The Role of Research Scientists in Adaptive Management Programs

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ABSTRACT

This thesis investigates the effectiveness of the Glen Canyon Adaptive Management Program (GCDAMP) in improving and increasing the contributions of scientists to natural resource management decision-making. Natural resource managers turn to scientists for assistance in understanding the complex natural systems they are charged with managing. However, interaction between scientists and decision makers is traditionally been described in terms of tensions and tradeoffs, which lead to a less than optimal utilization of scientific information in policy decisions. The primary cause of these tensions is a mutual lack of understanding of the differences between the norms of practice within the scientific and policy communities, respectively. Adaptive management is a promising strategy to resolve these tensions.

The GCDAMP is one of the most developed adaptive management programs in the country. This research compares the experience of GCDAMP scientists with that of scientists within the US Geological Survey (USGS). USGS is a research science organization within the Federal government, and as such is constantly facing the tension between science and policy. Their experience is used as a proxy for typical interactions between scientists and policy makers.

The study found that GCDAMP scientists contributed more freely, to more aspects of decision-making, than scientists working with more traditional policy formulation processes. The main reason for this was the strong and secure role scientists play in the GCDAMP as compared to more tenuous and less consistent roles played by scientists in decision making processes in which USGS scientists participate. The strong and secure role allowed for much more frequent and substantial collaborative interaction between scientists and decision makers. This interaction clarified to each group the norms of practice within the communities of the others and created negotiated space in which scientists could engage in activities useful to policy decision-making but which USGS scientists generally avoid. While the emphasis on scientific experimentation in management action characteristic of adaptive management was a major driver of improved collaborative interactions, the collaboration itself proved to be equally, if not more, important to improving the contribution of scientists to GCDAMP management decisions.

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CHAPTER 1

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Introduction

This chapter introduces the reader to the context and content of this thesis. The thesis seeks to shed light on the difficulties scientists report having in contributing to public policy decisions and the potential of adaptive management to ease these difficulties. US Geological Survey scientists were interviewed to study this problem. The Glen Canyon Dam Adaptive Management Program was the case studied for this thesis and is one of the most developed of its kind in the country.

The Problem

Natural resource management often involves teasing solutions from complex problems that are poorly understood and which are unique in their particulars if not their overall structure. When designing these solutions, the facts matter. It isn't enough that all the stakeholders agree on management steps. Practices actually have to be compatible with the physical realities of the system being managed. "To the extent that such policy decisions are to be useful, they must be consistent with the best available information on how the system works; its physics, chemistry, geology, and biology."[1]

The "facts" that we say matter here necessarily include empirical information generated through the scientific method. Scientific information is by no means the only way to observe and understand natural systems, but it is generally seen as "the best game in town"; the most effective method to form a practical understanding of natural phenomena"[2,3,4] Scientists are trained to generate this understanding. In many cases however, facts about the behavior of the system can only be generated by observing what happens under management practices. This draws scientists into the design and implementation of management programs in a different and more substantial way than under previous regimes.

Unfortunately, conventional understandings of the interaction between scientists and policy makers describe this participation in terms of difficult tradeoffs and incompatibilities between standards and customs prevalent in the science and policy communities, respectively.[5,6] These include problems with policy-makers asking questions scientists do not feel they can answer, and scientists providing answers that policy-makers do not understand.[7] Insecurities regarding how their information will be used force scientists into unfulfilling and less valuable roles when supporting public policy. They need assurances that their reputation as scientists will not be harmed by the outcome of their participation when that outcome is beyond their control. These assurances take the form of a greater understanding of the policy process, a greater ability to communicate demands of scientific rigor and a clear and secure role within the policy process. Frequent and substantive interactions between scientists and stakeholders become necessary to achieve these ends. The lack of this interaction results in the exclusion of some scientific information from consideration in policy decision-making, reducing the quality of those decisions.[8]

The experience of the US Geological Survey (USGS) scientists seems to bear these theories out. As research scientists within the Federal government, they describe many of the same difficulties in interacting with decision-makers that the theories do. USGS scientists feel participation in question framing, data interpretation, and policy formulation expose them to political pressures and compromise their reputation for objectivity and credibility. This fear of exposure causes them to limit their activity in support of policy. Even when they produce valuable information, they express frustration that it is apparently not used by decision-makers. "The data's there." said one USGS scientist. "It's undeniable. You say, 'No one's going to disagree with USGS about the numbers.' But there's a great deal of people just ignoring the data and that's a problem."[9]

Throughout its history, the Survey has vacillated between emphasizing basic research (favored by the scientific community) and applied research (favored by government officials). These shifts in emphasis indicate a tension between their commitment to basic science and the norms of practice in the science community and their obligation to support Federal policy decisions in a manner that respects practice within the policy community.[10] USGS has seen these activities as distinct, separate, and difficult to synthesize within a single project because of the differences in the kinds of questions they address and the kinds of work products they produce.[11,12]

Adaptive management is one of the most promising strategies to make the interaction between scientists and policy makers more productive. Designed as a strategy to manage complex and dynamic systems, adaptive management makes a greater understanding of the system an explicit goal of management schemes, thereby creating a substantial role for scientists in setting policy. Adaptive management is generally applied as a collaborative approach, fostering productive interaction between different groups of stakeholders including managers, concerned citizens or organizations, and experts supporting the management effort. Adaptive management holds the potential to integrate science and scientists into natural resource management decisions in a more effective way, producing more effective management strategies than ever before. This is a relatively new approach with which public and private-sector land managers have little experience. It is still unknown whether adaptive management can accomplish these goals consistently, or what aspects of implementation improve or worsen the interactions between scientists and policy makers.

The Study

This thesis presents evidence that adaptive management strategies do allow scientists to participate more extensively in policy decision-making than more traditional methods of policy formulation. The evidence is the product of a study of USGS scientists that answered the following question:

> Do scientists have greater ability to contribute to policy decisions within the Glen Canyon Dam Adaptive Management Program than within more traditional science-intensive policy decision-making processes?

The term 'scientist' is used here to denote a research-grade scientist who spends, or has for a major portion of their career spent, their time doing original research for publication or for a client. The Glen Canyon Dam Adaptive Management Program is an adaptive management program initiated to recommend operating strategies for Glen Canyon Dam on the Colorado River to the Secretary of the Interior. The study addressed the question by examining two major sources of information:

1. The first part of an intra-agency USGS discussion on practice called the Dialogue on Science Impact. The Dialogue on Science Impact explored ways in which USGS scientists can "link the science with societal issues… [by] engaging collaboratively with decision makers and other stakeholders in understanding the role of our science in some contentious issues."[13] This is supplemented with interviews of two other USGS scientists.

2. Interviews with scientists currently or formerly working at the Grand Canyon Monitoring and Research Center (operated by USGS) focusing on what activities they engage in and what difficulties they face in interacting with stakeholders.

Operated by USGS, the Grand Canyon Monitoring and Research Center (GCMRC) is the research arm of the Glen Canyon Dam Adaptive Management Program (GCDAMP), which is the adaptive management case studied for this thesis. This thesis compares and contrasts typical practice of USGS research scientists working in support of policy decisions to that of GCMRC scientists working in the GCDAMP. It begins by laying a theoretical framework for analyzing science policy interactions within traditional policy decision-making processes and within adaptive management processes (Chapter 2). The thesis then explores the case by assessing the organizational context in which USGS scientists practice, highlighting important issues that affect their practice. With this in mind, a picture of the typical practice of USGS research scientists working in support of policy is painted as described by the scientists themselves (Chapter 3). This picture is then contrasted with the practice of GCMRC scientists within the GCDAMP (Chapter 4). The implications of this contrast are explored in Chapter 5.

As seen below, the Grand Canyon is a classic complex natural resource management problem, and the GCDAMP appears to provide an effective means to apply scientific information and methodologies to it.

The Case

The Grand Canyon as Complex System –

The Colorado River, has been called "the most controversial and regulated river in the United States."[14] The Glen Canyon Dam, located 15 miles upstream of Grand Canyon National Park has dramatically altered the hydrologic, ecologic, and economic characteristics of the River and the Canyon through which it flows. The pre-dam Colorado flowed at rates of approximately

80,000 cubic feet per second (cfs) in the spring flood season and approximately 3,000 cfs during the rest of the year with minimal daily fluctuations. From 1963 when it was built, until the 1990s, the Glen Canyon Dam was operated as a "power peaking facility" allowing "power max flows" through the dam. This operational strategy produced uniform flows on the Colorado River that over the year, never exceeding 30,000 cfs, with daily fluctuations between 12,000 and 16,000 cfs. Power max flows reduce flow at night and during the workday and maximize flow during the morning and evening when residential power use is highest.[15] The pattern produced by power max flows has been likened to "turning your spigot on full blast and then cutting it off."[16]

"In the meantime, public interests that might previously have been considered distantly secondary or even frivolous have become potentially serious considerations affecting the operation of the dam."[17] For example, more than 90% of sediment flowing down the Colorado River is trapped behind the dam, making the water clear and starving beaches, sandbars, and the river banks for sand. These features are now eroding away. The elimination of spring floods has allowed vegetation to build on the remaining bars, reducing the amount of sand that blows off of them and onto the river banks via wind. The reduction in wind blown sand deposited on the river banks is causing Native American archeological sites along the River to be uncovered by erosion. The dam draws water from the bottom of the upstream reservoir (Lake Powell), making it colder than pre-dam river water. Cold clear water is ideal for non-native trout, which have created a blue-ribbon trout fishery and attendant local recreational fishing industry. However, it is very detrimental to endangered native fish species such as the humpback chub, that are adapted to warm turbid water. Fluctuating flows also lead to unpredictable conditions for rafters and the loss of the sand bars eliminates many important camp sites for local river guides. This is a small sample of the effects of the dam on the canyon ecosystem. "Whether interpreted as negative or positive, no one questions that the Colorado River ecosystem is not the same as it was before the dam." A group of laws and regulations collectively referred to as the "Law of the River", have been instituted to reinforce irrigation and power production interests, which have traditionally been dominant.[18]

The Colorado below the Glen Canyon Dam is a classic example of the types of complex systems confounding resource managers and government decision makers.[19,20,21] Management actions have many consequences of variable predictability, which when taken in totality are both beneficial and detrimental to different resources. For example, some of the impacts of a 3-month shift in dam operations in 2000 to produce a lower, steadier flow followed by a spike of high flow at the end are described below.

> "The impacts of the low steady summer flow... were fairly positive for downstream ecology but not definitive. The low flows seem to have increased downstream water temperatures, enhanced some spawning by native fish species, and created some near shore habitat beneficial to plant species. On the less positive side, the low flows reduced flexibility in power generation and whitewater thrills while increasing the number of accidents, particularly groundings, for commercial river-runners."[22]

Scientists' ability to predict the effects of dam management actions is extremely limited. At the same, "There's always going to be tension" in setting policy for valuable resources. "The stakeholders are never going to love each other and the stakes are huge."[23] Many parties demand information on the impact of management actions. Scientists studying the system can get caught in the middle because "the research results are going to have real implications for people, so there's always a lot at stake here."[24]

These unforeseen consequences prompted the passage of the Grand Canyon Protection Act in 1992, which required dam operations to avoid damage to downstream natural resources. The problem is, no one is entirely sure how to do that. The River can never be restored to pre-dam conditions. New resources and human activities such as power production, irrigation, and trout fishing, that exist solely due to the dam's presence, also enjoy protection. There is no going back now. Managers are tasked to determine an operating strategy that serves a vast set of interests that have never existed in complete harmony before.

Glen Canyon Dam Adaptive Management Program –

To meet this challenge, the GCDAMP attempts to integrate the generation of scientific information into the operation of the Glen Canyon Dam and the management of the Grand Canyon ecosystem. Initiated in 1996, the GCDAMP is a collaborative decision-making process involving representatives of various interests within the Colorado River Basin that makes recommendations to the Secretary of the Interior regarding the operation of Glen Canyon Dam. The GCDAMP is the most developed adaptive management program in the United States.[25] Barry Gold, former Director of the GCMRC, the research arm of the GCDAMP has called the program, "education for the next generation of managers."[26]

Scientists within the GCMRC tell a different story of the science-policy interface than their colleagues in other parts of USGS. They describe much more substantive knowledge of, and involvement in, management issues and much more substantive interaction with managers and decision makers. These scientists participate in framing science questions, interpreting data, and formulating management options in ways that their colleagues in other parts of USGS feel are inappropriate or dangerous to their reputations as objective scientists. This participation takes the form of negotiation over experimental design and management actions. Medium positions between the political requirements of decision-makers and the technical requirements of scientists are reached to the benefit of both groups. GCMRC scientists appear to feel less threatened and more confident in their role within the GCDAMP than their USGS colleagues do when involved in other policy decision-making processes.

This study found that GCMRC scientists are able to do these things in the GCDAMP because their role is larger and more secure. They are able to play this role because the production of scientific information is an explicit goal of the program and because the GCMRC has been a stable and ever-present institution that has been available to assume new and expanded duties throughout the GCDAMP's history. This expanded role has allowed them to maintain a permanent and local presence and to interact frequently and substantially with stakeholders and decision makers. Through this interaction, GCMRC scientists have gained perspective on the requirements of the policy process, and stakeholders have gained perspective on the requirements of scientific investigation. This fostered greater confidence on the part of the scientists to participate in activities that have potential risks for them, such as question framing, data interpretation, and policy formulation. The interaction and its results are primarily responsible for the increased effectiveness of GCMRC scientist's efforts to contribute to GCDAMP decisions. The interactive part of the scientists' role was played by the leadership of the GCMRC, allowing staff scientists to conduct research largely separated from stakeholders and management issues.

While this study appears to demonstrate that adaptive management techniques facilitate a larger role for scientists in policy decision-making, the technical content of GCDAMP decisions was not evaluated. This thesis makes no claim as to the effect of adaptive management on the quality of decisions, only on the ability of one group to contribute to them.

Notes

[1] NRC. 1995. p. vii.
[2] Jasanoff, S. 1992. p. 195
[3] Sarewitz, D., *et al.* 2000. p. 11
[4] Allen, T. F. H. *et al.* 2001. p. 476.
[5] Jasanoff, 1990.
[6] Cash, *et al.* 2003.
[7] NRC. 1995.
[8] Susskind, L. 1994.
[9] USGS. 2003. p. 12.
[10] Rabbitt, M. 1989.
[11] USGS. 2003.
[12] NRC. 1995.
[13] USGS. 2003. p. 2.
[14] Lowry, W. 2003. p. 93.
[15] Lowry, W. 2003. p. 95.
[16] Lenard, S. 2004d. p. 11.
[17] NRC. 1996. p. ix.
[18] Lowry, W. 2003. pp. 96-7.
[19] Roe, E. 1998. pp. 1-14.
[20] Allen, T. F. H., *et al.* 2001.
[21] Lowry, W. 2003. pp. 18-20, 92-96.
[22] Lowry, W. 2003. p. 115.
[23] Lowry, W. 2003. p. 112.
[24] Lenard, S. 2004c. p. 8.
[25] Lowry, W. 2003. p. 130.
[26] Lowry, W. 2003. p. 91.

CHAPTER 2

Theory on the Interaction of Scientists and Decision-makers

This chapter lays out a theoretical framework in which to analyze the practice of scientists working in support of policy decisions. The traditional conception of the science/policy interface is one of tension between different professional cultures, while the theory behind adaptive management and collaborative approaches to decision-making and fact finding posit that more productive interaction is possible.

The Interaction of Scientists and Decision-makers as Dilemma

Prevalent theory on the interaction between scientists and decision makers highlights the differences between professional cultures within the scientific and policy-making communities. A National Research Council report on science and coastal policy described the differences this way.

> "At the very heart of the issue of the use of science for policy making is the fact that science is concerned with inquiry, description, and explanation, whereas policymaking is concerned with governance of human behavior... Science should hold to the standards of objectivity, reliability, and validity. Policymaking should reflect human values, advocacy, and leadership... The scientist must know theory, methodology, and techniques. The policymaker must know constituencies, governance processes, and value orientation expressed as legal mandates."[1]

The report states that the cultural differences arise from differences in education and training, institutional affiliations, and rewards and incentives. These factors continually reinforce different standards and customs of practice throughout the careers of scientists and policy makers. The report then said that the differences in practice lead to a lack of communication and understanding between scientists and decision makers, the lack or misuse of one group's products by the other, and a generally competitive rather than cooperative interaction that limits the impact of science on policy and limits the utility of scientific information perceived by decision makers or decision-making bodies. The result of these differences is that scientific information is excluded from consideration in policy formulation.[2]

This divide is also perceived within technical disciplines. Jasanoff has described the difference between basic science and science produced to support policy decisions as that between "research science" and "regulatory science", respectively. Research science, according to Jasanoff, is oriented more toward "the extension of knowledge and competence without any regard for practical application." Some scientists may assume that their work will support practical applications in the future even if none are apparent at the moment. The latter is "concerned solely [with increasing and improving] the stock of existing practically useful techniques, processes, and artifacts."[3]

In addition to their relation to the practical, research and regulatory science differ in their relation to time and to the validity of knowledge. According to a United Stated Geological Survey (USGS) scientist "[research] science is always developing and its past conclusions are always subject to challenge as new information is generated, while decision making is inevitably focused on particular points in time where action must be taken."[4] Research science is an ongoing process without a clear point at which one can say a question has been "answered". Information is certified as valid through scientific peer-review and publication. In contrast, regulatory science frames its questions as discrete problems that must be solved by methods as permanent as possible. Jasanoff writes that 'regulatory science' is "designed to fill gaps in the knowledge base relevant to regulation…" at a particular point in time and within the framework of the current understanding of the problem. Information is certified as valid by precedent, and the acceptance of key constituencies.[5] The two approaches to science have substantial differences in the assumptions of practice regarding uncertainty, validity, and innovation.[6]

Cash, *et al.* contend that these differences in culture lead to a dilemma for scientists who try to produce knowledge that is useful to decision-makers and acceptable to scientific peers. They describe this dilemma in terms of tradeoffs between credibility, salience, and legitimacy. Credibility refers to the scientific validity of information, and is defined by its acceptance within the peer community of scientists. Salience is defined as its relevance to the needs of decision makers. Legitimacy is defined as the level to which the information is trusted by stakeholders and decision makers. According to Cash, these three attributes are related in such a way that gains in one imply losses in the others. [7,i] Efforts to maximize credibility generally seek to

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[i] The relationship between these attributes that Cash describes is similar to another that may be more easily grasped. I was once told by a chemist working on EPA Superfund Site Assessment projects that one can obtain results of

concentrate on answerable questions of interest to the peer community with long-range studies that involve only highly trained personnel. Efforts to maximize salience may seek to address policy-relevant questions that cannot be answered definitively on timelines that do not allow for in-depth study. Efforts to maximize legitimacy might involve stakeholders and decision makers in data gathering using lengthy processes and specially modified experimental protocols to expose them to the methods and assumptions behind the results but compromise data quality and/or project schedules.

A main reason these theories conclude scientists face tradeoffs and dilemmas when involved in policy-making is that they are based on a highly structured and linear model of policy formulation that involves first collecting and processing all relevant information, designing a solution, and then implementing that solution[8,ii]. If effective, the solution will bring about the desired state affairs and can then be maintained. Evaluation of the solution's effectiveness is also part of this model, but it is generally oriented toward comparing the solution against expected results rather than reevaluating the consistency of the policy goals with updated understandings of the problem being solved. This model is at the center of practice within the policy-making community. It is not very compatible with solving complex problems, with the way scientific research is conducted, or with fostering a give and take between information providers and decision-makers. It is not compatible because it assumes that a policy problem can be understood in its entirety and it does not allow for changes in the understanding of the problem after a decision has been made. The inability to update the information upon which action is based as new facts come to light requires a high level of certainty that the current understanding of a problem fits with the physical realities of that problem. Scientists often cannot provide that certainty or feel that it is impossible. However, these dilemma's may the reduced to workable tensions given a less rigid method of policy formulation.

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chemical analyses from a contract laboratory that are either accurate, fast, or cheap. One can get any two, but not all three. Fast cheap data will use inaccurate methods, cheap accurate data will take a long time to receive, and fast accurate data will be very expensive.

[ii] Emery Roe states that "The ideal model for policy research is frequently assumed to have up to five components typically undertaken in a linear and tightly coupled fashion:

- First, a baseline survey identifying policy needs…;
- second, rational planning to identify options to meet these needs;
- third, cost-benefit analysis, or something like it, to determine the optimal option;
- four, implementation of preferred option as planned;
- and last, once policy has been implemented, a full-scale evaluation."

Adaptive Management as an Alternative

Adaptive management is one of the most promising solutions to the dilemmas described above. It integrates the production of knowledge about a system with management of that system, allowing for more powerful experimental programs while simultaneously taking management action on a time scale acceptable to decision-makers. This approach is extremely well suited to management of the Glen Canyon Dam because it is such a complex system and because the goals of the management regime are not clear as yet. According to a scientist who has worked on the River, "The only way that you can find out some of the things you need to know [about the River] is by implementing the management action as an experiment."[9] Scientists have been calling for a collaborative approach to investigation of the Colorado River involving stakeholders since 1983.[10]

The 1997 GCMRC Strategic Plan defined adaptive management as follows:

> "Adaptive management begins with a set of management objectives and involves a feedback loop between the management action and the effect of that action on the system. . . . It is an iterative process, based on a scientific paradigm that treats management actions as experiments subject to modification, rather than as fixed and final rulings, and uses them to develop an enhanced scientific understanding about whether or not and how the ecosystem responds to scientific management actions."[11]

The adaptive management approach redefines the management problem to make the production of long-term credible scientific information using an integrated ecosystem-based approach a major goal. The GCDAMP formally designates the GCMRC as the main source of scientific information.

GCDAMP is a collaborative approach that includes collaboration between different stakeholders, between stakeholders and scientists, and between scientists of different disciplines. A collaborative approach is defined here as a process in which the outcome is the product of an organized negotiation between various parties or stakeholders in which ideas and perspectives are shared by participants and examined by the group.[iii] These approaches have the potential to bridge the gap between scientists and decision-makers by creating negotiated spaces in which different types of knowledge and frames of reference can interact productively. They can create

[iii] This definition says nothing of the decision rule by which action is determined (e.g. consensus, majority rules, official decides based on legal authority, etc.)

a framework with mutually understood and accepted ground rules in which scientists can safely contribute to policy negotiations, and in which stakeholders and decision-makers can productively contribute to the design and conduct of scientific investigations. Collaborative approaches have the potential to bridge the gap between scientists and decision makers, simultaneously increasing legitimacy, credibility, and salience by fusing the production of scientific knowledge or consensus with the political and social processes underlying a particular policy problem.

Collaboration can increase legitimacy by exposing stakeholders to the capabilities and limitations of scientific methods, and the data and reasoning behind scientific conclusions. It can increase salience by exposing scientists to management issues, allowing them to frame scientific questions that better address policy problems and by allowing stakeholders or decision-makers to frame hypotheses for scientific investigation themselves.[12] Interaction with stakeholders can make plain to scientists the social dynamics of a problem in a way that is very difficult to achieve through second hand information obtained from other experts, regulators, or the literature.[13]

Collaboration can also increase the credibility of the information by fostering technical pluralism through the interaction of experts representing different disciplines and points of view. Technical pluralism is the interaction and representation of numerous expert disciplines in one process.[14] GCDAMP's integrated ecosystem-based approach to scientific investigation promotes this interaction, though interviewed scientists reported varying degrees of interaction with scientists from other disciplines. In working together, scientists from different disciplines expose each other to the "paradigmatic 'framing' assumptions" that underlie current thinking in each field. These assumptions can then be addressed, acted on, or discarded so that they do not become the basis for conflict later.[15] In addition, collaborative interaction of professionals with lay people or with experts from other disciplines "[requires] that experts de-jargonize their work and acknowledge the fundamental value preferences that their views inevitably reflect."[16] This all serves to improve the quality, and facilitate the general acceptance, of scientific information so that it can be acted upon.

Successful collaborative approaches improve the technical content of, and reduce subsequent challenge to, an outcome by creating a common understanding of the problem among participants.[17] A common understanding of policy problems and of the dynamics of scientific investigation can help stakeholders and scientists determine the proper role for scientific information within the decision-making process. A common understanding of existing scientific information can reduce the likelihood of advocacy science conflicts.[18]

These approaches have the potential to facilitate interaction between groups operating under different assumptions of practice, allowing them to communicate more effectively. This communication may help resolve some of the dilemmas outlined in the previous sections that arise from those different assumptions. The GCDAMP appears to be achieving these goals to some extent. Gold described the process in optimistic terms when he was Director of the GCMRC, "We have one set of science and we can put all the decision makers in one room."[19]

Notes

[1] NRC. 1995. pp. 27-29.
[2] NRC. 1995. pp. 27-29.
[3] Jasanoff, S. 1990. pp. 76-79.
[4] USGS. 2001a.
[5] Jasanoff, S. 1990. p. 77.
[6] Bradshaw, G. A., *et al.* 2000.
[7] Cash, D., 2003. p. 8086
[8] Roe, E. 1998. pp. 5-7
[9] Lenard, S. 2004c. p. 3.
[10] Lowry, W. 2003. p. 97.
[11] NRC. 1999. p. 6.
[12] Roe, E. 1998. p. 11.
[13] Brooks, H. 1984. p. 46.
[14] Scherr, E. 1997. pp. 17-18.
[15] Andrews, C. J. 2002. p. 182.
[16] Walker, G. B., et al. 2001b. p. 11
[17] Jacobs, K., et al. 2003. p. 36.
[18] Ozawa, C. et al. 1985.
[19] Lowry, W. 2003. p. 102.

CHAPTER 3

Roles and Dilemmas of Practice for USGS Scientists

This chapter presents the typical practice of US Geological Survey scientists engaged in policy-driven science as they describe it. The first section lays out the organizational context in which USGS scientists work, including the history of research science in the Survey, and several key factors that affect the way USGS scientists operate. The following sections present an account of how USGS scientists describe their practice. Their activities are so varied that they cannot be captured in a single narrative. Therefore, I describe a role set, comprising 6 roles that USGS scientists play at different times, or sometimes simultaneously. Their account of practice largely corroborates accepted theory describing the science-policy interface in terms of tensions. Most of the policy decision-making processes USGS scientists are involved with are traditional linear processes and they describe difficulty meeting the demands of decision makers while staying true to standards set by the scientific community.

Organizational Context of the United States Geological Survey

This section provides background to better understand USGS as a context for the practice of a scientist. Focus will be placed on the history of variable but constant commitment to basic research science at USGS, the current reflection on practice there, the Survey's reputation for objectivity and neutrality, the funding structure for research projects, and the task of recruiting and keeping talented research-grade scientists.

There are significant contextual elements, of which the reader should be aware in thinking about USGS. The USGS is a research science organization within the Federal government. "The agency's current mission is to supply information that contributes to the effective management of a variety of natural resources and that promotes the health, safety, and well-being of the nation's citizens."[1] USGS conducts original research, environmental monitoring and data collection, mapping, science consulting to other Federal agencies, and some outreach and education. The Department of the Interior and its agencies are the Survey's primary 'customers'.[2,3,i]

The fact that all of its 13 Directors have held PhDs in physical sciences and that 6 have been members of the National Academy of Sciences reveals the Survey's broad commitment to research science.[4] This presents a unique and interesting case for study of the role of the scientist because USGS scientists work in an organization committed to research science and face constant pressure to make contributions to the public policy problems faced by regulatory agencies. USGS leadership sees advantages to practice on both sides of this divide and is actively pursuing ways in which to bridge the gap between them.

A History of USGS Research Science –

USGS is currently undergoing a shift from concentrating on basic science research conducted in relative isolation from regulatory agencies and the public, to conducting research more closely related to policy problems while more closely interacting with others. The historical cycle of shifts from basic to applied science and back sheds light on this transition. This history shows that USGS has been punished by Congress both for neglecting policy-driven science in favor of basic research, and for becoming involved in contentious policy debates.

USGS was originally organized to survey and map the territories of the United States in response to a recommendation from the National Academy of Sciences.[5] As the Department of the Interior has assumed responsibility for managing different natural resources from minerals to forests to water to land, the USGS has surveyed and characterized them. The Bureau has conducted many types of work to fulfill its mission. "Alternative emphases on basic and applied research" have occurred throughout the Survey's history. Support for basic research has varied historically and policy issues have always shaped the fortunes of the Survey. Typically, "when economic security or defense was not a critical issue, Congress has been more likely to question the relevance of the [Survey's] work."[6]

When originally founded, the Survey's scientists focused almost exclusively on identifying and characterizing natural resources. Just two years later, the Survey's second

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[i] USGS uses this term to refer to organizations and individuals who use USGS science to serve Department of the Interior agencies and the public. The term will be used in this thesis to refer to organizations that use USGS science products.

director John Wesley Powell shifted emphasis to basic research. "Powell allowed the staff to choose not only their methods, but the subjects they would investigate as well." Research areas varied widely, including geology, paleontology, chemistry, and physics. [7]

Starting in the late 1880's, USGS became involved in specific policy decisions. USGS land classifications led to the temporary closure to claim of large amounts of western lands. The USGS Director was involved in the passage of the Forest Management Act of 1897. USGS staff were also involved in arbitration of the Anthracite Coal Strike of 1902. In 1905, the USGS Director headed a committee investigating ways to increase the effectiveness and utility of Federal science.[8] Many current USGS scientists shy away from involvement in projects that involve this level of involvement in politics and conflict.[9]

Congress refocused USGS's work in the 1890's toward applied regulatory-science-type projects because it was felt that current practices were not serving the economic interests of the nation. The scope of USGS research was considered too broad. There is also evidence that the agency was in bad favor because of the Powell's politics and because of controversy arising from the closing of western lands based on USGS classifications in the 1880s. Even after this challenge, basic science remained an integral part of the geological branch of the Survey. The trend toward applied science continued as the 1905 committee on Federal science concluded that basic research science was best conducted by the private sector and that government science should be oriented around specific problems rather than around disciplines.[10] As industry developed, mineral and energy resources took on greater national importance (especially during WWI). This development added incentive to focus on economic geology.[11] Fiscal constraints also pushed USGS scientists toward more practical efforts of data collection and mapping for which outside funds could be obtained.[12]

The emphasis on applied science caused severe personnel and prestige problems for USGS that prompted a swing back toward basic science in the 1920's. Because the previous emphasis had been on "economic geology", USGS scientists interested in this type of work went to industry to make higher salaries. At the same time, the Survey's prestige in academic circles, which had been quite high, deteriorated. USGS came to be known as the "Department of Practical Geology" and it became difficult to recruit new scientists. Chief Geologist and future USGS Director Walter C. Mendenhall said in the 1920s "There can be no applied science without science to apply."[13]

After WWII, the USGS grew considerably. While the main focus was on resource identification, the Federal government placed a great emphasis on science during this period making "greater demands for both traditional and innovative research". USGS activities were a good match for new national priorities of scientific and economic competition with the Soviet bloc. Until the National Science Foundation was established in 1950, almost all Federal funds to support earth science research flowed through USGS, making it a preeminent earth science institution. The USGS budget doubled during the 1950s and quadrupled again during the 1970s. "The USGS responded to this by setting its own research agenda with relatively little intervention from the rest of the government."[14,15] USGS scientists, especially those in the Geology Division, had great freedom to define projects based on scientific curiosity. USGS scientists began emphasizing the quality of science as measured by traditional scientific standards. The applicability of projects to present problems faced by government agencies or the public diminished in importance. In this way, the survey took on an academic atmosphere. One USGS geologist described it as "just like graduate school".

This heyday of research science has faded since the post-war era. The USGS budget has not increased in adjusted dollars since the 1980s. In the 1990's, concentrating on basic science drew criticism from Congress as it did a century previous. In 1994 and 1995, the Contract with America advanced by the new republican Congressional majority proposed elimination of USGS.[16] While it survived, the Survey was forced to lay off approximately 500 staff during the budget standoff in 1995. The layoffs all came from the Geology Division, which has the deepest commitment to basic research.[17,18] The National Biological Service was merged into USGS as the Biological Resources Division, which kept the size of the Survey roughly the same.[19] The USGS currently identifies itself as a science and information agency for the Department of the Interior. Department of the Interior agencies are the Survey's priority clients because USGS is funded through Interior.

Reflection on Practice at USGS –

The tension between practicing research science and contributing to policy decisions became acute when the USGS threatened with elimination in the mid-1990s. The Survey is still responding to that threat and is trying to redefine its organizational mission and culture.

According to a USGS hydrologist in 1994, "[USGS is] undergoing a cultural change, asking ourselves who are our customers, why are we here? The new focus will have to be on the needs of society and not just science for science's sake." [20] This effort is largely focused on increasing the prominence of USGS, its contributions to public policy issues, and the recognition it receives for those contributions.

The new outlook represents a significant change for the Survey that places very different demands on USGS scientists than they have been responding to for the last half-century. USGS scientists have traditionally managed their relationship to public policy by emphasizing the separation of science from politics. One USGS scientist noted in 2003 "how different it used to be in USGS when scientists advised the client what they needed and then went away until the final report was delivered."[21] This separation allowed the gap between policy culture and science culture at USGS to widen. They now face demands for greater interaction with regulatory agencies and the public that demands integration across disciplinary and organizational boundaries and an increased emphasis on outreach and communication. These demands make it hard to maintain a distinct boundary between science and politics and they have prompted a reflection on current practice within the USGS. The USGS has engaged in numerous activities to build a vision for the future including the following.

- The drafting (1997) and revision (1999) of a strategic plan for the agency involving approximately 200 public and employee stakeholder meetings.[22]
- 2000 and 2001 customer listening sessions, in which USGS solicited input for its strategic direction from major consumers of its products. These sessions were attended by other Federal agencies, natural resource advocacy groups, and industry and scientific professional organizations
- Commissioning of a 2001 National Research Council review of USGS entitled "Future Roles and Opportunities for the U. S. Geological Survey"
- A 2003/2004 intra-agency discussion on maximizing the impact of USGS science on societal decisions called the Dialogue on Science Impact

These activities focused on increasing the salience and legitimacy of USGS science while preserving credibility. The following emerged as necessary steps to accomplish these goals:

- Increased interaction with "customers" and responsiveness to their needs. In particular, customers have stressed providing information in a timely manner, communicating science to decision makers and the public more effectively and in a manner more applicable to present decisions, and presenting policy implications of the science to decision makers.

- Enhanced partnerships between USGS and educational, industrial, and government organizations.
- Increased integration of research within the different disciplines to address complex problems.
- Increased involvement in resource management efforts and more proactive identification of science issues needing resolution.
- Increased effort for long-term data collection, monitoring, and trend-spotting activities such as the National Map and the National Streamgage Network. This includes organizing, coordinating, and packaging databases and other work.
- Preservation of USGS's core basic science programs and the standards of objectivity and credibility for which they are currently known.[23,24,25,26]

Reputation for Objectivity –

Both the USGS staff and organizations that they work with draw on a vocabulary of objectivity and neutrality to describe the value of the Survey's work in support of policy-making. USGS's conception of objectivity and the standards of practice they have developed to maintain it have developed during the period of emphasis on research science over the last half-century. Preserving this objectivity is a major priority as USGS refocuses on applying their science to policy issues.

According to a USGS hydrologist in 1994, "What makes us unique is that we are and always have been an unbiased agency..."[27] A senior USGS official called USGS's "scientific excellence and objectivity" the "foundation for the organization."[28] Some scientists recognize that experience and values affect even scientific conclusions, but all USGS scientists are committed to producing unbiased scientific products and information and feel that this is essential to the credibility of their work.[29] USGS scientists describe their legitimacy in terms of perceptions of objectivity. "Regardless of how objective we really are, perception is everything, and if we ever lose that perception of being objective we are in really big trouble" said one USGS scientist in 2003.[30,ii]

[ii] This is not unique to USGS. Many scientists see objectivity and neutrality, or at least the perception of it, as essential to their legitimacy as producers of factual information [Jasanoff, S. 1987. p. 196.].

This commitment to objectivity shapes the way questions are framed, research is designed, and data is collected and interpreted. That USGS information is both credible (objective) and legitimate (perceived to be objective) makes its science much more salient than would otherwise be, and thus makes USGS an attractive partner for decision makers. USGS sees a commitment to objectivity as one way to resolve Cash's dilemma and produce information valuable to members of both scientific and policy cultures. Thus, USGS is very protective of its reputation for objectivity.

USGS scientists feel their reputation and lack of bias comes from their long history of producing quality science, and from their lack of regulatory authority. "We have developed a credibility over the last 115 years" said a USGS hydrologist.[31] USGS's identity as a non partisan may also derive from its commitment to research science, where objectivity or lack of bias play an important role in practitioners accounts of what they do. This history works on both the national level and also within smaller communities. For example, one scientist felt part of the reason the MWRA agreed to work with USGS on the Boston Harbor Cleanup was USGS's prolonged presence within the Massachusetts area at Wood's Hole.[32]

Because USGS lacks any direct regulatory authority, scientists have been able to avoid taking specific positions policy matters.[iii] According to the Western States Water Council, "States prefer to have the neutral, data-centered USGS do the science and monitoring, rather than the DOI bureau that manages the land on which the science is conducted."[33] A USGS scientist described a contentious resource conflict in which:

> "a lot of [the agencies participating] and the States had statutory authority, EPA had statutory authority, the Fish and Wildlife Service, so on... a lot of these entities in a sense, were advocates. And so USGS [without any regulatory authority] was viewed as an entity that had nothing to gain other than providing good information that everybody could use to solve the problem."[34]

Their reputation for objectivity has been instrumental in getting USGS involved in many projects centered around conflict. The Western States Water Council has said that "[in contentious issues,] USGS data are the one thing that opposing factions can agree on."[35] An example is the preliminary discussions for the Missouri River Environmental Assessment Program (MoREAP) and cooperative work with the Massachusetts Water Resources Authority

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[iii] USGS did at one time have regulatory authority. Between 1925 and 1982, they regulated extraction of mineral and other resources through the Conservation Branch. USGS lost this role when the Minerals Management Service was formed.[iii]

on the Boston Harbor Cleanup.[36,37] USGS scientists feel preserving this reputation is essential to maintaining the Survey as a viable and relevant science agency.

References to USGS's efforts to preserve their objectivity are present throughout this document. These efforts are centered around preservation of a set of practices and standards that produce objective information. These references to objectivity are not meant to challenge theory describing the subjectivity of observation, but instead to highlight the tensions that USGS scientists feel as they practice science within their organization.

Funding –

Not surprisingly, the availability of funding has always been a strong force shaping the direction and focus of work within USGS. USGS has depended on cooperative agreements with States and other Federal agencies for mapping and data collection activities. Around the turn of the century, Congress's concentration of appropriations on practical projects forced USGS scientists to seek private-sector funds for basic research. In the 1920's, less than 30% of USGS mapping and water gaging was funded through direct appropriation, the rest being funded from other government entities.[38] Funding for research expenses constituted as little as 5% of USGS direct appropriations in the mid-1990's, the rest being consumed by personnel and overhead costs.[39] This meant that USGS scientists needed to seek out external clients to fund a full research program. USGS scientists have "very strong interest and concern about [the] balance... between objectivity and providing resources for our science." Many fear that a lack of control over question definition resulting from dependence on research funds from an interested party may force them to conduct research designed to support a particular position. They feel that, even if this does not occur, the perception of being beholden to funders who have agendas in the issue at hand is damaging to USGS's reputation.[40] These concerns cause USGS scientists to limit their involvement in projects related to contentious issues.

Personnel Development –

USGS scientists who participated in the Dialogue on Science Impact complained the new emphasis on application of USGS science to policy problems requires a lot of work that does not support their professional development. USGS experienced similar difficulties in the 1920s. At that time staff left as focus shifted toward economic geology. Scientists moved either to industry where they would be paid much more for the same work or to academia where they could engage in more basic science research.[41]

A prominent aspect of USGS's employee evaluation system for top-level scientists, the Research Grade Evaluation (RGE), is heavily oriented toward a research science model. The RGE reportedly rewards little else besides publication of original articles in scientific journals. While publications are only one of four major evaluation areas, USGS scientists see it as by far the most important. According to one scientist, "You submit your application for your next promotion and it's based on what you've done, productivity. They may count the number of manuscripts you have. They will do that for sure. If you're taking money [for a project] that doesn't really lend itself to being published, it makes it difficult to get a promotion." The interaction and involvement in policy processes suggested in the new focus at USGS is officially recognized under this system, but is not rewarded, "because technical assistance doesn't count for near as much as research production as far as manuscripts." Another scientist explained that technical assistance activities oriented toward helping decision makers use data after its produced are not rewarded because "its extremely difficult to quantify impact." The effectiveness of technical assistance efforts are difficult to document and therefore difficult to evaluate or reward.

Not all USGS scientists are evaluated under the RGE. It is most common in the Geology Division. Publishing papers is also reportedly "very very" important in the Biological Resources Division. One USGS biologist said, "it certainly is [important] in BRD, because that's how the scientists get their promotions." [42] Research for this thesis indicated that the structure of the RGE is the predominant factor in the incentive structure under which USGS scientists prioritize their activities and that this structure rewards publication of scientific papers almost exclusively. However, this may be somewhat biased as the majority of interviews were with scientists from the Biological Resources Division or the Geology Division. The RGE was also discussed in the Dialogue on Science Impact, but it was not possible to identify individual speakers or the division in which they are employed.

Most senior scientists who have worked under this system for many years, and most new scientists who are attracted to the USGS, value this type of professional development most, and feel they must publish in order to build a professional reputation. These performance criteria ensure a high level of credibility for USGS science. The evaluation system fits well the culture and goals of USGS during the post-war period, but does not reward the new activities USGS is exploring. These activities include outreach and education, participation in lengthy collaborative processes, basic data collection, and science communication or translation. The lack of recognition limits the amount of time USGS scientists are willing to spend on these types of activities.

In addition, USGS scientists find it hard to pursue an area of expertise when their research questions are constantly defined by external funders.[43] These are difficulties that arise from operating within an organization following a research science organizational model but working within a government context. Problems challenging and rewarding talented research-grade scientists are especially serious as the USGS workforce ages.[44]

That USGS does not reward technical assistance shows how oriented they are toward research science. USGS scientists working today have to overcome this organizational obstacle to engaging decision makers more proactively.

Roles Identified by USGS Scientists

When describing their practice, USGS scientists talk about a surprisingly diverse array of activities that they see as distinct from one another, but are all part of their 'job' as scientists at USGS. To analyze the pressures and opportunities that are part of their work, I divided their activities into six roles that identify different aspects of their activities. These are:

- Hypothesis-Driven Scientist
- Data Collector
- Consultant/Expert
- Science Communicator
- Convener/Mediator
- Stakeholder

The roles were defined based on comments made by USGS scientists during the first session of the Dialogue on Science Impact (DSI) and two interviews of USGS scientists. However, scientists did not specifically mention the roles. The roles represent collections of activities that scientists said they engaged in, and which they distinguished from one another. During the first session of the DSI, USGS scientists and leadership discussed ways in which the Survey could maximize "the impact of science on **societal** decisions."[iv]

The discussion focused on three main areas: best practices in achieving science impact, challenges or areas that require improvement, and how to maintain scientific excellence and objectivity while increasing science impact. During the discussion, USGS scientists described aspects of their practice, problems that they face, and ways in which their performance could be improved. Finding ways to make USGS more relevant and influential within the Department of the Interior is a major aim of the Dialogue. This is not relevant to the topic of this thesis. However, because USGS's mission is to produce scientific information for use in policy decision-making, how USGS scientists describe their current practice and the problems they identify when working to support policy decision-making can provide great insight into the question of how effectively USGS scientists interact with policy makers under typical circumstances.

These roles and the dilemmas of practice that are encountered within them are described below. Additional information from interviews with two other USGS scientists also contributes to the discussion in this chapter.

The Hypothesis-Driven Scientist

Hypothesis-driven science describes basic academic-style research science that is driven by the curiosity of the researcher rather than a policy need. Hypothesis-driven science is what Jasanoff calls research science, and what USGS sometimes calls core research. It involves conducting experiments to advance scientific knowledge in a particular area and it is usually conducted without significant involvement from non-scientific collaborators. Most USGS scientists see this activity as distinct from science conducted in response to a client need.

[iv] Emphasis in original

Credibility is paramount for hypothesis-driven research. Salience and legitimacy are not emphasized. USGS scientists generally define hypothesis-driven science as that about which they can publish papers in refereed science journals rather than (or in addition to) client reports. USGS core research is often related to policy problems, but is generally not directly applicable to specific and present decisions. USGS core research investigates topics such as the effects of contaminants on wildlife, the underlying processes that lead to natural disasters, the design of new scientific and environmental monitoring technologies, the ecology of sensitive and protected habitats, and the relationship between groundwater and surface water resources.

This is a major function of USGS that the leadership is dedicated to preserve through the recent and coming changes to the organization. According to USGS, "customers [also] urge USGS to take the leadership role in setting the national research agenda." 'Customers' here include universities, environmental and resource advocacy groups, private industry groups, and other government agencies. Academic institutions in particular feel that USGS "carries a large leadership responsibility" and that its science "profoundly affect[s] the intellectual direction of the profession of geology" and is "indispensable to the nation."[45,46]

Hypothesis-driven science has the potential to become "science that produces results that are so right and so true that they make it into text books. And then they change the fundamental framework of the next generation of decisions."[47] Hypothesis-driven science can have (and has had) enormous impact on policy when the general principles it formulates are applied to policy problems. This impact can vary widely however. One USGS scientist argued that science based solely on internally-generated hypotheses may explore questions of relevance only to the personal interests of the researcher. He described USGS science in the post-war era saying, "Our agency 20 years ago did a whole lot less reimbursable [contract] science than we do now. And at that point, a lot of the people were determining their own research program. I think [the work they did had] a tendency to lead to a little narrower focus. I think it leads to 'hobby science'. I think it can lead to less applied science."[48]

According to one USGS scientist, hypothesis-driven science is "why a lot of us got in this business, but is a very small part of [what USGS scientists do]."[49] This role is the heart of the science culture, but it does not serve well the immediate needs of policy-makers. Such an emphasis is placed on credibility in hypothesis-driven research that scientists allow little room to accommodate the interests of decision-makers or the public. USGS scientists also need to be able to frame the question and interpret the data to ensure the research addresses a need within the field and supports further research. This level of control is often not available for client-driven projects. Therefore, while valuable, it is difficult to secure resources for hypothesis-driven science. In addition, it does not advance in the short-term many of the organization's new goals for increased prominence within the Federal government, increased customer service, and increased impact on societal issues. However, hypothesis-driven science cannot be abandoned in favor of policy-driven science because the maintenance of a scientific staff involved in science at the forefront of their disciplines is one of the things that make USGS valued as a source of information.[50]

Both time and resource constraints prevent projects funded by other agencies from asking questions about the fundamental workings of a phenomenon presenting the policy problem. There is little room within contract science project budgets to "ask why" (as USGS geologist Herman Karl puts it).[51] Instead, they collect sufficient data to apply the current understanding of the phenomena to the problem. USGS scientists find it difficult to formulate interesting and relevant hypotheses to research in the context of this "rarely innovative" regulatory science, especially for studies the scope and focus of which are defined by other parties. Clients want to know only things that are relevant to that specific case and will usually not pay for more. Even minor additional measurements taken to enable the results to answer another question are usually out of the scope of policy science projects with tight budgets. Finally, even if a publishable paper can be produced from client-driven work, because the client has paid for the data, they control it and may restrict its release for legal or administrative reasons. According to one USGS scientist, this is not common, but is always a possibility.[52]

Notice the above quote speaks of today's hypothesis-driven science affecting "the next generation of decisions." This indicates a vast difference in the time frame upon which hypothesis-driven science and policy questions are addressed. That difference contributes significantly to the difficulties in combining hypothesis-driven and policy-driven research. Hypothesis-driven science can be accelerated, but not rushed. Because hypothesis-driven research explores ideas at the forefront of a discipline, it is generally not immediately applicable to policy problems. Additional resources can speed progress, but the timing of discoveries cannot be predicted and therefore deadlines cannot be reliably met. In addition, new discoveries can take years or decades to be confirmed by further research and then to be communicated effectively to decision makers. In contrast, policy decisions often have very definite deadlines (by definition within the scope of this "generation" of policy decisions) and studies undertaken to support those decisions need to meet those deadlines as well.[53]

While seen as distinct, USGS scientists do try to integrate hypothesis-driven components, the results of which they can publish, into client-driven projects. Two ways in which this happens were identified in research for this thesis. The first is to use policy science projects to answer basic science questions. Monitoring and data collection studies conducted in support of policy efforts are designed to document conditions for testing curiosity-driven hypotheses. The data is analyzed further to produce publishable articles after a product has been delivered to the client. Funding and time constraints often make this difficult. However, one USGS scientist stated that "there's enough overlap so that by collecting the data necessary to answer the management question, you come across different interesting science findings."[54] The second is to apply basic science questions to policy issues. This is highly appropriate for complex issues that are not yet fully understood. However, an open process that is comfortable with experimentation, such as adaptive management programs, is necessary.

One success story that appears to be bridging this gap so far involves the Cottonwood River in Minnesota. A Department of the Interior agency requested a recommendation for artificial flow levels on the River. USGS had been conducting hypothesis-driven "work on the regeneration requirements of [the] cottonwood and grazing... Some of that [work] made it into the BLM's [Bureau of Land Management] Federal Reserve water rights. It did make it into license conditions." This is an example of the second way. Their current work on the Cottonwood is an example of the first way. "Although it's supported by BLM, [it is directed by], our sense of what needed to be done over the long term. So we're trying to do a 25-year study a year at a time. And it's mainly our vision that a long-term study was needed. So it's that sort of... USGS synthesized... paying attention to what the needs are and defining a piece of science that needed to be done in the absence of someone there with a checkbook [to fund the entire project]."[55]

USGS's Department of the Interior customers are requesting that USGS base more of its core research on or around policy questions. The Bureau of Land Management has gone so far as to suggest that USGS scientists "anticipate future management actions and develop long-term (strategic) science programs designed to predict and address both the fundamental and applied science needs of future land and resource management actions."[56] This would require a shift in how research questions are generated at USGS. Scientists would have to spend much more time involved with public issues and activities in order to be aware of management issues in intimate enough detail to study them effectively. Consequently, they would spend less time involved in professional activities related to the scientific disciplines they practice.

That client-driven and hypothesis-driven science are difficult to combine presents USGS with a dilemma. The opportunity to conduct hypothesis-driven science attracts talented young scientists that USGS needs to continue its activities. It also develops the skills of USGS personnel, keeping them on the cutting edge of their field so that they are able to develop the tools and conduct the research that clients value so much. Finally, it provides a base to answer future policy questions. The importance of original research for professional development is seen in the fact that USGS's performance evaluation of research-grade scientists rewards publication in scientific journals almost exclusively. In particular, junior scientists find it difficult to acquire funding from USGS itself to conduct hypothesis-driven research. At the same time, they are feeling pressure to publish to build their careers and advance within the organization.[57]

USGS leadership and scientists measure success in this role largely by published scientific papers. This is the primary measure of performance for research-grade scientists. It is also the currency of the academic science community, which is the institution at the center of hypothesis-driven research outside USGS. While impact on "the next generation of decisions" is greatly esteemed, USGS scientists can exert little control over whether this actually occurs. That impact also generally occurs so long after the initial discovery that it cannot act as a measure of success that has any bearing on how scientists practice this type of science.

The hypothesis-driven scientist role represents the culture of science. This section shows the difficulties USGS scientists have in integrating this role into policy-driven regulatory science. The difficulty derives from the difference between this role and the interests and customs of the culture of policy. Contributing to a traditional linear decision-making process requires science to accommodate these interests. The other roles include activities scientists undertake to serve those interests and the following sections describe the tensions between them and the hypothesis-driven scientist.

Data Collector

This role involves a substantial commitment to collect physical data and uphold standards of data quality without the explicit intent of answering a question or confirming a scientific hypothesis. The data is generally published and used by others for any number of applications. This is also the most routine type of regulatory science as defined by Jasanoff. It is often needed to verify the state of a system according to the current understanding of it. Decision makers engaged in traditional linear decision-making processes make extensive use of the data collector's products.

The best example of a science agency successfully playing this role is the USGS streamflow gaging system. USGS has installed gages to measure stream flow along streams and rivers across the country. More than 850,000 station-years of data have been collected over the history of the USGS.[58] "But the point is that so infrequently are those data interpreted[by USGS scientists. USGS puts] out the reports and then the rest of the world can interpret them."[59] These data are used by governmental and non-governmental agencies of all kinds to inform regulatory and policy-making activities of every type. The National Council for Science and the Environment commented on USGS data collection efforts, saying "Surveys, inventory, and monitoring may not be "sexy" science, but they are needed to help managers…"[60] Almost all USGS customers surveyed in the 2000 and 2001 listening sessions stressed the value of USGS monitoring data in management decisions.

The streamflow gaging system is an example of a large-scale constitutive program. This role is essential in providing baseline data for site-specific studies. One USGS scientist referred to this as "foundation science" because it provides shoulders for other studies to stand on.[61] Susskind's account of "trend spotters" extends this role and suggests new value in it. A trend spotter is a scientist who, through measurement and observation, notices changes in environmental conditions over time to indicate problems that need attention.[62] This is the most sensitive, and perhaps the only mechanism by which society at large can become aware of new environmental issues. Many academic, industry, and government institutions have stressed the importance of USGS national-scale monitoring efforts serving this function.[63]

USGS environmental monitoring data have achieved an almost idealized status as accurate factual information. "I mean when people talk about USGS water data it is God's written law. It is correct."[64] "In contentious issues, USGS data are one thing that opposing factions can agree on."[65] This is largely due to USGS's reputation for objectivity. It is also likely that data collected constitutively, and not to support any particular decision, is considered to be more trustworthy because it is not associated with any parties that have a stake in the decision. These two factors make USGS data much more legitimate than that collected by regulatory agencies.

Data collection is very useful to the policy community, though they generally seek to answer simpler questions than those scientists find fulfilling to investigate. There is substantial overlap between this and the consultant/expert role because scientists are often asked to do this type of work for site-specific projects. Site-specific data is commonly needed for environmental management decisions.[66] However, the cheapest and quickest way to gather the data does not leave much room for hypothesis-driven science. One USGS scientist complained, "What I have trouble with is people coming to me with projects that don't have a lot of science in them. They have a lot of data that needs to be collected or something, but you have to be fairly creative in figuring out how to make science out of some of that data."[67] Results of such studies are very hard to publish, and thus scientists are not motivated to conduct them or rewarded for doing so.[68]

As useful as it is, this role appears to take minimal advantage of scientists' valuable skills, and is least fulfilling to professional researchers. Data collection involves a lot of routine travel, measurement, and data management and little interpretation or experimentation. In many cases, this work requires fully-trained research scientists to ensure credibility and legitimacy of the results. The data collector role is fulfilling for the scientist on a project-specific basis only when they can contribute to deciding what is collected. When problem definition, study design, and data interpretation are determined solely by the client, this role is frustrating for scientists.

One way USGS is looking to ease the tension between putting resources into basic data collection and concentrating on hypothesis-driven science is by making data collection less labor intensive. New technologies that allow for data to be collected remotely or even automatically from *in-situ* monitoring equipment will make this role much easier and less expensive. These technologies will enable researchers to place monitoring equipment and leave it in the environment to collect data and transmit it to a laptop on site or even onto the internet. A USGS scientist described the potential change well.

> "[To conduct sediment monitoring] in the old days, you had to go down to the river at regular intervals and physically collect samples of water. They'd go back to the lab. They'd be centrifuged. The sediment would be sorted, sifted, weighed. You'd figure out the fraction of different sediment particle sizes. Now we have Doppler backscatter instruments in the river. We have laser systems that measure particle size and sediment concentration. And we're doing that through data loggers at 15-minute intervals as opposed to monthly like we used to do. The next step... is to set up two-way satellite communication with those stations so we don't even have to send people [there] anymore to get detailed data 4 times an hour on how much sediment load is in the river."[69]

Success in this role is largely measured on technical grounds and is attained by producing, credible data that is consistent over large scales of time and space. In addition, the data should be useful to public- and private-sector actors. For data not collected as part of a specific project, USGS needs to listen to managers to discover where and what type of data needs to be collected and how it should be managed and packaged to maximize salience.

The data collector can serve the interests of either community depending on how the data collection studies are designed. Most data collection is funded to support regulatory activities, however. This section described the difficulties scientists have in trying to satisfy both sets of interests within specific monitoring projects.

Consultant/Expert

This role is referred to by USGS scientists as 'contract science' or advisory science'. In this role, scientists are paid, or their research expenses are covered, to research a question formulated by a third party. This role raises many of the same tensions as the hypothesis-driven scientist, but from a different direction. The consultant/expert is the most common role for scientists supporting policy decision-making processes and therefore was the most talked about during the Dialogue for Science Impact. The dynamics of this role are influenced greatly by client demands, and thus by the type of decision-making process in which they are engaged. In the way most policy-making is organized, scientists are hired by one or more participants in a decision-making process to answer specific questions. Scientists also play this role when serving on scientific advisory or review panels.

This role allows scientists to obtain resources they can use for research above and beyond that appropriated by Congress to USGS. External agencies engaging USGS in contract science have provided as much as one fourth of USGS's total operating budget in recent years.[70] Competition is fierce for the small pot of research money available directly from USGS. Providing information to other agencies as part of the consultant/expert role is the most direct contribution USGS scientists currently make to policy decisions. However, to deliver this information effectively requires scientists to design their work to respond to the expectations and requirements of the policy community. These concerns limit the control USGS scientists have over their work. Customers retain varying degrees of control over question framing, study design, and interpretation of data and they use that control to serve the goals and standards of policy-makers rather than those of scientists. USGS scientists find it difficult to negotiate compromises between these two sets of interests. The lack of control raises concerns about potential compromises on norms of practice for science; the maintenance of their reputation for objectivity, their ability to ensure the credibility of their work, and their ability to develop professionally by producing science that is relevant to their fields of study.

These concerns arise from the fact that study design has a great and predictable impact on what the results will imply for policy. In particular, control over how the research question is framed, and how the data are interpreted determines which observations are made, and which are reported or signified, respectively. Several USGS scientists remarked during the DSI "that the questions that are asked can impact the answers."[71] Stakeholders may also try to direct the investigation toward a particular conclusion or action. Quite obviously how data is interpreted affects what management action they might suggest. The importance of this impact is evidenced by the fact that environmental laws requiring industry to produce scientific information to support regulation make interpretation of data a government function. This guards against bias by interested parties who produce the data.[72]

The risk to USGS of biased questions or interpretation increases as uncertainty increases. Indeed, as Sheila Jasanoff has written, "in areas of high uncertainty, political interest frequently shapes the presentation of scientific facts and hypotheses to fit different models of reality."[73] Thus, it is particularly important when addressing complex issues that USGS scientists be able to defend the assumptions underlying question framing and data interpretation. They also need to be especially wary of how assumptions provided them by a funding agency will be interpreted by other stakeholders.

USGS scientists worry about being drawn into value disputes by participating in science projects over which they have little control. If USGS produces an unbiased answer to a biased question, or produces unbiased data that gets used to support a biased interpretation of how a natural system works, that bias could be associated with the Survey. One scientist specified the ways in which a customer's direction could 'impact the answers'. "I want to be really clear that we're not talking about lying. I mean we're not talking about lack of objectivity in the sense of cooking data or lying. We're talking about the presumption of bias in where you do the work, exactly which questions get addressed, how that information gets provided, and to whom."[74]

USGS's work on pallid sturgeon in the Missouri River provides an example of this dynamic. The US Army Corps of Engineers (the Corps) "controls the management" of the river and the US Fish and Wildlife Service "approves or disapproves of their management style" based on its impact on endangered species. "And yet both of them have come to us and funded us to do research on the most threatened of the endangered species on the River, which is the pallid sturgeon." The priorities of the two agencies sometimes conflict. "There have been times when the [USFWS] has indicated to us that some of the things that the Corps may be willing to fund us to do is not what they consider the highest priority." Each agency has a different set of questions that reflect their approach to the management problem and their priorities with respect to conflicting interests. According to one USGS scientist, USGS approaches the Corps saying "'Look, you need to look at this and this and this and this if you want our objective, multiple-hypothesis approach.' The funding agency goes, 'Oh no, we don't want to do that part. We want to do this part.' Why? Because that's their advocacy."[75] Agreeing to these terms would increase the salience of the research products by targeting research dollars to exactly the questions that follow from the regulatory agencies current understanding of the problem.

These conflicts also interact with USGS's organizational commitments within the Federal government. The Corps requested USGS to submit a research proposal on "anything impacting survival and reproduction of the pallid sturgeon in the Missouri River." USGS asked the Fish and Wildlife Service to comment on their proposal because, "it is very important for [USGS] to get buy-in from the Fish and Wildlife Service because our funding comes through the Department of the Interior and our mission... is to be the science agency for the Department of the Interior management agencies... So yeah, we do feel an obligation, more so to the Fish and Wildlife Service than to the Corps."[76] The Fish and Wildlife Service is within the Department of the Interior. USGS's institutional context within the Department of the Interior appears to restrict their freedom to evaluate the merit of research priorities and produce science that they can defend as unbiased. Scientists within USGS are very concerned about getting caught up in these types of turf battles.

Within the context of current practice, USGS scientists seek a balance between compromising on practices that they have instituted to promote objectivity and legitimacy or losing their salience. Some USGS scientists respond to the above tension by embracing a variant of Jasanoff's technocratic ideal.[77] They rely on scientific institutions such as peer-review to ensure their objectivity and legitimacy, and credibility. One scientist stated that he insists the results of any study he conducts be published in a peer reviewed journal. "And that if we don't feel that we can define a research question... and produce a publishable product in peer-reviewed literature then we've not hesitated to walk away."[78] Others attempt to separate science from values by "staying within your science;"[79] limiting their activity to that which can be termed "objective" so as to "best serve public policy by living within the ethics of science, not those of politics."[80] This often restricts their contribution to the provision of data to answer pre-determined questions without judgment and with only the simplest and most defensible interpretation. The USGS has rules limiting the ability of its scientists to make statements of opinion or professional judgment to the public or to decision-makers.[81,82] It has become part of the culture of USGS to take great care when releasing information to clients, as this exchange in the DSI shows.

> "A: One of the things is that in writing (especially in our internal documents) to stay away from opinion. Being very cautious about stating opinions rather than stating alternatives. So you can say, 'If you choose this path here's some possible results that will come.' But to state an opinion that this is what should be done, I think you have to stay away from that. And I think you've had, in the past few years some scientist who have stated opinions that have caused some problems.
> B: I would take that even beyond published opinions into conversational opinions, especially with potential cooperators. Because they form a lot of their opinion about us based on what we say in conversation, and we may have a lot of opinions on unsubstantiated issues or things we don't have data on. But we have had a very good culture in the past. I know when I came on in the Survey it was just pounded in my head that being unbiased and objective and not doing that sort of thing. And I think we need to maintain that culture."[83]

For fear of being seen as advocating a particular action, USGS scientists reduce the salience of their information by not applying the data directly to the problem at hand in a way that provides solid guidance to the decision-maker. Decision-makers who do not feel confident drawing conclusions from the data may then cast them aside in favor of other considerations that are more clearly articulated. The data's ultimate contribution to the decision is then minimal. Because of this many of USGS's customers repeatedly stated that they "would like to see management implications iterated in USGS reports and other products."[84]

This method of avoiding threats to objectivity is no longer viable. Getting USGS scientists to go farther in applying their data to management problems is also a goal of the new changes in practice at USGS. According to Allen, this is a necessary and possible condition of integrating science into policy making. "Informed as to the consequences and probabilities associated with a decision, good scientists make up their own minds, and take responsibility for that. Science can offer high-quality justification for making decisions and taking actions and scientists must not shirk that responsibility…"[85]

Different scientists see the balance struck at different points along the continuum. Comments from USGS scientists indicate that staff within the Water Resources Division are more likely to restrict their products to simple data with no interpretation at all.[86,87,v] One person stated "I have several times over the years said to folks in Water Resources, 'How come you guys never do a long-term analysis of this stuff and show what the trends are? In fact you folks even developed some of the statistical tools to do it.' [They respond] 'Well, we want to stay out of that arena.'" That scientist feels interpretation is appropriate for USGS as long as it is consistent with available data. He continued, "… when I all of a sudden show a flow pattern and there's a slope and that slope is going up, and I interpret it to say that the high flows are increasing, that's an interpretation. It can be viewed as an opinion, but I can back it up with statistics and everything else. An opinion is, 'I think this, irrespective of the data.'" Several other scientists said that opinions become inappropriate when they begin to advocate a specific action. One responded to the above comment, "if you added a 'therefore' to the end… 'Therefore, this means that you should do this.' That makes your first statement into an opinion."[88]

[v] A potential explanation for Water Resources Division scientists hesitation to offer interpretation is that they work on major water bodies, which are some of the most contested natural resources in the country. Accusations of bias are much more prevalent in situations of intense conflict.

USGS scientists sometimes feel great pressure to provide these types of interpretations or judgments. One scientists recalled, "We had a General in here who asked 'If you were in my shoes, which flow regime would you recommend? We get these questions and we can't play dumb because we are the experts." This shows clearly that USGS scientists do feel an obligation to contribute to policy decisions. Because USGS's mission is to serve as a science and information agency for the Department of the Interior, they are priority customers for USGS. Therefore, this pressure is especially strong when it comes from Department of the Interior Agencies. One scientist described this dilemma during the DSI.

> "We still have some sense of responsibility to Department of the Interior. At one point it was a big part of my job to offer advice and judgment to people in the Department of the Interior about what they should do. Not just data, not just interpretation of that data, but judgment about what was likely to happen or what was likely to be a defensible position or what was likely to win them a court case. And I don't know. Like I tell you, we're not talking about lying for anybody. And that's fine to say you're never going to offer recommendations about what ought to be done. But what if the person asking is somebody from the Secretary's office."[89]

This statement shows more than just an allegiance to Interior. It shows a lack of trust on the part of scientists that their superiors from the policy community will respect the scientists' commitment to norms of scientific practice.

Sometimes, scientists are hesitant to venture into interpretation and recommendation because of old-fashioned politics. One scientist described the pitfalls of interpreting water resources data as described above, saying, "what he's talking about here is *the most* politically charged issue on the River, while we're showing something that is going to make [the US Fish and Wildlife Service] look bad. That really makes it dangerous to get out there and try to show it…"[90] The US Fish and Wildlife Service is a Department of the Interior agency. In addition, the Biological Resources Division, which was added to USGS in 1996, was previously the research arm of the Fish and Wildlife Service.[91] These organizational ties create a certain level of allegiance or obligation for USGS to other agencies. USGS also fears becoming the target of political attacks motivated by the implications of their data rather than its quality. USGS scientists respond to actual or potential political pressure by saying nothing rather than reporting biased results.

Funding is usually the primary incentive to take on client-driven of projects and is also the primary cause of accusations of bias. Funding pressure is a particular threat to USGS objectivity. According to one scientist, "One of the critical things was being in a position to be able to walk away… But if you are in a position where it's a down year in your district and you are desperate to bring in some funds, you are not going to walk away from something that you could see some pitfalls for."[92] This dynamic is also seen in the example of the pallid sturgeon work on the Missouri River where USGS scientists see funding for an entire project being threatened if certain experiments are added. According to one USGS scientist, "we are stuck right on dead center with that right now with the Corps of Engineers in that sturgeon project. We have an entity that only wants us to look at 'this, this, and this. And as scientists we say, 'There are multiple other causes that as good scientists we need to eliminate.' And they're saying, 'Well we don't need any of it then.'"[93] This influence is typically not as explicitly linked to specific results a funding organization wishes to see. The first scientist mentioned in this paragraph added, "I don't think that I have dealt with a [customer] who came to me with an agenda and expected us to come up with certain results. Everybody comes to us because we are perceived as being objective… That isn't to say that it isn't a problem in other places and doesn't have the potential to be a big problem in the future."[94]

Some USGS scientists feel taking funds from action agencies jeopardizes their reputation regardless of how they conduct the science. "When you take somebody's money, the presumption is that you're working for them." "Regardless of how objective we really are, perception is everything, and if we ever lose that perception of being objective we are in really big trouble." USGS scientists recognize that in certain conflict situations there will inevitably be, "those folks that don't like the way the outcome is [who, if the Corps of Engineers funds a project] will say, 'Well, you guys… (and I have been accused of this…) 'you're just a pawn of the Corps."[95] One of the main conclusions from the first discussion of the DSI was that USGS should provide at least some of the funds for each study when possible to retain some level of autonomy. In particular, the point was made that the salaries of USGS personnel should be funded internally.

Control of information as well as content is a point around which credibility is sometimes sacrificed for salience and vice versa. Decision makers will often ask for information within a timeframe that allows them the most freedom of action, thereby serving their needs most effectively. Credibility sometimes demands that work be done on a much longer timescale. Work must sometimes be done at certain times of the year or must sometimes be repeated to ensure consistent results. Data must be validated or peer-reviewed and uncertainties identified and characterized. These requirements involve delaying the release of results when preliminary data may be available. These delays limit the salience of information because it is unavailable when certain courses of action are possible. On the other side, demands for timely data can limit the credibility of information by forcing the use of restricted or abbreviated scientific methods to meet project deadlines.[96] Timeliness of data provision was a major concern of USGS customer's at the 2000 and 2001 listening sessions.[97,98]

For some USGS scientists, an awareness of the impact of their own values and perspective on scientific judgment is another reason they refrain from making recommendations for action. Their values and perspective always affect their work, but when their work affects vested interests of others, the influence of their values becomes a threat to their reputation for objectivity. One offered a method to get around this problem and still offer salient recommendations.

> "When I'm in this situation, I'll preface it with this, 'My training is in natural resources in college. I will give you a recommendation based upon my knowledge in that realm. And consequently, by definition it's going to be biased because I can't give it to you as a grain operator, I can't give it to you as a geomorphologist or as a riparian ecologist. It's my recommendation based on my knowledge set. And you as a decision maker need to recognize that I'm just this piece of a bigger puzzle."[99]

"It's not just based on your knowledge set," added another scientist. "it's also based on your values. And that's the whole problem because when you are asked for an opinion..., it's not just the science, it's also based on the values of whoever is making that decision."[100]

USGS scientists give up a great degree of salience in restricting themselves to simple reporting of data. According to one scientist, "the impact of [USGS] science has depended on our ability to express results in the metric of [the] decision. There is a political and institutional environment that defines the decision variables. As far as science can be expressed in terms of those decision variables, it gets used." Reporting data that are one or two steps of analysis away from having meaningful implications to a public dispute is safe because stakeholders don't associate USGS with a position that data may support. However, "if it is not quantifying what they are going to make the decision on; whether it's a minimum flow, or whether it's the form of the operating criteria for a particular reservoir, [the data] largely doesn't get used."[101]

It is sometimes difficult for a scientist to develop themselves professionally in this role. While the scientist gains varying levels of control over framing the question in this role, there is little control over problem definition. Clients come to the USGS and bring their technical interests with them. A career of this type of work affords little opportunity for a researcher to pursue a particular area of interest. Some USGS scientists end up wondering, "How can a new research-grade scientist develop an area of expertise if she's... always answering a client's question."[102] Serious concern was expressed within the DSI over this topic as it also has consequences for the ability of USGS to attract top-quality personnel. USGS leadership is also looking for their scientists to become more proactive in the consultant/expert role. They are asking their scientist to begin identifying the science needs of decision makers *before* those decision makers ask for assistance. Engaging potential clients and "hustling our products" gains USGS entry into policy decision spaces they might not have had access to had they waited for someone to come to them with information needs. It also helps produce client-driven and funded projects that, because USGS scientists have defined them, are more suited to the production of credible, as well as salient science.[103]

The National Institute for Water Resources commented in 2001 that, "The USGS motto is, '*Science for a Changing World.*' This requires both an understanding of the changing world and the kinds of information and data it needs".[104] An understanding such as this is best attained through involvement in management efforts, stakeholder groups, public processes, and the like. This involvement exposes scientists to the management problems faced by decision makers and stakeholders. It also builds relationships with decision makers and stakeholders that are essential to building legitimacy and trust required for people to ask them for information. Scientists may need to conduct significant educational efforts to show stakeholders and decision-makers how scientific information could be used to support decisions. This outreach work overlaps considerably with the science communicator role. Most scientists have not yet developed the skills to do this effectively.[105,106,107] The involvement also allows the scientists to become familiar enough with the management issues to identify information needs.

Some scientists have been doing this for a long time, but for many, this will be a very new aspect of their role as consultants. At present, the performance evaluation system for research-grade scientists primarily rewards published articles. The significant time and effort required to become involved in management processes and educate other participants is not rewarded. Scientists also complained there were no funds available within USGS for these activities . "We'll never pay for that part of it, we'll never pay for the outreach part" said one

DSI participant. Senior leadership present responded that current reform efforts may address the evaluation and funding issues.[108]

An excellent example of where the gap between science and policy was successfully bridged, and where data was 'expressed in the metric of the decision' is a nutrient loading model for the Neuse River Estuary in North Carolina developed by Borsuk *et al* at Duke University. In response to a 1998 requirement from the North Carolina Legislature to reduce nitrogen loading of the river by 30%, this group designed a model to predict the effects on the river of various management strategies. However, it was recognized that the presence of specific substances in the Neuse River was not what was negatively affecting the public or specific stakeholders but instead it was the more tangible effects of that pollution which was the real "problem" public action was trying to solve. Thus, the model was designed not to predict the average concentration of specific biologically active nitrogen compounds, but instead to predict the likelihood of adverse effects of these compounds that impact public use of the estuary. [109]

The group worked with the public through a survey, public meetings, and stakeholder interviews to compile a list of the most significant negative effects of nutrient pollution such as odor, toxic algal blooms, and fish kills. These items informed the selection of output parameters for the model, "[linking] specific stakeholder interests to the scientific understanding of the ecological system".[110] In a sense, this completed an additional step in the calculations that the decision makers have to perform than is usually done by scientific studies.

The public outreach work was done by social scientists and other professionals. The natural science experts generally maintained control over the actual design of the model and on how citizen input was used. In addition, the model designers stated, that while "refinement of objectives may be possible via further stakeholder discussion; [even] with such iterations... eventually the analyst must exercise some judgment in the interpretation and representation of stakeholder preferences."[111] Despite this, the modelers believe the information produced is more valuable because of citizen input. In this case, both question framing and additional data interpretation were used to produce data that was both salient and credible, and was more legitimate for having involved stakeholders in its production. The structured public input, conducted using accepted social science techniques, allowed stakeholders to determine the output variables of the model while also allowing the scientists to maintain and document the credibility of the study design.

USGS is changing it's conception of success in this role. Formerly, it centered around the publication of scientific papers, and the maintenance of objectivity. Increasingly, it is being measured by its "impact on societal decisions." The redefinition of success expands the role immensely, requiring scientists or other USGS personnel to become intimately involved in management processes to familiarize themselves with the information needs of decisions at hand, promote USGS information products by forming relationships with decision-makers and stakeholders and educating them on how the products could be used. The new aspects of the consultant/expert role will increase the salience of USGS information considerably. However, impact on a decision is very hard to measure based on the content of the decision itself, and depends on many things completely out of the control of the scientist.

We see here the pull of USGS's commitment to support government decision makers. Scientists recognize their obligations but describe a lack of control over how they can contribute. In addition, they express a lack of trust over how their data will be used and how that will reflect upon them. This has caused many of them to shrink from the more risky aspects of the consultant/expert role, lessening the contribution their efforts make to policy decisions.

Science Communicator

Science communicator (or translator, as it is sometimes called) describes a role for scientists in describing, presenting, or reporting scientific concepts and results in a format that is easily understandable by non-technical personnel. In other words, this role creates products that go beyond study reports full of technical jargon and attempt to express scientific results in terms that are understandable and relevant to decision makers and the public. This role is described frequently in the literature. Susskind has written that "communicators take responsibility for making the work of [other scientists] understandable to a larger audience."[112] The CALFED program, an integrated science decision-support program in the San Francisco Bay area, established improved communication of scientific information as one of its major goals.[113] USGS scientists generally described this role as an add-on to the traditional consultant/expert role. According to comments made during the DSI, scientists feel this role increases the utility and influence their science has with decision makers, but clients rarely support or request science communication work directly. The most common circumstance in which scientists play this role is when presenting results to a customer. They also present to public meetings, though not as often and generally as invited guests at meetings held by regulatory agencies.[114]

Science communication includes the presentation of data in easily accessible, non-technical formats and media to make them more accessible to general audiences. It also includes general training and education to lay people and decision makers to enable them to understand more technical products. This is done either with specific groups of people involved in specific decision-making or management processes or as part of more general educational campaigns. An example of the general efforts is USGS's regularly participation in public events on the Missouri River. USGS personnel construct science displays and present science to the public at fairs and river cleanup efforts.

Science communication centers on maximizing salience because it makes information more useful to decision makers and others who are not trained in the relevant scientific disciplines. It makes science more easily accessible by people within the policy community and therefore amplifies the contribution scientists make to a decision. Unfortunately, the science culture has not traditionally valued such activity. Scientists are not trained to do it, reward systems do not motivate them to do it, and many feel it is not part of their role as scientists.

This role may involve a substantial interpretive component and has the potential to influence the types of conclusions that can be drawn from data. It can therefore produce the same anxiety among scientists that recommending policy options does. Some USGS customers believe science translation involves "identifying implications and impacts" of science. Its scope is limited, however. The role as defined here does not include any aspect of question framing, study design, or analysis. Some USGS scientists do feel that communication is important and have put effort into it themselves. They have become frustrated with the challenge of doing so effectively. One scientist recounted an effort to present the results of alternative flow regime models on the Internet in which he was unable to make it digestible enough to be learned in the time he felt people would spend on it.

> "...[Another scientist] and I worked really hard to try to make this thing comprehensible. And when I take it to people who don't understand how you read these graphs, or what it really means, it takes a minimum of a half hour. And they get it then. And they are just blown away by what they learn. When you put something like that on the web and expect someone to take a half hour to learn it by self-educating themselves [it is unlikely that they will]."[115]

This is not uncommon. Many scientists lack the communication and educational skills required to effectively inform lay people about the content, implications, and limitations of study results.[116,117] Education curricula in the physical sciences include little concerning the presentation of data outside the scientific community or the communication of more abstract concepts to untrained audiences. According to one study, 75% of conservation biology employers and faculty surveyed stated that training on "explaining science and values of biodiversity to lay public" was a high priority, while less than 20% of employers or degree programs offered courses on the subject.[118,119]

Resources are scarce for this type of work, and it is not rewarded in the performance evaluation system. A USGS scientists describes how this has limited the amount of work he can do in this area.

> "There's very little reward system here for [outreach and education]. For example, we could have held workshops on these things. We could have educated all kinds of people. But the money I got to do mine came from a contract... When [another scientist] did it he didn't get any money. He just did it on the side... Nor is there much of a reward system for the scientists."[120]

The lack of resources and emphasis has meant that the communication and media skills and tools necessary to do this have not been developed within USGS. This is imperative if scientists are to play this role. Most of the discussion on tool development during the DSI centered on communication.

There is also disagreement over how powerful communication techniques can be. Scientists are often asked to make things simple and clear for decision-makers who are used to policy memoranda that outline, analyze and make recommendations on an issue in two pages. One scientist expressed frustration during the DSI that "if you understand how to read the [data], it's very clear what the decision should be" and if it could be effectively communicated to stakeholders and decision makers the decision would be much easier to make. Another responded "in that case, you can't do it because it's too complex... It's too detailed... We have to educate people about it."

This is especially problematic for communicating uncertainty.[121] The statistical concepts and the intimate knowledge of experimental protocols that are sometimes necessary to fully understand the type and extent of uncertainty integral to some conclusions are very hard to convey to untrained individuals. Without a clear mutual understanding of the uncertainty with which conclusions are made, "what begins as someone's choice ends up perceived as fact by someone else."[122] Scientists often fear that interpretations or conclusions which are expressed with a full complement of caveats as to the uncertainty surrounding them will be attributed to them as unsupported statements of fact.[123] It is very hard to make a clear and concise statement that includes three different scenarios with a full statistical analysis of the likelihood of each. Many scientists feel it is impossible to accurately communicate the science without going to these lengths, regardless of how effective that may be in reaching its intended audience.[124] This is a big part of the tendency for scientists to limit their products to data reporting. "Being informed as to the consequences and probabilities associated with a decision" (as Allen says) does not put one in such a defensible position if they cannot communicate them to critics.

Many feel research scientists are not the best people to perform this function because they do not have the necessary skills and because their time is better spent doing research. One model is to employ personnel with scientific training or experience in a central office who would specialize in data presentation and communication.[125] Scientists at USGS have complained of not having "a part of our organization that we can go to and say… 'Look here's [the data]. Make this so anybody can understand it.'"[126] USGS has been urged by many of its customers to "consider creation of a technical assistance corps consisting of non-research grade scientists to provide consultation, liaison between researcher and land manager and increased application of science to land management decision-making"[127]

There is room for creativity in this role, especially if people from non-scientific disciplines are involved. Dr. Paul Younger of the University of Newcastle upon Tyne participated in a project that used art to communicate various scientific aspects of a community wetland project constructed to remediate a polluted stream. According to Dr. Younger, "People with creative skills could perhaps find methods of articulating the complexity of the problems that face scientists working in this area by stripping them down to reveal areas of importance." The landscaping around the wetland was designed with the help of an artist in residence. Her aesthetic additions highlighted key elements of the physical processes that were occurring in the wetland as it treated polluted runoff. The art allowed residents to more easily access the science. Collaboration between the artist and the scientists and engineers working on the project was difficult and the artist was not able to participate substantively in the design of the wetland itself as was originally intended by the community. However, the collaboration was considered to be a success.[128]

The DSI did not include any examples of USGS scientists making progress in overcoming the tensions surrounding skill building or reward systems for science communication. While some scientists have taken it upon themselves to play this role, the general consensus among DSI participants and other interviewed scientists is that this role is best played by "somebody in technical assistance who knows databases and computers" and has more specialized communication skills.[129]

Success in this role is defined by how effectively science is communicated to its intended audience, and how broad that audience is. On a project-specific scale, success is achieved when the relevant stakeholders and decision makers have been fully informed on the science of a particular issue. On a broader scale, a successful product is one that reaches a great number of people and deemed relevant and understandable. The goal of these broad-scale activities is to educate the public and gain public recognition for USGS science.

Science communicator is a key role in effectively bridging the gap between the science and policy communities. However, it is not valued enough in the culture of science that scientists are motivated to do it, or to acquire the necessary skills. DSI participants described it in terms of presentation of specific results and not in terms of the basic capabilities, limitations, and quality standards of scientific research. This is likely because most USGS scientists do not work with specific decision makers over long periods so the time investment to teach basic concepts would be considered wasted. Scientists do feel this function is best performed by non-research-grade personnel.

Convener/Mediator

Convener/Mediator is a role in which scientists bring together stakeholders to a policy decision to form a dialogue around technical issues. Scientists' traditional image as 'objective' and 'neutral' actors make them uniquely suitable to play the role of convener or mediator in a collaborative process. This role falls outside the traditional relationship between experts and decision makers and requires proactive efforts by scientists to identify relevant and important scientific issues that are inhibiting parties from coming to agreement. While not traditionally a function for scientists, some examples exist where USGS has played this role, and proactive issue identification and the development of collaborative approaches to fact finding are major goals of the USGS Science Impact program.

The scientist or science organization as convener/mediator would only organize discussion around technical issues on which they have expertise. Convening dispute resolution processes around scientific issues may be ideal for more intense conflicts. A common approach to addressing value conflicts is to "base continuing dialogue" on "shared or overarching principles."[130] Most parties want 'a decision based on sound science', though their views on what that looks like may differ. This principle, aligned as it is with principles of the scientific community for objectivity and credibility of information, can provide a strong focus for constructive discussion on the facts underlying a dispute, if not on the dispute itself. If processes convened around science issues do not attempt to resolve a dispute, success in gaining consensus around a 'single text' of scientific understanding can bring stakeholders together. Even if consensus is not reached, the stakeholder interaction around technical issues disconnected from the central issues in the dispute can help form trust.

This role could be used to convene processes involving scientists, or bring other actors together around science-intensive issues. Processes involving primarily scientists could help validate new theories that an actor seeks to propose for application to a problem. This capacity could help an organization certify changes in knowledge and provide legitimacy to new information so that it can be integrated into accepted practice in policy circles. Jasanoff states that certifying new knowledge is an important function of scientists supporting policy-makers.[131]

USGS has explored this role in Project INCLUDE (Integrated-Science and Community-Based Values in Land Use Decision-Making). This project, which ran from 1998 to 2002, sought to develop methods to engage actors from the physical and social sciences and local stakeholders in collaborative decision-making processes to tackle land management issues.[132] This role would advance USGS's goals for increasing their ability to identify science information needs and "provide a focus on an issue".[133] It may however also expose USGS by enmeshing them to a much higher degree in heated political conflicts.

While they are grouped together here, convening and mediating are distinct functions that have distinct consequences on an organization's relationships with other actors. Mediation requires neutrality, which would bar a scientist or science organization playing this role from taking any stand on any issue. Most science organizations would be very comfortable with this. The act of convening a decision-making process may have value-content inherent in the identification and framing of an issue for resolution. The science organization playing this role would have to be careful not to allow this function to interfere with its reputation for objectivity. That risk may be especially acute if the science organization is part of a larger organization (e.g. USGS within the Federal government) and is convening a process on behalf of, and under the direction of, other interested parties.

The Biological Resources Division of USGS, specifically the Columbia Environmental Research Center (CERC) acted as a convener in the Missouri River Environmental Assessment Program (MoREAP) in the mid-1990's. CERC Director, Bill Mauck, was a central figure in this effort. In response to new information needs created by the 1993 flood, the US Army Corps of Engineers (the Corps), who operate the dams on the Missouri River, set out to rewrite their Master Manual, which directs operations of those dams. Mr. Mauck observed the considerable conflict between various users of the Missouri River. He also perceived a significant lack of scientific information regarding many of the issues around which the conflict had revolved.[134]

Differences of opinion regarding the science of issues such as wildlife habitat, flood probabilities, and the economic importance of barge traffic have worked their way to the heart of many of the disputes on the Missouri. In a 2000 airing of *Talk of the Nation* on National Public Radio, representatives of a State water resources agency, the U.S. Fish and Wildlife Service, farm interests and environmental interests debated issues related to the revision of the Master Manual. There were repeated calls to "go back to the facts." Because "all we can do is go with the numbers that are in front of us." Unfortunately, not everyone had faith in that approach, or in 'the numbers in front of them'. The Fish and Wildlife Service representative defended his science, which was represented by "a document with over 500 references to back up our proposal." The farm interest representative responded that, "I don't have a lot of studies... All I know is what I see living down there." These conflicts weren't just between experts and non-expert stakeholders. Poor coordination and communication hampered consensus on the science among trained managers as well. The State representative complained "part of the issue here is that we really don't have the Corps' modeling for the Fish and Wildlife Service Plan. Maybe [the Fish and Wildlife Service representative] has seen that but we certainly haven't."[135]

Mauck became involved with the Missouri River Basin Association (MRBA), a group of representatives from the eight basin states, eight Federal agencies, and the Mni Sose Tribal Water Rights Coalition.[136] He went to meetings and formed relationships with members of the association. Mauck says these interactions helped the MRBA and other stakeholders to trust the USGS and the CERC. He was then able to get key stakeholders to agree to meet and discuss science needs for managing the Missouri. He credits the support the stakeholders showed in putting the workshops together to the trust formed through interaction with the stakeholders rather than any scientific or technical capability.[137]

USGS then provided the financial resources from the State Partnership Program "to basically pull together all the different technical groups within the [Missouri River] Basin and had a series of workshops. The consequence was basically the development of a document that outlines what [science is needed to manage the Missouri River]."[138] This document is a proposal for the MoREAP program. The Master Manual has been updated and the MoREAP program has never been funded. However, there is still a need for centralized environmental monitoring of the Missouri River and congressional legislation to fund MoREAP has been filed every year. Opinions within USGS vary as to whether MoREAP will become a reality.

According to USGS scientists, they were able to convene many of the technical regulatory agencies, all with different agendas and constituencies because, "USGS has the credibility, the objectivity, the lack of advocacy. That's why they were viewed across the Basin as an entity that could do this in an objective fashion..." "an entity that had nothing to gain other than providing good information that everybody could use to solve the problem."[139] According to USGS scientists, this could not have been done by any regulatory agency because stakeholders would perceive that agency as biased toward its regulatory mandate. Even the same staff, working for the US Fish and Wildlife Service (within which the Biological Resource Division existed prior to the early 1990's) would have had much more difficulty. "Now if I had been in research at the Fish and Wildlife Service" said Mauck, "they wouldn't' have listened to me at all because the perception is that you have an agenda, you sort of know what the answer is supposed to be, as far as the Fish and Wildlife Service was concerned. So the biggest thing we had going for us was being part of USGS."[140]

Scientists don't often played this role explicitly in the past and a broad new set of skills that most scientists do not possess would be necessary to play it effectively. In addition, mediating a dispute or decision-making process takes a lot of time that most scientists do not feel they have. However, USGS scientists often do control a part of decision-making processes that everyone is involved in and has a stake in. This is the production of information to support the decision. They could produce this information in such a way as to involve stakeholders in the research, and foster interaction regarding technical issues that may be less contentious than other parts of a conflict. No research was actually conducted as part of the MoREAP case. USGS hired outside facilitators to manage the negotiations between scientists and between stakeholders over design of the program.

The convener/mediator role may be played more effectively by a science organization than by individual scientists because of the broad skill set involved. Specialized mediators and facilitators can accomplish these goals for the organization as a whole while allowing scientists to concentrate more on research. They can also help design more participatory research programs in which stakeholders can take part. USGS has developed some capacity for this. The Policy Analysis and Science Assistance Program at the Fort Collins Research Center includes staff with expertise in conflict resolution, multi-party negotiations, and social sciences. Their mission focuses on integration of physical and social sciences for application to policy problems. However, they conduct negotiation training for natural resource professionals and conduct conflict assessments (termed stakeholder assessments by the DSI participant) for government decision makers.[141,142]

Scientists must participate in these activities for them to be effective. The interactions involved can be very useful for familiarizing stakeholders with the science, and with the scientists who produce it. This will build trust in the science and increase the chances that all the stakeholders can agree on one set of scientific information. It will also allow scientists to familiarize themselves with the management conflicts so that they can produce more salient information that is more easily applicable to specific management decisions.

Success in this role would comprise progress in opening dialogue on contentious issues. Another part of success for USGS in particular would be an increase in the level of understanding among stakeholders of the technical aspects of a dispute, independent of whether the dispute had moved toward resolution. The common acceptance of a single body of scientific information, or the institution of a program to create such information with the backing of all stakeholders would be a common goal of USGS convened or mediated processes.

The MoREAP case is a great example of a USGS scientist bridging the gap between science and policy to engage stakeholders in a discussion of the potential use of science for managing the Missouri River. The aspects of USGS the derive from research science activities, including their perceived objectivity and expert knowledge of relevant scientific areas, was essential to the success that they found in becoming a trusted neutral of sorts for the MoREAP talks. This is one of the less common ways in which scientists can contribute to policy decisions.

Stakeholder

Some members of the scientific community have argued that scientists, as producers of a unique type of knowledge, have a moral duty to advocate for the values that follow from that knowledge[143,144] The stakeholder role involves action either within or outside the traditional consultant/expert role in order to influence decisions. This action includes simply actively advancing opinions regarding proper outcomes of decision-making processes. It can also involve purely political acts such as scientists on government advisory panels "[talking] loudly and [making] sure there are some reporters in the room" when sponsoring agencies do not appear to be taking their advice into account.[145] Advocacy does not imply dishonesty.[146] Whether a scientist is promoting their own personal agenda or that of a client, it is only the extreme and unethical case that involves misrepresentation of data. This role puts the scientists on par with stakeholders and decision-makers with regard to their input into the process. As can be seen above, USGS scientists actively avoid this role by strictly adhering to standards for objectivity and avoiding the expression of scientific opinion. However, their interests are expressed in their work at various times.

The stakeholder role frees the scientist to engage in all aspects of the decision-making process from issue definition to selection of action. However, within collaborative processes, this role strips the scientists of much of his or her distinction as a unique source of information. A stakeholder scientist's contribution becomes simply another viewpoint from which to try to understand the problem. Susskind argues that "it would be disastrous if scientists became nothing more than just another interest group pushing their own agenda" because scientific information would then be suspect and its contribution to decision-making would be lessened.

This is a likely scenario if there were a general shift in the ethics of science that allowed or condoned advocacy. However, it is not clear that the consequences would be so dire if science ethics were to establish clear guidelines for the conduct of advocacy. These guidelines would require full disclosure of one's agenda, or at the very least, public repudiation of objectivity and neutrality within a particular decision-making process or investigation. It is conceivable that scientists declared as advocates could enjoy an increased freedom of action while other scientists enjoyed trust as an objective expert. Some scholars even feel that recognizing the personal agendas of scientists improves the legitimacy of scientific information because "Values are so inherently part of the scientific process that failing to explore the manner in which they interact produces a science that serves unacknowledged masters."[147]

USGS scientists observe this role in other agencies who have scientific capacity and statutory authority to regulate certain activity. One person in particular recounted the situation before the MoREAP was convened in which "a lot of these agencies and the States had statutory authority. EPA had statutory authority, the Fish and Wildlife Service, so… a lot of these entities, in a sense, were advocates."[148]

USGS does not play this role explicitly. So much of their identity and organizational mission is oriented toward objectivity and lack of bias that it would be largely impossible to openly play a stakeholder role. However, individual USGS scientists do have opinions about how the issues they work on should be resolved. One scientist said of a particular issue, "if you understand how to read the [data], it's very clear what the decision should be."[149] His judgment may be based on good scientific information, but it is a judgment none-the-less. These views almost certainly affect USGS's efforts to ensure client-driven science addresses certain questions.[vi] During the discussion on question framing, one scientist recognized that promoting certain questions over others reflects the values of the promoter, even when they are ostensibly doing so in the pursuit of scientific credibility. "[USGS scientists] end up advocating for certain questions a lot of the time. And that's probably a good role. But it isn't completely objective, you might say."

Another scientist recognized a potential organizational bias within USGS that might affect the research they do, stating that " I'd almost rather be taking the Corps' money and doing the research that they want, and showing that we can do that in an unbiased manner than taking

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[vi] See the *Consultant/Expert* Section for more on this.

our own money [and doing our own research], which could be perceived as 'Well, I know all you guys, because you're a bunch of environmentalists and you're answering the question that you want to answer that help the river go this way or that way.'"[150] Another potential source of organizational bias noted in the DSI and in interviews is USGS's obligation to Department of the Interior agencies. These obligations produce a pressure to accommodate the interests of those agencies. This pressure is described in the Consultant/Expert section of this chapter. One scientist said in an interview, "[USGS is] closer to the US Fish and Wildlife Service than they want anybody to know. And that's come up a couple of times." However, whether and how these pressures impact the content of USGS science products is a major concern for the organization. That scientist continued to say, "So you just have to be careful. Once you lose your integrity, your dead as a scientist."[151] USGS does its utmost to maintain their reputation for objectivity.

Another potential advocacy role USGS scientists identified was ostensibly issue-neutral, but can affect the outcome of decision-making processes none-the-less. This role is advocating for additional research to support careers, staff, or professional prestige. One scientist commented that this occurred during the later stages of the MoREAP discussions.

> "In my personal opinion, [the trust USGS gained from being an objective neutral] degenerated somewhat as time went on because USGS did become an advocate, and it became an advocate for resources to do the project. And so then... over time what happened was that we lost some trust because it became, 'You're only doing all this because you want the money to do the program',"[152]

The new organizational goal of science impact contributes to this in an indirect way. One aspect of science impact was described at the beginning of the DSI as follows.

> "How we link the science with the societal issues. How we look for ways that science can actually impact the decisions, rather than just supporting a customer need. We're trying to take it a step further from saying, 'One of our customers is asking us for help, and we will provide the data or information that they're requesting' to more completely understanding what will be the use of that science and how can that science best influence the decision..."[153]

A major reason USGS is pursuing this is to better demonstrate its contribution to more high-profile government functions. If it can show that its information is being used, by documenting the presence of USGS information in decision documents, or its influence on government action, it has a strong case for continued funding and support. However, even if this information is unbiased and objective, it will not be neutral to the outcome of the relevant decision. Therefore, advocating that decisions account for this information fits the stakeholder role even though USGS may have no stake in the actual outcome.

There may even be a consistent bias in how USGS information affects decisions that, if consistently advocated for, would place a bias on USGS's positions as an organization. Certain types of environmental problems can only be perceived using scientific or technical methods. Ozone depletion, health effects of air pollution and the impacts on wildlife habitat of different development patters are examples.[154] Consistently advocating for the inclusion of scientific information in public policy decisions advances environmental interests sensitive to these issues. This may be one reason why USGS is seen by some as "a bunch of environmentalists." Recent calls within USGS for integrated study of issues by multiple disciplines within physical and social sciences will help offset this bias. However, USGS will likely never deviate substantially from its primary identity as a physical science organization.

A tangible example of this is the efforts of Dr. Paul Younger, Professor of Hydrochemical Engineering at the University of Newcastle upon Tyne. He played this role when he became involved with a small former mining village in northern England called Quaking Houses in the late 1990's. Residents of the village were engaged in a collaborative community planning effort to address pollution of nearby streams from the tailings piles of abandoned coal mines. They eventually built a wetland passive treatment system to reduce pollution in runoff from the piles. Dr. Younger, offered to this effort much more than just his expertise in hydrology, chemistry, and engineering. Indeed, he was not well informed about this type of water treatment and when he became involved and "had to become an instant expert on the subject."[155]

Dr. Younger became involved at a point where the residents were writing letters to government agencies requesting action. He was motivated by the scientific nature of the problem and by an affinity for former mining villages, in one of which he is was raised. "I'm a scientist," said Younger "but I'm from that background, and to put my scientific and engineering skills towards work of scientific merit for what I consider to be my people, my real live community... is a real thrill."[156] Younger designed the wetland and brought technical resources to the project. He also helped gather funding for the final project and coordinated events and workshops were at the University of Newcastle. Younger and his graduate students spent a large amount of effort designing the final wetland, all the while coordinating with residents and funders within the collaborative process. In working with the residents Younger felt like a "full collaborative partner" even though he also felt he was sometimes treated by community members like a "technician."[157]

Outside the community process, Younger advocated for action on the Quaking Houses' pollution problems by gathering funding and applying university resources to the problem. Within the process, he advocated for the importance of functional aspects of the wetland relative to aesthetic and cultural aspects that he felt at times were getting more attention from community members. At the same time, Younger produced in the wetland a teaching and research tool to support his research activities. He published several scientific papers based on the work done in Quaking Houses and one of his graduate students based his doctoral thesis on it.[158,159] Though his work with Quaking Houses, Dr. Younger was able to advance personal interests associated with revitalization of northern England mining towns while producing original science and publishing several papers. In doing so, he crossed several lines USGS scientists wouldn't dare by openly petitioning government officials for resources to build the wetland and by pressing community members to ensure that the more functional aspects of the wetland design were accepted. No mention was made in available literature of any damage done to his reputation as a scientist.

Success in this role could be defined as advancement of whatever agenda the stakeholder scientist held. It could also be defined as successfully managing a commitment to unbiased science with the presence of interests related to the outcome of a decision-making process. However, success would also have to depend on not damaging the reputation of that scientist, and perhaps of scientists in general, as objective sources of information. USGS scientists would have a particularly heavy burden in this regard because the Survey's reputation for objectivity is so crucial to achieving its organizational goals. Within current practice at USGS, scientists cannot play this role openly and therefore probably should not do so at all.

This section shows the significant task USGS scientists have in managing their interests while remaining 'objective.' In traditional policy formulation processes, they are managed behind the scenes. Deliberation is not used to allow parties to evaluate the actual impact of organizational or personal biases of the scientists.

Notes

[1] NRC. 2001. p. 3
[2] NRC. 2001. p. 6
[3] Lenard, S. 2004a.
[4] USGS. 2002a.
[5] Rabbit, M. 1979, p. 3.
[6] NRC. 2001. pp. 27-28
[7] Rabbitt, M. 1989. "The First Quarter-Century."
[8] Rabbitt, M. 1989. "The First Quarter-Century."
[9] USGS. 2003.
[10] Rabbitt, M. 1989. "The First Quarter-Century."
[11] NRC. 2001. p. 24
[12] Rabbitt, M. 1989. "The Second Quarter-Century."
[13] Rabbitt, M. 1989. "The Second Quarter-Century."
[14] Rabbitt, M. 1989. "A New Age Begins," "The Survey at 100."
[15] NRC. 2001. pp. 27-35
[16] Petit, C. 1995.
[17] Causey, M. 1995.
[18] *The San Francisco Chronicle.* 1995
[19] NRC. 2001. p. 31.
[20] McCabe, M. 1994.
[21] Peine, J. 2001.
[22] USGS. 1999. p. 3
[23] USGS. 2000.
[24] USGS. 2001.
[25] NRC. 2001. p. 31
[26] USGS. 2003.
[27] McCabe, M. 1994.
[28] USGS. 2003.
[29] USGS. 2003.
[30] USGS. 2003.
[31] McCabe, M. 1994.
[32] Lenard, S. 2004a.
[33] USGS. 2000.
[34] USGS. 2003.
[35] USGS. 2000.
[36] USGS. 2003.
[37] Lenard, S. 2004a.
[38] Rabbitt, M. 1979. pp. 18, 26.
[39] McAllister, B. *et al.* 1995.
[40] USGS. 2003.
[41] Rabbitt, M. 1989. "The Second Quarter-Century"
[42] Lenard, S. 2004g.
[43] USGS. 2003.
[44] USGS. 2000
[45] USGS. 2000.
[46] USGS. 2001.
[47] USGS. 2003. p. 11.
[48] USGS. 2003. p. 21.
[49] USGS. 2003. p. 19.
[50] USGS. 2001.
[51] Karl, H. 2003. Personal communication with author. Herman Karl is Chief Scientist at the USGS Western Geographical Science Center.

[52] Lenard, S. 2004g.
[53] Bradshaw, G. A., *et al.* 2000.
[54] Lenard, S. 2004f. p. 12.
[55] USGS. 2003. p. 12.
[56] USGS. 2001.
[57] USGS. 2003.
[58] USGS. Undated.
[59] USGS. 2003.
[60] USGS. 2000.
[61] USGS. 2003. p. 11.
[62] Susskind, L. 1994. p. 76.
[63] USGS. 2001.
[64] USGS. 2003. p. 25.
[65] USGS. 2001.
[66] Lenard, S. 2004g.
[67] USGS. 2003.
[68] Lenard, S. 2004g.
[69] Lenard, S. 2004d.
[70] NRC. 2001. p. 31
[71] USGS. 2003. p. 27.
[72] Jasanoff, S. 1990. p. 42.
[73] Jasanoff, S. 1987. p. 195
[74] USGS. 2003. p. 20.
[75] USGS. 2003. p. 21.
[76] Lenard, S. 2004e. p. 3.
[77] Jasanoff, S. 1990. pp. 15-17.
[78] USGS. 2003. p. 24.
[79] Lenard, S. 2004g.
[80] Kendler, H. 2003.
[81] USGS. 1994. Appendix A.
[82] USGS. 2002b.
[83] USGS. 2003. pp. 26-27.
[84] USGS. 2000.
[85] Allen, T. F. H., *et al.* 2001. p. 484.
[86] USGS. 2003. pp. 25-26.
[87] Lenard, S. 2004g.
[88] USGS. 2003. p. 25.
[89] USGS. 2003. pp. 26.
[90] USGS. 2003. p. 15.
[91] Lenard, S. 2004g.
[92] USGS. 2003. p. 21.
[93] USGS. 2003. p. 21.
[94] USGS. 2003. pp. 24-25
[95] USGS. 2003. p. 19.
[96] Peine, J. 2001.
[97] USGS. 2000.
[98] USGS. 2001.
[99] USGS. 2003. p. 27.
[100] USGS. 2003. p. 27.
[101] USGS. 2003. p. 11.
[102] USGS. 2003. p. 22.
[103] USGS. 2003. pp. 1-3.
[104] USGS. 2001.
[105] USGS. 2003.
[106] Cannon, J., *et al.* 1996.

[107] Clark, T. 2001.
[108] USGS. 2003. pp. 12-16.
[109] Borsuk *et al.* 2001. pp. 355-357.
[110] Borsuk *et al.* 2001. pp. 357-360; 363-364; 369.
[111] Borsuk *et al.* 2001. p. 370
[112] Susskind, L. 2003. p. 77.
[113] Jacobs, K. 2003. p. 34.
[114] Lenard, S. 2004e. p. 6
[115] USGS. 2003. p. 12.
[116] USGS. 2003. pp. 12-13
[117] Cannon, J., et al. 1996, pp. 1281
[118] Cannon, J., et al. 1996.
[119] Clark, T. 2001. pp. 37-38.
[120] USGS. 2003. p. 13.
[121] Bradshaw, G. A., *et al.* 2000.
[122] Song, S. 2001. p. 983. Quoting Cozzens & Woodhouse's contribution to The Handbook of Science and Technology Studies published in 1995.
[123] USGS. 2003. p. 27
[124] Bradshaw, G. A. *et al.* 2000.
[125] Rigg, C. 2001. p. 87.
[126] USGS. 2003. p. 14.
[127] USGS. 2001.
[128] Kemp, P. 1999. pp. 68, 87-90, 95-108.
[129] Lenard, S. 2004g.
[130] Susskind, L., *et al.* 1997. p. 166
[131] Jasanoff, S. 1990. pp. 194-211.
[132] Peine, J. 2001.
[133] Shapiro, C. 2003.
[134] Lenard, S. 2004h.
[135] Plato, I. 2000.
[136] MRBA. Undated.
[137] Lenard, S. 2004h.
[138] USGS. 2003. p. 3.
[139] USGS. 2003. pp. 3, 6.
[140] Lenard, S. 2004h.
[141] USGS. 2004.
[142] USGS. 2003. pp. 17-18.
[143] Clark. 2001.
[144] Leshner, A. 2003.
[145] Jasanoff, S. 1990. p. 98
[146] Susskind, L. 1994. p. 72.
[147] Song. 2001. p. 982.
[148] USGS. 2003. p. 7.
[149] USGS. 2003. p. 14.
[150] USGS. 2003. p. 21.
[151] Lenard, S. 2004g.
[152] USGS. 2003. pp. 7-8.
[153] USGS. 2003. p.2.
[154] Eden, S., 1996. p. 188.
[155] Kemp, P. 1999. p. 52.
[156] Kemp, P. 1999. p. 50
[157] Kemp, P. 1999. p. 99
[158] Kemp, P. 1999. pp. 109-118
[159] Jarvis, A. 2000.

CHAPTER 4

Roles and Dilemmas for Scientists in the Glen Canyon Dam Adaptive Management Program

This chapter provides background on the Glen Canyon Dam and efforts to manage it and describes how scientists play each of the roles discussed in Chapter 3 in support of those efforts. The chapter shows how scientists within the Glen Canyon Dam Adaptive Management Program (GCDAMP) have made great progress in overcoming the central problems facing USGS scientists when participation in policy decision making. Despite their success, these problems do persist in one form or another.

History and Structure of The Glen Canyon Dam Adaptive Management Program

Recognizing the impacts of Glen Canyon Dam on the Grand Canyon ecosystem, the United States Bureau of Reclamation (BOR) authorized the Glen Canyon Environmental Studies (GCES). The BOR operates Glen Canyon Dam for the Department of the Interior. These studies, which ran from 1982 until 1995, were conducted to characterize and attempt to predict the impacts of changes in dam operation. The GCES laid a good foundation for understanding the natural systems on the River, but did not integrate information from different scientific disciplines and did not include any information on cultural resources such as recreational amenities or Native American archeological sites. According to the National Research Council, the GCES also did not adequately extrapolate management implications or recommendations from scientific data. The studies were adjusted to compensate for these shortcomings, moving toward "inquiry… consistent with the ecosystem concept, thus encompassing a full range of management options as the basis for analysis of the effects of dam management. While this adjustment came to late to be fully effective, the conceptual advance itself is highly significant…" The BOR also incorporated external expertise into the studies through external review and contracting of scientific investigations.[1]

In 1992, Congress passed the Grand Canyon Protection Act, which required the BOR to operate Glen Canyon Dam "in such a manner as to protect, mitigate adverse impacts to, and improve the values for which Grand Canyon National Park and Glen Canyon National Recreation Area were established."[2] This is, in fact, as vague as it sounds. The Act forced managers to formulate the goals of any management strategy for the dam as well as the means to attain those goals. Pre-dam conditions are almost impossible to achieve without removing the dam. While there is support for this option among some environmental groups, enough political and economic interest is vested in the dam that its removal is generally considered "not a realistic possibility." Some have gone so far as to describe that notion as an "outlandish example of environmental dementia."[3] In addition, resources like power generation and recreational fishing that exist because of the dam also enjoy protection. Therefore, the pristine state of the River cannot be used as a guide to set goals for management of the River and operation of the dam. The Act also required that an environmental impact statement be prepared for Glen Canyon Dam and for a monitoring program to be established with consultation to many diverse stakeholders. The Glen Canyon Dam Environmental Impact Statement was completed in 1995 and recommended the creation of an adaptive management program for the Dam in which United States Geological Survey (USGS) was to be involved.[4] The GCDAMP was initiated in 1996.

The GCDAMP is a collaborative stakeholder process funded by revenues from the generation of power on Glen Canyon Dam. It is an advisory group empowered to recommend management actions to the Secretary of the Interior, who makes all decisions regarding operation of Glen Canyon Dam. The program is funded by power generation revenues of Glen Canyon Dam. The GCDAMP has four main components.

- The Adaptive Management Workgroup (AMWG), which is the main collaborative stakeholder group and decision-making body.
- The Technical Workgroup (TWG), which represents the AMWG on technical issues.
- The Grand Canyon Monitoring and Research Center (GCMRC), which conducts and coordinates research.
- The Science Advisory Board (SAB), which conducts periodic reviews of research products and programs.

The Adaptive Management Workgroup –

The AMWG is the deliberative decision making body of the GCDAMP consisting of representatives of 25 stakeholder organizations. AMWG members are generally resource managers or government officials whose training and duties are not primarily technical. The AMWG approves all research conducted by the program, including budgets for all GCDAMP activities, and makes recommendations for management actions to the Secretary of the Interior. Currently however, there is little in depth deliberation in the AMWG and for the most part it approves plans formulated by the TWG and/or GCMRC.[5] The organizations represented on the AMWG are listed in the following table.

Adaptive Management Workgroup Membership

The Secretary of the Interior's Designee - Chair	
Cooperating Agencies	
U.S. Bureau of Reclamation	U.S. Fish and Wildlife Service
U.S. Department of Energy	National Park Service
U.S. Bureau of Indian Affairs	Hualapai Tribe
Navajo Nation	Southern Paiute Consortium
San Juan Southern Paiute Tribe	Pueblo of Zuni
Hopi Tribe	Arizona Department of Fish and Game
Colorado River Basin State	
Arizona	California
Colorado	Nevada
New Mexico	Wyoming
Utah	
Recreational Interests	
Grand Canyon River Guides	Federation of Fly Fishers
Environmental Groups	
Southwest Rivers	Grand Canyon Trust
Federal Power Purchase Contractors	
Colorado River Energy Distributors Assoc.	Utah Associated Municipal Power

Source: GCDAMP website. Available at http://www.usbr.gov/uc/envprog/amp/amwg/amwg_members.html.

The Technical Workgroup –

The TWG consists of one representative from each of the AMWG member agencies. TWG members are generally well trained in technical or scientific disciplines, though some exceptions exist. The TWG's role is to identify information needs, interpret research results, and formulate management options in collaboration with the GCMRC and to approve GCMRC research plans and budget. The TWG has begun to exert an increasing level of control over GCMRC operations. According to one GCMRC manager, "there is a tendency for the TWG to be more involved in management aspects now than technical." This is causing some tension, as he added that, "It would be better if there was more focus on the technical aspects."[6]

The Science Advisory Board –

The SAB is composed of independent scientists from universities or government agencies. They are selected by the chairman of the SAB, David Garrett. Garrett, the first Chief of the GCMRC, was selected as chair by the GCMRC. The SAB reviews GCMRC science products and also conducts reviews of various program elements.[7,8]

The Grand Canyon Monitoring and Research Center –

The GCMRC consists of 34 USGS scientists, technical specialists, and support staff. It is housed in USGS facilities in Flagstaff Arizona, but is funded by the BOR, as is the rest of the GCDAMP. Twenty of the 34 GCMRC positions are in the Integrated Science Program, which conducts physical science research.[9] The central function of the GCMRC is to "develop annual monitoring plans, coordinate all research, and manage all data collection related to the GCDAMP."[10] The GCMRC also does a considerable amount of in-house research. The GCMRC has gone beyond these duties to identify information needs, interpret data, and formulate management options with the TWG.

A former GCMRC scientist described the interaction of the groups like this:

> "We brought back to the TWG a 5-year [research] plan that said, 'Here's what we need to know. , The only way that you can find out some of those things that you need to know is by implementing the management action as an experiment. We wanted to understand (for example) what temperature increases in slower water would do to productivity and recruitment of fish. The only way that you can do that experiment is as a management action. There are risks in there [to carry out a management action]. That's where the collaboration and the negotiation would occur [to balance information needs with resource management priorities]. We would propose a set of management actions, present them to the TWG. There would be a dialogue there. When an agreement was reached, things would be moved up the line to the AMWG with a recommendation. There wasn't always agreement between the scientists and the TWG. Where there wasn't agreement, we would agree to bring different perspectives to the AMWG. The goal of course, was to try to reach agreement."[11]

The activities of these groups have changed considerably over the short history of the GCDAMP. Therefore, their precise roles are somewhat like moving targets and are difficult to describe definitively. According to Barry Gold, "The way it was envisioned is not the same as the way it has been implemented."[12] In the original design of the GCDAMP, the AMWG and TWG identified information needs, set the research agenda, interpreted the results of research, and formulated management recommendations for the Dam. The GCMRC was to contract out and coordinate research projects. Early GCDAMP guidance documents specified the GCMRC to be between 5-6 people whose primary duty was to coordinate the contracting of research to outside bodies. The growth that has occurred since then has consisted primarily of an increased in-house research and information management capability.[13,14] GCMRC now does more research for GCDAMP in-house than was ever envisioned, which has come with a concomitant growth in budget. The budget is approved by the AMWG every year, but this growth is still a point of tension and may be one reason the TWG has begun exerting more control over GCMRC operations.

Since 1996, "there has been some creep in the way the relationships have evolved." The GCMRC has become a driver of many AMWG and TWG activities as roles have shifted toward what is described above. The main direction that these changes seem to be taking is that technical aspects of GCDAMP activities such as experimental design or operationalizing management objectives into measurable goals are sliding toward the GCMRC. A major reason for this is likely the GCMRC's full-time presence within the GCDAMP. TWG and AMWG representatives meet only periodically and labor-intensive tasks would naturally fall to an organization with full-time dedicated staff.[15] The GCMRC is also operated as a scientific organization (and currently by a scientific organization) and thus its organizational mission and reward structure is more closely aligned with this type of work. In Thus, the functions of each group have not always been clear to, or agreed upon by, participants in the program.[16,17,18]

Scientist Roles Within the Glen Canyon Dam Adaptive Management Program

The GCMRC is where the bulk of scientists and research resides within the GCDAMP and its role makes up much of the role of the scientist in the program. It also houses all USGS personnel within the GCDAMP with the exception of two SAB members. Therefore, this thesis focuses on the GCMRC.

When thinking of the roles in the context of a single project, or a single scientist, it becomes clear that one person cannot play all the roles at the same time, even if they are all being played by someone on the project. The GCMRC has actually split the roles between the Center leadership and staff and contract scientists. The leadership (including the Center Director and Program Managers) play the roles that interact more with the policy community, such as convener/mediator, stakeholder, and science communicator. These roles embody more of Jasonoff's democratic ideal[i]. Other scientists at the GCMRC played the less interactive roles such as data collector, hypothesis-driven scientist, and consultant/expert. Their interaction with stakeholders and decision-makers are somewhat limited and formal, though this varies by individual as seen below. Their activities embrace more the technocratic ideal as they stress isolation of experts in the conduct of research[19]. This split was explicitly described in interviews and borne out by the fact that, throughout their interviews, science managers spoke much more about the management dynamics of the program while "bench-level" scientists spoke more of specific scientific studies. One GCMRC scientist described it this way. "The responsibility for really understanding the policy implications fell to the GCMRC Director and Program Managers… And then the scientists below them wanted to really focus on doing good science." Between the activities of both groups, it appears there is effective stakeholder input into the production of scientific information and scientific input into the framing of questions.

The hypothesis-driven scientist, consultant/expert, and science communicator are by far the most prevalent roles within the GCDAMP. Activity within the data collector, convener/mediator, and stakeholder roles is minimal among GCMRC scientists either because the role is inappropriate for this context, the GCMRC has not chosen to adopt the role, or a support structure for the role has not yet been developed.

Hypothesis-Driven Scientist

GCDAMP scientists and stakeholders both seem to have taken to heart the need to expand the current understanding of how Glen Canyon Dam affects downstream resources.

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[i] Jasanoff's democratic ideal involves the participation of non-experts and the incorporation of non-expert perspectives into scientific investigation. She contrasts this to a technocratic ideal in which scientific investigation is isolated from non-expert perspectives and has a greater influence on policy decisions to the exclusion of other views.

They try to integrate testable hypotheses into all GCDAMP research. Because of the commitment to long-term experimentation and learning, there is a higher commitment to credibility than there might be for other contract science projects. The GCDAMP bridges the gap between the needs and expectations of scientific and policy cultures with greater or lesser effectiveness through negotiation between the GCMRC and the TWG or AMWG. As might be expected, the GCDAMP doesn't bridge this gap with complete efficiency. Conflict of interest, resource constraints, and the tension between salience and credibility are still present within the GCDAMP. For instance, the NRC has stated that, because BOR is also a stakeholder in the process, only by making the GCMRC completely independent of BOR money will it be able to produce completely independent and credible science.[20]

The tension within USGS over how to conserve its core research while attracting research funding is somewhat ameliorated. GCDAMP science employs USGS scientists but is funded by BOR. This type of program allows USGS to fulfill the "large leadership responsibility" for advancing the earth sciences that its customers place upon it without excessive expenditure of base appropriations. Resource constraints are evident however in the tension over the growth of the GCMRC. Stakeholders appear to have balked somewhat at funding expanded research activities of USGS scientists within the GCMRC.[21]

However, the more interesting resource constraints related to the hypothesis-driven scientist are those involving experimental management actions. While management actions are a very powerful experimental tool, they are also extremely expensive and consequential. GCMRC scientists frequently compromise on experimental design to accommodate resource interests. One GCMRC scientist described the tension in this way:

> "Our scientists are always trying to implement the best experimental design, the largest sample size, the most replication, the most solid experimental design... But we all realize that there's more to designing the perfect experiment than just sample size. You have to consider the resources that are available to you in terms of people or money. And in this particular case, the will of this Federal Advisory Committee [the AMWG]. So there are times when we present what we consider to be the best possible experimental design and either because of the reality of limitations on the program or the will of the various stakeholders that we interact with, we feel like we have to compromise the experimental design a little bit."[22]

A GCMRC scientist described an example of the kind of compromise that needs to be worked out between scientists and stakeholders.

> "The experimental flows program is in its second year [of an experiment to document the impact of a specific flow regime.] This year we had a request from the Department of Energy representative on the AMWG, to change the flows of Glen Canyon Dam. We had fluctuating flows ranging from 8,000 cfs to 20,000. They wanted to go to 25,000. They asked us what our opinion would be of the effects of this action on the resources. I indicated that... from a resource perspective, the change seemed reasonable. One area that I brought to their attention was that since we have an approved experimental design in place and we're two years into it, changing the flows would be like changing the temperature in an environmental chamber in the middle of an experiment. Even though it might be negligible in terms of an effect, there's always the possibility that the change will lead to increased uncertainty. The stakeholders decided that that was a reasonable risk that they were willing to take. We can still conduct the experiment. We just have to have some additional caveats inserted into our results. So that's kind of a give and take."[23]

The GCMRC is also bound by a host of laws protecting resources along the river including the Endangered Species Act, the National Historical Preservation Act, the National Environmental Protection Act, and the Law of the River. The GCMRC must document compliance with all these laws and the BOR must file with the appropriate agencies to document compliance of all flow experiments for the dam. There was discussion at one point within the AMWG over whether the information value of a particular experiment warranted an exemption from some of these regulations. In that case, the group decided that it did not.[24,25]

In fact, there appear to be limits to the contribution that hypothesis-driven science can make to adaptive management efforts dealing with complex problems. While many people argue that the complexity of management problems makes hypothesis-driven science more useful, one GCMRC scientist said it was that complexity that made hypothesis-driven research inappropriate in some cases. "Unless you've got some antecedent data or some kind of a reference or control system, there's nothing to test your hypothesis against."[26] He provided this example to illustrate this.

> "In 2000 there was a set of short-term experiments referred to as the Low Steady Summer Flow. When the workplan was developed for that, all the science people as well as some of the stakeholders got together and created a portfolio of projects that they thought should be done to understand what happened with LSSF and each one of those had associated with it x-number of '*testable hypotheses*'... And although I've never done it I hazarded a guess that if they had gone back to the LSSF projects, there were 100-some-odd individual hypotheses and I suspect only a small handful of those were ever actually tested in a data sense.[27]"

The desire to incorporate testable hypotheses into all projects has persisted within the experimental flows program beyond the 2000 Low Steady Summer Flows experiments. In the future, the GCDAMP may attain a sufficient level of understanding to incorporate hypotheses into most experiments. However, that scientist does not think so. "In a large-scale ecosystem like the Grand Canyon, there's simply a lot of things we're never going to know. There's always going to be uncertainty. It's simply not an obtainable goal to have the same level of understanding in the Grand Canyon that you might have in an experimental pond in your back yard." In the short-term especially, because the need to comply with the Law of the River and other regulations prioritizes management interests over information interests, one may have to,

> "... just accept that original hypothesis-driven science is not something that's going to typify at least some parts of adaptive management programs... You have to be satisfied with understanding that if you're trying to increase the size of certain sand bars, or features of the geomorphology of the river and if a particular flow regime produces that result, you may not have the luxury of understanding all the bed-load processes and all the wave mechanics and everything else that contributed to that. You might just have to be happy with the result.[28]"

This scientist suggested that specialized training in adaptive management techniques was lacking in GCDAMP and was necessary to strike a productive balance between science practice and policy practice.

Some scientists confirmed the presence of programmatic limitations to the kind of science done for GCDAMP for the purposes professional development. To overcome these limitations requires a "self-starting creative scientist".[29] "You know if scientists are good they're always going to do some of their own research. [The job of the GCMRC program managers] was to push back and to make sure that if it was their own research, it was needed to address a question that the TWG had asked." This person made an exception for questions the TWG hadn't asked because it "appeared too basic to them but it was what we needed to do."[30]

Another scientist described physical limitations as well. "The scope of the GCDAMP is very restrictive. You're stuck within the Colorado River corridor and in fact the bounds of the system are basically from the Dam down to the slackwaters of Lake Mead and up to about the 97,000 cfs mark on both sides of the River. A very narrow scope." This person held up an exemplar that had overcome these limitations. Ted Melis, manager of the Integrated Ecosystems Science Program has developed tools for measuring sediment size and concentration in river water that have many potential locations. He has received a good deal of attention. According to this scientist, "The Grand Canyon was not big enough to hold Ted! His experience has gone all over the country." Tool development seemed to be a common endeavor. Most of the scientists questioned about this issue described examples of successful hypothesis-driven science that included the development of either remote sensing equipment, underwater survey methods, or population sampling methods.

All the scientists I spoke with who were in a position to do so indicated that they were able to publish original scientific papers from the work they were doing for the GCDAMP. By this measure, GCDAMP scientists are succeeding in this role. The program seems to be fairly successful at easing some of the tensions made apparent by the Dialogue on Science Impact (DSI). Hypothesis-driven science has been incorporated into the goals of decision-makers and a method for reaching agreement on the divergent priorities of scientists and decision-makers has been developed. The tensions that derive from those divergent priorities persist, but elimination of these tensions is likely not feasible.

Because there is an explicit role for hypothesis-driven science within the management goals of the GCDAMP, this role appears to contribute more to the generation of decisions than it does in other processes. GCDAMP has achieved a good deal of success making hypothesis-driven science a workable management goal. This does not appear to be solely at the expense of resource use interests. The GCDAMP has developed a mechanism for working out the differences between the demands of the scientific and policy cultures. This mechanism is collaboration and negotiation between the GCMRC and the TWG. This kind of negotiation with decision makers was not described by DSI participants. They presented a much more rigid model of interaction in which trade-offs were much more prevalent than mutually beneficial compromise and the ability to "walk away" was always considered an option. GCMRC scientists described the model of interaction in the GCDAMP as allowing more substantial and consistent contributions by GCMRC scientists to decisions.

Data Collector

The data collector role within the GCDAMP revolves around the proposed core monitoring plan. A core monitoring plan would provide for collection of certain environmental data consistently over a 10-20 year time period. Scientists could then track changes in the ecosystem and better evaluate the impact of management actions. In 1999, the National Research Council recommended that the GCDAMP institute a long-term monitoring plan.[31]

A scientist who joined the GCMRC within the last year noted however, he "was amazed to find out they did not have a current strategic plan... The program did not have a long-term core monitoring plan to decide, 'We're going to commit, maybe 40% of our resources to a consistent core monitoring program that we're not going to monkey with. We're going to let it run for 10 or 20 years.'" This will help fill in data gaps and provide consistency in measurement. Because this plan is not in place yet, interview subjects said little about who would do the monitoring and how it would be done. One scientist responded to inquiry about this role that "USGS does that but I haven't been involved in many of those kinds of projects."[32] The importance of this activity however is underscored by the above discussion on the necessity of antecedent data in forming testable research hypotheses.

Consultant/Expert

The GCDAMP appears to effectively facilitate the interaction of decision-makers and scientists in the consultant/expert role. GCMRC scientists did not express the same kinds of anxieties over bias and their reputation for objectivity that scientists did in the DSI. They described frustration over politics and budget wrangles, but did not recount any experiences in which they felt their reputation for objectivity was threatened. This allowed some of them to expand the consultant/expert role into question framing and data interpretation in the way that USGS is encouraging its scientists to do, and which the DSI participants expressed reservations about doing.

One major reason for this expansion may be that, instead of being hired to answer one specific question or a set of questions as part of a finite and limited effort, GCMRC staff scientists are engaged in trying to answer all of the questions for the foreseeable future. This allows GCMRC scientists to become more engaged in the management issues underlying the science they are doing by increasing their exposure to those issues. They also become more comfortable with, and familiar to, the organization using their products (in this case, the AMWG). The long-term nature of the project lessens the threat that a customer will pull funding for a project if they feel the scientist is not investigating what they want them to.

Increased interaction between producers and users of information, for any reason, is known to increase the salience of information exchanged between them.[33] A DSI participant stated that, "in identifying the issues that have science impact, you have to be involved on a lot of different committees in the community and in other agencies. When they call meetings, go and participate and find out what their problems are. That's really where you find out what the issues are on all kinds of different scales."[34] The many requests by USGS customers for long-term on-site placements of USGS scientists supports the idea that scientists are better able to produce salient data when they have established relationships with relevant actors.[35]

The difference in practice between two of the scientists interviewed for this thesis demonstrate the result of scientists having a long-term local presence. The first is a USGS employee stationed at another location who was hired through the GCDAMP for a finite period to conduct specific studies. When asked what his role in the GCDAMP process was, he responded with very technical descriptions of his studies. He described frequent and active collaboration with other scientists within and outside his area of expertise in which information was exchanged and experimental protocols were adjusted to make data usable to other researchers.[36]

The substance of his interactions with stakeholders related purely to technical matters regarding his work and that of collaborators. He did not report discussing issues beyond his observations and the results of his studies, including any of the management issues in the Grand Canyon. His interaction with the TWG and AMWG were restricted to formal presentations of data.[37] When asked how he had interacted with the TWG and AMWG, he replied,

> "The only time that I've met these people... I know a few of them on the committee, but it's like any other committee. They meet and discuss what they've seen and the directions that the various researchers are going in. I'm sure there's a lot of discussion that goes on behind the scenes because one of the things they have to do is come up with good ideas and good recommendations that are going to carry the project forward to come up with positive results... So I'm sure there's a lot of interaction with them but I don't know. I've not been privy to that part of it."[38]

He did not involve himself in any part of the program besides those studies he was contracted to perform. This makes sense for a contracted scientist who does not reside in the area. His lack of involvement did not impede the scientist's ability to conduct highly credible scientific studies. This picture resembles the typical consultant/expert who answers a pre-determined question and turns in a report without unnecessary interaction with the customer.

The second scientist is stationed at the GCMRC and has a long history of work in the Grand Canyon. When asked what his role was, he responded that he had worked in the area for many years and had recently been tasked to formulate a recommendation for management action for the AMWG. The second scientist displayed an extensive knowledge of management issues on the River from the annual patterns of water input into Lake Powell to the threats to archeological sites along the River to the exact count of the vote in the AMWG that decided on the management action his work had contributed to and who voted against it. He said he had learned all this from "having attended some of the AMWG meetings and TWG meetings and having been to several of the Grand Canyon Science Symposium meetings where the different groups present their research findings." He did not consider these activities to be an explicit effort to inform himself of the broader concerns or to interact with stakeholders. He characterized them as just "being part of the program."[39] This scientist's interactions resulted in the submission of an unsolicited research proposal to study a phenomenon of significance to stakeholders that he said he learned of while talking with them at an AMWG meeting. The proposal has been funded and the study is underway.[40] The second scientist was able to perceive an information need that he likely would never have become aware of except through interaction with stakeholders, and design a project to fill that need in a way the stakeholders likely would never have been able to do themselves. This type of participation and involvement is most feasible and most productive when done by scientists working on a project for the long-term and who are located physically near the land or resource being managed.

The second scientist is not typical within USGS and his knowledge of management issues exceeded the requirements of his position. Neither 'bench-level' nor contract (outside GCMRC) scientists were required to make themselves aware of management issues. While "everybody has some level of awareness," the GCMRC leadership is responsible for being "a link between the managers and the scientists... Part of their job would be to understand what the managers want done."[41,42] It was recognized that "there is and probably always will be in these kinds of processes, frustration on the part of the bench-level scientist for always bumping into the management interface. Some of the scientists feel that it is an impediment."[43] Scientists feel that dealing with stakeholders and managers takes time away from more important science and makes them less effective. This division of labor "made sense" to one GCMRC scientist,

> "because there is a great potential for scientists to get caught up in a cycle of continual brushfire issues with stakeholders. We have a lot of meetings with the TWG and the AMWG and a variety of ad hoc and permanent subcommittees. So there's some efficiency in designating a small group of people who have primary responsibility for those interactions rather than letting everybody be subject to their call."[44]

Thus the second scientist's interactions with stakeholders were not a central part of his role as a consultant/expert. They did however enable him to greatly increase the salience of his research, identifying information needs and framing questions to meet them.

Despite the benefits described above of having scientific capacity dedicated to the GCDAMP, which can be more exposed to the management issues, stakeholders reportedly feel that work done by GCMRC scientists can be inferior to science done by contractors hired through competitive bid. "There's a bit of a perception" said one scientist "that there's a little less rigorous competition and peer-review on things that are done internally by the Center as opposed to being outsourced... [the stakeholders] feel that if we are doing things in-house, we are not reaching out and taking advantage of the best scientific work out there through a competitive process." This scientist called these views "not necessarily warranted" and said they were largely the product of "some rather unrealistic expectations about what science can do." However, the lack of a competitive process to assign projects apparently affects the legitimacy of that work.[45] The quality of GCMRC scientific products relative to those produced by outside contractors was not investigated as part of this thesis. If stakeholders perceive GCMRC science to be of lesser quality, that would represent a major impediment to GCMRC effectively providing science to support Glen Canyon Dam management policy.

Another unique aspect of working in the consultant role on such a large long-term project with an ecosystem focus is the level of interaction among disciplines that is required. This varies from scientist to scientist. Interestingly, the first scientist above interacted with other scientists frequently and productively, while the second complained that he had few opportunities to collaborate with scientists from other disciplines. A recent restructuring of the GCMRC has formalized many avenues for interaction between disciplines and created the Integrated Ecosystems Science Program. "They have squad meetings every month where speakers from each of the different projects address the latest results and ideas. We want everybody talking and sharing information so that you know what I'm doing and you can get involved if you want to and I know what you're doing and I can get involved if I want to."[46]

The consultant role played within the GCDAMP also differs from the typical one described in Chapter 3 because of the standing that the GCMRC has within the process. The leadership of the GCMRC play the consultant role when they coordinate, perform, and contract out GCDAMP research. The TWG and AMWG are the clients in this role. But the GCMRC has a somewhat more equal standing in deliberations over GCDAMP science than a typical consultant would. "The intent was to have some sense of parity between the science agency [the GCMRC], the management group [the AMWG], and a set of independent science advisors [the SAB]."[47]

The GCMRC leadership can make suggestions with more confidence that their commitments to credibility will be respected. This situation allows the GCMRC leadership to more effectively bridge the gap between the practices of research science and policy. This standing also allows scientists to be a full partner in question framing and interpretation. Research questions have come from both the TWG or AMWG and from the GCMRC. According to one scientist, "In some cases, the experiments were requested by the AMWG or the TWG in response to conditions that they say developed in the basin. In other cases GCMRC proposed them because we felt that there would be something learned by a new set of management actions."[48]

During negotiations regarding study design like those described in the hypothesis-driven scientist section of this chapter the GCMRC often has to compromise on the credibility of the experiment in order to satisfy resource demands. They felt comfortable doing so however. "We don't feel like the science was compromised to the degree that USGS would look like we weren't capable of doing good science."[49] Their main obligation when this happens it to make sure the AMWG is making an informed decision. In one scientist's words, when compromises are made "it's our job to let [the AMWG] know that, 'OK, now your uncertainty has increased. Yes we're able to do this, we can accommodate that.'" They also feel an obligation to maintain some minimum standards of credibility so they instead "might say, 'We can't do it at all. Forget it. We're not going to wade in there and do something because this looks like bad science.'"[50]

It appears that GCMRC scientists are comfortable with compromises that their colleagues in other USGS programs would find unacceptable so they don't have to 'walk away' and can work out mutually beneficial solutions to problems. At the same time, they are comfortable with their ability to "walk away" from certain proposals or demands. A reason for this may be that they are more familiar with the management issues and understand the motivations behind the AMWG's decisions. They are therefore able to rationalize the compromises in terms of factors that do not compromise legitimacy, such as real resource constraints.

This does not mean that the GCMRC can or is willing to do anything the stakeholders ask of it. Several scientists mentioned what they saw as unworkable demands placed upon them by the TWG or AMWG.

> "Oftentimes the expectation was, 'Oh, can't you simply go out and do 'X' and get us answer A or B so we can move on.' And there was a lot of need to discuss uncertainty in science, and what you can know and can't know, and how long it takes to do something... From a manager's perspective, they want this information yesterday. From a scientists perspective, it may take two weeks or two years to get you what you need."[51]

The idea that this indicates a need for better understanding on the part of stakeholders may be a defensive reaction by scientists to requests that are difficult to fill. Managers request information that meets these criteria; scientists see this as difficult or impossible to provide; and they conclude that managers are ignorant of the requirements of credible science. Available interview materials do not indicate whether this conflict is a result of ignorance on the part of managers, inflexibility on the part of scientists, both, or perhaps neither. However, even if GCMRC scientists are being inflexible, they are rationalizing the disagreement in terms of ignorance rather than mal-intent, which is the basis of a much more workable conflict.

When discussing compromise on study design DSI participants appeared to describe assume the worst case scenario of intentional tampering with experimental design to influence results in order to protect themselves. This policy decreased their capacity to contribute to some decisions. GCMRC scientists' understanding comes from being part of the project for a long time and from interacting with stakeholders to identify information needs and interpret data. Here, the program works within a middle ground between the practice of scientists and of decision-makers that is a constructed through negotiation between the two groups.

GCMRC scientists have also been able to participate in formulating management actions. In 2002, GCMRC scientists helped the TWG recommend a flow experiment to direct the operation of Glen Canyon Dam. GCMRC scientists started discussion within the TWG by designing draft recommendations that applied the current scientific understanding of the canyon to management options for the dam. A scientist who was involved described this task as difficult "because we had to not just explain the science but... in a lot of cases, managers wouldn't even know what to ask, or we wouldn't know what their limitations were on us. So we kind of had to guess what they wanted and then tell them how to operate the dam..." Information on 'what they wanted' came primarily from a program manager involved in the process who reportedly attends TWG and AMWG meetings regularly.[52]

The adaptive management approach has made credible scientific information a central goal of the program, but it has not erased the conflict between credibility and salience. The familiar tension is described by a GCMRC scientist, as "balancing quality with relevancy ... that's one of the other tensions that informs this kind of process."[53] This scientist described his approach to this dilemma as follows, "I looked at the AMWG essentially as a board of directors. I felt that any science that we proposed needed not only to be credible and of high quality, but had to pass scrutiny and review by the AMWG. That if we couldn't explain it to them and have them understand why it was relevant, then we couldn't get it done."[54] This shows a high degree of sensitivity to policy needs and an acceptance of their legitimacy on the part of scientists.

Stakeholders are also sensitive to the needs of scientific practice. However there have been instances where the interests of the stakeholders in the outcome have affected the conduct of research, though the GCMRC has generally been successful at maintaining a high standard for the science. One example is the experimental protocol used to estimate endangered humpback chub populations. There is currently controversy over the fact that the fish populations are being estimated using different methods in the upper and lower Colorado Basin, respectively. One method consistently reports lower populations than the other. The GCMRC commissioned an extensive scientific review of the processes, which concluded that the GCMRC method was correct for the assumptions being used to model the populations. "So there was no support for doing concurrent methods [both methods at the same time]. But when [GCMRC] made the presentations to the TWG and the AMWG, the decision was still to do the concurrent sampling. So again our experimental design, or our science has not been compromised, but what's happened is, a political decision was made to use two methods, which the experts said was unnecessary. And that dilutes funding a little bit, but nevertheless, we still accomplish the research and produce credible science."[55] This is an example of interaction between scientists and decision-makers leading to a workable compromise between the needs and standards of the cultures of each community.

Protection of resource interests, including profitability of power generation also weighs heavily on how studies are designed. One GCMRC scientist described this saying, "There's a lot of scrutiny [of proposed experiments] on the part of the power users saying, 'Hey Hey, this is going to cost us $2 million a month. We want to know that we're going to get some bang for the buck.' And bang for the buck is a reasonable expectation."[56] 'Bang for the buck' was described as the potential to document a beneficial operational method for the dam that would recoup the expense associated with it by reducing other costs, such as Endangered Species Act compliance costs. Negotiations between the TWG or AMWG and the GCMRC over study design sometimes took on a very explicit interest focus. Barry Gold recounted an instance in which "The water and power guys said we'll give you more water [for another flood experiment], but we want you to look at larger [daily] fluctuations than allowed in the environmental impact statement."[57,ii]

Timing of data release proves to be just as significant an issue for the GCDAMP as for other USGS projects. GCMRC insisted that all data be reviewed prior to release to the AMWG and TWG. "If [the GCMRC] had done a study and discovered that something was really in trouble immediately and that immediate action would have been taken, [they] would have brought that to the committee. But for the most part [they] tried to deliver data after it has some level of review.... [This policy led] to tensions, and concerns," said one scientist. "I'm not sure how we could have handled it better. At the end we started getting pushed quite a bit and so we started presenting preliminary information, telling people that it was preliminary and that it hadn't been peer-reviewed." There were particularly strong demands for release of preliminary data indicating a decline in humpback chub populations in the late 1990's. "Fortunately, it didn't change after it was reviewed, so it was ok."[58]

Funding issues are also of concern for the GCMRC. The GCMRC follows the suggestion of some Dialogue on Science Impact participants that USGS always contribute some funds to every project. Because the GCMRC is housed within USGS facilities in Flagstaff, Arizona, some USGS resources are being contributed to the program. However, staff salaries, which were emphasized to be of special importance at the DSI, are funded by BOR. This was stipulated in the Grand Canyon Protection Act. The NRC said in 1999 that this compromised the independence of GCMRC science.[59] The TWG has also begun to exert some control over GCMRC operations during budget reviews, threatening its independence. A GCMRC scientist

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[ii] Larger daily fluctuations would greatly enhance power revenues.

described this, saying, "[The TWG can get] very specific. They can say, 'We don't support that research.' 'We want you to eliminate that project and reprogram the money over here.' They can say 'We don't agree that you should fund it to that degree, we want you to fund it to this degree.' And it might be more, it might be less." GCMRC is looking into the propriety of the TWG's influence on research that may impact their interests. "We've had some Federal solicitors provide us with some information on whether TWG and AMWG members should even be able to vote on issues that affect them because of the whole conflict of interest issue. That has yet to be fully resolved."[60]

The group exerting pressure on the GCMRC is a representative stakeholder group rather than an individual stakeholder. This could alleviate some of the risk of perceived bias because the modifications to GCMRC research represent a consensus of stakeholders. However, TWG actions are products of whatever internal dynamics reside within that group, and some stakeholders may have disproportionate influence on group decisions. Interactions within the TWG were not investigated as part of this study though GCMRC scientists reported that some TWG members have less technical training than others, which could produce a disparity in the ability to participate in deliberations.[61]

The consultant role, as it is played in the GCDAMP has not overcome all the dilemma's facing it in other USGS projects. However, it does appear to 'create a negotiated space' in which GCMRC scientists feel more comfortable interacting with policy-makers than their USGS counterparts who participated in the DSI. Within this space scientists have shown a greater awareness and sensitivity to the concerns of stakeholders and vice versa. This awareness allows scientists greater freedom of action and therefore, greater contribution. The GCMRC is also achieving many of USGS's Science Impact goals. GCMRC leadership, acting as consultants are engaging in issue identification, question framing, and interpretation while maintaining standards for credibility and objectivity. Thus far, their science has been a major determinant of management actions for Glen Canyon Dam, and has done so in a very tangible and recognizable way. In these ways, GCMRC scientists are succeeding admirably at this role.

Science Communicator

Former Director of the GCMRC Barry Gold stated that "being able to deliver scientific information in a way that all of the stakeholders could understand it" was one of the most difficult tasks within the GCDAMP.[62] Science is most often communicated to stakeholders via formal presentations at AMWG and TWG meetings. "We tried to have at every AMWG meeting, a presentation on some of the work that was ongoing so that people could understand what we were doing and what research results were coming up." The communication at these meetings "mostly happens through written materials and then conversation about those materials."[63] These presentations were generally tailored to a "semi-technical audience".[64]

Several GCMRC scientists stated "There was a lot of need to discuss uncertainty in science, and what you can know and can't know, and how long it takes to do something..."[65] Making clear how science works to inform the debate on tradeoffs between salience and credibility, was a central function of science communication in the GCDAMP.

> "It was important to be able to explain to the stakeholders why you had to [do certain experimental] treatments. The way you did them, the challenge of working without controls or replications. The sensitivity of monitoring programs. Because all of [the experiments] have two costs associated with them. One is the financial cost and the second is the cost of... What happens if you've run an experiment and you haven't done the data collection, the research and monitoring in a way that you can say something conclusive, either positive or negative, from the experiment."[66]

Another scientist agreed that GCDAMP participants needed training on the fundamental capabilities of science. He went farther to say that "the stakeholders, as well as the scientists have little or no formal training in adaptive management... That creates a few bumps in the road." These bumps in the road repeatedly took the form of unrealistic expectations of what science can accomplish when studying a highly complex and uncertain system and how adaptive management seeks to design management strategies for Grand Canyon resources "without necessarily the luxury of understanding all the processes and mechanisms that are involved in causing changes in those resources."[67]

Another route of communication is the annual Grand Canyon Science Symposium. This is a scientific conference that aims to "inform members of the AMWG, the TWG, and the public on the recent findings of scientists funded by the GCMRC to conduct monitoring and research of the Colorado River ecosystem."[68] The symposium is geared toward scientists and does not include specialized programming for laypeople.

There have also been several participatory strategies used. Stakeholders were taken on tours of the GCMRC and allowed to participate in hands on computer modeling.[69] AMWG members were taken on a one-week river trip to learn about the ecosystem first hand and "to try to give them a... feel for why certain things were being done."[70] AMWG members are also invited to attend certain peer-review sessions of broad scope called protocol evaluation panels. According to one scientist, few AMWG members ever attended these meetings.[71]

These participatory efforts were made only up to a point where they did not "compromise the process" of research.[72] The GCMRC was organized such that the major burden of communication with stakeholders fell to the leadership within the Center. Staff scientists were left free to pursue research without extensive interaction with AMWG or TWG members.

One would need to ask AMWG members or other public audiences for an accurate view of how successful GCMRC's science communication efforts were. Because this was outside the scope of this thesis, I will not venture to evaluate their effectiveness. It appears that a great deal of effort is spent engaging the TWG and AMWG members and communicating to them. The goal of these efforts that was most often discussed in the interviews was not communicating research results, or physical aspects of the ecosystem. Little effort appears to be spent tailoring the presentation of results to lay audiences. This may be because the TWG and AMWG are made up either of technical personnel or resource managers that have likely been exposed to these issues before. Instead the scientists interviewed spoke most about teaching stakeholders the dynamics of the scientific method and its strengths and weaknesses. The scientists believed that making clear the issues considered important within the science community was essential for productive cooperation between the scientists and the TWG and AMWG. The long term role of the GCMRC scientists may have made these efforts more worthwhile because they facilitate future interactions.

Convener/Mediator

This role was never played explicitly by GCMRC scientists. In fact, Barry Gold stated in reference to a strategic planning effort early in the history of the program that AMWG members needed to "figure out a way to bridge your differences, but don't force the scientists to bridge those differences."[73]

GCMRC's expanded role did foster a productive atmosphere within the GCDAMP. GCMRC's efforts to organize action around scientific activities allowed stakeholder's to interact while doing something other than discussing divisive interest conflicts. The GCMRC also hosted river trips for AMWG members that helped stakeholders form more positive relationships with each other. Fostering interaction around less contentious issues than those that make up the dispute is a common strategy for diffusing tensions in collaborative processes.[74] The prestige of the 1996 experimental flood, which received national press coverage, also served to reinforce in stakeholders a perception of the value of the GCDAMP process.[75]

Interviews with AMWG members are necessary to determine the success of GCMRC in this role. So far, the GCDAMP is a functioning collaborative process and some have credited the GCMRC's work as a positive force in that process.

Stakeholder

GCMRC does not intentionally play this role. However, one scientist expressed concern that "there are times when the [GCMRC] scientists believe that they are acting from a value-free position advocating for science, and the stakeholders don't perceive it that way. Or the stakeholders perceive it as advocating for science that is not relevant to the decision-making at hand."[76] This may be an example of what a DSI participant described as being an "advocate for resources to do the science." The growth of staff and in-house activity within the GCMRC has been resisted by the AMWG and the TWG. This may be a reason behind the TWG's efforts to exert control over GCMRC funding and operations.

According to one GCMRC scientist, "there's some truth to that. We have a staff of people, particularly in the biology program that... have legitimate full-time career appointments with the Federal government. So to keep them gainfully employed we have to ask them to do some of the work that we might otherwise outsource."

Because GCMRC is not playing this role intentionally, has not declared itself to be a stakholder, and has not disclosed any agenda it may hold, no success in this role is possible.

Notes

[1] NRC. 1996. pp. 1-10.
[2] Lowry, W. 2003. p. 101.
[3] Lowry, W. 2003. pp. 98-9
[4] NRC. 1999. p. 1.
[5] Lenard, S. 2004d. pp. 1-3.
[6] Lenard, S. 2004d. pp. 1-3.
[7] EMI. 2002.
[8] Lenard, S. 2004d. p. 3.
[9] GCMRC. 2004.
[10] Lowry, W. 2003. p.103.
[11] Lenard, S. 2004c. p. 3.
[12] Lowry, W. 2003. p. 103.
[13] NRC. 1999. p. 129
[14] Lenard, S. 2004b.
[15] Lowry, W. 2003.
[16] Lenard, S. 2004d. p. 3.
[17] Lenard, S. 2004b.
[18] NRC. 1999. pp. 126-130.
[19] Jasanoff, 1990. pp. 15-17.
[20] NRC. 1999. p. 127.
[21] Lenard, S. 2004b.
[22] Lenard, S. d. pp. 6-7
[23] Lenard, S. 2004d. p. 6.
[24] Lenard, S. 2004c. p. 5.
[25] Lenard, S. 2004d. p. 13.
[26] Lenard, S. 2004b.
[27] Lenard, S. 2004b. p. 7
[28] Lenard, S. 2004b. p. 6.
[29] Lenard, S. 2004d. p. 16.
[30] Lenard, S. 2004c. p. 10.
[31] NRC. 1999. p. 83.
[32] Lenard, S. 2004f., p. 12.
[33] Roe, E. 1998. p. 11.
[34] USGS. 2003. p. 28.
[35] USGS. 2000.
[36] Lenard, S. 2004.
[37] Lenard, S. 2004.
[38] Lenard, S. 2004.
[39] Lenard, S. 2004f.
[40] Lenard, S. 2004f.
[41] Lenard, S. 2004c. p. 5.
[42] Lenard, S. 2004f. p. 11.
[43] Lenard, S. 2004c. p. 5.
[44] Lenard, S. 2004b.
[45] Lenard, S. 2004b. p. 7.
[46] Lenard, S. 2004d. p. 16.
[47] Lenard, S. 2004c. p. 2.
[48] Lenard, S. 2004c. p. 4.
[49] Lenard, S. 2004d. p. 6
[50] Lenard, S. 2004d. p. 7.
[51] Lenard, S. 2004c. p. 6.
[52] Lenard, S. 2004f. p. 7

[53] Lenard, S. 2004c. p. 6.
[54] Lenard, S. 2004c. p, 5.
[55] Lenard, S. 2004d. p. 8.
[56] Lenard, S. 2004d. p. 12.
[57] Lowry, W. 2003. p. 114.
[58] Lenard, S. 2004c. pp. 8-9
[59] NRC. 1999. p. 127.
[60] Lenard, S. 2004d. p. 6.
[61] Lenard, S. 2004d.
[62] EMI. 2002.
[63] Lenard, S. 2004c. pp. 7-8.
[64] Lenard, S. 2004d. p. 18.
[65] Lenard, S. 2004c. p. 6.
[66] Lenard, S. 2004c. p. 7
[67] Lenard, S. 2004b. p. 6.
[68] GCMRC. 2003.
[69] Lowry, W. 2003. p. 132.
[70] Lenard, S. 2004c. p. 7.
[71] Lenard, S. 2004c. p. 8
[72] Lenard, S. 2004c. p. 8.
[73] Lowry, W. 2003. p. 108.
[74] Smith, M. 1999. p. 991.
[75] EMI. 2002.
[76] Lenard, S. 2004c. p. 2.

CHAPTER 5

Findings and Recommendations

General Findings

Chapter 3 recounts a number of difficulties US Geological Survey (USGS) scientists perceive when dealing with decision-makers. These accounts appear to bear out the theoretical dilemmas outlined in Chapter 2. The difficulties can be described in terms of the differences between the cultures of the scientific and policy communities. The scientists complained that decision-makers often ask them to do things that do not meet standards of practice within the scientific community. They are asked to produce data faster than is feasible, to release data without proper review, to tailor their investigations to support a certain understanding of a problem rather than evaluating that understanding, and to spend time and resources communicating information to untrained audiences. The Dialogue for Science Impact (DSI) participants outlined the difficulties inherent in shifting USGS practice to accommodate the demands of policy-makers. They highlighted differences between the USGS's new organizational goals and the values of practice that have been emphasized in USGS during the post-war period. These values stressed the independence of the researcher, and the value of scientific norms in determining the quality of information. USGS scientists also stressed the incompatibility between these new demands and the reward system that has developed to reinforce values USGS emphasized during the post-war period.

While USGS scientist are doing excellent work of great importance, I concluded from the comments made during the DSI that the main factors limiting USGS scientists contributions to policy decisions was a lack of flexibility and a suspicion of the motives behind decision-makers requests or demands. These problems are the result of a pattern of short-term interactions with policy-makers in which spending time communicating the basics of practice on each side of the science-policy gap is not worthwhile. In addition, scientists rarely come to the table with decision makers as equals, and therefore act defensively because they do not have the power to represent their interests in negotiations with decision-makers who are funding their projects. At the same time, decision-makers lack knowledge on how to effectively put scientists and their work products to use. Scientists have ideas about how this could be done but lack the skills or opportunity to teach those ideas to decision-makers.

The dilemma's described in the DSI center around a perceived tradeoff between credibility and salience, though some examples of attaining a measure of both simultaneously came up. Most notable of these was USGS's work on the Cottonwood River. USGS scientists largely see legitimacy as tied up with credibility. Discussion at the DSI indicated that, by and large, they feel if they can defend their science as credible according to the standards of the scientific community, it will be legitimate in the eyes of other users. Accounts of their reputation for objective and unbiased science, which was described as widespread, valuable, and the product of their commitment to credibility, largely support this.

Chapter 4 shows these difficulties are still present in the Glen Canyon Dam Adaptive Management Program (GCDAMP). However, Grand Canyon Monitoring and Research Center (GCMRC) scientists describe them in terms much less intractable than those used in Chapter 3. While the Adaptive Management Workgroup (AMWG) was often described in the same terms used to describe decision-makers in Chapter 3, GCDAMP scientists spoke of more substantive interactions with the AMWG and the Technical Workgroup (TWG). That scientists at the GCMRC are able to confidently participate in question framing and data interpretation activities that their USGS colleagues in other programs shy away from indicates that the collaborative nature of the GCDAMP allows for a better understanding of the demands and interests of science and of policy-making across the divide between those communities and a more substantial contribution from scientists to policy decisions.

The main reason for the greater impact of GCRMC scientists is that they have a more full and secure role within the decision-making process. Their role is derived from the explicit emphasis in the GCDAMP's charge to integrate scientific discovery into the management strategy. However, the GCMRC has assumed a much larger role than was originally envisioned for it. This is likely due to two factors: the GCMRC's full-time staff resources and its organizational orientation toward scientific research. No other part of the GCDAMP possesses either of these traits.

This role reduces the insecurities that each group brings to the table when negotiating over experimental design. The GCMRC's permanent status has made scientists' funding more secure, thus reducing its potential influence upon them. It allows GCMRC to establish long-term relationships with stakeholders and allows their staff to build up a history of exposure to the management issues related to the dam. Scientists are therefore more aware of the considerations that stakeholders must take into account when making requests of the GCMRC. Scientists also have an incentive to spend time and effort teaching stakeholders about the general dynamics of scientific research, giving them a greater awareness of the considerations scientists have to make when responding to these requests. The permanent full-time staff also allowed for a division of labor within the GCDAMP between scientists specializing in communication and interaction with stakeholders and other scientists specializing in conducting research. The direct communication of the norms and requirements of science and policy cultures is evidenced by the awareness of scientists about policy concerns and the efforts of scientists to teach stakeholders about the capabilities and limitations of science. No DSI participant reported doing this with any other decision makers.

All this serves to make scientists and stakeholders more comfortable working with each other and making compromises to accommodate each other's interests. Flexibility is increased and GCMRC scientists are able to engage more in question framing and data interpretation. A drawback of the localized permanent science presence is that motives of self-preservation are attributed to it. That the institution is funded by one of the stakeholders contributes to this perception. The science organization feels pressure to justify its existence by concentrating on developing methods to recoup the costs of its operation.

Information collected for this thesis suggests that adaptive management including a strong secure role for the scientist is a promising approach for resolving many dilemmas of practice for USGS scientists. However, it should be noted that a difference in the method of data collection for the DSI and interviews with GCDAMP personnel exists, and that this may contribute to the contrast between the two images of practice they produce. The DSI was an effort to identify problems in current practice and was conducted in a familiar setting with people who work for USGS. This environment was designed to make participants comfortable discussing weaknesses in their professional performance. While most of the interviewees seemed to be quite frank, GCDAMP scientists were speaking with someone outside the organization to whom they may have been less inclined to reveal the shortcomings in their work within the program.

Recommendations

This study found that the collaborative aspects of the GCDAMP, rather than the experimental aspects, were the main factor allowing scientists to contribute to management decisions. Under the original program design, the GCMRC would have been basically a science contracting office. The relationship between the contract scientists conducting research for the GCDAMP and the AMWG or TWG members would have been very similar to that described by DSI participants with neither group substantially informing the other of the basis behind their needs. The interaction between GCMRC and the stakeholders makes their relationship much more productive. Based on the above analysis of comments by USGS and GCMRC scientists, the following recommendations can be made to the design of adaptive management programs for maximization of input from scientists.

- Scientists need to be engaged with an adaptive management program for long time periods.
- Scientists need to regularly engage stakeholders in dialogue regarding experimental design in a forum oriented toward consensus.
- A permanent organization with enough scientists on staff to allow for specialization of roles is helpful for avoiding tensions between the desire to conduct research unmolested and the necessity of interacting with stakeholders and decision makers.
- Explicit efforts should be made by both scientists and stakeholders to discuss openly and directly the underlying constraints on action and standards of practice prevalent within their professional culture.

Limitations

The most significant limitation to this study is that only scientists were interviewed. No attempt was made to obtain information on the perspective of TWG or AMWG members about the contribution of the GCMRC to decisions. One GCMRC scientist said, "I think in talking about a collaborative process… it's important to get the perspectives [of multiple parties] because there are times when the scientists believe that they are acting from a value-free position advocating for science, and the stakeholders don't perceive it that way."[1] Further research building upon this study should focus on the perspectives of AMWG and TWG members and should perhaps also interview decision-makers who work with USGS in other contexts as well.

Notes

[1] Lenard, S. 2004c. p. 2

Bibliography

1. Allen, T. F. H., Tainter, J. A., Pires, C., Hoekstra, T. 2001. "Dragnet Ecology – 'Just the Facts Ma'am': The Priviledge of Science in a Postmodern World." *Bioscience*, Volume 51, Issue 6, pp. 475-484. June.
2. Andrews, C. J. 2002. Humble Analysis – The Practice of Joint Fact-Finding. Preager, Westport, Connecticut.
3. Beretan, Kathi. 2003. "Managing Complexity, or the Information Needs of Adaptive Co-Management: The Durham, NC Air Quality Case." MIT E-planning Seminar given 21 November.
4. Bradshaw, G. A., Borchers, J. G. "Uncertainty as Information: Narrowing the Science-Policy Gap." *Conservation Ecology*, Volume 4, Issue 1, Article 7.
5. Brooks. H. 1984. "The Resolution of Technically Intensive Public Policy Disputes," *Science, Technology & Human Values*, Volume 9, Issue 1. pp. 39-50. Winter.
6. Cannon, J., Dietz, J., Dietz, L. 1996. "Training Conservation Biologists in Human Interaction Skills." *Conservation Biology,* Vol. 10, No. 4, pp. 1277-1282.
7. Cash, D., Clark, W., Alcock, F., Dickson, N., Eckley, N., Guston, D., Jager, J., Mitchell, R. 2003. "Knowledge Systems for Sustainable Development." *Proceedings of the National Academy of Science*, Vol. 100, No. 14, pp. 8086-8091
8. Causey, M. 1995. "Geological Survey Layoffs." *The Washington Post.* 14 August.
9. Clark, T. 2001. "Developing Policy-Oriented Curricula For Conservation Biologists: Professional and Leadership Education in the Public Interest". *Conservation Biology,* Vol. 15, No. 1, pp. 31-39
10. Corburn, J. 2002. "Street Science: The Fusing of Local and Professional Knowledge in Environmental Policy," Thesis for completion of Doctor of Philosophy in Urban Planning, Massachusetts Institute of Technology. June.
11. Ehrman, J. R., Stinson, B. L., 1999. "Joint Fact Fining and the Use of Technical Experts," in The Consensus Building Handbook, eds. Susskind, L., McKearnan, S. and Thoman-Larmer, J.. Sage Publications, Thousand Oaks, California.
12. University of Michigan Ecosystem Management Initiative (EMI). 2002. "A Conversation with Barry Gold." Obtained from the EMI website at http://www.snre.umich.edu/emi/events/conversations/gold.htm. Website accessed 29 April 2004.
13. Fischer, F. 2000. Citizens, Experts, and the Environment. Duke University Press, Durham, London.
14. Grand Canyon Monitoring and Research Center (GCMRC). 2003. "Colorado River Ecosystem Science Symposium 2003: Programs and Abstracts." Obtained from the GCMRC Internet website at http://www.gcmrc.gov/symposium/2003/2003presCD/Program%20and%20Abstracts.pdf. Website accessed 30 April 2004.
15. GCMRC. 2004. "GCMRC Personnel." Obtained from GCMRC Internet Website at http://www.gcmrc.gov/Personnel/Pers.htm. Website accessed 29 April 2004.
16. Hajer, M. 1995. The Politics of Environmental Discourse: Ecological Modernization and the Policy Process. Clarendon Press, Oxford.

17. Jarvis, A. 2000. "Designing, Construction, and Performance of Passive Systems for the Treatment of Mine and Spoil Heap Drainage", Doctoral Thesis Abstract. Obtained from the Hydrogeochemical Engineering Research and Outreach Program Internet Website. Available from http://www.ceg.ncl.ac.uk/research/hero/Abstracts/Adam%20Abstract.htm. Website accessed 10 February 2004.
18. Jacobs, K., Luoma, S. , Taylor, K., "CALFED: An Experiment in Science and Decision Making." *Environment*, Vol. 45. Issue 1, pp. 30-41. January/February.
19. Jasanoff, S. 1987. "Contested Boundaries in Policy-Relevant Science." *Social Studies of Science*, Vol. 17, No. 2, pp. 195-230.
20. Jasanoff, S. 1990. The Fifth Branch: Science Advisers as Policy Makers. Harvard University Press, Cambridge, Massachusetts.
21. Jasanoff, S. 1992. "Science, Politics, and the Renegotiation of Expertise at EPA." *Osiris*, Second Series, Vol. 7, Science After '40, pp. 195-217
22. Kemp, P., Griffiths, J. 1999. Quaking Houses – Art Science and the Community: A Collaborative Approach to Water Pollution. Jon Carpenter Publishing, Charlbury, Oxfordshire.
23. Kendler, H. 2003. "Should Scientists Remain Objective?". *Science*. Vol. 301, pp. 310-311.
24. Leshner, A. 2003. "Public Engagement with Science." *Science*, Vol. 299. P. 977.
25. Lenard, S. 2004. Interview with USGS scientist. 29 March.
26. Lenard, S. 2004a. Interview with USGS scientist. 10 March.
27. Lenard, S. 2004b. Interview with USGS scientist. 27 April.
28. Lenard, S. 2004c. Interview with USGS scientist. 13 April.
29. Lenard, S. 2004d. Interview with USGS scientist. 13 April.
30. Lenard, S. 2004e. Interview with USGS scientist. 12 March.
31. Lenard, S. 2004f. Interview with USGS scientist. 2 April.
32. Lenard, S. 2004g. Interview with USGS scientist. 26 April.
33. Lenard, S. 2004h. Interview with Bill Mauck (USGS former). 26 April.
34. Lowry, W. 2004. Dam Politics: Restoring America's Rivers. Georgetown University Press. Washington, DC.
35. McAllister, B., Chandrasekaran, R. 1995. "When Federal Employees Become Surplus; Layoffs at Geological Survey Suggest Turmoil that Many Agencies Will Face." *The Washington Post*. 15 August.
36. McCabe, M. 1994. "Shock Wave at USGS Over GOP Plan to Cut Agency: Scientists Say Quake Studies Would Suffer." *The San Francisco Chronicle*. 23 December.
37. Missouri River Basin Association (MRBA). Undated. "Information About the Missouri River Basin Association Internet Website." Obtained from the Missouri River Basin Association Internet Website at http://www.mrba-missouri-river.com/photo.htm. Website accessed 27 April 2004.
38. Moore, C. W. 1986. The Mediation Process: Practical Strategies for Resolving Conflict. Jossey Bass, San Francisco.
39. National Research Council (NRC). 1995. "Science, Policy, and the Coast: Improving Decisionmaking." National Academies Press, Washington, DC.
40. NRC. 1996. "River Resource Management in the Grand Canyon." National Academies Press. Washington, DC.

41. NRC. 1999. Downstream: Adaptive Management of Glen Canyon Dam and the Colorado River System." National Academies Press. Washington, DC.
42. NRC. 2001. "Future Roles and Opportunities for the U.S. Geological Survey." National Academies Press, Washington, DC.
43. Norton, G. 2002. "Conservation in the 21st Century: A New Environmentalism". Remarks presented by Interior Secretary Gale Norton at the National Press Club. 20 February. Obtained from the Department of the Interior Internet Website at http://www.doi.gov/news/020225.html. Website accessed 29 November 2003.
44. O'Reagan, B., Moles, R. 1997. "Applying a Systems Perspective to Environmental Policy". *Journal of Environmental Planning & Management*, Volume 40, Issue 4, pp. 535-538. July.
45. Ozawa, S., Susskind, L. 1985. "Mediating Science-Intensive Policy Disputes." *Journal of Policy Analysis and Management*, Vol. 5, No. 1, pp. 23-29
46. Peine, J. 2001. Report on the Eastern Region INCLUDE Workshop. 5 December.
47. Petit, C. 1995. "Babbitt Tells Scientists to Beware; He Appeals For Help to Block Federal Cuts." *The San Francisco Chronicle*. 17 February.
48. Plato, I. 2000. "Missouri River Flow Change" *Talk of the Nation*. 29 September. Audio file obtained from National Public Radio Website at http://www.npr.org/ramfiles/totn/20000929.totn.01.ram. Website accessed 15 March 2004.
49. Rabbitt, M. 1979. "A Brief History of the U.S. Geological Survey." U.S. Government Printing Office, 1979-281-363/1.
50. Rabbit, M. 1989. "The United States Geological Survey, 1897-1989." *US Geological Survey Circular 1050*. Obtained from the USGS Internet Website at http://pubs.usgs.gov/circ/c1050/index.htm. Website Accessed 29 November 2003.
51. Rigg, C. 2001. "Orchestrating Ecosystem Management: Challenges and Lessons from Sequoia National Forest." *Conservation Biology*, Vol. 15, No. 1, pp. 78-90.
52. Roe, E. 1998. Taking Complexity Seriously: Policy Analysis, Triangulation, and Sustainable Development. Kluwer Academic Publishers, Boston, Dordrecht, London.
53. *The San Francisco Chronicle*. 1995. "Former Geological Workers Fight Layoffs." 10 November. No by-line.
54. Sarewitz, D., Pielke, R. A. Jr. 2000. "Prediction in Science and Policy," in Prediction: Science, Decision-making, and the Future of the Nation, eds. Sarewitz, D., Pielke, R. A. Jr., Byerly, R. Jr. Island Press.
55. Scherr, E. 1997. "Consensual Versus Hierarchical Approaches to Environmental Decision-making: The Case of the Massachusetts Military Reservation," Thesis for completion of Master in City Planning, Massachusetts Institute of Technology. June.
56. Shapiro, C. 2003. Interoffice Communication to Dialogue on Science Impact participants, RE: Project Summary. Undated.
57. Smith, M. "The Catron County Citizens Group: A Case Study in Community Collaboration" The Consensus Building Handbook, Sage Publications, Thousand Oaks, CA. pp. 985-1009.
58. Song, S., M'Gonigle, M. 2001. "Science, Power, and System Dynamics: the Political Economy of Conservation Biology," *Conservation Biology*, Vol. 15, No. 4. August.
59. Susskind, L. 1994. Environmental Diplomacy: Negotiating More Effective Global Agreements. Oxford University Press, New York, Oxford.
60. Susskind, L., Field, P. 1997. Dealing With an Angry Public: The Mutual-Gains Approach to Resolving Disputes. Free Press, New York.

61. Turner, C. 2003. "An Experience in John Day, Oregon – The Need for USGS Agenda-less Science in Collaborative Partnerships." Internal USGS Report.
62. Tytler, R., Duggan, S., Gott, R. 2001. "Public Participation in an Environmental Dispute: Implications for Science Education", *Public Understanding of Science*, Vol. 10, pp. 343-364.
63. United Stated Geological Survey (USGS) Ethics Committee. 1994. "Considerations and Examples of Speaking Out on Public Policy Issues." 21 October.
64. USGS. 1999. "U.S. Geological Survey Strategic Plan: 2000-2005." Obtained from USGS Internet website at http://www.usgs.gov/stratplan/stratplan_rev.pdf. Website accessed 25 April 2004.
65. USGS. 2000. "A Conversation with Customers: What the USGS Heard, 2000 Customer Listening Session Report." Obtained from the USGS Internet website at http://www.usgs.gov/customer/conversation/. Website access 13 April 2004.
66. USGS. 2001. "Science, Society, Solutions: Future Roles and Opportunities, Customer Listening Session, October 11, 2001." Obtained from the USGS Internet website at http://www.usgs.gov/customer/conversation/. Website access 13 April 2004.
67. USGS. 2001a. Intra-agency Communication, "Best Practices Project: Illustrative Examples of Problems and Possible Solutions." 16 July.
68. USGS. 2002. "USGS Vision, Mission, and Strategic Direction." Obtained from the USGS Internet Website at http://www.usgs.gov/stratplan/vision.html. Website accessed 1 December 2003.
69. USGS. 2002a. "Directors of the US Geological Survey." 19 August. Obtained from the USGS Internet website at http://www.usgs.gov/bio/USGS/directors.html. Website accessed 23 April 2004.
70. USGS. 2002b. U.S. Geological Survey Manual, USGS Manual Sec. 500.5.1.b. Obtained from USGS Internet website at http://www.usgs.gov/usgs-manual/500/500-5.html. Website accessed 26 April 2004.
71. USGS. 2003. Dialogue on Science Impact, Discussion 1. 31 October. Transcript prepared by S. Lenard.
72. USGS. 2004. "Policy Analysis & Science Assistance." USGS Internet website. 24 March. Available at http://www.mesc.usgs.gov/research/400/400.asp. Website accessed 27 April 2004.
73. USGS. Undated. "Surface-Water Data for the Nation." Obtained from the USGS Internet Website at http://waterdata.usgs.gov/nwis/sw. Website accessed 29 November 2003.
74. Walker, G. B., Daniels. S. E. 2001a. "Natural Resource Policy and the Paradox of Public Involvement – Bringing Scientists and Citizens Together", in Understanding Community-Based Ecosystem Management. The Haworth Press, Inc., New York.
75. Walker, G. B., Daniels. S. E. 2001b. Working Through Environmental Conflict – The Collaborative Learning Approach, Preager, Westport, Connecticut, London.