

Atmospheric Science and the Constitution of Public Policy: The Case of the National Acid Precipitation Assessment Program (NAPAP)¹

Policy analysis involves creating problems that are solvable by specific organizations in a particular arena of action. A problem in policy analysis, then, cannot exist apart from a proposed solution, and its solution is part of an organization, a structure of incentives without which there can be no will to act.

Aaron Wildavsky, 1989

Abstract: Developed for the American Meteorological Society, 2002 Summer Policy Colloquium, this case study explores the National Acid Precipitation Assessment Program (NAPAP) as an example of science-policy assessment. The case study consists of three primary sections: Part I provides a short background and summary of the acid rain issue and the NAPAP program; Part II articulates three “propositions,” framed to address important issues concerning the application of scientific data and information in a policy context; and Part III evaluates NAPAP in terms of science-policy assessment criteria developed by the Global Environmental Assessment (GEA) project. The case study also explores ways in which the “NAPAP model” might be instructive for other large-scale, multi-disciplinary environmental assessment issues, such as global change.

Part I: Acid Rain and the U.S. National Acid Precipitation Assessment Program

Acid rain was discovered in England in the latter decades of the nineteenth century. However, it did not become a policy issue until about 1967, when the Swedish scientist Svante Oden and a scientific committee appointed by the Parliament of Sweden succeeded in calling the world's attention to the phenomenon at the United Nation's Conference on the Human Environment. Norway was the first European country to initiate a national program of research. Much of what was learned about the phenomenon was discovered through European, Scandinavian, and Canadian national research programs.

¹ This case study was adapted from an Island Press publication entitled “Predictive Modeling of Acid Rain: Obstacles to Generating Useful Information,” by Charles Herrick. *In Prediction: Science, Decision Making and the Future of Nature*. Island Press has granted permission to use its publication for this case study and to disseminate the completed case study on the AMS web site.

In the early 1970s, a number of U.S. scientists gained national attention by asserting that lakes in the Adirondack Park and other pristine areas of upper New York, Vermont and New Hampshire were dying from "acid rain." Environmental groups joined the debate, claiming that acid rain was damaging forests and lakes across the northeastern United States and Canada. The possibility that acid rain was responsible for observed damages to agricultural crops was also a matter of concern. It was argued that acid rain was caused by sulfur dioxide emissions from large, coal-burning power plants, mostly located in the Midwest and along the Ohio River Valley. Situated to take advantage of the region's high-sulfur coal reserves, these thermoelectric facilities provided much of the power for the U.S. industrial heartland. Emissions from these power plants were vented through tall smokestacks to help diffuse combustion by-products, thereby reducing local pollution. The use of tall stacks caused sulfur dioxide to be lofted into the atmosphere, where it could be transported by prevailing winds, mixed with precipitation and other "acid precursor" pollutants, and deposited in the Northeast in the form of acid rain.

Congressional leaders reacted to public outcry and demanded large reductions in emissions of sulfur dioxide from Midwestern power plants. However, the cost of reducing emissions was predicted to be very high, which raised the specter of increased electricity costs and increased unemployment in the high-sulfur coal industry. The acid rain debate was therefore regionally divisive, pitting states in the Northeast against those of the Midwest and the Ohio River Valley. The debate was punctuated by scientific uncertainties concerning the scope, nature, and magnitude of the acid rain phenomenon.

Efforts to assess the causes and effects of acid rain were initiated late in the Carter administration; research was continued and expanded under the Reagan administration, which endorsed the Acid Precipitation Act of 1980 (Title VII of the Energy Security Act of 1980, P.L. 96-294), creating a ten-year research program, the National Acid Precipitation Assessment Program (NAPAP). The NAPAP research program was directed by an Interagency Task Force composed of senior officials from the Departments of Agriculture, Energy, and the Interior, the National Oceanic and Atmospheric Administration, the Environmental Protection Agency, and the White House Council on Environmental Quality.

The scientific justification for NAPAP's research program was based on numerous uncertainties associated with acid deposition causes and effects. The policy justification for NAPAP was based on the need to better characterize the acid rain problem before committing the nation to a potentially costly and regionally divisive control and mitigation regime. This improved understanding of acid precipitation and its effects was to be utilized in a diagnostic and prescriptive context, specifically to derive and evaluate alternative policy scenarios. In other words, NAPAP was a clear example of science being marshaled to establish a foundation for environmental policy formulation.

The “Conventional” View of NAPAP: Sterling Science Lacking Policy Relevance: Studies conducted under NAPAP covered a broad range of disciplinary terrain, focusing on the following areas: emissions of acid precursor pollutants; atmospheric transport and chemical transformation dynamics; acid deposition regimes and air quality monitoring; effects on surface

waters, aquatic life, forests, agricultural crops, building materials, and cultural artifacts; human health and visibility degradation; and economic analysis of alternative control and mitigation strategies. NAPAP coordinated its research, monitoring, and assessment activities with states, academia, key international acid deposition research programs, and other nonfederal research organizations. NAPAP also reviewed the status of acid deposition control technology development programs, such as those conducted by the Electric Power Research Institute and the Department of Energy-sponsored Clean Coal Technology Program.

Most participants and observers agree that NAPAP was successful in meeting its scientific goals. This characterization is supported by at least four criteria: (1) the program funded and produced hundreds of successfully peer-reviewed articles and studies; (2) its major research components conducted regular programmatic peer review sessions, with a very high degree of positive evaluation; (3) evaluations performed by independent review bodies consistently cited high-quality science; and (4) program critics point to factors such as political manipulation of program reports, but never claim scientific incompetence. Specific areas of scientific accomplishment are shown in Exhibit 1, below.

Despite the wealth of scientific understanding created by NAPAP, almost all retrospective evaluations of the program are at least mildly critical of its lack of direct input into the policy process. (Roberts, 1991; Rubin, Lave, and Morgan, 1992; Kopp, 1993) At base, much of this criticism springs from the program's failure to articulate an unambiguous policy prescription ahead of the political schedule to reauthorize the Clean Air Act Amendments. Consider the following chronology: Vice President George Bush announced his support for acid rain reduction during the presidential campaign in 1988 and proposed legislation soon after his inauguration in 1989. However, there was no formal, publicly available statement of Principal Findings from NAPAP until June 1990, when the 1989 NAPAP Annual

Exhibit 1 – Scientific Accomplishments of NAPAP

Inventories: Development of the first continental-scale inventories of SO₂, NO_x, and VOCs.

Trends: Development of spatial and temporal trends in the chemistry of precipitation across the U.S. from 1980 through 1990.

Transformations: Improved understanding of the chemical transformations of airborne SO₂, NO_x, and VOCs, and their reaction products during transport from their point of origin to their ultimate deposition on soils, vegetation, surface waters, and materials.

Modeling: Development and partial validation of a prognostic, nonlinear model - the Regional Acid Deposition Model (RADM).

Gradients: Characterization and analysis of temporal, spatial, and elevational gradients in the chemical exposure of forests in a region extending from southeastern Ontario to western North Carolina.

Status Surveys: Development of methods to conduct regional surveys of the acid-base status of surface waters. These methods were applied to lakes and streams in several regions of the nation.

Linkages: Increased understanding of the linkages among both current and cumulative deposition of airborne sulfur and nitrogen compounds and the interactions of those substances with (a) the acid neutralizing capacity and other chemical properties of bedrock and soils; (b) the acidity and especially the alkalinity of surface waters; and (c) the nature, health, and productivity of aquatic ecosystems.

Impacts: Improved understanding of the effects of sulfur and nitrogen compounds on many natural and economic resources including agricultural crops, natural and commercial forests, agricultural and forest soils, aquatic ecosystems, human health, cultural artifacts, and the aesthetic quality of vistas in natural parks and other regions of the country.

Source: Cowling, 1992

Report was issued (NAPAP, 1989a). The Senate and House of Representatives passed their respective versions of the 1990 Clean Air Act Amendments in April 1990, and final passage of the Clean Air Act Amendments of 1990 occurred on October 22, 1990. President Bush signed the Amendments into law on November 15, 1990 (P.L. 101-549). By contrast, the initial draft of the NAPAP Integrated Assessment was completed in September 1990 and the document published in November 1991. (ORB, 1991) NAPAP was clearly behind schedule, at least in terms of the political acid rain debate. But there are two other ways in which it has been argued that the Program failed to meet its policy goals.

In the first place, little of NAPAP's plan to conduct an integrated modeling exercise was actually realized. (Smith, 1994) In most cases, NAPAP's predictive models were exercised in stand-alone disciplinary studies, integrated only in the sense that they employed deposition and/or air concentration estimates derived from the transport and transformation models as a basis for effects calculations. In most cases, NAPAP's models were not designed with integration in mind - they utilized discipline-specific constructs, assumptions, and variables. In many cases, models in the same discipline area (e.g., forestry effects) were not constructed to "nest" together, leading to a situation in which researchers could speak confidently about acidic deposition impacts on individual tree branches but not about impacts to whole trees, tree stands, or forests. In the end, NAPAP staff combined model-based information with monitoring data, findings from mechanistic and controlled exposure studies, survey information, and other research results to derive a composite picture of acid deposition causes and effects. NAPAP program managers referred to this as a "weight of evidence" approach.

In the second place, NAPAP's research program did not address key policy questions that actually animated the acid rain debate of the late 1980s. For instance, NAPAP was virtually silent on the issues such as the impacts of acid rain controls on regional coal mining employment (Rubin, Lave, and Morgan, 1992); it said little about the cost-benefit differences among the contending proposals for eight, ten, and twelve million tons of sulfur dioxide reduction. Likewise, NAPAP's aquatic and terrestrial effects studies provided little illumination on issues surrounding the timing, geographic dispersion, and sectoral focus of proposed control regimes. NAPAP research also failed to address issues pertinent to emissions trading, such as the problem of regional hot spots and the potential for economic savings (See Exhibit 2). Instead, NAPAP's 1990 Integrated Assessment Report answered questions such as: "How does acidic deposition affect red spruce at high elevation?" "How do simulated changes in ozone affect crop yields?" and "How much does light scattering by particles contribute to visibility reduction?" (NAPAP, 1991) In other words, NAPAP's findings were not transparently pertinent

Exhibit 2 – “Hot Spots” and Acid Rain Control

The Clean Air Act Amendments of 1990 instituted an innovative "cap and trade" system under which total SO₂ emissions were limited but individual sources were offered the option of either controlling emissions or purchasing excess emissions allocations under the trading program. During congressional debates over the acid rain provisions of the act, it was feared that strong emissions gradients, or hot spots, would result if sources in close geographic proximity to one another decided to purchase excess allotments rather than opting for SO₂ controls. It was argued that such a scenario was plausible even if the overall cap was not exceeded.

to the policy issues being debated prior to the formulation and passage of Title IV of the Clean Air Act Amendments of 1990.

The 1990 Clean Air Act Amendments and the 1991 USA-Canada Bilateral Air Quality

Accord: Elements of a “Solution” to the Acid Rain Problem: In 1990, Congress established an acid rain control program under the Clean Air Act Amendments. Administered by the U.S. Environmental Protection Agency, the primary goal of the program was to achieve reductions of 10 million tons of sulfur dioxide (SO₂) and 2 million tons of nitrogen oxides (NO_x). For SO₂, the program places a mandatory ceiling, or “cap,” on nationwide emissions from electric utilities, and allocates emissions to these pollution sources in the form of *allowances*. An allowance is an authorization to emit a single ton of SO₂. At the end of the year, sources must hold an allowance for each ton of SO₂ they emitted (See Exhibit 3 for additional background on SO₂ control under the CAAA). Extra allowances may be “banked,” carried over for future use, or sold to other companies. Sources must continuously monitor their emissions to assure that reduction objectives are achieved and sources are in compliance. (EPA, 1999)

Nitrogen oxides are treated differently under the Clean Air Act Amendments. Instead of using a cap and trade mechanism, Title IV calls for NO_x to be reduced by means of an enforced emissions rate for each source. This approach provides utilities with the opportunity to find cost-efficiencies while ensuring that overall emissions reductions are achieved by allowing emission rates to be averaged across a utilities boilers. (op cit)

Exhibit 3 – Sulfur Dioxide Reductions and Electric Utilities

Approximately 8.5 million tons of the CAAA reduction is coming from electric utilities. The utility reduction is occurring in two phases. In Phase I (January 1, 1995 - December 31, 1999) each of about 260 generating units at 110 plants receive annual allocations of sulfur dioxide allowances. In Phase II (effective January 1, 2000), the affected population consists of Phase I units plus about 700 more plants.

The signing of the USA-Canada Air Quality

Accord in 1991 came less than a year after passage of the Clean Air Act Amendments. Using 1980 emissions as a baseline, U.S. commitments under the Bilateral Accord included a 10 million ton reduction in sulfur dioxide emissions by the year 2000; and a 2 million ton reduction in nitrogen oxides emissions by 2000. Canadian commitments included a 2.3 million ton reduction in sulfur dioxide emissions by 1994, with a cap at 2.3 million tons from 1995-1999; and a 100,000 ton reduction in nitrogen oxides emissions (below a year 2000 forecast of 970,000 tones). While the 1991 Bilateral Accord did include a dispute resolution mechanism, it was not a legally binding policy instrument, and included no “hammer” provisions if either party failed to meet its commitments.

Part II: Science-Policy Applications – NAPAP as a Case Illustration

The following discussions are intended to stimulate discussion regarding several key aspects of NAPAP. Configured in terms of three “propositions,” discussion topics are framed to address important science-policy issues, using NAPAP as a case illustration. In order, the propositions address:

1. The policy relevance of scientific research,
2. Organizational issues associated with planning and conduct of science-policy assessments, and
3. Issues that impact the stability and continuity of long-term research and assessment programs.

Proposition 1: *NAPAP provided a policy relevant perspective on acid deposition vs. NAPAP did not provide a policy relevant perspective on acid deposition...*

Discussions of the role of science in public policy have long centered on the tension between rigor and relevance; or the notion that rigorous scientific research sometimes lacks policy applicability, while policy-relevant research tends to be swayed by political motivations and lacks objectivity and rigor. Where did NAPAP fall on the continuum between rigor and relevance?

Congress's stated objective in establishing NAPAP was to determine whether acid precipitation was a problem and, if so, what could be done about it. The problem with such a charge is that acid rain can be characterized from numerous valid perspectives: chemical, meteorological, biological, ecological, social, and others. Within each of these perspectives, further specialization is not only possible but, from a research point of view, absolutely necessary. However, technical characterizations developed under one disciplinary regime may be quite irrelevant or substantively inconsistent with approaches utilized under another discipline. They are likely to involve different spatial and temporal scales, different degrees of analytical detail due to different levels of expertise or funding, different assumptions concerning nonmeasured parameters, broadly divergent (and sometimes inconsistent) modeling approaches and statistical testing procedures, and so on. Indeed, constructs and methodologies can vary substantially within disciplines. The following examples illustrate the sort of intra disciplinary pluralism that came to typify NAPAP research. (Herrick and Jamieson, 1995)

- Aquatic damage from acid deposition can be characterized in several ways. If damages are stated in terms of the number of lakes affected, then projections of decreased deposition appear to provide a substantial decrease in damages. If the same projection is expressed in terms of percentages of affected lakes, then the decrease in damage appears less significant. If acidity is characterized in terms of pH (the standard chemical measure of acidity) rather than acid neutralizing capacity (ANC), then future gains would be smaller still. Moreover, the choice of a reference pH value can radically alter the number of "acidic" surface waters.² Numerous decisions must be made: A national scale assessment discounts regional variation; a focus on chronic acidity produces a different perspective than one including short-term episodes; analyses dealing with the current

² Surface water acidity depends on many factors, including the pH of precipitation, the chemical composition of watershed soils and bedrock, the flushing rate of a water body, the presence of nondeposition sources of acidity (e.g., organic acidity or mine drainage), and a variety of other watershed-specific factors.

situation may inadvertently miss longer-term processes threatening future degradation; and monitoring for direct effects may not reveal possible indirect or synoptic effects. Still another consideration is whether chemical acidification has actually harmed aquatic life. All of these measures are valid, but no one (or combination) of them is intrinsically more correct – or policy relevant – than others.

- A major impetus for acid rain control was the fear of damage to aquatic resources. NAPAP's aquatic effects research team determined that 4 percent of U.S. lakes and 8 percent of streams were acidic, with values that varied from region to region. Florida had the highest percentage of acidic surface waters (33 percent of lakes and 39 percent of streams). In the mid-Atlantic Highlands, mid-Atlantic Coastal Plain, and the Adirondacks, 6-14 percent of lakes and streams were chronically acidic; about three times that number were subject to periods of temporary acidification (days to weeks) due to storms and snowmelt conditions. Yet as soon as these facts were reported, other scientists argued that many lakes were naturally acidic because forest soils and organic decomposition produced a "normal" acidic condition, especially for smaller lakes. In other words, lakes and streams may indeed have been acidic, but not necessarily because of air pollution. Indeed, some scientists argued that the dominant theory of surface water acidification was wrong, that it failed to address natural factors controlling surface water chemistry.

If edification is one's objective, then it does not matter whether surface water acidification is characterized in terms of pH or ANC. Once the research questions have been appropriately bounded and documented, the matter is settled. However, the policy context does not accommodate the "luxury" of a bounded, or disciplinary, perspective. This dynamic is especially pertinent to science-policy-assessment initiatives predicated on the development of "authoritative" findings and information.

NAPAP found it difficult to move beyond a disciplinary outlook, approach, and structure. Indeed, the outline for NAPAP's integrated assessment was predominantly oriented toward exposition of basic facts on a discipline-by-discipline basis. (NAPAP, 1989) Disciplinary boundaries are helpful in "normal" science; however, they present difficulties in science-based analysis of policy issues. Disputes tend to arise over the boundaries between disciplines, resulting in a lack of consensus concerning which rules, constructs, and methods are most relevant or "weighty" in a given situation. This, in turn, leads to disputes concerning the strength and validity of scientific evidence. Disputes such as these can bedevil the process of integrated research; in particular, such disputes can prolong the assessment process and create opportunities for policy entrepreneurs to "game" the research process.

As argued above, NAPAP was unable to address acid rain as a coherent policy problem. Instead, it remained many separate issues, each bounded by disciplinary and methodological conventions. Defining its activity in terms of disciplinary science, NAPAP lacked the nondisciplinary perspective that would have allowed it to characterize acid rain in terms of a set of policy options (Herrick and Jamieson, 1995; Rubin et al., 1992). In other words, NAPAP was able to produce a

"banquet" of data and findings but unable to help nonspecialist decision makers to determine which "dishes" should weigh most heavily, or indeed, even be considered in the policy choice. (Herrick and Jamieson, 1995)

But perhaps there is a different "take" on this perspective. Democratic government is based on the presumption that an informed citizenry is able to make sound decisions. NAPAP's banquet of high-quality findings was equally available to all sides of the acid rain debate, enabling policy advocates to draw upon scientific findings and model-based projections to develop whatever policy scenarios they saw fit. Can scientific information and predictive modeling activities add value in a policy context even if they do not address specific policy prescriptions?

Knowledge utilization theorists, such as Webber and Weiss distinguish between the *instrumental* and *conceptual* uses of scientific data and information. (Weiss, 1981; Webber, 1992; Scott, 2002) The instrumental use of scientific information implies that scientific outputs have direct application in the formulation or administration of a specific policy regime. The conceptual utilization of science implies that scientific outputs have been incorporated into broad, public discourse regarding a general topic, issue area, or state-of-affairs. Based on observation of European assessment programs dealing with a variety of environmental issues, Scott argues that the conceptual use of scientific information is likely more prevalent and more significant than instrumental use. "Instrumental use is often restricted to relatively low-level decisions, where the stakes are small and users' interest relatively unaffected. Conceptual use, which does not necessarily involve the immediate or direct application of conclusions to decisions, can gradually bring about major shifts in awareness and reorientation of basic perspectives." (Scott, 2000) Going further, Webber asserts that it is easy to "focus too narrowly on use [of scientific data and findings] as a behavior attributed to an individual policy maker, while under-emphasizing the importance of dissemination and diffusion activities over which policy makers exert little control." (Webber, 1992)

Most of NAPAP's critics have focused on the program's high-visibility reports and studies. (Roberts, 1991; Rubin et al., 1992) Few acknowledge or seriously consider the fact that NAPAP and Task Force staff responded to numerous congressional queries and requests for information. Many inquiries were also received from governors and other state and local officials, NGOs, and other interest organizations. In addition, NAPAP and task force staff fielded hundreds, perhaps thousands, of telephone queries and requests for information. Many of those phone conversations were with key congressional staffers. NAPAP staff were also generous in their dealings with the media, answering hundreds of questions in real time. Much to the chagrin of the Task Force, some of the program's data and findings actually debuted in the popular media, with a series of articles by the syndicated columnist Warren Brookes gaining particular notoriety. For from being absent from the Clean Air Act debate, a case might be made that NAPAP findings were actually ammunition for frontline troops in the Clean Air Act debates. While NAPAP's various assessment reports may not have "settled" the acid rain policy debate, they at least assured that the public debate was fueled by solid information, rather than "junk science."

Some observers take this perspective a step further, arguing that NAPAP data and findings set

the stage for the acid rain policy decisions embodied in the Clean Air Act Amendments of 1990. (Russell, 1992) In the late 1970s and early 1980s some scientists and much of the public believed that acid rain posed a grave, immediate, and irreversible threat to the health and productivity of aquatic and terrestrial ecosystems. By contrast, other scientists and some of the public believed that air pollution was a predominantly an urban problem, that the acids present in precipitation were much too dilute to have significant effects on any but the most sensitive lakes and streams, and that acid rain was unlikely to affect crops or forests. Given this polarization and lack of a defining majority on either side, political action was probably impossible. Even if an acid rain control policy could have been forced through Congress, the scars would have made compliance difficult and tainted the atmosphere for cooperation on other environmental issues.

By the time NAPAP concluded its decade of research, these extreme views had converged into a more moderate middle ground. The flow of information from NAPAP may thus have educated the public and decision makers throughout the program's life, effectively "enrolling" more and more advocates into a moderate middle ground. By the time NAPAP's final assessment reports were released, a large proportion of the U.S. population was aware of the issue, the poles of debate had collapsed, and parties on all sides recognized that there was enough merit on the other side that a compromise solution was both possible and legitimate. Under that perspective, NAPAP findings may have provided value not so much through provision of a science-based policy prescription, but as a heuristic device to help highlight issues and areas of scientific congruence, disagreement, and uncertainty.

Proposition 2: The NAPAP organizational structure was conducive to the development of policy-relevant, objective scientific assessments of acid deposition vs. the NAPAP organizational structure was not conducive to development of policy-relevant, objective scientific assessments of acid deposition...

NAPAP involved 12 Federal agencies, hundreds of scientists within and outside of the federal government, and cost more than a half billion dollars. NAPAP was managed through an interagency mechanism consisting of six "leading agencies," each with a different mission, focus, and basis of research expertise. This organizational structure had the constructive effect of coordinating the research activities of the different federal agencies. The program's research funding, workshops, and joint publications helped create an "epistemic community" surrounding the acid rain issue, which may have helped to nourish the dialogue that led eventually to a policy solution. However, NAPAP had no true "lead agency" with both budgetary and administrative authority over program activities. Instead, the program evolved a consensus management approach that required all six lead agencies to approve NAPAP's reports, testimony, research plans, and other official documentation prior to their release to the President, Congress, and the public.³ It is argued that this led to compromise solutions in which research and assessment results were frequently "watered down" to suit the differing positions and missions of the lead agencies and their stakeholders. (Winstanley et al., 1998; Cowling, 1992)

³ In the case of Congressional testimony or responses to Congressional inquiries, Office of Management and budget approval was also required.

While NAPAP may have published compromise solutions, it may be a mistake to pin this on the dilution of research results. It has been suggested that NAPAP was overly influenced by the political leadership of its lead agencies. However, as was argued under Proposition 1, above, the policy salience of NAPAP's findings is itself a matter of legitimate dispute. NAPAP did not have a single, clear, and cohesive policy story to tell; for that matter, NAPAP failed to characterize and evaluate alternative policy scenarios. Instead, NAPAP remained hunkered in mainstream, disciplinary science, answering questions that were restricted in scope (e.g., "What is the effect of acidic deposition on high-elevation red spruce?"), confined to specific disciplinary paradigms, and not readily amenable to application in a broader policy environment.

With the exception of the White House Council on Environmental Quality and the Environmental Protection Agency, NAPAP was run by old-line science agencies. Those agencies never demanded that NAPAP break out of its disciplinary research program and pursue integrated assessments of alternative policy scenarios. One take on the NAPAP experience is that it suggests the need for a new institutional arrangement to help create and sustain a match between social issues, the research agenda, and the methodological needs of policy analysis. Apart from the (now defunct) Office of Technology Assessment (OTA), the federal environmental regime includes no institution for the ongoing integration of "what policy analysts want to accomplish and what researchers can reasonably achieve." (Sarewitz, 1996) Perhaps the policy application of scientific research and findings might best be accomplished through an organization separate from those that conduct the scientific research on a particular issue. Such an arrangement would create an organization with no wiggle room to claim partial success for broadening the scientific knowledge base with its results, even if they weren't policy relevant. Perhaps such an organization could "commission" research agencies to develop state-of-the-science reports, use contractual mechanisms to specify the models to be built and their capabilities, and maintain channels of constructive negotiation with the science community over the timing and plausibility of specific tasks. Under such an arrangement, scientific research, model development, and policy analysis would be conducted in parallel, not sequentially. As demonstrated by NAPAP, the typical sequential application - basic research, followed by model development and integration, followed by policy analysis - allows too few opportunities for policy analysts to steer and influence research and prediction activities.⁴

As another alternative, NAPAP might have adopted an explicitly "interactive" style of research and assessment. Drawing mostly on the European experience, Huberman, Scott, and others argue that the relevance of research can be enhanced if researchers and policy practitioners jointly define and elaborate research strategies. Under such a model, the research and assessment teams would "devote a substantial amount of time and energy...negotiating with potential users the particular questions about which [they] are most passionately and urgently interested." (Scott, 2001) It could be argued that NAPAP was not nearly proactive enough in its efforts to seek policy and stakeholder input, or more pertinently, in an effort to establish sustained dialog with the policy community. To be sure, NAPAP communicated its findings to

⁴ Note on the concept and role of boundary organizations...

the policy community, but its outreach was mostly “reactive,” as opposed to reflexive and interactive.⁵

Still another alternative might involve a combination of adaptive management, *ex post* program evaluation, and environmental monitoring. Such an approach would draw on both the theory of policy sciences (Herrick and Sarewitz, 2000; Lasswell, 1997; Brunner and Ascher, 1992) and the growing use of adaptive approaches to ecosystem management. Rather than predicating action on the reduction of uncertainty, the adaptive approach to environmental policy acknowledges that both our ability to craft public policy and our scientific understanding of natural phenomena are imperfect. As explained by Kai Lee (1993):

[An] adaptive policy is one that is designed from the outset to test clearly formulated hypotheses about the behavior of an ecosystem being changed by human [use or intervention] ...If the policy succeeds, the hypothesis is affirmed. But if the policy fails, an adaptive design permits learning, so that future decisions can proceed from a better base of understanding... Adaptive management is highly advantageous when policy makers face uncertainty, as they almost always do in the environmental arena.

This fact may help to illuminate an effective role for science in policy making - not to attempt to predict and dictate policy choices but to monitor the effectiveness of those choices after they have been made.

As an alternative to the large-scale, long-term research and modeling program played out under NAPAP, Congress and the administration could have acknowledged the uncertainties associated with the acid rain debate and initiated an "experimental" series of spatially and temporally restricted control regimes. Indeed, by the mid-1980s, several states and Canadian provinces had already initiated acid rain control programs. Such regimes could have been federally subsidized and monitored for comparative outcome. Regimes that appeared effective could have been replicated and ineffective approaches

Exhibit 4 – The Environment’s Response to the Clean Air Act

- Ecosystems most severely impacted by acid deposition, such as the Adirondacks, have not yet shown signs of recovery. Some scientists believe that further reductions in SO₂ and NO_x may be necessary.
- Some surface water chemistry trends in New England are showing signs of recovery, as indicated by a rise in acid neutralizing capacity.
- In the Northeast and Mid-Atlantic regions of the U.S., sulfate levels in precipitation have declined by up to 25%, mirroring reductions in SO₂ emissions. No distinct regional trends in wet deposition of nitrate have been detected; which is consistent with NO_x emissions trends that have remained constant over the past decade.

Source: U.S. EPA, 1999

⁵ The interactive style of research would appear to be inconsistent with recent calls to *separate* the government’s science and policy functions. See for example, “Blueprint 2001: Drafting Environmental Policy for the Future,” published by The Business Roundtable (<http://www.brtable.org/document.cfm/496>)

modified or terminated.

Ironically, Title IX of the Clean Air Act Amendments of 1990 did include provisions for policy evaluation, ongoing monitoring, and progress assessment. Title IX reauthorized NAPAP as a mechanism to evaluate the effectiveness of the acid rain provisions of the Clean Air Act, including the effectiveness of the emissions trading program mandated under Title IV. To their credit, Congressional authors of the 1990 amendments recognized an opportunity to establish an adaptive policy regime. However, most observers agree that implementation of Title IX has been weak and sporadic. Acidic deposition monitoring networks have shrunk due to funding cutbacks, model validation activities have been postponed, and research on mechanisms has been curtailed.

Proposition 3: *NAPAP stayed “true” to its original design vs. NAPAP did not stay true to its original mandate and was diverted by politics...*

When issues are scientifically complex and politically sensitive, it is perhaps inevitable that it will be difficult and controversial to delineate at the start of the program a precise and unyielding scope of study (Winstanley, et al, 1998; Allen and Gould, 1986). Particularly with a 10 year program, it can be expected that the scientific understanding will evolve and policy interests will change.

By establishing NAPAP, Congress intended to conduct research to guide policy action. The stated purposes of Title VII of the Acid Precipitation Act of 1980 were:

1. To identify the causes and sources of acid precipitation;
2. To evaluate the environmental, social and economic effects of acid precipitation; and
3. Based on the results of the research program...[to] take action to the extent necessary and practicable (A) to limit or eliminate the identified sources of acid precipitation, and (B) to remedy or otherwise ameliorate the harmful effects which may result from acid precipitation.

Title VII mandated a wide variety of scientific and analytical activity, ranging from basic causal research (objective 1), to socioeconomic impact assessment (objective 2), and included applied policy analysis and a mandate for prescriptive policy development (objective 3). The NAPAP interagency management team went through several exercises intended to articulate linkages between policy needs and the Program's research objectives. The policy focus embodied in P.L. 96-294 is reflected in NAPAP's early organizational structure, which included eight scientific and technological research categories and a ninth category called *Assessment and Policy Analysis*. Articulated in NAPAP's initial assessment plan, the goal of the assessment and policy analysis function was to "provide an objective basis for establishing sound energy production, resource management and environmental protection policies" (NAPAP, 1981). The plan stated that such information is "urgently required because (1) there is a growing national and international concern about acid precipitation and its effects; (2) projected changes in energy policies...could result in the emission of more precursors of acid precipitation; (3) present information on acid precipitation is insufficient to support the development of models capable of

predicting its occurrence and assessing its consequence; and (4) a number of potentially irreversible effects of acid deposition have been postulated, but if, when, and where these may occur cannot now be predicted with confidence."

NAPAP's early policy focus is also reflected in the program's first annual report, published in January 1982, which summarized NAPAP's Research Policy Focus in terms of three questions about acid precipitation: "(1) What is it? (2) What are its impacts? [and] (3) How can it be effectively managed?" (NAPAP, 1982a). During the program's first annual review meeting, agency scientists and outside observers (from nongovernmental organizations, and industry) developed a list of "Task Force Outputs Which Answer Policy Questions." In this exercise, specific policy questions were formulated and specific (expected) research outputs identified that would help to answer each question. The meeting was structured around four topics, one of which was entitled "Research and Assessments to Address Policy Concerns." It is clear from the meeting report that NAPAP scientists were aware of the need to address specific policy issues and to do so quickly (NAPAP, 1982b).

But NAPAP's initial policy focus was soon to dissipate. As mentioned above, NAPAP's initial organization structure included an Assessment and Policy Analysis category, funded at \$1.36 million (8 percent of the NAPAP budget). By the time the 1983 Annual Report was published, the "Policy Analysis" research category had been eliminated, and replaced simply by "Assessments" (NAPAP, 1983). NAPAP's 1984 Annual Report indicates a pervasive turn away from policy objectives as a source of program direction. For instance, a four-page section of the report entitled "Highlights of Program Accomplishments" does not address or even allude to the policy relevance of NAPAP's research and monitoring accomplishments; indeed, it does not even use the word "policy." Moreover, a section entitled "The Role of Science" circumscribes NAPAP's research domain and admonishes policy officials to make the "subjective judgments" necessary to determine an appropriate response to the acid precipitation issue:

Decision makers, not researchers, must decide the level of scientific information necessary for decision making. Scientists attempt to define at any point in time what is known, with what level of certainty, and what is not yet known...Some of the issues which decision makers address require making a host of subjective judgments for which scientists have no special expertise. For example, scientists have the task of relating the response of ecosystems to the amount of acid deposition they receive; but it is the role of the policy maker to determine the acceptable level of response - whether emissions should be limited further, and by how much, considering the social costs and benefits in addition to other factors (NAPAP, 1984).

Clearly inconsistent with two of the three original program directives articulated in Title VII, this statement also removes economics and policy analysis from the "appropriate" sphere of scientific activity and seeks to draw a well-defined boundary between the research and policy processes. After 1984, economics and integrated assessment virtually disappeared as program priorities, replaced by an emphasis on the primacy of basic, "curiosity-driven" science (ORB, 1991). After

the appointment of a new NAPAP director in 1988, the program again turned toward the development of integrated, policy-focused assessments. The plan for NAPAP's final assessment described twenty-five diverse policy and control scenarios; however, most of these scenarios were never formally modeled, or for that matter, used to frame analyses.

Despite late efforts to return NAPAP to its “roots,” it would seem that, overall, the Program did not stick to its initial mandate, a conclusion supported by the NAPAP Oversight Review Board (ORB):

It is our judgement that the assessment function to which NAPAP’s scientific and technical findings were to contribute was not as fully successful as the research process. The assessment function should have been the central focus of the NAPAP endeavor from the first, but it was not adequately addressed, supported, or carried through at key points of the Program. (ORB,1991)

In its final report, the ORB evaluated the NAPAP experience and articulated a series of nine “lessons learned” for future science-policy assessment initiatives. Three of the ORB lessons deal directly with the issue of programmatic continuity.

- **Obtain and Maintain Political Commitment:** It has been argued that political pressures influenced NAPAP’s research and assessment portfolio, reporting protocols, and overall approach toward public communication. (Moore, 1990; Winstanley et al, 1998) Political interest in NAPAP waxed and waned over the Program’s ten-year life span, both on the part of the Executive and Legislative branches. The ORB suggests that NAPAP’s managers should have worked harder to involve their political overseers, creating a more stable environment for research, monitoring, and policy assessment activities.
- **Take Steps to Assure Continuity:** “Long-term research and assessment programs require continuity in vision, goals, and implementation if they are not to disintegrate into loosely related projects or to wither as initial enthusiasm wanes.” (ORB, 1991) Long-term assessment activities require a managerial regime that is at least somewhat insulated from changes in political leadership. The ORB suggests several specific mechanisms to assure program continuity: (1) key research and program leaders should be appointed for the duration of the program; (2) the assessment and coordinating functions should be managed by an independent office, rather than the participating agencies; and (3) program funding should be tied to a long-term budgetary plan, backed by the informed approval of OMB and relevant Congressional committees.
- **Provide for Independent External Programmatic Oversight:** It was late in its programmatic tenure before NAPAP established a standing external review and advisory body. Comprised of distinguished scholars and research managers, the ORB became a powerful constituency, independent of political vicissitudes and bureaucratic rationalities. Were such a body in place throughout NAPAP’s life-span, it might have helped the Program to execute its mission in a more stable manner.

Part III: Reviewing NAPAP in Terms of Criteria Developed by the Global Environmental Assessment Project

Founded in 1995, the Global Environmental Assessment (GEA) Project has evaluated the effectiveness of a variety of domestic and international assessment efforts, including issues such as climate change, ozone depletion, tropospheric air pollution, biodiversity, and chemical pollution.⁶ As a result of this work, GEA has come to view assessments as “social processes linking knowledge and action in public policy/decision contexts, usually entailing the creation of discrete products (e.g. models, forecasts, reports) and typically conducted within an institutional framework of rules, norms and expectations. (Eckley et al, 2001) GEA research suggests that assessments are effective to the degree that they are viewed as credible, salient, and legitimate to users.

- **Credibility** addresses the scientific and technical believability of the assessment to defined users. Credibility can be gained based on the process by which the information in the assessment was created, or by the credentials or other characteristics of those producing the assessment.
- **Salience** reflects the ability of an assessment to address the particular concerns of a user. An assessment is salient to a user, if that user is aware of the assessment, and if that user deems that assessment relevant to current policy or behavioral decisions.
- **Legitimacy** is a measure of the political acceptability or perceived fairness of an assessment to a user. A legitimate assessment process has been conducted in a manner that allows users to be satisfied that their interests were taken into account, and that the process was fair. Participants must believe that their interests, concerns, views, and perspectives were included and given appropriate weight and consideration in an assessment if they are to grant the assessment legitimacy.

Based on evidence and arguments discussed under Parts I and II of this report, above, it would seem that NAPAP provides support for the GEA proposition that assessments should be understood as “social processes” linking knowledge and action in a decision context. NAPAP’s management and institutional context had a clear impact upon the type of research questions that the Program addressed. It seems clear that alternative institutional arrangements and priorities could have lead to the development of a significantly different overall assessment of the acidic deposition phenomenon. This notwithstanding, it is tricky to characterize NAPAP in terms of the GEA categories, with the possible exception of “credibility.”

Credibility: As discussed earlier, most observers express nearly unqualified respect for NAPAP’s scientific output. Even so, it is perhaps worth recalling that there were episodes during which NAPAP struggled with issues of basic scientific credibility. In particular, the Executive Summary of NAPAP’s *1987 Interim Assessment* was heavily criticized by both U.S. and Canadian reviewers, resulting in some “tense” Congressional hearings and the hurried

⁶ For more on the Global Environmental Assessment (GEA) project, see <http://environment.harvard.edu/gea>.

development of several response documents. This notwithstanding, NAPAP enjoyed a high degree of scientific credibility.

Saliency: Did NAPAP's findings "resonate" with their intended users? This depends on one's perspective. If saliency is understood in terms of the Program's instrumental value in policy formulation or implementation, then it probably has to be scored as low; however, if saliency is understood in a conceptual sense, then NAPAP might score quite high. Either way, it is probably indisputable that NAPAP's effectiveness would have been enhanced by a more proactive, aggressive, sustained, and interactive communications philosophy. In my view, NAPAP tended to view communications as a "bolt on" exercise at the end of the research and assessment process, not as an ongoing, reflexive activity.

Legitimacy: The ambiguity associated with saliency (above) makes it difficult to assess the legitimacy of NAPAP. As I have already suggested, NAPAP produced a banquet of high quality data and findings. This resulted in a situation in which stakeholders from all points of the policy spectrum could pick and choose among NAPAP outputs, finding data and research results to support their particular perspective. (Herrick and Jamieson, 1995) Indeed, there were spirited debates over the "soul" of NAPAP, whether the program did or did not support the need for acid rain controls. In this sense, it might be argued that NAPAP was very "legitimate" because it was whatever anyone wanted or needed it to be.

NAPAP as a Model for Other Assessment Issues: This case study will be discussed during the AMS Summer 2002 Policy Colloquium. Input from colloquium discussions will be used to revise the case study and articulate a perspective on NAPAP's applicability as a model for other large-scale, multi-disciplinary environmental assessment issues.

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Appendix I

Major NAPAP Reports and Documents

Early Planning Documents

National Acid Precipitation Assessment Plan, Interagency Task Force on Acid Precipitation, January 1981.

Annual Reports

Interagency Task Force on Acid Precipitation: First Annual report to the President and the Congress of the United States, January 1982.

NAPAP Annual Report 1982 to the President and Congress.

NAPAP Annual Report 1984 to the President and Congress.

NAPAP Annual Report 1985 to the President and Congress

1987 Annual Report to the President and Congress, National Acid Precipitation Assessment Program.

1988 Annual Report to the President and Congress, National Acid Precipitation Assessment Program.

1983-85 Review and Assessment Documents

Critical Assessment Review Paper. Volume I, Atmospheric sciences; Volume II, Effects Sciences. EPA Report No. EPA/600/8-85. Environmental Protection Agency, Office of Research and Development, Washington, DC.

The Acidic Deposition Phenomenon and Effects: Critical Assessment Document. EPA Report No. EPA/600/8-85. Environmental Protection Agency, Office of Research and Development, Washington, DC.

NAPAP (1987) Interim Assessment

NAPAP Interim Assessment: The Causes and Effects of Acidic Deposition. NAPAP, Washington, DC. September, 1987.

- Volume I: Executive Summary
- Volume II: Emissions and Controls
- Volume III: Atmospheric Process and Deposition
- Volume IV: Effects of Acidic Deposition

NAPAP (1990) Integrated Assessment

Plan and Schedule for NAPAP Assessment Reports, January 1989

Assessment Plan Update, August 1989

NAPAP 1990 Integrated Assessment, November 1991

Acidic Deposition: An Inventory of Non-Federal research, Monitoring, and Assessment information, National Acid Precipitation Assessment Program, January 1990.

NAPAP (1990) State of Science and State of Technology Reports (27 topical reports)

Post 1990 Program Planning

Mission, Goals, and Program Plan: Post 1990, The U.S. National Acid Precipitation Assessment Program, Public Review Draft, November 1991.

