Elisabeth A. Graffy
U.S. Geological Survey

Meeting the Challenges of Policy-Relevant Science: Bridging Theory and Practice

Thinking About Public Administration in New Ways

Ongoing public debate about the role of science in policy making signifies the importance of advancing theory and practice in the field. Indeed, assumptions about the science–policy nexus hold direct implications for how this interface is managed. A useful lens on contemporary themes is offered by the experience of a federal environmental science program that launched an ambitious effort to enhance capacity for policy relevance while protecting a commitment to sound, impartial scientific inquiry. This was achieved by developing an explicit conceptual model and implementing corresponding strategies that addressed critical gaps in capacity for policy-relevant research, analysis, and communication while supporting existing capacities. This article describes and evaluates the capacity-building effort from the dual perspectives of deepening an understanding of successful practice in the field and advancing a conceptual understanding of the science–policy nexus. It illustrates the challenges facing practitioners and the need for greater interaction between theory and practice.

Frequent calls to craft science-based policy, enhance the societal relevance and accountability of science, and more clearly delineate the threshold between the use and misuse of science in policy making highlight the importance of the science–policy nexus. However, responses to these calls tend to be ad hoc and circumstantial. The relationship between science and policy is commonly assumed to be a linear one in which scientific "truths" are disseminated to policy makers who may or may not accept them, or as an incomprehensibly complex, highly charged interface where scientific and political cultures inevitably clash on epistemological or value-laden grounds. For practitioners, neither set of assumptions is a satisfactory guide for creating effective linkages between science and policy development. Pressure is particularly great in the environmental and natural resources arena, where decisions about land use, competition for water, energy development, climate, natural hazards, public health, and species protection are widespread and may have multibillion-dollar implications, as well as consequences for human health, safety, and quality of life. There is a critical need to develop better theoretical understandings of the science–policy nexus and practical management strategies that are capable of enhancing the accountability and policy relevance of scientific research while preserving its core of independent inquiry.

There is a critical need to develop better theoretical understandings of the science–policy nexus and practical management strategies that are capable of enhancing the accountability and policy relevance of scientific research while preserving its core of independent inquiry.

This article makes a contribution on both fronts by presenting a heuristic model of science–policy interaction and examining its practical value in the experience of a federal environmental science program that, responding to contemporary challenges, sought to enhance its capacity for policy relevance while protecting its commitment to sound, impartial science. When that effort began in the mid-1990s, it was experimental and innovative, with no known comparable precedents. The science–policy model that guided the effort was not previously available in the literature and demonstrated its value as a strategic management and diagnostic tool. Clearly, how the relationship between science and policy is conceptualized holds important implications for practice, and the critical importance of building stronger bridges between theory and practice to meet the challenges associated with meaningful pursuit of policy-relevant science and science-based policy cannot be overstated.

Background and Impetus for Change

The National Water-Quality Assessment (NAWQA) Program of the U.S. Geological Survey (USGS) has the unique responsibility of undertaking comprehensive

Elisabeth A. Graffy focuses on policy development and its interaction with organizational and societal change, particularly as related to agriculture, environment, and the sustainability of natural resources (and of the human communities that depend on them). She has given public presentations nationwide on the relationship between science and policy. She has served in state, city, international, and federal positions, most recently with the U.S. Congress and the Department of the Interior. Her writings appear in many reports and in articles that have appeared in *Society and Natural Resources*, the *International Journal of Global Environmental Issues*, and other publications.
E-mail: egraffy@usgs.gov

monitoring of rivers, streams, aquatic ecology, and groundwater in about 50 major river basins nationwide. Initiated in 1991 in response to congressional inquiries as to whether water conditions were improving as a result of the Clean Water Act and related initiatives, the provision of useful information to resource managers and policy makers was considered an implicit but somewhat unarticulated part of the program's mission.

The primary mission of the USGS as a whole includes earth science investigations that emphasize data collection and environmental monitoring, with historically little direct involvement in national policy processes. Indeed, scientists are legally prohibited from making policy recommendations, and adherence to these constraints had resulted in a culture that discouraged scientists from responding to the information needs of policy makers except by providing technical documents and data sets.

A perception took hold among the senior USGS management during the mid-1990s that Congress was unwilling or unable to use scientific information as traditionally provided and that public concerns about the agency's relevance were growing. These perceptions were based partly on cautionary anecdotes and partly on a string of tight budgets that were seen as evidence of a decline in the status of public support for science. Closer to home, the so-called Contract with America, adopted by the Republican majority in Congress during 1994 (U.S. House 1995), involved a goal of shrinking the size of the federal government, and the USGS was one of several agencies suggested for elimination (Gauvin 1995; Miller 1995).

An additional factor in the overall impetus for change was the Government Performance Results Act of 1993, which elevated expectations regarding the results and accountability exhibited by all federal agencies. Defining goals for improving results and accountability in agencies offering direct services to citizens seemed straightforward, but that task was far less clear in a science agency whose historical mission was to provide high-quality data and reports that might indirectly affect the lives and livelihood of citizens but that had little direct service-related contact with them. As an initial response, the agency improved its dissemination of reports and statistical data sets, and the volume of postings to the Internet expanded dramatically in a trend that continues to the present time. This strategy proved to be valuable but insufficient for alleviating all concerns about relevance, and fresh examination of the complexities of the science–policy relationship led to the effort described in this article.

It is helpful to understand that while concerns about enhancing the policy relevance of science may have seemed to grow out of situational political pressures, they did not emerge suddenly or without a broader societal context. The societal trend for many decades had been a gradual shift from somewhat unquestioning public support for scientific inquiry that characterized the period after World War II to a respectful but more skeptical regard for science (Lewenstein 1992; Tarlock 2002; Yearley 1988). The idea that science was apart from and somehow above society became overtaken by a view of science as part of society, and questions of accountability correspondingly arose. By the 1990s, calls for scientists to engage more effectively with society had become quite common, from scientists who sensed a new dynamic emerging (Guston, Woodhouse, and Sarewitz 2001; Lubchenko 1998; National Research Council 1998; Toman 1998), from policy makers who saw the importance of scientific involvement in practical problem solving (Boehlert 2002; Ehlers 2002), and from civil society with its emphasis on participatory democracy (Addis and Lee 1996; Beierle and Cayford 2002; Ingram and Schneider 1998). These calls cited the need to improve the quality of public decisions by using more science, to increase the accountability of science to society and social values, or a mixture of the two. They reflected a heightened awareness of the unresolved normative and pragmatic tensions surrounding society's authority over and accountability to science, and science's authority over and accountability to society (Ingram and McDonald 2002; Moss 1982; Tarlock 2002).

The direct effects of these broader social trends on USGS water-quality science activities may have been delayed, possibly by insulating institutional factors or simply because the pertinent scientific capability that enabled interaction with the water policy domain was just emerging in the 1990s. Indeed, the NAWQA had to "create" much of the science on which the program's work was based (Miller 1995, 2003). In any case, the maturation of the program coincided with broader historical and political forces that may have magnified situational pressures, and the NAWQA program was under substantial pressure to demonstrate policy relevance. As the agency's flagship water-quality program, it was closely watched when it launched an effort in 1995 to increase the relevance of its scientific information to national policy making, confronting logistical, managerial, and cultural challenges along the way. Could policy relevance be enhanced without crossing the line into recommending policy? What were the goals for enhancing policy relevance? Could policy relevance occur without fundamentally undermining the scientific, independent culture of the agency?

Over six years, this effort demonstrated the feasibility of making monitoring, analysis, and communication more responsive to the needs of managers and policy makers without sacrificing scientific credibility. Results suggested that the new strategies may even have helped sharpen scientific analysis while making findings more useful to nonscientists. The interplay between the conceptualization of the science–policy nexus and the strategies adopted by practitioners was illuminated as well because the strategies adopted flowed fairly directly from the heuristic model that guided the effort. Key choices made along the way would likely have been quite different if a different conceptual model had been adopted at the outset. At the same time, trust in the conceptual model was strengthened when reliance on it led to more effective practice. The realization of a recursive relationship between concepts and action leads to a greater appreciation of the need to link theory and practice more effectively in this field.

Methods and Approach

The experiment recounted in this article did not originate from academic inquiry but rather from a practical need to meet a program management challenge, and the methodological rigors associated with academic research are not always accepted as timely or entirely applicable in the dynamic atmosphere of practice. However, there is great interest among practitioners in discovering better ways to manage resources or solve problems. The methods used in this case were developed to satisfy the evaluation needs of practice but were rooted in styles of academic analysis in order to support fuller evaluation of the results and lessons learned.

When the effort began, little academic scholarship was available to serve as a direct guide, and no comparable cases from other agencies were available to use as role models. There was no consensus among the agency's senior management as to whether enhanced relevance would result from simply marketing existing scientific information better or whether it would require more profound institutional change. There was substantial confusion about the nature of the science–policy relationship, the cause behind the current challenge, and the potential solutions. Confronting this challenge, therefore, entailed several phases: developing a clearer concept about the nature of the science–policy nexus; assessing the contemporary challenge and corresponding goals and solutions; and initiating a plan that could move successfully from concept to action. Evaluation of results, while sometimes regarded as a luxury in the arena of practice, was a seminal aspect of this effort. Not only was it necessary to confirm whether stated goals were being achieved, but additional issues and observations that emerged during the effort and prompted interest in evaluating whether the concepts and techniques related to science-policy dynamics and organizational change could be replicated and generalized beyond the effort at hand.

Practitioners often speak of learning by doing, and the methods illustrated in this article go a step further by systematically linking doing and reflecting. Such an approach seeks to achieve a more holistic understanding and supports a mutually reinforcing, interactive relationship between theory and practice. Methods that encourage disciplined reflection on one's own practice in order to deepen theoretical understanding and inform future practice are found in several fields. In philosophical terms, an embeddedness of theory and practice is termed *praxis* (Dixon and Dogan 2003). In education, the process of integrating doing and reflecting is called *action research* (McCutcheon and Jung 1990, 148). In organization and management, *action science* connotes a process of critical reflection that can lead to changes in thought and action (Putnam 1999), and *practical theorist* denotes a scholar who can "span boundaries" between theory and practice, deliberately seeking to overcome alienation between them (Hoffman 2004). Similarly, the anthropological approach of ethnography is a method of immersion in the very social systems or organizations under analysis, relying heavily on personal observation, experience, and interviews (Humphreys, Brown, and Hatch 2003; Peterson et al. 2002).

These intellectual touchstones suggest the importance of firsthand participation, and yet a valid concern about such approaches may be the potential for participant bias. Indeed, in the present case, the author participated directly in, designed, and led core elements of the programmatic effort described. However, risks of bias may be mitigated by the suite of methods employed and outweighed by the value of gaining perspectives that would otherwise be impossible to obtain or without which improvements in theory and practice might be impeded or even impossible to achieve. In this case, the absence of guidance in the existing scholarly literature or in the experiences of other programs to meet the extant challenges suggested that a disciplined, reflective participant approach offered the greatest opportunity for learning.

To offset the risks of subjectivity, participant analysis and observation in this case were augmented by metrics that were designed to test achievement of program goals, surveys and focus groups to provide impartial feedback from external users, and a post hoc literature review to provide a context for deeper reflection and evaluation of results and lessons learned. Metrics were determined collaboratively within the NAWQA program's national management team based on the goals of the policy relevance plan; these will be described more fully later. Surveys were designed and conducted by the author and other management staff according to standards of professional practice, with the aim of obtaining standardized feedback from users about the credibility, understandability, and usefulness of scientific information developed during the effort. Focus groups were conducted by a third party and included a cross-section of people from diverse backgrounds who had been exposed to information products. Scholarly literature was reviewed a priori but found to be insufficiently relevant to guide the effort; a wide array of literature from several fields was reviewed retrospectively in an attempt to shed further light on lessons, problems, and observations that were illuminated through practice. The difficulty of assembling that literature reinforced the earlier sense of fragmented scholarship that had posed an initial barrier to its influence on practice. On the other hand, the discovery of similar themes in many fields suggests the potential for vibrant multidisciplinary research.

Scoping Needs, Barriers, and Opportunities

As an initial step in developing a programmatic strategy for this effort, informal interviews with USGS scientists and congressional policy staff, conducted by the author during 1995 and 1996, revealed the prevalence of extraordinarily different cultures of thought and practice. In keeping with the known importance of cultural frames for defining shared priorities, outlooks, and even definitions of problems and their viable solutions within an organization (Howard-Grenville and Hoffman 2000), these interviews bore out the extent to which cultural differences erected barriers to effective communication, and a lack of regular interpersonal interaction between scientists and policy staff fostered a mutual belief in stereotypes that discouraged collaboration.

Policy staff expressed frustration that science, as typically provided, was often too vague or general for the policy issues that needed to be understood or the decisions that urgently needed to be made. Staffers were more accustomed to reviewing information that was already structured around particular actions or decisions, often in the format of advocacy positions. They generally did not have the personal expertise or time to digest raw scientific information, nor did they view it as their mission to do so. The tendency of scientists to respond to policy-driven questions by requesting new funding for multiyear studies instead of providing rapid problem-solving assistance was a common staff complaint. An underlying message was that although scientific information could obviously be useful, it was also unpredictable in relevance and availability, and policy decisions could not be held up because of it.

For their part, most USGS scientists lacked a basic familiarity with the process of policy development and felt apprehensive or even disdainful of its seemingly chaotic nature. While scientific organizations commonly exhibit these reactions and assumptions (Gregory and Miller 1998; Rich and Oh 2000; Weigold 2001), interviews suggested that a lack of familiarity with the policy arena led to fears and stereotypes. Many agency scientists were worried about the reputedly short attention span of policy makers or the irrationality of the policy process. Some dreaded interacting with the policy process because prior experiences, to which they referred as "fire drills," had been stressful, time-consuming, and not unambiguously successful. They equated being asked to respond to policy needs as being asked to "dumb down" science. Some feared that by engaging with policy making in any way, they would appear to have discarded objectivity and lose credibility with their scientific peers. Many were convinced that time spent on policy matters would bring penalties in promotion because assisting policy makers was not valued as highly by supervisors as collecting and analyzing data. It was widely recognized by staff scientists and managers that senior scientists frequently engaged in policy-related activities and were valued for doing so, but such conduct was strongly viewed as risky for ambitious junior scientists.

The historical interest of science agencies in policy is said to reside in the politics of science funding, with the chief objective of communication to popularize science for its own sake and to garner public support (Lewenstein 1992). This legacy was a potent and visible influence as agency scientists reported feeling torn between viewing work with policy makers as opportunities to support public problem solving and as a vehicle for building appreciation of and "selling" USGS science. While these two views are not always mutually exclusive, the agency's primary emphasis on promoting science rather than supporting public decision making was clearly reflected in the high priority given to building good public relations with congressional budget committees (which provide annual funding to science agencies) and the comparatively low priority given to building effective consultative relationships with authorizing committees (which craft and oversee natural resource and environmental laws). In fact, implicit institutional disincentives discouraged any shift in resources away from the budget process, thus preventing many opportunities for demonstrating relevance to policy development.

All in all, these initial interviews highlighted key barriers to enhancing policy relevance. Negative stereotypes and concerns related to achieving professional success were prevalent and surprisingly similar among scientists and policy staff, especially, though not exclusively, among those with little substantive experience at the science–policy nexus. A variety of cultural, institutional, and historical characteristics impeded mutual understanding and respect, discouraged trust and collaboration, and failed to promote regular, much less improved, communication or mutual learning. Most scientists interviewed were keenly interested in relevance, but few perceived the existence of a serious relevance problem beyond the need for more effective public outreach, and this suggested that proposals for change in other areas of activity could be met with reluctance or outright resistance. However, these initial interviews strongly indicated that outreach alone would be inadequate to address program goals.

Most scientists interviewed were keenly interested in relevance, but few perceived the existence of a serious relevance problem beyond the need for more effective public outreach, and this suggested that proposals for change in other areas of activity could be met with reluctance or outright resistance.

The draft plan for enhancing policy relevance (Graffy 1996) clarified working assumptions about the science–policy relationship and identified a range of strategies that could lead to improvement. These working assumptions eventually evolved into the heuristic model described later and many of the suggested mechanisms were strategically aimed at building out from or augmenting existing or familiar ways of doing business, focusing on making changes that held seeds of transformation. For example, an emphasis emphasis on two-way communication signified a shift away from historical assumptions about the linearity of information dissemination from scientists to decision makers, offering opportunities to develop mutual understanding and respect as well as to become aware of emerging issues in a timely fashion. Accordingly, scientists were encouraged to attend meetings and nontechnical forums at which policy issues were being discussed. Briefings for congressional staff (focusing on authorizing committees and analysts on whom they relied) and stakeholders were scheduled more frequently and supported by careful preparation and sometimes direct facilitation.

Policy-relevant analysis and assistance were incorporated into the official work plans on which professional evaluations were based, thereby ensuring that they would be given attention, and the definition of "science products" was explicitly widened from reports, fact sheets, and data sets to a wider "portfolio" of briefings, informal dialogues, innovative graphical indicators and data displays, new types of reports, and more accessible Web sites. The peer-review system for policy-relevant science products was expanded beyond traditional scientific colleagues to include members of the policy and public decision-making communities as well. A mixture of training opportunities and management decisions worked together to create recognition within the program culture of the value, feasibility, and practicality of improving the policy relevance of science communication and, in some cases, of scientific research itself. As a fundamental strategy, using and tweaking familiar institutional elements within the USGS as springboards for change proved to be effective.

A Heuristic Model of Science–Policy Interaction

The foundation of the plan for enhanced policy relevance was a conceptual framework or heuristic model of the science–policy relationship. Given the absence of off-the-shelf guidelines to inform such an effort, an original conceptual model was developed: the "functions of scientific information" (FOSI) model (table 1). The FOSI model depicts a relationship between science and policy making that emphasizes the instrumental value of information in the policy process and offers a language to describe the universe of possible science–policy interactions. It assumes that, rather than being irrational, policy makers view scientific information in terms of its functional value for achieving their goals of influencing or directly formulating and implementing legislation and rules that create or manage social change. This leads to a heuristic that links specific stages of policy development with corollary functions of scientific information, thereby illuminating a variety of opportunities for and limitations of the role of information in the policy process.

This model differed substantially from assumptions about the intrinsic value of scientific information held by many natural scientists. The FOSI model explicitly sought to break down simple assumptions and stereotypes and open up dialogue about what scientists were already doing and what else they might do (perhaps even should do) to further enhance policy relevance. The model helped NAWQA scientists understand that scientific information is not an immutable entity and

Table 1 A "Functions of Scientific Information" Model Linking Science and Policy

	Stages of the Policy Process	Corollary Functions of Science Information	Diagnostic Questions
1	Issues emerge	Announce discoveries	What did you find?
2	Frame issues	Put issues into perspective	What does it mean?
3	Set priorities	Test decision options and scenarios	What matters? What can I do?
4	Legislate priorities/ goals	Validate choices or trade-offs	What supports this position?
5	Implement goals	Enable implementation	Where? How?

Source: Adapted from (Graffy 1996, 1999).

that the policy process, though dynamic and unpredictable in some regards, possesses an internal logic that can be planned around. Correspondingly, the FOSI model was used as a high-level strategic planning and diagnostic tool to guide the design of various facets of the capacity-building plan and manage long-term engagement by researchers on specific policy issues. It helped identify current research that was already policy relevant, support planning to increase policy relevance in promising areas, and steer involvement away from stages of the policy process with the least potential for impact and the most opportunity for frustration.

Feedback from program scientists suggested that a conceptual model of this kind appealed to their analytical inclinations, and it became both a critical management tool and an important training tool. It offered transparency about what program scientists were already doing that was policy relevant, what may have made previous experiences in the policy arena so stressful and frustrating, and what they were now being asked to do to enhance the policy relevance of their work in the future. In many cases, scientists realized upon reflection that stressful "fire drills" had often occurred when initial engagement with the policy process occurred at stages 3 and 4 of the FOSI model, in which information may be used chiefly to validate or refute policy positions under debate and during which there may be little receptiveness to general information and great potential for politicization of science.

The ease with which the FOSI model served as a common ground of understanding in a multidisciplinary context (including hydrology, biology, social sciences, and geology) ultimately increased its credibility and usefulness. The appeal of the model was initially somewhat surprising, but it was consistent with the fundamental strategy of the policy-enhancement effort: Use familiar elements, in this case an analytic model, with a new twist to instigate new ways of thinking. Although functions of information were a new way of thinking for scientists who believed deeply in the intrinsic value of data and information, the analytical approach of the model turned out to be well suited to the science culture of the organization, and the sense of control afforded by the model may have made it easier to commit to policy relevance as a way of doing business.

The policy process is not, in real life, as linear and sequential as the FOSI model might imply, nor does every issue flow through the process at the same pace. However, the highly stylized heuristic simplifies this very complex process in a way that highlights transitions in the role of scientific information for policy development, leading to more relevant and timely planning, analysis, and communication. The ability to conceive of policy issues over a multipart process or life cycle allows information sharing to occur iteratively and over a longer planning horizon, which is more compatible with scientific culture than unpredictable, narrow windows of opportunity. Heightened awareness of policy stages and corollary roles for scientific information makes it possible to diagnose policy needs on an issue at any given point in time, which, in turn, helps decide whether and how to engage. At which stage in the policy process might an issue be? How quickly is the process moving? What role(s) for scientific information exist?

Assessing the Status Quo

At the outset of the capacity-building effort, many scientists asked whether the effort to enhance policy relevance was needed, as they knew that scientific data were already being used in natural resource management and regulatory frameworks. How, they wondered, could policy relevance be further enhanced? Was change really necessary? In order to establish a clear rationale for enhancing policy relevance, careful evaluation was needed to determine existing successes and gaps to be addressed, and this was facilitated by reference to the FOSI framework. A review of existing activities, for example, indicated that NAWQA scientists were already quite experienced at two stages of the policy process: stage 1 (announcing discoveries) and stage 5 (enabling implementation). However, most had very little experience with stage 2 (putting issues into perspective) and stage 3 (testing decision options and scenarios), and most had, as would be expected, a limited and sporadic role in stage 4 (legislating). Based on this review and the initial scoping exercise, which suggested that gaps at stages 2 and 3 were linked to calls for greater relevance, the rationale for enhancing policy relevance involved recognizing existing capacity while putting an intensive focus on building greater capacity for framing and scenario-testing.

Recognizing Existing Capacity for Policy Relevance

The first stage of the policy process may be considered a powerful "win–win" for science–policy interaction, and it is no wonder that announcing discoveries is a form of policy relevance that is especially inviting for scientists. Some scientific discoveries need little translation or interpretation to be policy relevant; their simple announcement is all the communication required. Scientific discoveries of this magnitude with regard to water quality may include the detection of unexpected contaminants in water resources that people use for recreation or drinking; such discoveries are given to generating newspaper headlines such as, "Region Leads Nation in Nitrate Pollution" (Gantry 2001). New discoveries and breakthroughs are inherently exciting for scientists and tend to naturally attract media attention. Some studies of science reporting indicate that large newspapers are especially likely to run environmental news (Weigold 2001) and that sensational stories on any topic are most likely to be covered (Treise and Weigold 2002), so sensational discoveries in environmental science may be among the most likely science stories to receive wide media attention. Media attention, in turn, plays an important role in raising issues to public attention (Blum 1998; Iyengar 1993).

During the period described in this article, the discovery of a fuel additive in groundwater illustrated this dynamic. The fuel additive methyl tertiary-butyl ether (MTBE), introduced as a gasoline additive pursuant to the Clean Air Act to help reduce levels of carbon monoxide and ground-level ozone, was detected by NAWQA scientists in the groundwater of several cities. Because no route by which MTBE might move from fuels to groundwater had been predicted, this unexpected finding qualified as a scientific discovery. It also qualified as an emerging policy issue because MTBE had been detected in drinking water sources, creating taste and odor problems and raising questions about more serious human health effects. Moreover, the discovery dramatized the possibility that policies aimed at protecting one part of the environment (air) could inadvertently degrade another part (water), implicitly challenging basic policy assumptions of the time.

The discovery of MTBE led to a flurry of media attention in affected states, with follow-up activity between NAWQA scientists and the White House Office of Science and Technology Policy, federal and state regulatory agencies, and Congress. NAWQA scientists testified at numerous hearings and retained a pivotal role in the scientific aspects of the policy debate over what, if anything, to do about MTBE. All of this increasingly complex engagement with the policy process began, however, with a simple, unassuming statement that MTBE had been found in groundwater. By simply "doing science," tremendous policy relevance had been achieved.

As mentioned, program scientists already had a long track record of success in enabling implementation of policies and programs (stage 5), even before the policy relevance plan was developed. Strong relationships existed to inform or collaborate with state and federal agencies with management jurisdiction over environmental quality, natural resources, public health, or agriculture—any jurisdiction that might include water-quality issues. Scientific data obtained through routine monitoring can be requested by these agencies to target vulnerable watersheds, devise cost-effective monitoring schemes, or verify the presence of a particular waterborne contaminant. If additional monitoring or analysis is required, cooperative agreements are commonly arranged to support additional work.

For example, on the basis of techniques demonstrated by the NAWQA program, the Washington State Department of Health invited USGS scientists to help assess the vulnerability of public water supply wells to pesticide contamination. The department hoped to streamline drinking water compliance monitoring required by the Safe Drinking Water Act in a way that minimized costs and maximized protection of human health. The NAWQA information on the occurrence of pesticides in the groundwater of specific counties, together with information about the soil and land use characteristics that were most often associated with pesticide contamination, enabled scientists to identify wells with low susceptibility to contamination and the department to thereupon obtain waivers to monitor less frequently at these sites. By employing this new monitoring regime, Washington State protected its drinking water resources while saving about $6 million each year over the old monitoring approach (Ryker and Williamson 1996).

Identification of Opportunities for Enhancing Policy Relevance

The capacity-building plan acknowledged the long history of program capacity in stages 1 and 5 but focused on identifying critical gaps in capacity and developing strategies for addressing them. Specifically, the plan proposed that increasing public exhortations for science to become more relevant, accountable, and responsive to societal needs, as historical trends indicated was occurring, pertained to an increased desire for scientists to frame issues more effectively and assist decision makers who were attempting to address priorities. This led directly to a strategy to increase capacity at stage 2 and stage 3 to, respectively, develop a greater facility for putting scientific issues into perspective for nonscientists engaged in policy development and for helping to assess policy options and scenarios. In addition, because the FOSI model depicts engagement with the policy process as accommodating recurrent efforts at analysis and communication on a given issue, an additional element was to experiment with following issues through several stages of the policy process when circumstances made that feasible.

Framing Scientific Issues for Policy Development

As stated, stage 2 (framing of issues) involves putting available scientific information into perspective for those engaged in policy development. The experiences of NAWQA scientists were minimal in this area, not least because of historical, institutional constraints and customs. Framing was not generally considered to be a seminal part of the business of doing science, which is characterized by specialization of disciplines, data collection, and highly formalized investigation. Framing is, conversely, a process of organizing available information, identifying knowledge gaps, and generally trying to structure understanding of an issue in ways that may involve cross-disciplinary and synthetic explanation. Thus, much effort was aimed at building the capacity for analysis and communication suited to this stage of the policy process and establishing its legitimacy as a component of scientific activity.

By framing the technical dimensions of policy issues, scientists can contribute substantially to structuring public understanding, public discourse, and decision making. But scientists may dismiss the importance of framing, viewing the need to incorporate scientific information into decisions as a requirement rather than a choice and the responsibility of decision makers (Rich and Oh 2000). However, it is widely understood that while information can shape policy decisions over the long run (Busenberg 2001), scientific information is not the only, nor necessarily the primary, informational input to policy development. The availability of information alone does not ensure that it will be—or can be—incorporated. Information that is ineffectively communicated or that lacks a framework that decision makers can readily understand is unlikely to feed into their thinking.

Effective framing may require credible explanation of even incomplete states of knowledge, and many scientists are especially reluctant to communicate research findings that are inconclusive. However, Representative Sherwood Boehlert (R-NY), chair of the House Committee on Science, put it this way: "Inconclusive science cannot be, in and of itself, a showstopper," and he went on to recount how incomplete scientific research was invaluable to policy makers in framing their understanding of acid rain, leading to action even before final evidence of its damage had been obtained (Boehlert 2002). Framing does not preclude admissions of uncertainty but rather puts all that is known and that which remains unknown into an understandable context.

Effective framing may require credible explanation of even incomplete states of knowledge, and many scientists are especially reluctant to communicate research findings that are inconclusive.

Building Capacity from Theory to Practice: Framing

Building capacity for framing scientific issues in a manner suitable for input into policy development could not be achieved in the abstract. A vehicle for improving practice was needed, and a pivotal management decision was made to require teams of scientists to coauthor "summary reports." Summary reports were emblematic of the expanded portfolio of science products, and they were designed to meet the needs of the external policy audience for information while providing a concrete vehicle for training program scientists. They were specifically asked to consider the summary reports as efforts to enhance policy relevance at stage 2—helping to frame or put water-quality findings into perspective within a larger context—rather than as a forum for simply announcing discoveries as they were accustomed to doing in stage 1. Scientists subsequently acknowledged that this insight marked a turning point in their approach to communicating policy-relevant scientific results.

A summary report was written for each river basin that the NAWQA program assessed. Multidisciplinary teams of scientists were charged with synthesizing the results of several years of water-quality investigation and placing these results within a context of previous studies, existing water management challenges, and regulatory and policy issues that applied both locally and nationwide. Furthermore, teams were required to explain their analyses in plain, journalistic language and to utilize graphics and other visual elements that were consistent with that style. These requirements proved to be challenging for many, and each report took several iterations and about two years to complete. In all, 36 river basin summary reports were completed between 1995 and 2001, and a final 15 reports were published by 2004. One national summary report that synthesized findings about pesticides and nutrients was also completed during this period, with several more national reports on other topics tentatively planned for future years.

Summary reports departed substantially from traditional technical documents, and significant management emphasis was placed on providing continuous support throughout their development with written guidance, intensive training workshops, and coaching. Training workshops involved presentations about the science-policy nexus, role playing to gain insight into the perspectives of prospective information users, guided analytical exercises to consider scientific findings in more synthetic ways, and iterative review of drafts in progress.

As scientists explored how their research findings could be made more accessible to policy makers and, gradually, the perceptual barrier that policy-relevant science was "dumbed down" science was replaced by a new regard for the role of highly disciplined critical thinking and communication strategies for making science–policy connections. It was not uncommon for scientists to begin the process with reluctance or skepticism and to leave claiming that their way of thinking (or as one put it, "brain chemistry") had fundamentally changed. Some came to regard analyzing and communicating science in a policy-relevant way as among the most intellectually difficult things they had ever done, to their surprise. Many remarked that their own understanding of water-quality findings was improved after considering their results from a more synthetic perspective. Years later, some of these same scientists, now managers themselves in other agency programs, sought out the guidance developed for the summary report effort in order to train their own staff scientists accordingly.

The summary report process and related training workshops turned out to be important catalysts for change, not only by familiarizing scores of scientists with new ways of thinking about the policy process and their role in it but also by developing unexpected cultural status within the program that legitimized the effort to enhance policy relevance overall. Completing a summary report became a rite of passage, and training workshops that were initially offered on a voluntary basis became required after multiple scientists who had been through them recommended that course of action to national program managers. This recommendation was immediately adopted, and this meshing of top-down and bottom-up perspectives reinforced a sense of credibility about the effort under way and increased momentum behind changes aimed at enhancing policy relevance.

By 2001, more than 100 scientists and other agency professionals had devoted substantial time and budgetary resources to summary reports and to a suite of related activities. All told, more than 100,000 copies of summary reports were printed for public distribution, and they were posted prominently on the program Web site. In the historical culture of the agency, investing so heavily in policy-oriented analysis and communication was definitely unusual and possibly unprecedented. Institutionally, the change required a consistent commitment from the most senior levels of management, displayed in a willingness to invest resources in nontraditional activities and to take risks by modifying cultural norms through the systematic introduction of new ideas into guidance, task plans, and programmatic elements already familiar to and required of program scientists. Multilevel buy-in throughout the organization, which was deliberately fostered but also developed spontaneously in unexpected ways, helped achieve acceptance of a view that capacity for policy relevance might be a legitimate part of "doing science."

Limits to Capacity Building: Scenario Testing

Although goals for enhancing policy-relevant science and science communication initially included framing issues and scenario testing (stages 2 and 3), the emphasis was placed on gaining mastery of framing. This emphasis reflected the realization, gained primarily through training and coaching, that capacity building was somewhat cumulative from one stage to the next, and also an acknowledgment of resource limitations within the program. Framing activities already consumed considerable time and funding, and scenario testing would entail a significantly greater investment in analytical methods and tools, thus consuming even more resources when budget pressures were already squeezing out traditional data activities.

The participation of scientists in scenario testing was poorly understood at the time and often conflated with making policy recommendations (a cultural and legal taboo). A hallmark of the transition from stage 2 to stage 3 in the policy process is the evolution from framing to advocacy of specific policy priorities and positions, and the corollary functions of scientific information also change, from structuring understanding to testing scenarios and options. As advocacy intensifies among policy makers during stage 3, scientific information is increasingly seen as validating (or contradicting) positions which policy makers seek to support (Rich and Oh 2000), and this increases the potential for science to become highly politicized. The need to preserve a clear separation between scenario testing and recommending policy is paramount, and the conceptual and pedagogical work of defining stage 3 activities and building analytical tools and training components would have required an enormous investment. In the end, NAWQA scientists were simply encouraged to refrain from actively engaging in scenario testing until they had firmly grasped the concept of functional roles of information in the policy process and had fully mastered the skills associated with framing issues.

Following Issues through the Policy Process

As an illustration of the effort to use the FOSI model to follow issues throughout their policy life cycles, consider the development of a new drinking-water standard for arsenic. Before the reauthorization of the Safe Drinking Water Act of 1996, questions had emerged about the appropriateness of the existing drinking-water arsenic standard (50 ug/L) because new studies showed human health effects associated with ingesting arsenic at far lower concentrations (stage 1). The potential economic and political effects of acting on these studies loomed large, as costly treatment of many municipal drinking-water supplies could be required. Congressional staff expressed frustration that little information was available regarding the presence of arsenic in drinking-water sources so that they could evaluate the scope of the problem—in other words, the issue needed to be framed more completely.

The USGS happened to have the most extensive data on arsenic occurrence, but the existing data sets were not integrated, and available technical articles were not in a form that would support congressional and stakeholder deliberation. NAWQA program staff consulted with the congressional committees involved in the Safe Drinking Water Act and set to work preparing the relevant information, hoping to offer it in a timely way to stage 2 dialogue. As the FOSI model predicted that the same information could also be relevant to stage 5, when the Environmental Protection Agency (EPA) would implement the reauthorized legislation, NAWQA program staff began to simultaneously collaborate with EPA staff to ensure that the arsenic data would be analyzed in formats that would be ultimately compatible with regulatory needs.

The NAWQA was unable to deliver framing information to Congress because of the length of time required to assemble and interpret the data, but it was successful in meeting regulatory implementation needs. Even though the final report was only in draft form when a new standard was proposed, on-going dialogue with EPA during the course of data analysis enabled regulators to gather the information they needed, in a format that facilitated their use. Consequently, reliance on the FOSI model provided several opportunities for policy-relevant input and the ability to plan over a longer research horizon to address these opportunities effectively.

Evaluating Practical Success

Measures of practical success related to enhancing policy relevance were designed to give feedback to program management and staff and, at the same time, reinforce realistic expectations about the role of scientific information in national policy development. Some had assumed that success meant direct impact on legislative language, whereas the effort undertaken to enhance policy relevance very explicitly rejected such a narrow view of the science–policy relationship in favor of a broader conception as depicted in the FOSI model. In keeping with the strategic goals of the effort, measures of success focused on advances in capacity to inform the context of policy development by helping to frame public understanding and by communicating scientific understandings in a manner that allowed it to enter public discourse and decision making more readily at several stages in the policy process.

One important measure of increased capacity was whether program scientists were observed to be increasingly engaged in and positive about accepting new tasks or, conversely, resisting them. By that token, the progressively high level of positive engagement by program scientists with the summary reports was deemed a critical indicator of success. These reports were the most demanding of the capacity-building tasks introduced, requiring years of intensive effort, and were at greatest risk of being undermined by various forms of organizational resistance; however, quite the opposite occurred over time.

Measures of greater uptake of scientific information in public and policy discourse included changes in the frequency or substance of telephone or e-mail inquiries from congressional offices, citations to program findings in policy-oriented reports by other organizations, and visits to summary reports pages of the program Web site. These measures were regarded as aggregating indicators, reflecting any or all of the effects of reports, congressional briefings, meetings, and all of the activities undertaken. Finally, to evaluate the potential for uptake of the summary reports themselves into public discourse, surveys were devised to provide feedback about their quality and usefulness to the intended audience.

A rigorous before-and-after comparison of phone and e-mail inquiries could not be achieved because of the logistical challenges involved in capturing all relevant data (for example, inquiries could occur in any one of 30 or more offices nationwide). Keeping fully abreast of changes to countless reports and Web sites throughout the Internet also proved logistically infeasible. However, periodic manual searches on a wide array of Web sites dealing with water-quality-related issues indicated that citations to NAWQA reports, fact sheets, and briefing materials were widespread and appeared to be on the rise during the period of evaluation. Anecdotal evidence, such as policy colleagues commenting favorably on the higher profile of the program's contributions, reinforced the sense of positive trends in terms of enhanced perceptions of policy relevance.

An effort to track visits to the summary report Web sites provided results that were suggestive but inconclusive. Daily visits to the program Web site increased during the six -month period during which they were tracked, but the change was not statistically significant. On the other hand, patterns of visitation showed that many visitors bypassed the main program homepage and went directly to summary reports, possibly indicating that the site was bookmarked or that popular search engines such as Google and MSN Explorer may have directed visitors there because of search terms (phosphorus in streams, pesticides, etc.). The most frequent visitors were from commercial, government, and educational Internet domains, followed by nonprofit organizations, generalized U.S. domains, military, and international users from at least a dozen nations.

This pattern of broad, heterogeneous interest was consistent with results of user surveys. Two specialized surveys were designed and administered by USGS personnel nationwide to standardize feedback about the credibility, understandability, and usefulness of scientific information products to intended users. The development of the survey instruments, qualification criteria for those surveyed, protocols for distribution of surveys, and analysis of survey results were performed by the author and others involved in management of the national policy relevance effort according to common standards of professional practice. Together, these surveys revealed a significant positive reaction to the summary reports, particularly by policy staff in national governmental and nongovernmental organizations, industry representatives, academics, peer scientists, journalists, state legislative staff, and educators.

One survey was designed to augment the traditional midcourse colleague review step for each report by adding two representatives of the local policy community. These surveys were designed centrally and distributed by the report team leaders according to specific protocols. These surveys contained 16 pieces of information: 12 items to be rated on a five-point scale (e.g., the publication was "too complex" through "too simple"); 1 question about the report section of greatest interest; 1 question about academic degrees held (used primarily to screen out traditional peer reviewers); and 2 open-ended questions about graphics that reviewers particularly liked and about suggestions for improving the publication. A total of 16 usable responses (a 50 percent response rate) from across the nation showed that the reports were perceived as believable, informative, and at satisfactory levels of complexity, length, and understandability. The feedback obtained was used to improve final drafts of the reports.

> The FOSI model proved to be an important diagnostic and strategic management tool, providing a conceptual foundation for a host of activities, focusing decisions, and highlighting opportunities for and limitations of science within the policy development process.

A satisfaction survey was distributed to 735 summary report recipients following the release of the final reports, selected randomly from within the seven business sectors contained in the contacts database (e.g., universities, utilities, nongovernmental organizations). The surveys were designed centrally and distributed electronically, with questions focusing on satisfaction with various report elements, expected use of the information, format preferences, and suggestions for improvement. Based on 237 usable responses (a 31 percent response rate), an overall satisfaction rate of 97 percent was reported. A particularly memorable comment came from a veteran of national environmental policy circles: "These reports are one of the more encouraging initiatives I have seen in a generally bleak picture" (USGS 2001).

In addition to surveys, focus groups conducted by an independent consulting firm in four locations nationwide determined that many aspects of content, format, and design of the reports supported effective communication of scientific findings and were useful and relevant to national and state level policy officials and stakeholders (Booz Allen Hamilton 1999). Room for improvement was noted, but the overall positive results were viewed as a validation of the effort to enhance policy relevance and of the institutionalization of summary reports.

In summary, the policy relevance effort was deemed a practical success. The FOSI model proved to be an important diagnostic and strategic management tool, providing a conceptual foundation for a host of activities, focusing decisions, and highlighting opportunities for and limitations of science within the policy development process. The summary report effort produced important information products and provided a vehicle for broader capacity building that extended beyond any specific report. Was this practical success coincidental or replicable? Could the concepts and techniques used in this effort could be applied successfully elsewhere?

Evaluating Conceptual Underpinnings

A critical survey of relevant literatures was conducted retrospectively in order to provide a context for further reflection on this practical experiment and, in particular, to evaluate the conceptual effectiveness of the FOSI model. This retrospective review—which ultimately touched on numerous areas including policy studies, science communication, organizational change, strategy, and public administration—confirmed the presence of fragmentation in the relevant scholarship and the difficulty of applying existing scholarship to challenges of real-life practice. The compatibility of themes across several fields of scholarship, however, demonstrates the broad salience of the issues under investigation and suggests the potential for vibrant cross-disciplinary research and experimentation to link theory and practice more effectively.

In common with prevailing policy process theories and frameworks (Birkland 2001; Sabatier 1999), the FOSI model assumes that policy actors are goal oriented and that uncertainty, rationality, beliefs, and opportunism are inextricably entwined with the policy process. The model somewhat uniquely suggests how the relative influence of these factors varies throughout the stages of the policy process by focusing on the degrees of openness by policy makers to new information throughout. In policy studies terminology, the FOSI approach could be interpreted as differentiating among stages where rational information-seeking behaviors are more likely to emerge and others where values, politics, or beliefs are more likely to dominate.

The FOSI model serves as something of a bridge between decision making and problem solving frameworks, which are defined, respectively, as "evaluating and choosing goals" and "fixing agendas, setting goals, and designing actions" (Simon 1992a, 1992b). By this measure, the FOSI model links problem solving and decision making by explicitly nesting decision making within a broad problem-solving process.

Agenda setting and agenda formation occupy a prominent place in both policy studies (Birkland 2001; Kingdon 1984; Sabatier and Jenkins-Smith 1999) and in communications theory (Carmines and Stinson 1993; Iyengar 1993). The FOSI model acknowledges and, indeed, highlights agenda setting throughout the early stages of the policy process. However, the focus on agenda setting provided by the FOSI model differs somewhat from other theories. Rather than seeking to explain how and why any one of numerous potential issues may move away from the pack into the central policy arena while others do not, the FOSI model is more concerned with how agenda setting with regard to a specific issue is triggered and progresses through its policy life cycle and, specifically, how information is functionally interrelated with that process. In this way, the FOSI model combines elements of the approach to agenda setting described in the policy and the communication literatures.

The stages approach conveys some sense of progression in the intensity of agenda setting, which affects the functions of information correspondingly. From a scientist's perspective, the value of information might be viewed as declining as a result. From a policy maker's perspective, the value of information may not decline as much as change in function (from informational to validational, for instance) from one stage to another. In either case, the diminished role of scientists themselves at advanced stages of public discourse on a given issue is consistent with the finding that "while scientific and political forces are both important to the debate, scientists become less dominant sources as the issue matures" (Trumbo 1996, 281).

"Policy stage" models, such as the FOSI model, have been criticized as offering an unrealistically linear view of a much more fluid process (Sabatier and Jenkins-Smith 1999), but their validity continues to be argued as well (deLeon 1999). Notwithstanding the reality that policy processes are far more dynamic than a linear heuristic model can describe, the empirical success of the FOSI model as a strategic and management guide suggests that the appropriateness of one type of model over another may depend on the purpose of its use. If the objective is to provide diagnostic or planning capability that enhances the quality of interaction between information providers and policy makers, then a stylized model that highlights major structural transitions in the policy process—which stages models are well equipped to do—may provide suitable conceptual rigor whereas, for other uses, it may not.

In communication theory, the FOSI model is more consistent with emerging models that stress the "interactive, contextual nature" of science communication, and less so with "diffusion" and "deficit" models that assume unidirectional transfers of scientific information to a passive or science-illiterate public (Clark and Illman 2001). It differs substantially from pervasive assumptions in the literature that science communication is conducted solely by journalists and in the mass media; indeed, one aspect of the NAWQA effort was its intent to build capacity among program scientists for science communication. This approach was debated at first on the grounds that communication specialists might be more effective, but the decision to build communication capacity among science staff may, in retrospect, have been another pivotal management decision leading to the success of the policy relevance plan. Weigold (2001) notes that science information specialists are often accorded little professional respect within their own institutions, an observation that is consistent with those made in the USGS case. Staff scientists would have felt little investment in the outcome of a plan to enhance science communication if it had been undertaken by information or communication specialists, and they would have likely been less receptive to feedback that affected the content of their research. However, because they were themselves the communicators, the line between policy-relevant communication and policy-relevant science was more porous, and improvements were seen in both areas.

With its emphasis on enhancing policy relevance by functionally tailoring research content and communication to policy development needs, the FOSI model reflects the notion of "civic science" that Clark and Illman (2001) describe as bringing "knowledge and expertise into the public arena . . . to illuminate science content in the context of societal issues." The model also strongly comports with and seeks to surmount the "divided communities" explanation for the low use of scientific information in policy making (Rich and Oh 2000), which posits a rift between the scientific and governmental or political arenas owing to four main factors: distrust or antagonism, different languages, different time constraints and worldviews, and absence of sufficient relevance of scientific information. Surveys used to evaluate the validity of this explanation found that increased interaction between the communities did not lead to greater utilization of information unless mechanisms were put in place to allow policy makers to give feedback to scientists about their concerns and needs. They also concluded that "a proper and easily understandable format for reports facilitates greater use of information." In the NAWQA program's plan to promote policy-relevant communication, these insights were suspected and acted on by designing specific mechanisms for feedback and new formats, like the summary reports and arsenic information. Validation of these efforts is, however, gratifying.

Conclusion

Any assumption that policy-relevant science means simply conducting sound research and disseminating findings to decision makers vastly oversimplifies the matter, but an assumption of insurmountable cultural differences between scientific and policy arenas is inadequate. Instead, the relationship between science and policy is complex, dynamic, and replete with rich opportunities for interaction. Many avenues remain for improving theory and practice in order to meet the challenges associated with meaningful pursuit of policy-relevant science and science-based policy. Practice without theory leads to ad hoc action, and theory without any connection to practice may fail to be relevant. Once a conceptual foundation for practice is chosen, however, it can have an enormous impact, as illustrated in this article.

The FOSI model, which guided this effort, exhibits strong parallels with existing scholarship on policy making, communication, and decision making, yet its emphasis on a multifaceted, functional relationship between science and policy was not found elsewhere in the literature. In practice, it was readily understood and accepted in a multidisciplinary context and showed itself to be a facile tool for managing synergistic elements of a successful strategy for enhancing policy relevance. This model fills a gap in the practitioner's toolbox for a tool that is conceptually sound and exhibits real-world utility, and further experimentation may show it to be a robust tool in a variety of circumstances. Policy development at the national level and the continuing federal emphasis on governmental accountability will continue to require and even demand further coevolution of theory and practice to meet present and emerging challenges.

References

Addis, James, and Betty Lee. 1996. Expanding Perspectives on Gaining Public Support for Management. *American Fisheries Symposium* 16: 42–46.

Beierle, Thomas C., and Jerry Cayford. 2002. *Democracy in Practice: Public Participation in Environmental Decisions*. Washington, DC: Resources for the Future.

Birkland, Thomas A. 2001. *An Introduction to the Policy Process: Theories, Concepts, and Models of Public Policy Making*. Armonk, NY: M.E. Sharpe.

Blum, Deborah. 1998. *Communicating Science and Engineering in a Sound-Bite World*. Testimony before the U.S. House of Representatives, Committee on Science, 105th Cong., 2nd sess., May 14.

Boehlert, Sherwood. 2002. Boehlert Kicks Off EPA Science Forum. News release, U.S. Congress House of Representatives, Committee on Science.

Booz Allen Hamilton. 1999. *U.S. Geological Survey National Water-Quality Assessment Program: Focus Groups for Customer Feedback on '91 Study Unit Reports*. Tysons Corner, VA: Booz Allen Hamilton.

Busenberg, George J. 2001. Learning in Organizations and Public Policy. *Journal of Public Policy* 21(2): 173–89.

Carmines, Edward G., and James A. Stinson. 1993. On the Evolution of Political Issues. In *Agenda Formation*, edited by William H. Riker, 151–68. Ann Arbor: University of Michigan Press.

Clark, Fiona, and Deborah Illman. 2001. Dimensions of Civic Science: Introductory Essay. *Science Communication* 23(1): 5–27.

deLeon, Peter. 1999. The Stages Approach to the Policy Process: What Has It Done? Where Is It Going? In *Theories of the Policy Process*, edited by Paul A. Sabatier, 19–34. Boulder, CO: Westview Press.

Dixon, John, and Rhys Dogan. 2003. A Philosophical Analysis of Management: Improving Praxis. *Journal of Management Development* 22(5–6): 458–82.

Ehlers, Vernon. 2002. *National Science Policy Study*. Hearing on "The Role of Science in Making Good Decisions, " U.S. House of Representatives, Committee on Science.

Gantry. 2001. Region Leads Nation in Nitrate Pollution. *Press Plus: The Press of Atlantic City Online*, March 13.

Gauvin, P. 1995. A Shaky Future for the Survey. Palo Alto Weekly Online, February 1.

Graffy, Elisabeth A. 1996. Stepping Up to the Plate: Concrete Ways to Link NAWQA's Science with Environmental, Agricultural and Natural Resource Policy. *Internal Guidance Document Draft*. Reston, VA: U.S. Geological Survey, National Water-Quality Assessment Program.

———. 1999. Enhancing Policy-Relevance without Burning Up or Burning Out: A Strategy for Scientists. Paper presented at the Conference on "Science into Policy: Water in the Public Realm, " Bozeman, MT.

Gregory, Jane, and Steve Miller. 1998. *Science in Public*. New York: Plenum Trade.

Guston, David H., E. J. Woodhouse, and Daniel Sarewitz. 2001. A Science and Technology Policy Focus for the Bush Administration. *Issues in Science and Technology*, Spring. http://www.issues.org/17.3/p_guston.htm [accessed July 28, 2008]

Hoffman, Andrew. 2004. Reconsidering the Role of the Practical Theorist: On (Re)Connecting Theory to Practice in Organization Theory. *Strategic Organization* 2(2): 213–22.

Howard-Grenville, Jennifer A., and Andrew J. Hoffman. 2000. The Importance of Cultural Framing to the Success of Social Initiatives in Business. *Academy of Management Executive* 12(2): 70–84.

Humphreys, Michael, Andrew Brown, and Mary Jo Hatch. 2003. Is Ethnography Jazz? *Organization* 10(1): 5–31.

Ingram, Helen, and Bryan McDonald. 2002. The State of the Natural Resources Literature—The

Troubled Relationship of Science to Environmental Policy: Some New Perspectives. *Natural Resources Journal* 42(3): 673.

Ingram, Helen, and Anne Schneider. 1998. Science, Democracy, and Water Policy. In *Decision Making under Uncertainty: The Nexus between Science and Policy*, edited by Elisabeth A. Graffy, 21–28. Carbondale, IL: Universities Council on Water Resources.

Iyengar, Shanto. 1993. Agenda Setting and Beyond: Television News and the Strength of Political Issues. In *Agenda Formation*, edited by William H. Riker, 211–30. Ann Arbor: University of Michigan Press.

Kingdon, John W. 1984. *Agendas, Alternatives, and Public Policies*. Boston: Little, Brown.

Lewenstein, B. V. 1992. The Meaning of "Public Understanding of Science" in the United States after World War II. *Public Understanding of Science* 1(1): 45–68.

Lubchenko, Jane. 1998. Entering the Century of the Environment: A New Social Contract for Science. *Science* 279: 491–97.

McCutcheon, Gail, and Burga Jung. 1990. Alternative Perspectives on Action Research. *Theory into Practice* 24(3): 144–48.

Miller, Timothy L. 1995. Chief, National Water Quality Assessment Program, U.S. Geological Survey.

———. 2003. Chief, National Water Quality Assessment Program, U.S. Geological Survey.

Moss, Thomas. 1982. Is There a Scientific Basis for Environmental Decision-Making? In *Science in Public Policy II*, edited by F. Sterrett and B. L. Rosenberg. New York.

National Research Council. 1998. *Future Roles and Opportunities for the Geological Survey*. Washington, DC: National Academy Press.

Peterson, M. Nils, Tarla Rai Peterson, Markus J. Peterson, Roel R. Lopez, and Nova J. Silvy. 2002. Cultural Conflict and the Endangered Florida Key Deer. *Journal of Wildlife Management* 66(4): 947–68.

Putnam, Robert W. 1999. Transforming Social Practice: An Action Science Perspective. *Management Learning* 30(2): 177–87.

Rich, Robert, and Cheol H. Oh. 2000. Rationality and Use of Information in Policy Decisions. *Science Communication* 22(2): 173–211.

Ryker, Sarah, and Alexander K. Williamson. 1996. *Pesticides in Public Supply Wells of Washington State*. Fact Sheet No. 122–96. Tacoma, WA: U.S. Geological Survey.

Sabatier, Paul A. 1999. *Theories of the Policy Process*. Boulder, CO: Westview Press.

Sabatier, Paul A., and H. Jenkins-Smith. 1999. The Advocacy Coalition Framework: An Assessment. In *Theories of the Policy Process*, edited by P. Sabatier, 117–68. Boulder, CO: Westview Press.

Simon, Herbert A. 1992a. *Decision Making and Problem Solving. Paper read at Decision Making*, London.

———. 1992b. *Decision Making and Problem Solving*. Edited by M. Zey. London: Sage Publications.

Tarlock, A. Dan. 2002. Who Owns Science? *Penn State Law Review* 10: 135.

Toman, Michael. 1998. Connecting Scientific Research Agendas to Societal Needs: Some Reflections. In *Decision Making under Uncertainty: The Nexus between Science and Policy*, edited by Elisabeth A. Graffy. Carbondale, IL: Universities Council on Water Resources.

Treise, Debbie, and Michael Weigold. 2002. Advancing Science Communication: A Survey of Science Communications. Paper presented at the National Communication Association Conference, November, Seattle, WA.

Trumbo, Craig. 1996. Constructing Climate Change: Claims and Frames in US News Coverage of an Environmental Issue. *Public Understanding of Science* 5: 269–83.

U.S. House of Representatives. 1995. Republican Contract with America. http://www.house.gov/house/Contract/CONTRACT.html [accessed July 28, 2008]

U.S. Geological Survey (USGS). 2001. Evaluation of the '94 Summary Reports. Internal Document, U.S. Geological Survey. National Water-Quality Assessment Program.

Weigold, Michael. 2001. Communicating Science. *Science Communication* 23(2): 164–93.

Yearley, Steven. 1988. *Science, Technology and Social Change*. Boston: Unwin Hyman.