilderness areas. There have been well-documented effects of air pollution on forests and streams. Atmospheric deposition is the major source of acid inputs to the Southern Appalachian region. There is a major ongoing research effort on air pollution effects, most notably the SAMI. This research effort includes long-term measurements of stream chemistry and application of acidification models. The major disadvantage of the region is that there have not been significant responses to recent decreases in sulfur dioxide emissions due to the fact that soils strongly retain atmospheric sulfur deposition.

Table 16. Qualitative evaluation rating for the Southern Appalachian Mountains.

1.	Well-documented impacts to a particular ecosystem function or service: *Yes.*
a.	impacts (specify): *Soil and surface water acidification; decreases in diversity in aquatic biota; possible impacts to tree species.*
b.	level of degradation (specify severe, moderate, mild): *Moderate.*
c.	importance of atmospheric deposition source (specify % and other sources): *Virtually 100%; some limited inputs of sulfur from local mineral deposits.*
2.	Quantifiable physical endpoints that can be linked to atmospheric deposition of Clean Air Act pollutants
a.	ecological (specify): *Soil and surface water acidification.*
b.	economic (specify): *Loss of fisheries; possible loss of tree species.*
3.	Available monetary values for at least some endpoints (if available): *Not sure possibly from the SAMI study.*
4.	Take advantage of existing initiatives to maximize use of available resources, avoid redundant research, and demonstrate multiple applications of ongoing project: *Yes, much work is going on in the southern Appalachian region; it would be good to take advantage of the SAMI study.*

5.4 <u>Rocky Mountains</u>

Upland watersheds in the Colorado Rocky Mountains are experiencing high levels of atmospheric deposition of nitrogen and mercury with well documented ecological effects on terrestrial biogeochemistry and water quality in the region. Soils and biota in these sensitive, thin-soiled landscapes have a limited capacity to assimilate chronic additions from deposition (Mast et al. 2003). Researchers have documented that there has been a shift from nitrogen-limitation to non-nitrogen-limitation in terrestrial ecosystems in recent decades attributed to increases in atmospheric nitrogen deposition (Williams et al. 1996). This change is derived from increases in emissions from stationary, automotive, and agricultural sources (Baron et al. 2000). Many forests in the region are at an advanced stage of nitrogen saturation with accelerated nitrogen cycling and with elevated nitrogen concentrations in fresh waters that are similar to those of highly disturbed forested ecosystems in the northeastern U.S. (Mast et al. 2003; Burns 2002; Fenn et al. 2003).

There are many advantages to considering the Rocky Mountain Region as an ecological case study. This region of Colorado has been the focus of extensive work by researchers in multiple locations on the effects of atmospheric deposition on vegetation, soil, and water quality The region and the research are highly visible to the public, with much of the work conducted in managed lands including National Forests, Rocky Mountain National Park, and Wilderness Areas. The ecological effects are clearly associated with changes in atmospheric deposition. Considerable work on the sources and fate of nitrogen has been done, and many reports have synthesized the numerous ecological effects of atmospheric deposition over space and time in the region (e.g., Williams et al. 1996; Baron et al. 2000; Heuer et al. 1999; Williams and Tonnessen 2000; Wolfe et al. 2001; Burns 2002; Mast et al. 2003; Fenn et al. 2003). Most of the documented ecosystem effects focus on biogeochemical cycling, shifts in plant and microbial communities, changes in biodiversity, and trends in water quality of wetlands, lakes and streams. While current nitrogen deposition rates in the Rocky Mountain region are low compared to some terrestrial locations in the northeastern U.S., they are high in the context of internal nitrogen cycling of the region, given low rates of nitrogen mineralization and low rates of biological uptake. Thus, small changes in deposition inputs to the region are likely to have observable and quantifiable effects (Bowman 2000; Burns 2002). Important data are available through long term research programs at Niwot Ridge (http://culter.colorado.edu/NWT/index.html), Loch Vale (http://co.water.usgs.gov/lochvale/index.html), and Rocky Mountain National Park (http://co.water.usgs.gov/projects/CO257/CO257.html). Further, there is ongoing monitoring at a number of NADP NTN and MDN network sites. Through these observations, changes in atmospheric deposition have been observed (Table 17).

Table 17. Summary of the pH of wet deposition, and wet deposition of sulfate and nitrate for long-term precipitation chemistry stations in the Rocky Mountains (2003). Data from National Atmosphere Deposition Program (NADP) http://nadp.sws.uiuc.edu.

Site	pH	Sulfate (kg S/ha-yr)	Nitrate (kg N/ha-yr)
Niwot Ridge	4.95	3.02	4.94
Loch Vale	5.26	1.24	1.53

Table 18. Qualitative evaluation rating for Rocky Mountains, CO.

1.	Well-documented impacts to a particular ecosystem function or service: *Yes.*
a.	impacts (specify): *Increase in nitrogen deposition at high elevations in front range, and ecosystem effects are well documented. Effects include shifts in plant species and algae, rates of forest & soil nitrogen cycling, changes in aquatic nitrogen fluxes.*
b.	level of degradation (specify severe, moderate, mild): *Moderate.*
c.	importance of atmospheric deposition source (specify % and other sources): *100% to forest/stream ecosystems; both mercury & nitrogen deposition are important atmospheric stressors being studied in this region.*
2.	Quantifiable physical endpoints that can be linked to atmospheric deposition of Clean Air Act pollutants

a.	ecological (specify): *Soil and surface water acidification, plant community response, amphibian response*.
b	economic (specify): *Change in forest structure and function – very important as this region includes wilderness areas and national park land.*
3.	Available monetary values for at least some endpoints (if available): *Uncertain. Forest species composition data may be available and could inform assessments of the change in commercial forestry values. Benefits transfer opportunities may exist for some recreational values.*
4.	Take advantage of existing initiatives to maximize use of available resources, avoid redundant research, and demonstrate multiple applications of ongoing project: *There is ample work on identifying sources and vectors of atmospheric inputs, ecosystem responses, and water quality responses. Information is also available on national park/wilderness area use.*

6. CHARGE QUESTION 20

6.1 Agency Charge Question 20

Charge Question 20. Does the Council support the plan for a feasibility analysis for a hedonic property study for valuing the effects of nitrogen deposition/eutrophication effects in the Chesapeake Bay region, with the idea that these results might complement the Waquoit Bay analysis?

The purpose of the Chesapeake Bay Property Value Feasibility Study (Markowski et al. 2003) (Feasibility Study) is to investigate the possibility of using a hedonic analysis of coastal area property values to estimate the benefits to waterfront and near-water front homeowners of reductions in atmospheric nitrogen deposition associated with the CCA.

The premise of the proposed Feasibility Study-- that changes in coastal area water quality can be ascribed primarily to fluctuations in atmospheric nitrogen deposition -- is tenuous. Paerl (1993) estimated that between 10 and 50% of anthropogenic nitrogen inputs to coastal estuaries come from atmospheric deposition. However, more recent evaluations (Carpenter et al. 1998; Boyer et al. 2002; Driscoll et al. 2003) suggest that this range may be high and, in fact, submit that eutrophic conditions observed in northeastern coastal areas stem more from non-atmospheric, rather than atmospheric, sources of nitrogen. In particular, Driscoll et al. (2003) found that atmospheric deposition to New York and New England estuaries accounted for only 14 to 35% of total deposition. Non-atmospheric nitrogen sources contributed considerably more to the eutrophic conditions of the estuaries (wastewater effluent, 36 to 81%; runoff from agricultural lands, 4 to 20%; runoff from urban lands, less than 1 to 20%; and runoff from forest lands, less than 1 to 5%). Consequently, while it is recognized that atmospheric nitrogen deposition contributes to coastal area eutrophication, its contribution would be overshadowed by non-atmospheric deposition sources to such an extent that any incremental effect of atmospheric deposition would be difficult to associate with waterfront and near-waterfront property values.

A second problem of the proposed Feasibility Study concerns the use of a nutrient deposition/eutrophication water quality model with hedonic property value studies in general. According to Leggett and Bockstael (2000), there is an absence in the environmental literature of hedonic studies dealing with water quality due to the fact that many water quality indices measure pollutants that are impractical for homeowners to observe or that do not directly impair the enjoyment individuals derive from their waterfront homes. In particular, Leggett and Bockstael (2000) specifically note three indices (i.e., dissolved oxygen, phosphorus, nitrogen), commonly used to measure water quality, that are normally obscure to homeowners. Of the three, nitrogen is recognized as the major limiting factor of primary productivity and most responsible for the process of eutrophication of coastal waters such as the Chesapeake Bay and Waquoit Bay (Ryther and Dunstan 1971; Howarth et al. 1996; Carpenter et al. 1998). High nitrogen levels can have adverse impacts on coastal area aquatic plants and animals, but, according to Leggett and Bockstael (2000), variations in such nutrient concentrations tend to go unnoticed by homeowners unless the high nutrient levels combine with the requisite chemical, biological, and physical conditions to cause episodic algal blooms and/or fish kills.

In an attempt to address this problem, the Feasibility Study suggests that three water quality indicators (continuous near-shore chlorophyll *a* measurements, coupled with annual measurements of near-shore submerged aquatic vegetation and periodic observations of macroalgal blooms) be used as a surrogate for time-series of nitrogen deposition. The proposed continuous measurement of chlorophyll *a*, which is a direct quantitative measure of primary productivity (National Research Council 2000) would be an appropriate indicator to track fluctuating eutrophic conditions (Whittaker 1972; Brewer 1979), and, therefore, nitrogen deposition in coastal waters. The EES has concerns with the assumption that chlorophyll *a* is indicative of nitrogen deposition to Chesapeake Bay. Moreover, the remaining two water quality indices would not eliminate the problem of a lack of direct awareness of water quality by the shoreline and near-shore populace. The Feasibility Study's water quality monitoring protocol could be strengthened with the inclusion of Secchi-disk transparency readings (to capture turbidity, a water quality index that volunteers could assist in providing, and for which users of the Chesapeake Bay might be able to observe changes over time), more frequent evaluations of near-shore submerged vegetation surveys, and frequent public media reporting of all the collected water quality data and its meaning.

Finally, the Feasibility Study indicates that time series ecological data would not be collected since such data are less important to a property value analysis than are high quality ecological data on variation across space. This is supported with the statement that since the spatial pattern of nitrogen sources and flushing environments does not change dramatically through time, the spatial pattern of eutrophication is also likely to be somewhat stable from one year to the next. While this rationale has some merit, the inclusion of time series data would make the proposed water quality investigation much more robust (Paerl et al. 1997) and would be consistent with the need to demonstrate how variations in nitrogen deposition influence eutrophic conditions in coastal waters. For example, Boyer et al. (in preparation) explore hydrological controls on variability in annual nutrient loading from the Susquehanna River watershed (at Conowingo, MD), which is the largest inflow of both water and nutrients to Chesapeake Bay. Nitrogen loadings from the river to the Bay exhibit large interannual variability, more than doubling between wet and dry periods typical of the past three decades (Figure 6). Knowing temporal variations in indicator values is important for interpreting monitored data (National Research Council 2000). This, in turn, could provide a much clearer understanding of how the varying eutrophic conditions might influence shoreline and near-shore property values.

Given the above, the EES recommends that the Council not proceed with the Feasibility Study as it is currently proposed. Rather, it is recommended that alternative case studies be explored that could be better correlated with atmospheric nitrogen deposition. This recommendation is based on the fact that nitrogen from other sources is not a perfect proxy for nitrogen from atmospheric deposition, so that variations in nitrogen from other sources cannot be used to predict the consequences of variation in nitrogen from atmospheric deposition.

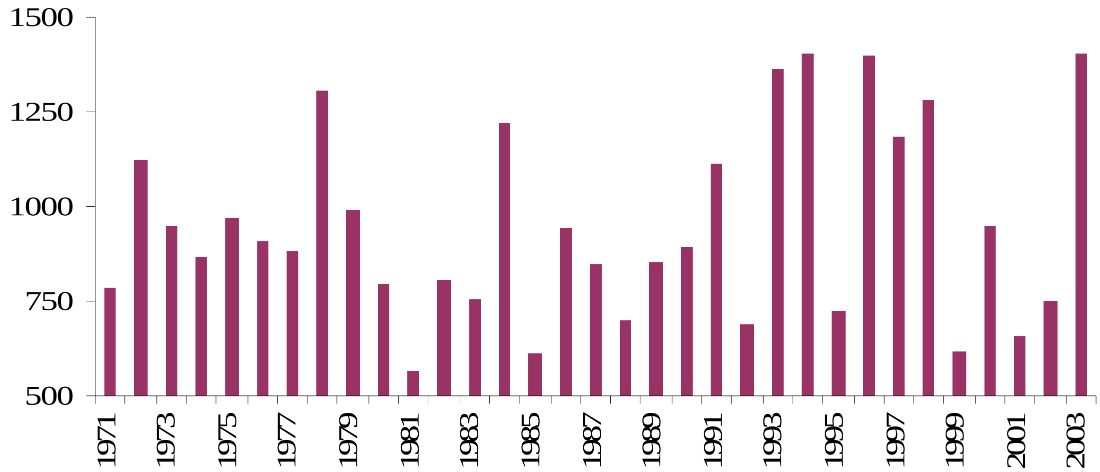

Figure 5. Nitrogen loadings (kg N km-2 yr-1) from the Susquehanna River to the Chesapeake Bay exhibit large interannual variability, more than doubling between wet and dry periods. Data from United States Geological Survey., 2005 National Water Information System (NWIS) for surface water and water quality http://waterdata.usgs.gov/nwis.

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8. BIOSKETCHES
OF EES MEMBERS AND PARTICIPATING COUNCIL MEMBERS

Biosketches of Ecological Effects Subcommittee	
Boyer, Elizabeth	Dr. Elizabeth W. Boyer is an Assistant Professor of Watershed Processes at the University of California, Berkeley in the Department of Environmental Science, Policy, and Management, and holds adjunct assistant professor positions at the State University of New York and at Syracuse University. Her research, in the area of eco-hydrology, involves characterizing how water and solutes are transported and transformed in the environment. She is interested in how human activities such as land use change and urbanization and natural variability such as droughts and floods influence ecosystems and water quality. Boyer has been elected Chair of an upcoming Gordon Conference on Catchment Science: Interactions of Hydrology, Biology & Geochemistry, and is active participant in activities of the American Geophysical Union and the International Nitrogen Initiative. Sources of recent funding include the New York State Energy Research & Development Authority, the US Environmental Protection Agency, and the US Department of Agriculture.
Castro, Mark	Dr. Mark Castro is an associate professor at the Appalachian Laboratory of the University of Maryland Center for Environmental Science. He holds a Ph.D. from the University of Virginia, Department of Environmental Sciences. He am a biogeochemist, specializing in the interactions between the atmosphere and terrestrial and aquatic ecosystems. He has completed several studies that document the impacts of forest management on soil trace gas fluxes. He has been involved in collaborative projects designed to assess the importance and impacts of atmospheric deposition on terrestrial ecosystems and estuaries. Currently, He is studying the movement of mercury from the atmosphere through mixed land-use watersheds into freshwater lakes and the biotic communities. In addition, He is establishing an atmospheric chemistry/meteorological station in western Maryland to examine the transport of pollutants into the Chesapeake Bay watershed. His research has been supported by national (NSF, NOAA, DOE), state (MDNR and MDE) and a private foundation (A.W. Mellon).
Driscoll, Jr., Charles T.	Dr. Charles T. Driscoll received his B.S. degree in Civil Engineering from the University of Maine in 1974. He received his M.S. in 1976 and Ph.D. in 1980 in Environmental Engineering from Cornell University. In 1979 he took a position on the faculty of the Department of Civil and Environmental Engineering at Syracuse University. Dr. Driscoll is currently University Professor of Environmental Systems Engineering and Director of the Center for Environmental Systems Engineering at Syracuse University. His teaching and research interests are in the area of environmental chemistry, biogeochemistry and water quality modeling. A principal research focus has been the investigation of effects of air pollution on forest, aquatic and coastal ecosystems. His research on effects of acidic deposition was initiated in the mid-1970s when he developed analytical techniques to determine the speciation of aluminum in solution and conducted field measurements to evaluate the forms of aluminum in acid-impacted waters and their effects of fish. Since that time he has used a variety of research approaches to study the effects of atmospheric deposition on forest, aquatic and coastal ecosystems, including field investigations, laboratory studies, long-term field measurements, whole-ecosystem manipulation studies, and the development and application of models. Dr. Driscoll has authored or co-authored more that 250 peer-reviewed articles, many of which focus on effects of acid rain. He has had more than 70 funded research projects, most of these were obtained from competitive research programs such as the National Science Foundation and the Environmental Protection Agency and many address impacts of air pollutants on forest and aquatic ecosystems. He is currently the principal investigator of the National Science Foundation Long-Term Ecological Research project at the Hubbard Brook Experimental Forest, New Hampshire. Dr. Driscoll has received numerous awards and honors. In 1984, he was designated as a Presidential Young Investigator by the National Science Foundation. He has provided expert testimony on ecological effects of air pollution to the Senate Commerce Committee and the House Science Committee. He has been acknowledged by Institute for Scientific Information (ISI) as one of the top 250 most highly cited researchers in two areas: environmental science and engineering. Dr. Driscoll has served on many local, national and international committees. He was a member of the National Research Council Panel on Process of Lake Acidification. He currently is a member of the National Research Council Committee of Air Quality Management. He is currently a member of the board of trustees of the Hubbard Brook Research Foundation and the Upstate Freshwater Institute.
Goodale, Christine	Dr. Christine Goodale is an Assistant Professor in the Department of Ecology and Evolutionary Biology at Cornell University. Dr. Goodale previously held postdoctoral fellowships at the Woods Hole Research Center (Woods Hole, MA) and the Carnegie Institute of Washington (Stanford, CA). She received her Ph.D. and M.S. in natural resources from University of New Hampshire, and an A.B. in biology, geography, and environmental studies from Dartmouth College. Her research centers on understanding the effects of human activities on temperate forests, including the direct effects of land-use change and the indirect effects of human alteration of carbon and nitrogen cycles. Key research questions include: How have direct and indirect human activities affected forest growth and net carbon accumulation? What factors control the spatial and temporal patterns of watershed nitrogen retention? How do the legacies of past disturbances affect current rates of carbon and nitrogen accumulation? Research approaches range from plot-level field studies to regional modeling and collaborative data syntheses.
Harrison, Keith	Keith G. Harrison has been employed with the state of Michigan for 24 years. For the last 12 years, he has held two concurrent positions within state government. He has served from 1992 -1997 as the Director of, initially, the Michigan Department of Management and Budget's Environmental Administration Division and, later (since 1997) due to interdepartmental transfer, the Michigan Department of Environmental Quality's Office of Special Projects (OSP)(1). He also has served since 1992 as the Executive Director of the Michigan Environmental Science Board. Concurrent with the two positions above, he currently is assigned as a consultant to the U.S. Environmental Protection Agency Science Advisory

	Board's Ecological Processes and Effect Committee, and from May to October 2001, he served as the Acting Director of the Michigan Office of the Great Lakes. Previous positions held within state government include two years as Environmental Affairs Manager for the Michigan Department of Corrections; five years as Senior Environmental Specialist for the Michigan Toxic Substance Control Commission, and four years with the Michigan Department of Public Health. Prior to state service, Mr. Harrison was employed as a Senior Ecologist with an environmental engineering firm; Chief Environmental Planner for a regional planning agency; and Sanitarian with a local county health department .Mr. Harrison obtained his Bachelor of Science degree in 1972 in fisheries and wildlife biology from Michigan State University and a Master of Arts degree in 1974 in biology (ecology) from Western Michigan University. He has been licensed since 1978 as a Registered Sanitarian and Registered Environmental Health Specialist, and, since 1981, has been certified as an Ecologist by the Ecological Society of America (ESA). In 2004, Mr. Harrison's certification was upgraded to Senior Ecologist by the ESA. Mr. Harrison's professional research and work have resulted in over 90 governmental and professional scientific publications addressing a wide variety of environmental, environmental health, natural history, and natural resources management topics. His areas of expertise are ecology, environmental science, and environmental health science. He has recently served as Michigan's representative to the Great Lakes Commission's Project Management Team on the development of a decision tool to review the use and management of Great Lakes surface and groundwater and as invited expert peer reviewer for the USEPA its Environmental Indicators Initiative for the United States.
Ollinger, Scott	Dr. Scott Ollinger is an Assistant Professor at the University of New Hampshire with joint appointments in the Institute for the Study of Earth, Oceans and Space and the Department of Natural Resources. He earned a Bachelor's degree in Ecology and Environmental Science from Purchase College in 1989 and Master's and Ph.D. degrees in Natural Resources from the University of New Hampshire in 1992 and 2000. His research interests include forest ecology and biogeochemistry with emphasis on basic ecological processes and interactions with human-induced environmental change. His current research involves understanding the combined effects of multiple atmospheric factors—including nitrogen deposition, tropospheric ozone pollution and elevated CO_2—on rates of productivity and carbon storage in forests. He is also interested in the use of foliar chemistry as an indicator of ecosystem carbon-nitrogen interactions. His work is part of the recently-formed North American Carbon Program and he currently acts as the principal investigator of a NASA aircraft remote sensing campaign. He has published on a variety of topics including climate and atmospheric chemistry, growth and nutrient status of temperate forests, and the use of hyperspectral remote sensing in regional ecological analyses. Dr. Ollinger's research has been funded through competitive grants from the National Aeronautics and Space Administration (NASA), the U.S. Department of Agriculture, the U.S. Department of Energy and the U.S. Environmental Protection Agency. In addition to his research activities, Dr. Ollinger teaches courses in Terrestrial Ecosystems and Forest Ecology and serves on several science advisory committees. Recent service in this regard includes the Hubbard Brook Research Foundation's Science Links Program, the Scientific Committee on Problems in the Environment (SCOPE) and the New York State Energy Research and Development Authority.
Stahl, Jr., Ralph	Dr. Ralph G. Stahl received his B.S. in Marine Biology from Texas A&M University (cum laude) in 1976, his M.S. in Biology from Texas A&M University in 1980 and his Ph.D. in Environmental Science and Toxicology from the University of Texas School of Public Health in 1982. After receiving his Ph.D., he was a Senior Postdoctoral Fellow in the Dept. of Pathology at the University of Washington in Seattle where he investigated the impact of genetic toxins on biological systems. Ralph joined the DuPont Company in 1984 and in the intervening years has held both technical and management positions in the research and consulting arenas. His research over the last 20 years has focused primarily on evaluating the effects of chemical stressors on aquatic and terrestrial ecosystems. He has been involved with oceanographic studies in the Atlantic, Pacific, Gulf of Mexico and Caribbean Sea, biological and ecological assessments at contaminated sites in the US and Europe, and numerous toxicological studies with mammals, birds and aquatic organisms. Dr. Stahl has been selected by USEPA, Army Corps of Engineers, SERDP, National Academy of Science, the Water Environment Research Foundation, NOAA and others to national peer review panels on ecological risk assessment, endocrine disruption in wildlife, and natural resource injury determination. He is active in the Society of Environmental Toxicology and Chemistry, serving on the Ecological Risk Assessment Advisory Group and the Technical Committee, and is a Diplomate of the American Board of Toxicology. He has authored over 25 peer reviewed publications and two books in environmental toxicology and most recently has been responsible for leading DuPont's corporate efforts in ecological risk assessment and natural resource damage assessments for site remediation. Dr. Stahl chairs the American Chemistry Council's Environmental Technical Implementation Panel that is implementing ecological research under the chemical industry's Long Range Research Initiative. He currently resides in Wilmington, Delaware, where in his spare time he enjoys woodworking, fly fishing and watching his son play soccer.

Biosketches of the Participating Members of the Advisory Council on Clean Air Compliance Analysis	
Trudy Cameron	Dr. Trudy Ann Cameron is the Raymond F. Mikesell Professor of Environmental and Resource Economics at the University of Oregon. She holds a Ph.D. in Economics from Princeton University, and was a member of the faculty in Economics at UCLA for seventeen years before moving to U of O in January of 2002. She has served as a member of the board of directors, as well as vice-president, of the Association of Environmental and Resource Economics, and as an associate editor for the Journal of Environmental Economics and Management and the American Journal of Agricultural Economics. For the EPA's Science Advisory Board, she has served on the Environmental Economics Advisory Committee and the Economics and Assessment Working Group of the Children's Health Protection Advisory Committee, and she now chairs the US EPA Advisory Council for Clean Air Compliance Analysis. Dr. Cameron's research concentrates on the methodology of non-market resource evaluation, with special emphasis on econometric techniques for the analysis of stated preference survey data. Her recent projects have included a study of popular support (i.e. willingness to pay) for climate change mitigation programs (funded by the National Science Foundation). A current project, begun at UCLA with former colleague JR DeShazo, uses stated preference survey methods to elicit household choices that reveal willingness to pay to avoid illness, injury, and death. The value of a statistical life is a key ingredient in the benefit-cost analysis of many environmental, health, and safety regulations, and this project seeks to more clearly identify how the context of such choices influences the public's willingness to pay for such policies.
Chestnut, Lauraine	Ms. Lauraine G. Chestnut, a manager at Stratus Consulting, Inc., is an economist who specializes in the quantification and monetary valuation of human health and environmental effects associated with air pollutants. She has 20 years of experience with Stratus Consulting and its predecessors working for clients including the U.S. Environmental Protection Agency, California Air Resources Board, Environment Canada, World Bank, and Asian Development Bank, quantifying the damages of air pollution, including human health effects, visibility aesthetics, materials damages, and crop damage. She has conducted original economic and survey research to estimate the value to the public of protecting human health and visibility aesthetics from the effects of air pollution. She has developed quantification models to estimate the health benefits of reductions in air pollutants that have been used to assess the benefits of provisions of the Clean Air Act in the U.S., proposed Canadian air quality standards, air quality standards in Bangkok, and elsewhere. Ms. Chestnut has published articles related to this work in Land Economics, Environmental Research, Journal of the Air and Waste Management Association, and Journal of Policy Analysis and Management, and as chapters in the following titled books: Valuing Cultural Heritage, Air Pollution and Health, and Air Pollution's Toll on Forests and Crops. Ms. Chestnut managed an epidemiology and economic study of the health effects of particulate air pollution in Bangkok, working closely with the Thai Pollution Control Department, the School of Public Health at Chulalongkorn University, and the World Bank. Ms. Chestnut co-authored publications on the Bangkok studies in the Journal of the Air and Waste Management Association, Environmental Health Perspectives, American Journal of Agricultural Economics, Journal of Exposure Analysis and Environmental Epidemiology. Ms. Chestnut received a B.A. in economics from Earlham College, Richmond, Indiana, in 1975, and an M.A. in economics from the University of Colorado, Boulder, in 1981. She is a member of the Association of Environmental and Resource Economists and of the Air and Waste Management Association.