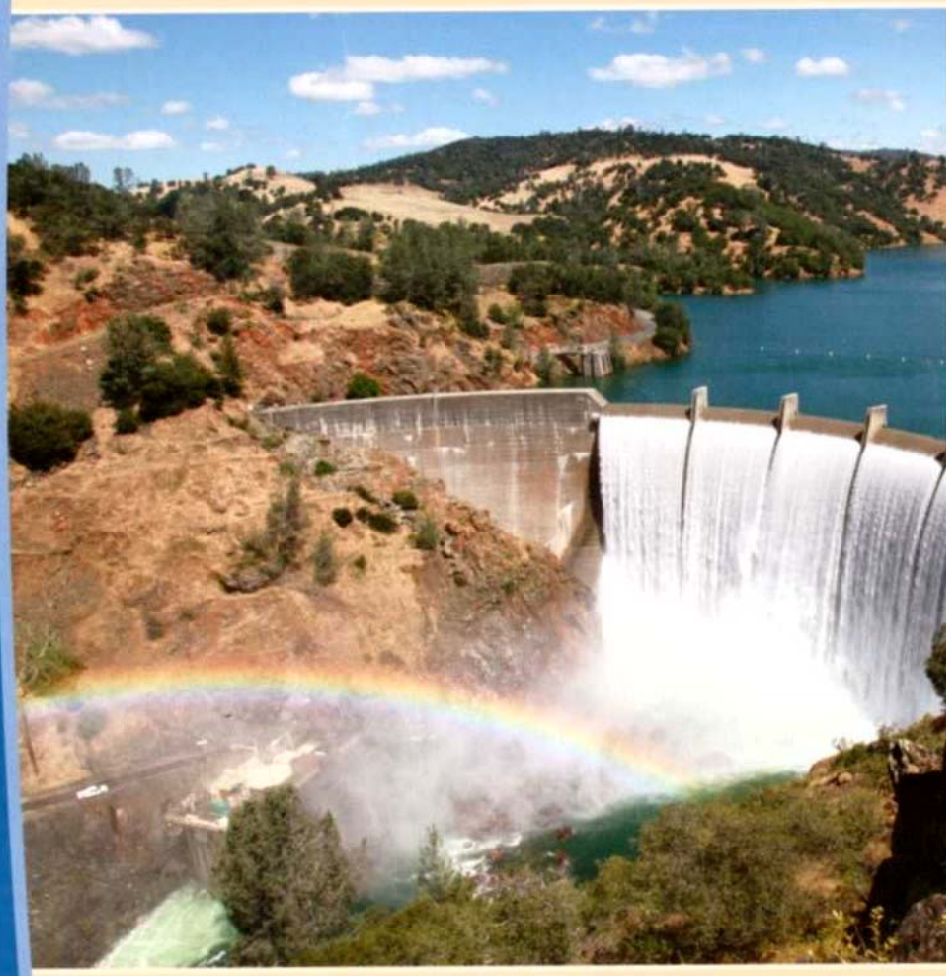
Converging Waters

Integrating Collaborative Modeling with Participatory Processes to Make Water Resources Decisions



Maass-White Series

AUTHENTICATED
U.S. GOVERNMENT
INFORMATION
GPO

Converging Waters

Integrating Collaborative Modeling with Participatory Processes to Make Water Resources Decisions

---

Lisa Bourget, Editor

May 12, 2011

Other Books in the Maass-White Series

The Institute for Water Resources, U.S. Army Corps of Engineers, publishes a series of volumes (the Maass-White Series) dedicated to Professor Arthur Maass and Gilbert White, luminaries in the field of water resources management. The series provides the practicing water resources community with valuable new works and reprinted classic works with commentary showing the development of water management theory, policy, and practice. The series is geared toward academics, policy makers, and practitioners in the field of water resources management.

Decision-Making Chronology for the Lake Pontchartrain & Vicinity Hurricane Protection Project, by Douglas Woolley and Leonard Shabman, March 2008.

The Evolution of Water Resources Planning and Decision Making, edited by Clifford S. Russell and Duane D. Baumann, 2009.

Harry E. Schwarz and the Development of Water Resources and Environmental Planning,edited by David C. Major, 2011.

Table of Contents

Foreword v

Preface ix

Chapter 1 1
Introduction
by Hal Cardwell

Chapter 2 9
The Purpose and Goal for CADRe
by Leonard Shabman and Kurt Stephenson

Chapter 3 23
Executing CADRe: Integration of Models with Negotiation Processes
by Kurt Stephenson and Leonard Shabman

Chapter 4 35
New Approaches in the Potomac River Basin and Beyond — Pioneering Work in the Development of Shared Vision Planning
by Erik Hagen

Chapter 5 59
Reflections of Computer–Aided Dispute Resolution (CADRe) on the Roanoke
by Brian J. McCrodden

Chapter 6 71
The Lake Ontario–St. Lawrence River Study
by William Werick

Chapter 7 91
Use of Modeling to Facilitate Interstate Collaboration on the Lower Susquehanna River
by Andrew D. Dehoff and Thomas W. Beauduy

Chapter 8 103
Drought Preparedness in Northern California: People, Practices, Principles and Perceptions
by Ane D. Deister

Chapter 9 115
CADRe in an Evolving Planning Environment–Rio Grande, New Mexico
by Vincent Tidwell, Howard Passell, and Jesse Roach

Chapter 10 127
Bringing CADRe to Contemporary Water Policy–Some Challenges
by Kurt Stephenson and Leonard Shabman

Chapter 11 137
Differences in How Modelers and Facilitators Approach Computer–Aided Dispute Resolution
by James L. Creighton and Mark Lorie

Chapter 12 155
Considering Convener, Stakeholder, and Decision–Maker Issues
by Lisa Bourget and Gail Bingham

Chapter 13 167
Training and Education
by Megan Wiley Rivera

Chapter 14 185
Conclusion
by Lisa Bourget and Hal Cardwell

Glossary 189

Bibliography 193

Appendix A–
List of Figures and Tables 209

Appendix B–
Abbreviations 211

Appendix C–
Contributors 215

Foreword

Water resources management is often challenged by the need to make decisions that address multiple objectives, involve diverse interests, and have far–reaching effects. The question of how to best engage a range of stakeholders and decision makers who often operate in different governance and institutional settings has rightfully captured considerable attention within the water resources community of practice. The answer to the question has continued to be refined as new concepts build on previous ones, technical advances offer new possibilities, and the social and political context within which all decisions are taken continues to evolve.

As early as 1864, George Marsh described the relationship between "Man and Nature"— documenting the impacts of human actions on the natural environment and developing an approach for considering those interrelationships. His work identifying the various benefits and impacts of planned reservoirs and recognizing the need to consider what is happening within a watershed has been credited with setting the stage for systems analysis for natural resources (Holmes and Wolman 2001).

Advances can be prompted by the cross–fertilization of seemingly separate fields. The Harvard Water Program deliberately integrated engineering practice with economic theory. Its goal was to improve water resources planning and design. From its start in the 1950s, it enabled a rich exchange of ideas that led to the development of new approaches. The creation of synthetic hydrology allowed limited data, such a stream flows, to be expanded in ways that enable more robust results. New methodologies with specific stepped approaches provided guidance for expanding the range of possible alternatives and maximizing possible benefits. The Harvard Water Program marked the beginning of multi–objective planning as practiced in the U.S. during the latter half of the twentieth century, greatly influencing an entire generation of water planners and decision makers (Reuss 2003).

Another thread in the evolving tapestry of water resources management can be found in the changing regulatory landscape and social activism of the 1960s and 1970s. Society demanded a stronger role in decision making, and legislatures responded. Increasingly, environmental legislation passed since the early 1970s, beginning with the National Environmental Policy Act (NEPA), has provided avenues for citizens and non–governmental organizations to influence the federal government's decision–making processes and outcomes for water and other natural resources projects.

Also during the 1970s, the use of alternative dispute resolution increased substantially. Initially viewed as an alternative to the often long and costly process of resolving litigation, the processes developed were increasingly used in other venues. Since 1990, the federal government has strongly encouraged agencies to make use

of a variety of consensual dispute resolution processes aimed at preventing and resolving disputes. These processes have become more common in water resources planning, where the resolution of disputes often benefits from the assistance of impartial facilitators or mediators to help reach agreement in settings characterized by many parties, many issues, high conflict, and low trust.

Scientific knowledge and technical capabilities have exploded in recent decades. New research yielding new connections about the complex interactions between water and life have advanced our understanding of how human intervention in hydrologic and geomorphic systems can impact the natural environment, particularly in unintended or unanticipated ways. At the same time, our evolving knowledge in the multi–disciplinary aspects of science affecting natural processes that we had previously assumed as fixed or stationary, such as with the climate, has led to new questions which only increase the uncertainty about how these interactions may change over time.

Meanwhile, technology has transformed what is possible, serving to facilitate both scientific and engineering advances and the way we can communicate even complex information. Certainly technology has informed science; the increasing capability of sensors and the wealth of information they can provide is but one example. Advances such as real–time information and the increased capability of our analytical models have benefited from the exponential growth of computing power— thus providing a firmer foundation and reducing uncertainty while informing such decisions as when to change the flow at a dam.

Technology's role within society is nothing short of astounding—it has not only facilitated these scientific advances, but it has also enhanced the breadth and speed at which information is communicated, while also allowing even more complex information to be conveyed within a simpler context. Visualization is one example. From limited Internet use in the 1980s and the introduction of the first Web browsers in the 1990s, today's connectivity democratizes information and interchange. Our ability to transparently conduct and communicate real–time simulations and visually display the response of natural systems to any array of different potential decisions and outcomes opens an ever–wider door to our ability to foster a broader understanding and stakeholder involvement in decision processes.

This book, with its focus on the opportunity that lies at the intersection of scientific/technical advances and procedural/social interchange, provides a useful stepping stone in the evolving path of water resources management. The U.S. Army Corps of Engineers Institute for Water Resources (IWR) has long promoted approaches that can lead to more robust information, more effective communication, and, it is hoped, better–informed decisions. Its Alternative Dispute Resolution literature, available at www.iwr.usace.army.mil/pubsearchS.php?series=ADR, was at the forefront of the evolution of more effective public participation techniques during

the post–NEPA period. Since the 1970s the involvement of civil society in the decision–making process was transformed at the Federal level, moving from the legacy model of public officials communicating with the public mainly through press releases and hearings, to more collaborative engagements which gradually emphasized more listening, transparent dialogue, increases in data sharing, and occasionally reliance on a shared or even a consensus–based decision process.

IWR also pioneered applications of Shared Vision Planning, a collaborative approach to formulating water management solutions that combines traditional water resources planning and structured public participation with the collaborative use of computer modeling. Shared Vision Planning (SVP) is a well–defined form of Computer–Aided Dispute Resolution (CADRe)—now becoming known as Computer Modeling for Decision Support, as this book explains— and some SVP applications are described here.

To its credit, in 2008 the Corps of Engineers also took the bold step of establishing a Conflict Resolution and Public Participation Center (CPC) at IWR to assist the Corps in implementing collaborative approaches in water resources decision making. CPC supports the use of Shared Vision Planning and a wide range of other conflict resolution approaches within the Corps. It also promotes a similar use across water resources planning and regulatory agencies, other institutions at other levels of government, and overseas through the IWR's International Center for Integrated Water Resources Management (ICIWaRM), which is affiliated with the UNESCO International Hydrological Program (IHP). IWR, through the CPC, also engages in partnerships with other agencies and organizations to further develop and refine new techniques, and to promote collaborative efforts and to jointly provide assistance to Corps of Engineers district offices and others in solving water problems and/or helping to resolve disputes. Such partnerships include IWR's relationship with the U.S. Institute for Environmental Conflict Resolution at the University of Arizona.

The importance of the work of the CPC was underlined by the President Obama's issuance of an Executive Memorandum on *Transparency and Open Government* in 2009, which emphasized harnessing technology for the purpose of promoting transparency, creating increased opportunities for the federal government to be participatory, and fostering a culture of collaboration that actively engages Americans in the work of their government.

Within that context, I am delighted that IWR has had the opportunity to work with the various authors on this book. The book complements other IWR publications, brings together under one cover the varying considerations inherent in integrating collaborative modeling with participatory processes, and provides a nexus for the next generation of practitioners with either of those backgrounds to gain an appreciation of the advantages that cross–fertilization offers.

I would like to offer my sincere thanks to the authors who gave their expertise, time, and talents to the development of this book. Thanks also go to Hal Cardwell, Director of the CPC, for his vision and leadership, and to Lisa Bourget for her dedication and skill as editor. Taking the book from conception to completion entailed hard work, numerous reviews, patience, and persistence. These efforts provide a cohesive reference for today, and a further sound building block for the future. May the future bring still further advances in the practice of water resources management, and may IWR be privileged to continue its support of such advances.

Robert A. Pietrowsky
Director, Institute for Water Resources
U.S. Army Corps of Engineers

Preface

This book has its origins in the palpable excitement and energy stemming from a first–ever gathering of people to focus exclusively on computer–aided dispute resolution. Participants hailed from federal and state agencies, universities, non–profits, river basin commissions, and the private sector. They brought varied expertise: computer modeling, facilitation, administration, science, conflict resolution, legal, research, public participation, and engineering, to highlight a few. What they held in common was experience in integrating computer modeling and participatory processes in water resources planning and management. What they achieved was a deeper understanding of how varying roles and approaches can lead to improved outcomes, a sense of community identity, and a desire for continued progress. The gathering sparked numerous efforts, including this book.

A group instrumental in planning that first–ever gathering—Hal Cardwell and Stacy Langsdale from the Institute for Water Resources, Len Shabman from Resources for the Future, and Kurt Stephenson from Virginia Tech— initiated work on this book. That core group, expanded over time to include Lisa Bourget from the Institute for Water Resources and Gail Bingham from Civic Dialogue Group, developed the framework and focus, identified chapter authors, and reviewed submitted text. Particular thanks are due to the chapter authors, who their time and expertise, for their efforts and patience with the overall pace of book development. Further thanks go to those who provided later comments and observations, including Dan Sheer of HydroLogics, Inc., and Jerome Delli Priscoli from the Institute for Water Resources. Lisa Bourget served as primary editor. The book resulting from these efforts is published under the auspices of the Institute for Water Resources, with chapter authors retaining primary authorship of their individual chapters. As such, the opinions and views contained in this publication are those of the authors and should not be construed as an official Department of the Army position, policy, or decision, unless so designated by other official documentation.

The book provides a touchstone in the development of computer–aided dispute resolution— an approach to decision making where parties negotiate agreements by communicating through a mutually developed and accepted computer simulation model. It builds on documentation previously available in alternative dispute resolution, Shared Vision Planning, and related areas. It complements other work recently underway, such as development of performance measures to assess the benefits of Shared Vision Planning and other collaborative modeling process, and the creation of a Web site with principles and best practices for collaborative modeling.

Lisa Bourget and
Hal Cardwell

Chapter 1

Introduction

by Hal Cardwell

Why this book on Collaborative Modeling for Decision Support / Computer-Aided Dispute Resolution (CADRe)?

Persistent conflict among competing stakeholders and decision makers is increasingly common in water resources management. Conflicts often bubble outside of the control of individual water management agencies. Major water resources decision making frequently results in gridlock, or a protracted, litigious decision process that takes years, costs significant sums of money, and fails to generate broad consensus on an acceptable decision. These conflicts occur because of both the complexity and uncertainty in the natural systems (disagreement over the facts) and the conflicting interests and values across individuals and groups. To address the technical complexity in water resources requires expertise in technical issues; to address the conflicting interests and values inherent in water management requires expertise in collaborative processes and understanding of the political context. To find our way out of the Gordian knot of water problems we need to integrate technical information with collaborative processes; we need to produce solutions that are both technically and politically doable. Luckily, we know how. (Or at least we are learning!)

Within the U.S. Army Corps of Engineers, the Institute for Water Resources (IWR) responded to this situation by developing and promoting the concept of using collaboratively built computer models to build trust and mutual understanding among stakeholders in water resources planning cases, while producing viable technical options that are understood and felt owned by technical and political stakeholders. By engaging stakeholders and decision makers early in considering a wider set of complex interactions, this "Shared Vision Planning" approach promotes more implementable water management decisions. The value of this approach is borne out by separate development of similar ideas such as participatory modeling, mediated modeling, and computer-aided negotiation. These approaches are similar in spirit and in many particulars— all employ technical modeling as the vehicle for engaging stakeholders and decision makers in shared decision making.

To share experiences about the use of transparent, collaboratively developed (or at least vetted) models to facilitate multi-stakeholder public decision processes, professionals at IWR, along with colleagues at Sandia National Laboratory and the U.S. Institute for Environmental Conflict Resolution, convened a workshop on Computer-Aided Dispute Resolution (CADRe) in September 2007. Those gathered at the CADRe07 workshop were convinced that the integration of expertise from the technical modeling side of water management, with the deep understanding of

environmental conflict resolution practices and techniques, was the way to move toward better water management decisions.. In isolation, neither the technical specialists nor the process professionals can solve complex water problems, but combining those skills provides a chance to make progress.

In the years since the CADRe07 workshop, changes have occurred that only reinforced the need to integrate the understanding of collaborative processes with technical expertise. Water problems have not abated as drought has become the way of life in the Southwest and as the understanding of water issues has risen in prominence nationwide. In late 2007, the White House's Subcommittee on Water Availability and Quality (SWAQ) identified the development of collaborative tools and processes for U.S. water solutions as a key element in a federal water research strategy (Office of Science and Technology Policy 2007) and a working group recommended an interagency federal initiative on "the integration of computer-based modeling tools within multi-stakeholder public decision processes for US water solutions" (Working Group 2007). May 2009 saw a group of technologists and process professionals come together for a broader look at the intersection of Technology and Environmental Conflict Resolution , which included strong contribution from the CADRe community and identified many of the same needs. And in October 2009, many of the same people from the CADRe07 workshop were joined by new faces in a CADRe09 workshop to discuss progress on developing best practices and performance measures for collaborative modeling, to investigate new case studies, and to develop a strategic plan for increasing the use of CADRe.

CADRe opens the door to improved collaboration, merging technical assessments with collaborative processes. At its best, CADRe builds a richer understanding of linked issues, fosters trust and improved communication, and yields a broader suite of supportable solutions to today's complex water resources issues.

This book describes achievements in resolving difficult water resources decisions through integrating computer modeling with negotiation processes, the excitement and sense of community at the CADRe07 workshop, and recent progress in building that community and the tools available to it. It documents and defines the current state of the field, seeks to build bridges between experts in technical and procedural aspects of water resources decision making, acts as a ready resource document with a wealth of references, and aspires to reach potential new practitioners. While this combination of technical systems modeling and collaborative processes has power applicable well beyond the bounds of water management, water is the focus of this book. No doubt the community of those using CADRe will continue to grow, and tools and techniques will continue to be refined; indeed, that is to be encouraged. This book will help to reach and inform a wider audience, increase understanding, and provide food for thought, thereby spurring increased use, including by potential new practitioners, and improved practice in water resources management and perhaps beyond.

What's in a Name?

Practitioners have not like the term Computer-Aided Dispute Resolution since it was coined in advance of CADRe07. In response, when practitioners met in 2009, they identified key common elements of practitioners:

- Collaborative modeling is a defining feature.
- Modeling/models are not the point or the primary product of the effort; the models are there to support a collaborative learning and decision-making process.
- The ultimate goal of these processes is to make decisions about natural resources problems (water especially) that improve environmental, economic, and social outcomes; circumstances often prevent our work from influencing decisions, but the ultimate decision provides our primary process design criteria.
- The collaborative process includes experts, stakeholders and decision makers.
- These processes are often applied to planning problems, but they can be applied in other contexts or particular pieces of the planning process (such as scoping) (Lorie 2010).

These "identity" discussions endorsed a new name for the practice: Collaborative Modeling for Decision Support, with a more detailed identity statement of "integrating collaborative modeling with participatory processes to inform natural resource management decisions." This new general name was felt to be more descriptive and inclusive— an umbrella term that can be used to describe what the community does as well as what it is, while recognizing that specific preferred brand names would continue to be used for specific applications and projects. Because this book was being finalized as these discussions were taking place, we retain the use of the term CADRe as well as other "brand" names such as Shared Vision Planning. This approach is consistent with how these practices have been described and are currently known. Going forward, we expect the new name of "Collaborative Modeling for Decision Support" to be adopted as an umbrella term to describe the practices, with "brand" names persisting. The book includes a glossary of commonly used terms.

What is this book on Collaborative Modeling for Decision Support / Computer-Aided Dispute Resolution (CADRe)?

This book was developed by turning to numerous professionals with a combined wealth of technical and process expertise. Each chapter reflects the views of its individual author or authors, after being honed by questions and comments from others. Taken together, the chapters encompass a variety of issues, diverse perspectives, and

varied experiences that collectively provide a thorough illustration of Collaborative Modeling for Decision Support / CADRe and its practice.

This book is divided into five sections: an introduction to CADRe; two sections that present six case studies— one with case studies using the approach to support immediate investment or operations decisions and one with case studies using the approach for visioning purposes; a discussion of the challenges and opportunities to improve water resources planning through its use; and a final section on conclusions.

Introductory Section

In Chapter 2, Leonard Shabman of Resources for the Future and Kurt Stephenson of Virginia Tech define and describe CADRe, noting its roots and its many names and incarnations. CADRe seeks to create a setting in which dispute can be effectively managed, greater understanding can be achieved, and agreement can be reached among participants regarding an implementable decision. CADRe merges two fields that have not traditionally intersected: public participation/negotiation/consensus building/dispute resolution and computer modeling. CADRe is different than computer modeling and different than traditional approaches of participation/negotiation/consensus building/dispute resolution. It provides an effective means to support human decision making. The chapter defines three types of disputes and describes CADRe's relationship to each, and it explores how CADRe can be evaluated for success.

Chapter 3 describes the integration of decision-support computer modeling (CA) into the processes of dispute resolution/negotiation (DRe) as the distinguishing feature of CADRe processes. Kurt Stephenson and Leonard Shabman identify three goals of this integration: to make technical analysis more responsive the needs of the negotiating parties; to make scientific and technical information more credible to multiple and disputing parties; and to provide a useful mechanism for collaborative negotiations to explore, create, and debate alternatives. The chapter introduces the concept of performance metrics that help participants understand how what they want to know is affected by various alternatives. It also explains how collaborative use of a model that incorporates these performance metrics supports negotiation and decision making.

Case Studies

After this description of what CADRe is and how it helps support decision making that might otherwise not be feasible, Sections II and III turn to applications of CADRe in U.S. water management. Case studies are presented by practitioners and are divided into two categories: those that use CADRe in support of a specific operational or investment decision, and those that use CADRe for visioning purposes. This distinction shows both the breadth of types of applications, and highlights the challenges of application at different stages in a planning process. One case study also provides a historical perspective of pioneering efforts to apply computer-aided

negotiation processes to water resource disputes, offering fundamental insight into the development of the field. Together the six case studies provide practical examples of the conflicts encountered and the varying approaches taken to resolve them. The case studies emphasize lessons learned and conclude with prescriptive summaries.

Chapter 4 explores important early developments in the origins of the field. Erik Hagen, former director of the Interstate Commission on the Potomac River Basin Co-Op, recounts how and why early CADRe processes emerged through water supply planning for the Potomac and were further developed during the National Drought Study into the Shared Vision Planning methodology. This story is presented with a recognition that many people have independently developed ideas that are reflected in CADRe, and that the Potomac / National Drought Study story represents one way (albeit an exciting and important way) that these ideas have developed and been applied. It shows how CADRe has helped an organization with little formal authority achieve increasing influence in joint decision making among powerful actors. Other case studies in this section (e.g., Chapter 9's Rio Grande) evolved differently, but have reached a similar place.

In Chapter 5, Brian McCrodden of Hydrologics, Inc. provides an example of how CADRe was used as a precursor to federal licensing for hydroelectric facilities on the Roanoke River. To issue a license, the Federal Energy Regulatory Commission (FERC) must determine that operation of the project is in the public interest. Because the original license had been issued decades earlier, the CADRe process on the Roanoke needed to address changed conditions, and a wide variety of interests including flood control capability and downstream environmental effects. McCrodden describes how computer-aided negotiations were used with stakeholders to find a supportable solution that could be presented to FERC, and presents perspectives of key participants from various stakeholders concerning the role of computer-aided negotiations and its effect on the overall process.

Chapter 6 explores the process used to provide the International Joint Commission (U.S.-Canada) with options for regulating water levels and flows in the Lake Ontario–St. Lawrence River system, with this regulation to be accomplished by managing flow through the Moses-Saunders Dam. William Werick of Werick Creative Solutions provides insight into a large-scale, technically ambitious Shared Vision Planning process involving numerous stakeholders in two countries over five years. He describes how modeling was integrated into the process from the very beginning, how it was driven by the needs of decision makers, how it connected experts and stakeholders, and how it illustrated the essential conflicts and key trade-offs under consideration.

In Chapter 7, Andrew Dehoff and Thomas Beauduy of the Susquehanna River Basin Commission describe the development of a recommended management plan for the Conowingo Pond, located in Maryland and Pennsylvania immediately upstream of

the Conowingo Dam on the Lower Susquehanna River. The Susquehanna River Basin Commission convened a workgroup representing interests of key stakeholders in the operation and use of the Conowingo Pond to resolve perceived conflicts and recommend sustainable and mutually beneficial operations. The chapter describes the composition of the workgroup; the interests, problems and conflicts it needed to address; the direct involvement of stakeholders in the development of a computer model; and the outcome and further recommendations resulting from the process.

Chapter 8 provides the first of two case study examples that use CADRe for visioning purposes instead of operational or investment decision making. Ane Deister of Entrix describes the Shared Vision Planning process used to bring together many interested parties with local and national experts to update previous drought and conservation plans, and to develop and fund a comprehensive drought preparedness program in El Dorado County, California. Deister portrays the key role of a Shared Vision Planning Model that provided an integrated framework for decisions, allowed stakeholders to weigh in early in the process, buy in at each stage, and ultimately support the outcome. She details the means by which the group used an iterative, interactive process with technical experts, stakeholders, decision makers, and the general public, and she emphasizes the role provided by the Shared Vision Planning and model development processes in making key information easy to understand and find, and in developing trust and acceptance.

In Chapter 9, Sandia National Laboratory's Vince Tidwell, Howard Passell, and Jesse Roach explore the adaptation of a CADRe process within an evolving planning environment for management of New Mexico's Rio Grande River. They consider the evolving collaborative processes and modeling as the planning process moved from one of regional water planning to one of water operations planning. By adapting both the process and the modeling to incorporate previous efforts, Tidwell et al. explicitly explore how CADRe could and should learn from and extend the work of previous modeling and collaborative process efforts.

Challenges and Opportunities for Improving Water Resources Planning
Section IV of this book reflects on the case studies to discuss the challenges and opportunities to improve water resources planning through the use of CADRe. It includes discussion of the challenges of confronting multiple decisions in highly structured regulatory processes, and explores the relationship between CADRe and traditional planning processes. The section reports on interviews with modelers and facilitators to gain their impressions of CADRe and includes a chapter addressing the perspectives of conveners, stakeholders, and decision makers. Finally, it explores a major challenge to implementing this blend of technical and process expertise—the need to develop practitioners through education and training in CADRe.

In Chapter 10, Kurt Stephenson and Len Shabman highlight some of the challenges in making CADRe effective within contemporary water resources planning

and decision making. Challenges to employing CADRe processes include resistance from possible decision participants, the structure of specific regulatory and decision processes, and opposition at a conceptual level on the appropriate role of expert analysis in collective choice. The authors cite the experiences of the Federal Energy Regulatory Commission in implementing new, more collaborative processes for hydropower relicensing as a potential counter to some of these challenges.

In Chapter 11, Jim Creighton of Creighton & Creighton, Inc., and Mark Lorie, an independent consultant, explore modeler and facilitator perspectives. Because CADRe processes require at least two distinct skill sets— that of a modeler and that of a facilitator—Chapter 11 looks at CADRe processes through interviews with seasoned professionals from both fields. These interviews showed that both groups have similar descriptions of how they approach CADRe. Creighton and Lorie argue that the results of their interviews indicate a common set of skills that, combined with practical experience, are necessary to develop modeler and facilitators who can conduct CADRe processes. The interviews also identify an important third role in CADRE: that of the individual or organization to convene these processes. Leaders within government agencies, water utilities, and river basin commissions need to be made aware of CADRe methods and their potential benefits.

Chapter 12 examines convener, stakeholder, and decision-maker issues. Lisa Bourget of the U.S. Army Corps of Engineers Institute for Water Resources and Gail Bingham of RESOLVE explore the particular challenges, viewpoints, and considerations that need to be taken into account when considering or undertaking a CADRe process. These range from time and cost considerations, to creating incentives to participate, to examining roles and (sometimes conflicting) expectations of agencies and stakeholders. The chapter addresses decision making as the culmination of a collaborative process and explores how different approaches can affect the outcome.

Chapter 13 addresses the challenge of increasing the number of professionals skilled in CADRe ideas and techniques. Megan Wiley Rivera of Hydrologics Inc. presents ideas on why and how to educate and train the next generation of managers as CADRe practitioners, conveners, and proponents. Wiley Rivera presents types of skills that are necessary for CADRe, cites existing training programs and stresses the importance of experiential learning. She argues that the interdisciplinary skill set needed for CADRe will broadly benefit the next generation of both the scientific and technical community as well as policy makers, creating lawyers who have a new model for negotiations of long-standing disputes, and scientists who can design studies to focus on pressing societal issues.

Conclusions

Chapter 14 provides concluding observations. It reiterates what CADRe is and is not. CADRe in its many applications and guises provides an approach to resolving

water resources disputes through integrating negotiation and bargaining with computer modeling, paying attention to both process and substance, allowing for collaborative learning, and providing support for decision making. While CADRe is not a guarantee of success, it can provide a path to success where other approaches may fail. Recognizing its potential, a community has formed and undertaken actions on various fronts seeking improved use and expansion. In a world fraught with compartmentalized scientific and technical knowledge, diverse and often conflicting interests, controversy and distrust, and dispersed decision making, CADRe provides an important way of helping water resource managers—working collaboratively with key partners in a setting that more effectively manages disputes— find supportable and lasting solutions.

Chapter 2

The Purpose and Goal for CADRe

by Leonard Shabman and Kurt Stephenson[1]

Introduction

Computer-aided dispute resolution (CADRe) is an approach to decision making where parties negotiate agreements by communicating through a mutually developed and accepted computer simulation model.[2] Although the acronym CADRe is used here, the approach has no single formal name, no single disciplinary origin, and no professional associations— although efforts are underway to bring practitioners under a new umbrella term of "Computer Modeling for Decision Support," as noted in Chapter 1. CADRe refers to various, largely independent and isolated efforts to integrate two rapidly growing, but generally distinct approaches to decision support: negotiation/bargaining as a means of resolving water resource decision making disputes, and development of computer-based systems models intended to provide analytical support for water resource management decision making. Forms of CADRe include shared vision planning (SVP), computer-aided negotiation (CAN), mediated modeling, stakeholder assisted modeling, and group model building (Sheer, Baeck and Wright 1989; Werick and Whipple 1994; Vennix 1996; Anderson and Richardson 1997; Van den Belt 2004; Palmer 2007). All this work seeks to explicitly integrate technical computer modeling into group problem solving in different contexts (water resources, ecosystem management, air emissions/climate change, corporate management, etc.). The focus of this chapter will be on use of CADRe in water resource management decision making, which is often the responsibility of government agencies but which also can be initiated through voluntary efforts by private entities.

The term "computer-aided dispute resolution" reflects an intentional and structured blending of these two approaches to decision support. Dispute resolution (DRe) makes reference to processes of negotiation and bargaining as a means for making water resources and environmental decisions. As the name implies, choices concerning use and plans for water resources will often be characterized by a lack of agreement on a preferred water management alternative. A lack of agreement becomes a dispute (the term used here) when normal agency decision processes and the choice made do not or are not expected to satisfy those affected by the agency decision and when those dissatisfied choose to or are likely to challenge that decision and, perhaps, seek a alternative decision though judicial or legislative proceedings. Computer aided (CA) makes reference to computer simulation models—and perhaps

1. Senior authorship shared equally.

2. While the word "model" may be used to describe a variety of constructs (mental models, conceptual frameworks, theoretical constructs), the use here refers to computer programs that predict key physical, chemical, biological, and economic elements of the water resource system.

visualization—to predict outcomes (or performance) of different actions (alternatives) taken to manage water or human behaviors in a watershed. CADRe includes systematic methods and processes to natural resource decision making that would be grouped under a general approach to decision making described as analytic-deliberative processes (National Research Council 1996, 2005, 2008; Maguire 2003).

Bringing "CA" together with "DRe" requires specialized skills and tools. Therefore, whether to proceed with a CADRe process requires first answering the question: How can, and when will, simulation modeling add value, in relation to cost, to a negotiation process for resolving a water resources dispute? Clearly the implicit premise behind this framing of the question is that a multi-party negotiation process for decision making/dispute resolution is preferred for the particular situation. CADRe can be utilized as a means to generate and analyze options and bring about agreement that would otherwise be impossible to achieve. This presumes that the disputing parties are willing to engage in a CADRe process—a subject we do not treat here. Of course, CADRe can be employed when disagreements do not reach the stage of a dispute. For example, CADRe might be used for reaching agreement on a long-term vision for a watershed and on setting long-term goals to guide future decision making. Parties can disagree on a vision or on a plan, but disagreements over the vision often can be resolved by modifying the plan to include a broader range of interests and concerns, grounded in an understanding of the implications and potential trade-offs. In this chapter we focus on CADRe application to a current or anticipated dispute (as defined above) over a specific regulatory action (e.g., considering a permit for a pollutant discharge or re-operation of a dam), a step in a planning process (e.g., conducting analysis of flows for an ecosystem restoration plan) and/or a budget decision. In such an instance, the prospect of perceived and real adverse consequences for decision participants makes it likely that disputes will be quite difficult to resolve.

Furthermore, we assert that the primary "success" of a CADRe process is reaching an implementable and lasting agreement on an agreed-upon alternative action among the decision participants in a dispute. Decision participants are those individuals, organizations, or coalitions that are engaged in, or defer to, the CADRe decision making process. Agreement in and of itself is not a success measure; however, agreement is an observable outcome of the CADRe process. Agreement is what we can observe, but a lasting agreement—in the presence of a dispute—only can be achieved in a CADRe process if a selected alternative makes all decision participants better off. Therefore, a CADRe process that secures agreement must have created joint net benefits and then distributed the net benefits so all participants judge themselves to be better off. If all participants, in their own judgment, are better off as a result of the selected alternative, and the process included all appropriate participants, then we assert that alternative is in the "public interest"— and we know that because there is agreement on the proposed alternative. This is a matter discussed further later in this chapter. Initial agreement on a plan is not all there is to a success definition.

Implementation of the plan should be accompanied by monitoring of the expected outcomes, using indicators for the same performance measures that were used to agree on a jointly preferred alternative. The learning about the outcomes of implementation should result in a renegotiation loop if necessary, so that agreement is maintained during implementation. The persistence of agreement during implementation is the true indicator of whether agreement is a reflection of the public interest.

We also recognize different success measures for a CADRe process that focus on other outcomes than the substance of an agreement, such as improvements in relationships (e.g., increased trust) that allow for constructive dialogue during and after the process, or aspects of the design and conduct of the process itself (e.g., transparency, efficiency, etc.) (National Research Council 2008). These include shared learning, as opposed to simply providing people with data that does not change their opinions, and development of respect for other decision participants' values and interests. These outcomes as measures of success mean that differences that led to a dispute are dealt with constructively, including in ways that allow for alternatives to be developed and agreed upon. These other measures of success are often preconditions for agreement for the issues at hand (when such agreement is possible), and can help build a foundation for tackling other issues in the future.

The Foundation for CADRe

CADRe is the blending of two areas of research and practice in contemporary water resources management. The first body of research and related practice focuses on governance systems and dispute resolution. Mediation professionals publish literature on how to design and conduct multi-stakeholder negotiations (Susskind, McKearnan, and Thomas-Larmer 1999). Numerous government agencies' programs and environmental management initiatives now include collaborative decision making, or enhancing stakeholder collaboration, as a central theme. Various processes, sometimes referred to collectively as alternative dispute resolution (ADR), environmental dispute resolution, or collaborative problem solving, have been endorsed and promoted by government agencies (Office of Management and Budget 2005; Council on Environmental Quality 2007; Federal Interagency Alternative Dispute Resolution Working Group Sections et al. 2007). An element of this literature also studies and assesses the conditions and barriers to successful negotiations (Bingham 1986; Wondolleck and Yaffee 2000; Bauer and Randolph 2000; O'Leary and Bingham 2003; Koontz et al. 2004). The literature extends to the normative question of which organizations should be party to the negotiation. Some of the negotiation literature also focuses on "joint-fact" finding and seeking agreement on technical information (Adler et al.; Ehrmann and Stinson 1999; Bingham 2003). However, ways in which computer simulation models can be used to synthesize scientific information, illuminate the functioning of complex systems, and facilitate the search and evaluation of alternatives in collaborative processes has drawn relatively little attention from these professionals.

The premise of the negotiation literature is that the obstacles to managing dispute largely reside in the process by which decision participants communicate with each other, although concepts of power and political structure often are incorporated. This literature examines ways to break down decision participants' preconceptions of adversaries, to develop constructive methods of dialogue (e.g., focus on interests, not positions), and to develop trust and understanding among decision participants. The premise of this literature is that many adversarial decision contexts leave opportunities for agreement and productive negotiation undiscovered.

Negotiation professionals emphasize the role that "integrative bargaining" can play in environmental and water resource dispute resolution. Integrative bargaining occurs when the process of negotiation identifies alternatives that increase the benefits to all decision participants. Sometimes side payments in the form of cash offers or changes in the rules for sharing of the use and access to the water and related land resources are added as means by which an integrative bargain can be struck. By contrast, distributional bargaining defines situations where decision participants must negotiate and decide among alternatives where there is a zero-sum outcome— one person/group can only benefit at the expense of another. An important premise of the well-designed CADRe process is that it can foster integrative bargaining as well as identify creative approaches for compensation in cases of distributive bargaining.

The opportunity of integrative bargaining rests on several behavioral premises. For example, confrontational and dispute-ridden situations present a common set of obstacles for creative group problem solving and the development of previously unknown but mutually beneficial alternatives (Fisher and Ury 1983). Strategies to overcome the barriers to the creation of such alternatives are a fundamental element of this professional field. In addition, professionals in this field believe that social decision making is an iterative learning process than involves an element of self-discovery. In contrast to some social decision making theories that assume participants come to a decision process with known, fixed, and given preferences, collaborative negotiation is based on the explicit assumption that preferences are constructed to a significant degree (Slovic 1995). Social decision processes in unfamiliar situations, in particular, have the capacity to shape and change stakeholder preferences for the alternatives themselves (Vatn and Bromley 1994; Sagoff 1994). Psychological research provides substantial evidence that preferences for outcomes are contingent on past experiences and an understanding of the costs and consequences of existing alternatives. The discovery and creation of new alternatives means that preferences among alternatives change and evolve.

Individual and group learning and shared experiences also can build social relationships between people. The development of social capital between multiple and competing decision participants facilitates integrative bargaining. As noted by Majone (1989, page 9) "… persuasion is a two way interchange, a method of mutual learning through discourse. Real debate not only lets the participants promote their

own views and interests, but also encourages them to adjust their views of reality and even to change their values in the process. … Fashioning mutual understanding of the boundaries of the possible in public policy is arguably the most important contribution that analysts can make to public debate."

The second body of research that CADRe draws upon is water resources simulation modeling. This body of work, developed largely independent of the negotiation literature, seeks to inform decision making with computer models that manipulate and interpret data in order to predict the relationship between selection of any alternative and attainment of different goals. This class of water resource modeling is focused on simulations to allow participants and decision makers in a negotiation to ask "what-if" questions and get answers, without taking physical action. Simulation models can be high or low resolution and can be expensive and time consuming to build or low cost to develop. Simulation models can also vary in terms of the level of geographic scale and disciplinary integration. However, the computational algorithms in simulation models can be transparent or opaque to the parties to the negotiation, although they are always fully understood by the model developer.

The water resource simulation modeling is motivated by the premise that there is a limited ability of any participant to comprehend and understand all the relationships with the complex system (Vennix 1999). Water resource systems are a series of interconnected and complex systems where changing or managing one system component will produce multiple consequences and outcomes elsewhere in the watershed. Such models are also a way to collect, synthesize, and represent scientific research and expertise in a systematic and coherent way. Ultimately, computer simulation models offer a way to represent system complexity that might be useful or tractable for decision participants.

CADRe processes, however, are not defined by the type of computer simulation model used. A variety of computer simulation models have been developed for water resources planning. Such models include OASIS, ModSim, RiverWare, WaterWare, WEAP (see Tate 2002 for a summary). Features of such software systems may support CADRe processes, but software alone cannot define CADRe. As discussed below, CADRe is defined here based on how and whether technical models are used and integrated in a collaborative process.

CADRe seeks to bring the knowledge about mediation/negotiation and simulation modeling approaches together (Sheer, Baeck and Wright 1989; Werick and Whipple 1994; Lund and Palmer 1997; Fredericks, Labadie and Altenhofen 1998; Tate 2002; Carmichael, Tansey and Robinson 2004; Tidwell et al. 2004; van den Belt, 2004; Palmer 2007). It is this integration that distinguishes CADRe in at least three ways.

First, a focus on how to organize participants and structure discussions to reach agreement or manage dispute is necessary but not sufficient. CADRe processes do

not assume technical knowledge and models are given from outside experts who are in agreement on "the science." CADRe processes integrate the development of computer-based models of the water resource system into the negotiation process. CADRe accepts the premise that knowledge is fragmented, dispersed among the decision participants and can be formal (technical training) and informal (based on experience and understanding of local conditions) (March 1982; Lindblom 1990; Ozawa 1991). Further, there is a limited ability of any participant to comprehend and understand all the relationships with the complex system (March 1982; Lindblom 1990; Vennix 1999). CADRe computer simulation models and group collaboration can facilitate a broader and shared understanding of system relationships and consequences, in a multi-disciplinary context. As a result, CADRe resists the tendency of decision participants to simplify the range of choice, the alternatives considered, and the assessment of consequences in order to deal with the problem of complexity.

Second, within a CADRe process, models must be explicitly designed in conjunction with the negotiation-based decision processes. The convener of the negotiation organizes the participants to facilitate joint discussions based on the principles and practices described in the collaborative process literature. The CADRe modeling can then begin from an appreciation of the values, interests, and analytical needs of the multiple participants to the negotiation. Indeed, CADRe begins from the premise that decision participants often have difficulty separating arguments about "what should be" from arguments about "what is" and so the process is designed to organize negotiations to reach agreement on what is, and then focus attention on what should be.

This coordinated development separates CADRe modeling processes from a significant portion of the technical water resources modeling literature and so resists the tendency to let technical analysis proceed with its own problem definitions, alternatives, and solutions. Science and technical analysis is critical to aid in the understanding of biological, chemical, physical, and economic consequences of different alternatives, but must be responsive to the needs of decision participants. Models and technical analysts should not presuppose what information participants need or dictate (intentionally or unintentionally) the selection of alternatives. Models should be at the service of decision making, not the means of deciding (Ozawa 1996). However, while models are explicitly designed in conjunction with stakeholder negotiations, the models also meet the technical and professional standards of constructing a logically consistent and valid model.

Third, within CADRe, decision participants rely on the model(s) as a focal point for their conversations. In this sense, the commonly agreed upon technical models serve a role analogous to the single text negotiation tool from which decision participants can organize their collective deliberations. The models are an integral way through which decision participants communicate with each other and discuss relationships

within the water resource system. The conversation through the model is the way that alternatives are discovered, debated, and decided upon.

While computer simulation models are an integral point of negotiations, CADRe accepts that decision participants themselves are responsible for weighing and deciding among alternatives and are the best collective judge of whether an alternative serves their interests and values. In CADRe, computer simulation modeling is to *aid* the decision participants and decision makers in discovering their preferences, as they jointly explore alternatives and options, with the modeling in support of the discovery process. In contrast, some decision support approaches seek to elicit preferences and values of decision participants and decision makers independent of an actual choice situation. This class of models attempts to identify optimal choices for the participants and decision makers. These include multi-attribute utility analysis and benefit-cost analysis (including non-market valuation) that presuppose goals or elicit goals and weights from decision makers as the basis for calculating the best alternatives. With such a perspective, analysts see their role as identifying what outcome and hence what alternative should be preferred, given the elicited preferences. In this approach to decision support, the experts are expected to identify the "optimal" alternative for the decision participants. CADRe process, however, rejects such modeling approaches (except for their use in an atypical iterative fashion that allows for participants' consideration, shared learning, and reflection of changed goals) because CADRe accepts the premise of the negotiation literature concerning the creative element of alternative formation and the social creation/construction of preference.

Why CADRe?

In recent decades there has been a diffusion of water resources decision authority away from the large and centralized bureaucracies toward multiple agencies of governments, each expected to exercise some decision-making responsibility for how water and related land resources of a watershed should be managed. Laws passed in the 1970s such as the Clean Water Act and Endangered Species Act have also given standing to non-governmental organizations (NGOs) to significantly influence water allocation, use, and management. These NGOs may form coalitions with those agencies of governments most compatible with their position (Sabatier and Jenkins-Smith 1993), or may remain outside any agency process and seek to exercise influence though legislative and judicial processes. At the same time, in many situations, there is no clarity of where decision-making authority resides. Instead, there are layers of review and appeal, often without a clear point where all the considerations are brought together, weighed, and a final decision made (Stephenson 2000; Shabman and Cox 2004). In this contemporary setting, shared and diffused decision making calls for new ways to manage decision participant dispute. CADRe is offered as one method of dispute management.

Disputes are over a specific decision or choice between individuals or groups having competing interests, different values, varying perceptions of a situation, troubled interpersonal relationships, or lack of trust based on past history or an imbalance of power. There are numerous categories and sources of dispute. We discuss causes of dispute in three categories: interest and value dispute, analytic dispute, and decision authority dispute. We do not suggest that this is the only taxonomy, but it does serve our purposes for this chapter (Lord 1979; Delli Priscoli 1990, 1996; Creighton 1998).

Interest and Value Dispute

Interest dispute occurs when an alternative will influence different decision participants' socio-economic well being. For example, a proposed water supply project of one local community may reduce future water supply development and community growth opportunities for a downstream community. Interest dispute may arise when an existing benefit (e.g., water for irrigation or navigation) is threatened by the new emphasis on mimicking historic flow regimes on a river in the service of ecological restoration or river recreation enhancement (Shabman 2008).

Resolution of interest dispute through CADRe will occur through the discovery of alternatives that all participants evaluate as making themselves better off than the status quo or with an alternative that they expect to emerge outside of the CADRe process. CADRe increases the chances of finding alternatives having mutually beneficial outcomes—what we describe above as integrative bargaining. CADRe also can identify and perhaps quantify the loss so that compensation of losses (real or perceived) can take place. Economic mitigation (cash compensation payments) is a long-standing form of compensation for harmed interests. Environmental mitigation requirements in current laws are a form of compensation for the public. Success in the CADRe context means that all decision participants realize positive net benefit in a common solution.

Value dispute arises over different opinions about whether an alternative is good for a community, rather than whether it is good for the individual decision participant. Value dispute can be more abstract and subjective than interest dispute. In recent years, water resources value dispute often centers on the relative importance of maintaining environmental conditions, or restoration of past conditions, versus protecting long-standing legal and de facto rights of individuals and communities to use water in ways that emphasize economic and social development goals.

Sometimes strongly held values within a broadly defined stakeholder group may come into dispute in the context of a single decision. For example, environmental organizations may confront a reservoir re-operation decision that will benefit habitat downstream of the structure, but may inundate habitat upstream of the structure. Few may have a direct personal stake in changes in flow regimes (unless you are a boater, rafter, or angler your self-interest may not be directly influenced by stream flow levels). Nonetheless, dispute over what instream flow ought to be can be acute.

Although resolution of value disputes may be facilitated by inter-group communication, value disputes also are embedded in the laws and regulations that set the framework for decisions which might need to be resolved by judicial or legislative action in which one view prevails over the other.

However, while a distinction between interest and value dispute can be described, in practice it may be difficult to draw such a distinction. For example, in the negotiation process decision participants may find offers of compensation so attractive that they agree to support an alternative. Whether that agreement is the result of having their interest satisfied or whether they have reconsidered their value premises as a result of engaging in a CADRe process may not be clear, or even relevant. A well-structured CADRe process will identify and clarify choices and trade-offs (see Chapter 3). If the result is agreement based on how the participants think about their own gains and losses, and if agreement is reached, then the process has been a success. Nonetheless, entering the CADRe process it may be helpful to at least be aware that, for some decision participants, certain values may be "non-negotiable" and may remain so. Recognizing this can help determine who might be asked to participate in a process, how the process may be structured, and what a reasonable expectation for the process might be.

Analytic Dispute

Analytic disputes are over the adequacy of the data, analysis, and models used to characterize problems, and the consequences of different alternatives that address the problem. This is often the principal source of dispute and may be based on breakdowns in communication among agencies, organizations, and individuals, or based on fundamentally different understandings about particular phenomena of common interest. Analytic dispute is initially the focus of the CADRe process through the shared model building process described in Chapter 3. For example, groups may have different perceptions of the effect of increased water withdrawals upon lake levels or on the legality of water withdrawals. Resolving or managing analytic dispute is challenging, given the complexity of our natural and social systems and the forward-looking nature of the planning process (what is and what will be). For example, technical analysis of existing technologies and water use behaviors can better inform, but rarely provide a definitive answer to, what per-capita water consumption or population growth in a region is likely to be in the future.

The traditional approach to resolution of analytic dispute is to call on technical experts who are expected to provide answers to questions posed to them. Decision makers then accept the expert assessment and make choices related to matters of interest and values.

However, today technical expertise itself is not a monolith. There has been the rapid expansion of the disciplines and tools for analysis of what might be broadly termed environmental sciences, where once only water engineers were looked to as experts.

Expertise is divided along more than just broad disciplinary lines—engineering, economics, ecology, law. For example, there is a whole sub-discipline of wetlands science that holds its own professional meetings and has its own peer-reviewed journal. This trend has infiltrated the social sciences as well. For example, the economics profession has a subgroup of experts whose attention is devoted almost entirely to tools for estimating money-equivalent values of services of natural capital. As the number of disciplines (and subdisciplines) and "experts" have grown, differences among experts within and between disciplines have become common. No agency can (relative to past years) make a claim of having the most or the best technical experts.

At the same time there has been a changing public acceptance of the role of expertise and a resistance to accepting the analysis of any single expert as definitive and objective. Suspicion of experts blossomed as widespread phenomena in the late 1960s and soon translated into a suspicion of government employees as experts, leading to suspicions of centralized or technical knowledge (Lach, Rayner, and Ingram 2005, 11). Today, parties with stake in an outcome may not accept the technical arguments of government or other experts without some form of external verification. At the same time, claims to have expertise and "sound science' on the side of your argument is still a significant advantage in any deliberation (Tarlock 2002).

CADRe offers a process to directly address and manage analytic dispute. The collective development, ownership, and use of a common analytical model provide decision participants a structure and forum to identify and debate sources of analytic disputes. The joint modeling process also provides a means to examine the consequences of different data assumptions, disputed technical relationships, and scientific and physical uncertainties. Of particular note, disputes often arise over the adequacy of the data and analysis for making a decision. CADRe processes can help stakeholders agree on when the analytical foundation is "good enough" for making choices among alternative actions.

Authority Dispute

United States water resources decision making is often described as if it were the product of the formal distribution of intergovernmental and intra-governmental decision-making responsibilities among executive branch officers and agencies, the legislatures, and the courts. However, these formal relationships alone do not fully characterize the locus of responsibility for making decisions about water use and management alternatives. No agency at any level of government has final decision authority and competing authorities exist between and within levels of government.

This diffusion of formal and informal authority to decide or to review and possibly veto decisions of another accelerated in the 1970s with the rapid expansion of federal laws and regulations affecting water resources (e.g., Endangered Species Act, Clean Water Act, National Environmental Policy Act). These new laws and regulations empowered different federal agencies, as well as citizen groups, to exert influence on

water and related resources decisions in new ways, often reflecting different value and interest positions and often challenging long-standing prerogatives of state and local governments. This diffusion of authorities, and the redistribution of power to influence water and related land resources use and management decisions, followed logically from the changing view of national water management goals. In addition, the 1970s environmental laws at both the federal and state levels brought new opportunities for citizen standing to sue, as a form of check and balance on the exercise of discretion by water management agencies (Shabman 2008, Delli Priscoli 2009).

Decentralized governance is how one author describes the current situation (Rogers 1993), while others refer to civic environmentalism (Landy and Rubin 2001), or to the democratization of environmental decision making (Ingram and Schneider 1998). Whatever the term, and whatever its result, there is a need to satisfy decision participants who have the power to advance their values and interests in administrative and legal arenas. If those with differing powers and legal authorities agree to a process that adopts established dispute resolution designs, CADRe then grafts model development onto that process as a way to focus the deliberations. Assembling decision participants and fostering communication through a model development process may aid in bringing those with different powers and authorities to agree on an alternative action. Achieving this commitment to the CADRe process, and then agreement, will be difficult if one party believes it has the power to impose a choice of an alternative on others; or that it has the ability to leave the CADRe process for another process that will serve its values and interests.

Evaluating CADRe

There will be criticism of defining CADRe success as reaching agreement among the participants in the CADRE process. This success definition, some will argue, may or will not equate with making decisions in the "public interest." Whether negotiated solutions serve the public interest can be a complex debate, but we offer here responses to two criticisms that will almost always be raised.

The first criticism will be over how representative the CADRe participants are of all possible agencies (including those expected to represent "public trust" resources), organizations, and individuals. CADRe participants must include all who have the authority and ability (power) to go outside the CADRe process to get a different decision that the group might agree to. Defining who has power can be difficult. For example, a local canoe club may have no formal power alone to affect a decision, but it can have influence when it acts in coordination with other groups if they are adept at using the press to affect public opinion. However, inviting participants based on their "power" will raise concerns over equity (justice) of who was chosen. A higher-level question is whether any selected group of stakeholders can be a substitute for democratic representation and decision making by the legislature, courts, and agency with authority delegated to them (Borton, Warner, and Werick 1998; Creighton 1998, 2002; Crenson and Ginsberg 2002).

This being said, any CADRe process design must balance the concern over the how representative the participants are of the public with the costs of decision making (decision-making delays and financial costs) that increase with the number of included groups. Also, there is a decreased likelihood of reaching agreement as group size increases. The public choice literature in economics, as well as the literature on environmental negotiation and alternative dispute resolution, includes numerous studies and recommendations about how this dilemma might be addressed through different ways to structure group participation, such as circles of influence (Werick and Whipple 1994), through the different roles that might be played by the convener of the negotiation (facilitation, mediation, and arbitration), and through specifically designed legislative or administrative procedures that offer opportunities to express opposition to the CADRe recommendations.

A second criticism is the possibility that there can be a shifting of costs to unrepresented parties, usually the general taxpayer or to "the environment." CADRe process participants may reach compensation agreements so that all decision participants deem themselves better off with the agreement that is made. For instance, a recreational fishing group may accept a series of recreational enhancements (boat landings, access points, etc.) as compensation for water management alternatives that would alter downstream flow. However, if the costs do not confront the CADRe participants who benefit from an agreement, the potential for cost shifting to others will make the outcomes acceptable for the parties to the negotiation but may come at a cost to the society at large. Therefore, a second criticism is that no agreement secured by shifting costs to parties outside the process who were unrepresented in the CADRe discussion (for example, general taxpayers or utility rate payers as a group) can be said to define the public interest. How these costs fall is often beyond the control of those who design and implement the CADRe process, but to the extent that there is significant opportunity for cost shifting to unrepresented parties, the claim that the success of the process (reaching agreement) equates to the public interest should be made with caution.

Conclusion

CADRe processes are a means for securing agreement on implementable actions in settings now characterized by conflict. CADRe processes are a means to achieve a greater understanding of the current situation, shape and evaluate alternatives and their implications, and reach agreement among decision participants. Ideally, a CADRe process facilitates joint learning while building social trust and understanding among participants in the process. In turn, this joint learning and social trust creates both the motivation and opportunity to discover alternatives that make all parties better off, as compared with the status quo.

Successful CADRe processes integrate computer-based simulation models with collaborative negotiation processes. This said, CADRe processes cannot guarantee that mutually agreeable decisions will be reached among affected stakeholder groups.

Indeed, it is likely that agreement can be reached upon analytic disputes and ways to satisfy different interests, but it is not certain that successful management of these differences will lead to productive dialogue and debate over all sources of dispute. Thus, what CADRe promises is not agreement, but another path to the possibility of agreement. Given the challenging contemporary water policy setting, the experience to date (including the case studies presented in this book) suggests that in many instances CADRe can be that path.

Today the art and practice of CADRe remains under development. Practitioners often work in isolation from one another and opportunities for shared learning are few. In the next chapter we suggest how CADRE processes might be structured. The subsequent chapters expand on and add to these basic ideas.

Chapter 3

Executing CADRe: Integration of Models with Negotiation Processes

by Kurt Stephenson and Leonard Shabman[1]

Introduction

There is a long history of efforts to support water resource decision making with computer simulation/optimization models. Initial efforts often were called decision support systems (DSS) and while this label persists in the literature, a variety of other names for computer-aided decision support systems have emerged (Thiessen, Loucks, and Stedinger 1998). Advances in computational capabilities, user interfaces, and graphical displays have made it possible to rapidly analyze data and display the results for decision participants and decision makers.

Even as decision support system tools have grown in capability, the focus of the professional literature rarely considers how to integrate these technical advances into decision making processes (Loucks 1995). Decision support system software is often developed independent of any specific decision process. When there is an application, the analysis often presumes a generic and single well-defined "decision maker" (a single government agency) with authority to make choices among various alternatives, rather than the complexity of multiple decision participants and decision points. Furthermore, decision support models often produce a single set of model outputs and performance metrics selected by the model builders. The results are then offered to decision participants for possible use without consideration of the causes or degree of the dispute, the number or diversity of parties involved, the matters in dispute, or the specific institutional setting (Lund and Palmer 1997).

The distinguishing feature of CADRe processes is integration of decision support modeling into the processes of dispute resolution/negotiation. Technical models for CADRe are developed to serve a place-specific negotiation, rather than being developed independent of or parallel to decision processes. This creates the opportunity for an explicit discussion of the criteria for determining the "best" answer to the water management questions confronting decision participants, rather than relying on a model based on an implicit set of criteria (often the modelers') to define decision outcomes. This integration of decision support models with the decision-making process allows considerations about the values and interests of those affected to influence how the model is built and used as much as the model influences how the process evolves.

1. Senior authorship shared equally.

Therefore, a first step in a CADRe process is not model building, but rather structuring the negotiation or decision-making process. There is an extensive literature on this topic (Schelling 1960; Deutsch 1973; Raiffa 1982; Fisher and Ury 1983; Lewicki 1985; O'Leary 2003; National Research Council 2008). For purposes of this chapter, two aspects of this step as being critical to CADRe are noted. First, there must be a decision on which agencies, organizations, and individuals will be asked to participate in the CADRe process and an agreement among them about the definition of the problem they are seeking to solve. The desire is to be comprehensive in reflecting the full range of values, interests, experts (scientific perspectives), and decision authorities that will be affected by the decision and/or are at the source of potential disputes. Second, there is a need to design a process that allows for different levels of participation. The use of the model, as will be described in this chapter, is to be a focal point for the communication between and among multiple groups and agencies. For this to happen there must be a trust in the model and that requires some decision participants to be engaged in the modeling. Because not every participant will be interested in or able to contribute to the modeling, the design challenge is how to assure that the decision participants trust those who are engaged in the model development process.

CADRe requires integrating technical simulation modeling into the collaborative negotiation processes in three dimensions:

- Collaborative development of the model outputs (Responsiveness)
- Collaborative development of the model mechanics (Credibility)
- Collaborative use of model (Usefulness)

This focus for integration ensures that the developers of analytical models and the models themselves are: 1) *responsive* to needs and concerns of decision participants, 2) *credible* to decision participants and decision makers (if different), and 3) *useful* to collective investigations and negotiation of alternatives. Each of the three dimensions is related to the others and attention to each requires the conscious attention of the model developer, in cooperation with the facilitator of the CADRe process. While these are not independent steps in executing a CADRe process, for purposes of exposition these dimensions are described in a sequence where discussion of each dimension builds on the discussion of the preceding one. Taken together, these dimensions of integration between technical model and collaborative negotiations represent the unique domain of CADRe processes.

Collaborative Development of the Model Outputs: Identifying What Decision Participants Want to Know

The purpose of integrating technical models with collaborative processes is to create useable knowledge *for decision participants*. Therefore, models must produce answers

or outputs that are meaningful to multiple and perhaps non-technical decision participants. The challenge to the model developer is to assure that the modeling is responsive to interests of decision participants, and is not organized to answer questions solely of interest to the modelers or scientists and technical experts.

Therefore, the first effort is to identify the decision participants' interests and concerns, the resulting questions they see as relevant, the information desired, and then the performance metrics of the model. These performance metrics are the indicators of outcomes of interest and concern to decision participants. Performance metrics are what measures of outcomes that decision participants want to know. Responding to these needs makes model outputs decision-relevant. When performance metrics are explicitly linked to decision participants' interests and concerns, the information generated is more likely to be responsive and, thus, to be used in the decision-making process. Performance metrics also must be measurable and must be capable of being predicted by the model with some degree of certainty (Sheer, Baeck, and Wright 1989; Gregory and Failing 2004). Thus the CADRe process starts with a collaborative process involving modelers and decision participants, when decision participants are lead through a process to articulate their questions and concerns, identify the information they are seeking to answer those questions, and then, with assistance from modelers, to agree on those specific performance metrics that they will use. Generally, because they are linked to the parties' interests, these performance metrics can be used to evaluate outcomes of different management choices. The process of developing identifiable performance metrics is a learning process that requires stakeholders to sharpen their own thinking about what aspects of the problem are important and critical to their interests and values, and may well encompass a broader set of conditions than decision makers originally envisaged (Gregory and Failing 2004). Also, these performance metrics are place- and situation-specific, and are not given from outside the process. While the burgeoning literature on indicators produced for and by scientists can help inform this process (Turnhout, Misschoemoller, and Eijsackers 2007), in a CADRe process indicators must emerge from the collaborative process, cannot always be defined in advance or in isolation by experts, and, in the best case, will be continually refined as the process goes on.

However, there is a central role for technical expertise in the development of performance metrics. For instance, risk and uncertainty are expressed and understood very differently between risk experts and nontechnical people (National Research Council 1996). Thus facilitators and model experts may have to investigate ways to translate metrics of risk and model uncertainty into expressions that are meaningful to stakeholders. Subtle differences in the phrasing of indicators could also influence the acceptability of a performance metric. For example, expressing risk of flooding as "probability of flooding" was found to inhibit negotiation while expressing the same notion as "the reduction in the chance of flooding from the status quo condition" generated more productive discussions (Gregory and Failing 2004). The expression of probability focused stakeholder attention on how far an alternative was from what

was considered an ideal (zero probability of flood risk), while flood risk reduction stressed the amount of improvement.

A second technical challenge is that some stakeholder objectives may not be readily translated into a measurable performance metric. Stakeholder objectives may be based on deeply felt but intangible or subjective values and beliefs (Sheer, Baeck, and Wright 1989). However, these cannot be dismissed or ignored. Developing performance metrics that resonate with all stakeholders is often one of the most creative and difficult challenges to developing CADRe models (Sheer 2007). While such values may be difficult to quantify, articulation and incorporation of such values are central to most problems and an essential requirement of any evaluation (Lord 1979; Sheer, Baeck, and Wright 1989).

Third, a multi-stakeholder and multi-agency process, responsive to these multiple concerns, can lead to many different performance metrics being developed. These metrics will, in all likelihood, be expressed in different units (dollars, flows, habitat, probabilities, etc). Multiple performance metrics may be more responsive to the dimensions of the problem important to stakeholders, but can increase the technical difficulty of presenting the comparison of alternatives. However, the number and content of the performance metrics can become more than a technical matter.

The more diverse the interests of the decision participants, the more diverse the performance metrics will be. For example, if federal funds are to be obligated there may be national objectives and metrics that are relevant to decision makers, but that may not be of interest to those who have more place-based objectives. Perhaps granting of a license or a permit for a proposed action by a federal agency may require meeting certain specified federal objectives. For example, the objective of a local water supply manager may be to secure storage in an existing reservoir to increase the safe yield of their water supply system. A local recreational group may have interest in the number and timing of whitewater boating days below the water supply reservoir. However, there may be a federal budget requirement to demonstrate that national economic development purposes are served by any proposed change to reservoir operations. For purpose of this chapter, we focus on the decision participants who have place-based objectives, because any alternative must always meet a test of local acceptability and earn support of the local population. However, we assume all required federal analyses would also be done.

Finally, development of performance metrics that are responsive to and reflective of decision participant needs serves a larger role than just facilitating negotiations or collaborative learning. Performance metrics can also serve the longer-term needs of implementing and monitoring outcomes. Performance metrics can be adapted and used as indicators that provide impacted parties a way to measure progress toward implementing the alternative selected. Performance metrics can facilitate learning

and adaptation to the original agreement as people learn and refine their understanding of how the system responds to different conditions.

Collaborative Support and Development of the Model Mechanics: Developing a Model that Credibly Reflects the Effects of Alternatives on Performance Metrics

Technical simulation models predict the changes in performance metrics under the existing conditions and from different water management or investment alternatives, as well as for a future condition without action. These predictions must be trusted by the decision participants and so the model structure and modelers themselves must be credible to the decision participants.

Model construction for CADRe includes the same elements of any model-building process: conceptual model development, definition of technical relationships and response functions between model variables, identification and selection of data inputs, and meaningful and understandable presentation of results. What distinguishes a technical model in CADRe is that credibility comes from the openness of the modelers to engage stakeholders in constructing the model so that all the decision participants believe the model provides an acceptable and trusted representation of the water management system.

Collaborative negotiation professionals have developed procedures and research to integrate technical expertise into negotiation processes. This work is sometimes described as "joint-fact" finding. CADRE processes extend this dimension of integration by a deliberate, structured, and collaborative organization of scientific knowledge, data, and technical expertise into technical models. These models allow decision participants a platform for more systematic examination, exploration, and discussion of possible outcomes and alternatives.

Conventional modeling approaches envision the role of the scientist and technical modeler as providing analysis and results to the decision makers. The CADRe modeling process allows for joint learning and exploration of the water resource system, the problem, and more mutually satisfactory alternatives. Involvement of the modeling processes can deepen and broaden decision participants' understanding of the linkages and relationships within the water resources system. This understanding can also facilitate better mutual understanding of how different groups' interests and objectives relate to and impact each other. Yet, knowledge flow is not one directional: from technical experts to decision participants. CADRe allows for the possibility that system understanding (day-to-day working knowledge) and supporting data, in addition to the earlier step of framing performance metrics, can also be provided from decision participants to modelers. Therefore, the model construction process becomes the focal point and the forum for decision participants to share knowledge and achieve a common understanding of relationships within the system. Model development becomes a center for collaborative learning. CADRe model

construction is the process by which to organize data, stakeholder knowledge, and scientific knowledge into a framework credible to all.

In most situations, not all decision participants will have technical expertise to actually construct a model or the data to inform different model runs. However, their participation often is necessary to build confidence in and a shared understanding of the model and its outputs. Recognizing this, some CADRe processes stress the direct collaborative construction of a model where a third-party modeler constructs basic elements of the model in the presence of decision participants (van den Belt 2004). This process might be simplified by a second approach in which decision participants communicate through a neutral and agreed-upon technical modeling expert. The expert would solicit direct input from stakeholders, but would work offline to develop the actual computer model (such as has been done, for example, by Hydrologics, a private firm). In yet a third approach, a subgroup of technical experts may be formed that direct or develop the technical models. This subgroup could include modelers sent by competing stakeholder groups to represent their specific interests. This subgroup would be directed and report back to the stakeholder (management or policy) group responsible for decision making (Werick and Whipple 1994; Call 2001).

CADRe technical models must be acceptable to decision participants if they are to be the basis for a common understanding of the alternatives being considered and their consequences for different performance metrics, and ultimately for assisting in the identification and discussion of alternatives. A range of model development requirements have been identified that would yield that result. All modelers undertake standard procedures for calibrating and verifying simulation models in order to increase their own confidence in the internal consistency of the model logic, in a model's ability to predict the outcomes of interest, and/or in order to have a sense of the magnitude and direction of error in model predictions. Knowing that these kinds of processes are employed will increase the acceptability and credibility of the models.

Equally important, if decision participants do not have confidence that the model adequately represents the system of concern, the CADRe models will be of limited value in negotiating agreements. Therefore, CADRe processes require a different process for verification by requiring the data, structure (technical relationships), logic, and predictions to "make sense" to the decision participants most familiar with the decision problem and to their trusted technical representatives. Toward that end, model architecture that is transparent to decision participants (or their technical representatives) can facilitate stakeholder confirmation and verification of data and technical relationships. This does not necessarily mean knowledge of the technical mechanics of the model, but rather the general ways the model elements are related to each other and how model output is produced. The inability of stakeholders to comprehend technical models has been cited as a major barrier to use of

a model in negotiation processes (Sheer, Baeck, and Wright 1989; Dahinden et al. 2000). The use of object-oriented system software (STELLA®, WEAP, PowerSIM) is often used to construct such models because of the visually appealing and transparent way system elements relate to each other (van den Belt 2004; Werick and Whipple 1994).

Once initially constructed, CADRe models should be subject to revision and modification because nearly all—and certainly the most useful—negotiation processes are evolving, learning processes. Thus, the development of performance metrics and the technical model needs to be an iterative process. CADRe processes recognize that decision participants often enter with both vaguely formed notions of the scope and nature of the problem being confronted and their own specific interests and values (Simonovic and Bender 1996). Unstructured problems mean that model boundaries, objectives, and performance metrics may shift and be refined over the course of the negotiation. Models and modelers in CADRe processes must be in a position to both accommodate *and* facilitate the developing knowledge of the decision participants about their own preferences and interests. Because the model development process is on-going and must maintain credibility, most CADRe processes develop some process for decision participants to continuously contribute and discuss not only data inputs, but also relationships within the model. Joint fact finding efforts can be part of coordinated efforts for decision participants to develop the data foundation, technical relationships, and response functions within the model. Indeed, some suggest that the process of model development lends credibility to the model and to the decision process as much as the technical features of the model itself (Grayson, Doolan, and Blake 1994).

Admittedly, the CADRe expectation that technical computer models are developed in service of a negotiation process can present special challenges to modelers. One major challenge is making the trade-off between complexity and transparency. Technical models are all expected to be capable of "accurately" representing how the water resource system works. While modelers may wish to increase model complexity to better model system response functions, complex models will reduce transparency, understanding, and responsiveness of the model to the evolving needs of a negotiation process (Korfmacher 1998; Dahinden et al. 2000; Roach and Tidwell 2007). The modeler needs to maintain sight of the goal of a stable and supportable agreement, which is facilitated by the negotiation process as well as the model, and make complexity/transparency trade-off decisions accordingly. At the same time, decision participants will need to understand that the accuracy of the model predictions—defined as how closely the model approximates the "true" value of some predicted outcome—is always limited (Oreskes, Shrader-Frechette, and Belitz 1994).

A second model development challenge is to anticipate and address analytic dispute and uncertainty among scientific experts, and possibly between experts and

nontechnical stakeholders. Technical models for CADRe are constructed on assumptions of how the relevant water resource system under consideration operates. Those technical assumptions are in turn based on scientific studies and analytical constructs from the physical, biological, chemical, and social sciences. The results from these studies may be in dispute and/or subject to significant uncertainty, and analytic dispute can reduce model credibility. For example, the returning adults of a migratory fish species may be of central concern to stakeholders. Yet, understanding the role of changing water quality or timing/duration/magnitude of flow levels on fish population is typically subject to considerable scientific uncertainty and perhaps professional disputes.

How and whether such disputed or uncertain response relationships are included in a technical model is important to building credibility for the model. Options to address scientific/technical uncertainty include conducting additional site-specific field studies, additional collaborative fact-finding, soliciting expert judgments to describe response functions, or developing acceptable, more identifiable surrogate response relationships (for example, estimating aquatic habitat rather than fish response). Gregory and Failing (2004) report stakeholder opposition to developing response functions based on expert judgment processes when data quality/scientific information is low.

The technical models themselves may help diffuse some scientific disputes by conducting sensitivity analysis around the system elements in dispute. In some cases, the range of scientific dispute over a particular modeled relationship may produce small differences in predicted performance metrics. Thus, a scientific dispute can effectively be set aside if it does not have immediate or significant impact on the policy decision under discussion.

A third challenge is maintaining the model focus on "if this … then that" relationships. Care must be taken to guard against embedding hidden value judgments in the model that are policy choices within the appropriate domain of the negotiations. The distinction is often difficult to separate and identify in practice. For example, the objective of one decision participant group might be to protect and enhance some biological measure of the status of a particular fish species. This interest might ask the question, "What timing, magnitude, and duration of water flow is needed to produce a healthy (or sustainable) fishery for species X?" Framing the question in such a way, however, requires the technical analysts and modelers to define "healthy" and "sustainable." Modeling becomes centered on trying to answer what is healthy or sustainable, but neither definition answers technical questions (Lackey 2007). The question the model should address is: "How will a population of fish species X respond to different water flows (magnitude, timing, and duration)?" This framing of the question focuses modeling attention on the stakeholder interest (fish species X), but will rely on the decision participants themselves to define what constitutes a "healthy" or "sustainable" fishery. The search for and identification of embedded

model assumptions and model structures that circumvent or obscure policy choices also requires open and continuing communication between technical modelers and process facilitators (if different parties). Helen Ingram and Anne Schneider (1998, p. 27) state that "the most fundamental flaw in contemporary water policy is that many value questions in which ordinary citizens have a great interest are being framed as technical questions."

The process of developing a common technical model provides the opportunity to identify and manage technical and scientific disputes and to avoid an end state described as adversarial science (Ozawa 1991; Busenberg 1999). Collaboration at this level is a way to manage analytic dispute and overcome suspicion of centralized knowledge or perceptions of stakeholder information/knowledge bias. In many ways this level of integration forms the foundation for the CADRe process—if stakeholders cannot develop a credible technical foundation for the collaborative decisions and negotiation, a CADRe process cannot achieve agreement in the face of interest, value, and authority dispute.

Collaborative Use of Model: Assisting Decision Participants in the Formulation and Evaluation of Alternatives

In a CADRe process the accepted models and model outputs are the primary venue and vehicle for multiple and competing groups to communicate with each other. CADRE processes assume decision participants bear the joint responsibility for negotiating and deciding among alternatives. CADRe models are intended to support, not substitute for, the process of deciding. Communication through a single but shared technical computer model (or a system of connected computer models) allows decision participants to refine their own values, interests, and acceptable trade-offs while also learning the same about others. The model becomes useful only if it *facilitates* the development and discovery of more satisfactory alternatives through low-cost experimentation by playing "what if" exercises with the technical models (Sheer, Baeck, and Wright 1989; Werick and Whipple 1994; Reitsma et al. 1996).

CADRe technical simulation models are developed in support of collaborative negotiations. CADRe models predict how different alternatives affect the performance metrics of interest to decision participants. As useful decision-aids, models foster and focus development of and debate over alternatives. With transparent displays of performance metrics, decision participants can clearly link policy alternatives to changes in the interests of individual decision participant groups. The transparency and access to the model invite and encourage decision participants to modify and develop more broadly acceptable alternatives. Decision participants can modify alternatives to examine how incremental changes can help or harm the interests of particular groups. Clearly identified or unavoidable losses encourage decision participants to develop creative solutions to provide adequate and acceptable compensation. Decision participants are challenged by the models to create and negotiate alternatives that would bring the group closer to an acceptable agreement.

Because CADRe processes rely on computer simulation models as an integral part of how decision participants formulate and evaluate policy alternatives, a useful modeling platform is one that increases the likelihood of mutual learning and discovery of alternatives that lead to agreement on a preferred alternative. The usefulness of the model can be increased in several ways. One way is to test the sensitivity of the model solution to input data or other factors that might be in dispute. Given scientific uncertainties and room for different views, the ability to accomplish rapid "what if" simulations of different technical and data assumptions may help participants agree on performance metrics, on alternatives that might be formulated, and how different alternatives might affect the performance metrics. The model constructs a virtual reality for decision participants to explore consequences of different policy alternatives. Through the investigation of different possible future outcomes, collaborators collectively form (construct) their preferences for different possible future states of the world.

Making the model useful to negotiating parties creates technical challenges. First, given the complexity of water resource systems and management alternatives, simulations will typically produce multiple outputs and complex combinations of performance metrics. Such models are also capable of processing thousands of "what if" scenarios. Yet model output must be conveyed to decision participants in ways that highlight trade-offs and facilitate comparison of alternatives. CADRe modelers must devote attention and creativity to devising quantitative and visual display devises that can present output on performance metrics that is understandable and accessible to decision participants. Just as the development and identification of performance metrics must involve creativity, the presentation of model outcomes must also involve an element of creativity. Synthesizing complex and multi-dimensional information into forms that are accessible (tables, graphs, visual displays, etc.) and meaningful to decision participants will facilitate mutual learning and the negotiation process.

Second, as new alternatives are developed by stakeholders, modelers will be confronted with new requests for new model output or modeled relationships. CADRe model design must include effective ways to facilitate the search and sorting of potentially thousands of variations of alternatives that might be of interest to stakeholders without removing effective control of that evaluation from stakeholders. For example, with decision participants' concurrence, model algorithms might be designed to remove clearly "inferior" alternatives. Inferior alternatives are those that cannot improve (or actually decrease) the desired outcome of any performance metrics compared to a baseline alternative. Another approach is to bound the range of feasible alternatives; Werick describes the use of "fence post" alternatives for numerous single-interest models that both illustrate the consequences for other interests and establish the likely outer limits of any supportable solution (Werick 2007).

The model must be used for what-if analysis in the pursuit of alternatives that can achieve support by the decision participants. Therefore attention must be paid to how CADRe technical models can best be integrated into negotiations. Access to and use of the technical models involves deciding whether model runs and output are only produced in common joint meetings or whether individual stakeholder groups are expected to use the model independently and outside organized group meetings. Experimental research suggests that different levels of model accessibility do not produce substantive improvements in stakeholder understanding of the system or more satisfactory negotiated outcomes (Zigurs et al. 1999). However, accessibility and transparency may defuse suspicions of "black box" models, particularly for those not already intimately involved in the negotiation process.

Questions of who operates the technical models must also be addressed. In some processes, the operation of the technical models may be delegated to an agreed-upon individual or expert group. Requests for different model runs are provided to the model experts by stakeholder groups. Other processes may strive to increase model accessibility by allowing users to directly operate and run the technical model. In such cases, user-friendly software interfaces are designed to allow decision participants themselves to actively experiment and manipulate model inputs, assumptions, and parameters. The degree to which stakeholders may actively use the model can have implications for model design. For example, extremely complex and technical models may limit the degree of direct use nontechnical stakeholders may have with the model or whether technical models can be effectively used "on-line" during group negotiations (Dahinden et al. 2000; Roach and Tidwell 2007). CADRe process must also decide how decision participants socially interact with each other and the model.

Gaming or what-if exercises are one way to engage decision participants in real-time interaction in developing, experimenting, and evaluating alternatives. Because games are played in a group setting, the process may build social trust and personal relationships between competing and perhaps distrustful parties. Such games, however, require computer models capable of quick modification and real-time simulation. Models that require more data input or that have significant run-time requirements need to solved outside the group process and the results brought back to the group. This model support process may allow more use of more complex modeling structures, but limit the building of trust among the group members.

This discussion stresses the role of CADRe models to facilitate mutual learning and negotiation by simulating cause and effect of different alternatives and revealing trade-offs among performance metrics. Such an approach differs from many decision analysis tools proposed or advocated within the water resources literature. Analytical tools and models, such as comprehensive benefit/cost analysis or multi-attribute utility analysis, purport to construct response models of the water resource system and then measure or weigh the preferences or values decision participants

place on all outcomes of alternatives. Such models weigh and aggregate stakeholder preferences either in dollars (benefit-cost analysis) or a system of subjective weights (multi-criteria analysis) into single quantitative rank alternatives that aims to identify the "best" or "optimal" alternative. Such approaches rely on analysts and analytical models, rather than collaborative negotiations, to identify the preferred alternative. In some applications, however, multi-criteria analysis might be used as a preference clarification tool to help focus stakeholder attention on their evaluation of trade-offs, and would not rely on the subjective weighting to select a preferred alternative (Rodrigo 2007; National Research Council 1996).

Thus, CADRe simulation models are *decision aids* rather than *decision optimizations*. CADRe models are designed in support of collaborative negotiations and are not intended as a substitute or replacement for them. CADRe processes avoid the presumption that models can decide for negotiating parties because behavioral assumptions implicit in the approach, including individual preferences, are being created and revised during negotiation, and because of analysts' inability to collect and know all values relevant to decision participants. As decision *aids*, CADRe models do not purport to solve the difficulties and challenges of deciding which outcomes are most important and what alternative is the best for all parties. CADRE processes are built on the premise that the responsibility for choosing rests squarely with the participants in the negotiation process.

Conclusion

This chapter has discussed ways to integrate technical models with a collaborative negotiation process. The three goals of integration are to make technical analysis more responsive the needs of the negotiating parties, make scientific and technical information more credible to multiple and disputing parties, and to provide a useful mechanism for collaborative negotiations to explore, create, and debate alternatives. The reason for achieving these aims is to increase the efficacy of scientific and technical analysis and to facilitate a more constructive dialogue between multiple parties with different knowledge bases, interests, and values.

This discussion, however, does not imply or dictate the specific processes used to achieve these broad ends. CADRe cannot be conducted by formula or by a pre-defined step-by-step process to make water resource modeling responsive, credible, and useful to decision participants. Most water resources decisions are made in unique and specific policy, economic, social, and physical settings. Consequently, each decision process will require different approaches to simulation model development and integration with the decision process. The chapters that follow illustrate the range of problems and problem settings, as well as a diversity of challenges and approaches needed to bring computer-based water resource modeling to the aid of collaborative decision process. It is the future challenge of CADRe to refine approaches to, and evaluate the effectiveness of, different approaches to the integration of technical models with collaborative decision-making processes.

Chapter 4

New Approaches in the Potomac River Basin and Beyond — Pioneering Work in the Development of Shared Vision Planning

by Erik Hagen

> *The Potomac has now yet another face: It is, from this moment on, a testing place where what is done will be watched and weighed, where hopefully what is achieved is elsewhere followed and fulfilled.*
>
> -Stuart L. Udall, Secretary of the Interior (1961-1969)
> in his introduction to The Potomac (Potomac Planning Task Force, 1967)

Introduction

Early efforts to include stakeholders in the development of models and seeking of solutions provide insight into both the use of then-new approaches and historical context for the field's subsequent development. This chapter presents the very early use of computer modeling exercises with stakeholders in the Potomac River basin by pioneers in what was then loosely termed Computer-Aided Negotiation. Those pioneers would further develop and refine their methods into a specific approach known as Shared Vision Planning.

The Washington Metropolitan Water Supply Problem of the 1960s and 1970s

The origins of Shared Vision Planning (SVP) can be traced to a vicious drought, far removed in time, and to a seemingly intractable water supply dispute, centered in the nation's capital.

The most severe drought since the Dustbowl hit the northeastern U.S. in the mid-1960s and many rivers, including the Potomac River, dropped to historic lows. The Potomac River is the main water supply for the Washington metropolitan area, and the low flow set off alarms throughout the region. The new low flow level of 388 million gallons per day (mgd) compares to a previous low flow of about 500 mgd. For decades, planners thought that 500 mgd was a reliable approximation of the lowest likely flow because this level was reached for several months during the most severe part of the Dustbowl drought of the 1930s.

The gravity of the situation was compelling. Washington's peak water demand from the Potomac River had at times exceeded the new low-flow of 388 mgd. If flows dropped as low as the 1966 low-flow level on a day that demands were high, Washington could face huge water shortages, and the Potomac River could cease to flow downstream of the intakes. Daily water demand exceeded the low-flow of 1966 41 times between 1971 and 1982 (Ways 1993). The risk is further emphasized when

one considers that this calculation does not allow for any water left behind in the river to sustain the river's ecology or to dilute the region's effluent.

The new low flow was dangerous enough, but it was devastating to contemplate when coupled with forecasts of extraordinary rates of growth. Population in the Washington metropolitan area was expected to grow from 2 million in 1960 to 5 million in 1985 (U.S. Army Corps of Engineers 1963) and to 8 million by 2000 (Palmer et al. 1980). Tremendous increases in water supply demand were forecast. Peak water demand in 2000 was expected to be twice the low flow of 388 mgd experienced in the 1966 drought (U.S. Army Corps of Engineers 1983).

In the 1960s through the mid-1970s, various plans were developed and massively expensive structural solutions proposed but the region could not come to an agreement as to how to solve the problem. A U.S. Army Corps of Engineers 1963 study suggested that 16 reservoirs be built in the Potomac basin, to meet water supply needs and to dilute the effluent from Washington's wastewater treatment plant into the tidal estuary downstream of Washington (U.S. Army Corps of Engineers 1963). Public opposition to new dams prevented their implementation in the early 1970s. Meanwhile, the implementation of secondary treatment at Blue Plains Wastewater Treatment Plant greatly reduced the need for inflow to the tidal estuary. The U.S. Army Corps of Engineers proposal for 16 dams was whittled down to six, then two.

A study conducted by the Corps identified the Washington region as one of three regions in the northeastern Atlantic seaboard facing potentially severe water shortage problems (U.S. Army Corps of Engineers 1977). By 1980, the Corps was successful at obtaining authorization for only one of the 16 reservoirs, Bloomington Reservoir (later renamed Jennings Randolph Reservoir.) Clearly, reservoirs were time-consuming to implement and faced significant public opposition and uncertainty. While the planned construction of Bloomington Reservoir helped, it alone could not solve the water supply problems of Washington. That would require a more creative solution.

Conflict Between Stakeholders

The three major Washington D.C. area water suppliers are: the Washington Aqueduct of the U.S. Army Corps of Engineers (Aqueduct), providing water to Washington, D.C. and portions of Virginia; the Fairfax County Water Authority, serving the suburbs of Virginia (now Fairfax Water): and the Washington Suburban Sanitary Commission (WSSC), serving the suburbs of Maryland. The current utility service areas, reservoirs, and drainage areas to the reservoirs are shown in Figure 1.

Fairfax Water and WSSC each had their own reservoirs in the early 1970s, but growth in their service areas required them to find new sources of water. Both looked to the Potomac River and planned to build or expand water intakes on the Potomac. These plans were of interest to the most downstream water supplier, the Aqueduct. There are very few months of the year in which the flow of the Potomac is

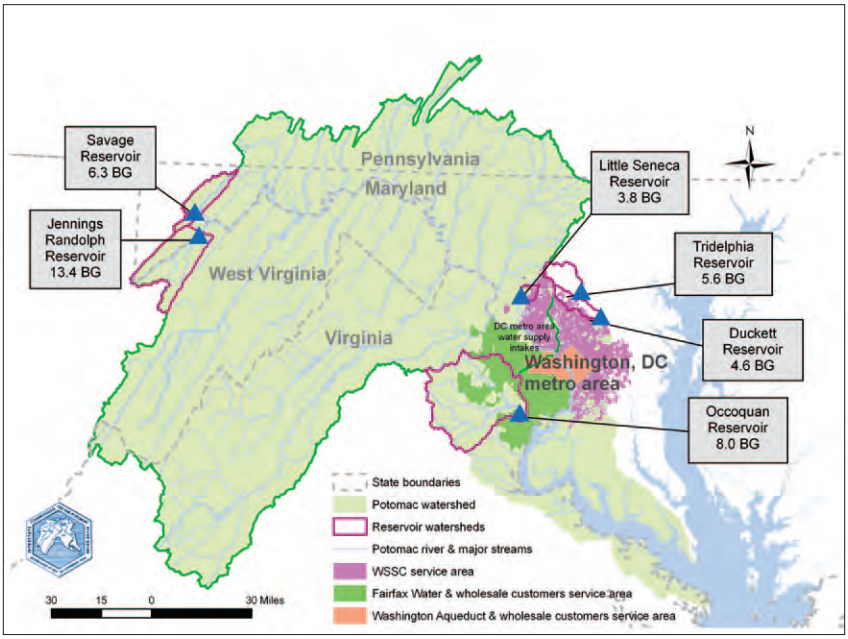


Figure 1: Potomac River Basin, Washington, D.C. Metropolitan Area water supplier service areas and reservoirs

not sufficient to meet the Washington, D.C. area's water supply demands. However, when severe drought occurs, the Potomac would be inadequate to meet the new demands by the upstream water suppliers and still meet the needs of the Aqueduct. The Potomac River is the Aqueduct's only source of water.

The Aqueduct is charged with supplying water to the White House and to Congress, as well as the rest of Washington, D.C. and a portion of Virginia. With the proposed Potomac withdrawals, the Aqueduct faced the bleak prospect of having little or even no water in the Potomac River at its intakes given the anticipated growth in the metro area's population. The combined capacity of the proposed upstream intakes was greater than the new low flow of the river, which could potentially deplete the Potomac River just when it was most needed during droughts. To prevent this from happening, the Baltimore District of the Corps blocked the development of the Fairfax Water and WSSC intakes under its authority to regulate structures in navigable waters until a mechanism was in place to share the water during droughts. After several years of negotiation, an agreement to share the water was signed in 1978, the Low Flow Allocation Agreement (LFAA). However, the Corps insisted on a provision that would allow any party to freeze the allocation formula (based on an average of five-year wintertime water use) in any year starting in 1988 or thereafter. Since the suburban water suppliers were growing and the District was relatively stable in population, this provision would cause proportionately greater

shortages to the suburban utilities. Recognizing that the Corps could block the intakes indefinitely, the suburban utilities and states chose to avoid federal courts and signed the LFAA, albeit with objections (Eastman 1986).[1]

The LFAA agreement did not address shortfalls in future water supply; it only allocated what water was available to the various water suppliers. Although they were in conflict over access to the water, the LFAA would later be amended to allow equitable sharing. The amended agreement arranged for incentives in favor of cooperation as opposed to competition.

- Aqueduct – Washington Aqueduct of the U.S. Army Corps of Engineers
- CO-OP – Section for Cooperative Water Supply Operations, Interstate Commission on the Potomac River Basin
- Corps – U.S. Army Corps of Engineers
- Drought Study– National Study of Water Management During Drought
- Fairfax Water– Fairfax County Water Authority
- FISRAC – Federal-Interstate State Regional Advisory Committee
- ICPRB – Interstate Commission on the Potomac River Basin
- IWR – Institute for Water Resources, U.S. Army Corps of Engineers
- LFAA – Low Flow Allocation Agreement
- SVP – Shared Vision Planning
- WSSC – Washington Suburban Sanitary Commission

The Metropolitan Washington Area Water Supply Study

Because of a lack of progress on development of a water supply solution, the Metropolitan Washington Area Water Supply Study[2] (U.S. Army Corps of Engineers 1983) was authorized by Congress in 1974. Congress allocated 3.5 million dollars for the study, which was to formulate viable solutions for Washington's water supply problem. To determine the study approach, the Corps initiated an extensive program to obtain public input on study efforts. A formal committee structure was established to encourage active and ongoing participation by governmental, non-governmental, and individual interests at all levels. This committee structure would involve the water suppliers, the states, the federal government, citizens and technical task forces, and local governments.

The study was slated to run in two stages, with a separate track for a pilot study on estuarine treatment. The first stage centered on early-action initiatives that could be implemented in fewer than 15 years and that attempted to make the most efficient use of water. The second stage would identify long-term solutions to the water supply problem. This study was begun in the context of no significant progress on

1. Harry Ways was the Chief of the Washington Aqueduct at the time of the signing of the LFAA, and is an author of a history of the Washington Aqueduct. He cites that the "removal of the freeze later became an important bargaining chip in realizing the cooperative Water Supply Coordination Agreement" (Ways 1993).

2. The Corps study lead for this project, James W. Haines, was the primary author of the study's *Main Report*, which provides a comprehensive and excellent summary of the background and early history of the Washington metropolitan area water supply issues and an overview of the development of regional cooperation.

Washington's water supply solution, a full ten years after the 1966 drought. There was strong sentiment by many organizations and individuals at the study outset to address the most immediate water supply needs as quickly as possible.

A broader water supply study for the entire Northeast—the Northeastern United States Water Supply (NEWS) Study (U.S. Army Corps of Engineers 1977)—was almost finished with a draft report available. The NEWS study, with a final report published in July 1977, outlined various projects for the Washington area, including reservoirs, local impoundments, raw water interconnections between water supply systems, desalting, groundwater withdrawal, and various pricing structures, among many other alternatives. Recognizing that considerable technical work had already been done, the Corps structured the initial stage of the Metropolitan Washington Area Water Supply Study to screen the NEWS study alternatives, with several criteria in mind. The most viable solutions were to be technically feasible, socially acceptable to area residents, environmentally sound, economically affordable, and most importantly, be implementable without direct federal involvement. It was felt that solutions that could avoid federal involvement would be easier to implement quickly.

The committees established by the study would become important venues for regional leaders to meet and consider various water supply solutions, including the collaborative solution that was eventually adapted. One of the more important committees was the Federal-Interstate State Regional Advisory Committee (FISRAC) as an advisory committee to the Metropolitan Washington Area Water Supply Study. FISRAC was formed to include the key decision makers for the metropolitan Washington area water supply matters.

After screening the NEWS study alternatives, the FISRAC committee deemed the interconnection option as one of several of the most acceptable options, deserving detailed attention. This interconnection idea, with significant modifications, would become part of the water supply solution. As it was envisioned at this point in time however, it was a stopgap measure that could not meet all of the future needs. Furthermore, this option would require some kind of regional coordination. The committee expressed an interest in a study to explore how to implement such a project, they were generally opposed to a single water and wastewater management agency to handle project implementation (U.S. Army Corps of Engineers 1983).

During the first stage of the study, as an alternative, an imaginative and ground-breaking water supply solution was conceived and its implementation solved the long-term water supply problem based on the operations and management of the existing infrastructure, albeit with modest changes. The means by which the solution was achieved and implemented also demonstrated the power of interactive collaborative modeling and laid the foundation for the field of Shared Vision Planning.

The Metropolitan Washington Area Water Supply Study would provide an important institutional structure allowing for the genesis and initial development of a

water supply solution. The study planners brought together the important decision makers in a structured framework, allowed them to define solid and non-prescriptive study planning objectives and begin the work of ranking and evaluating various alternatives. This provided a collaborative environment in which the water suppliers began discussing a regional agreement.

ICPRB Involvement

The Interstate Commission on the Potomac River Basin (ICPRB) was "established by Congress in 1940 to help the Potomac basin states and the federal government to enhance, protect, and conserve the water and associated land resources of the Potomac River basin through regional and interstate cooperation." As an inter-jurisdictional organization chartered with regional cooperation to solve problems, the ICPRB was perhaps ideally placed to help develop a solution. Its compact allowed for flexibility, allowing the creation of new sections within the ICPRB to address issues of concern within the watershed. ICPRB's geographical purview covered the affected jurisdictions of Maryland, Virginia, and Washington, D.C., and was not seen as beholden to any one jurisdiction or water supplier. Moreover, engineers at the ICPRB first developed the notion that the solution to Washington's water supply problem lay entirely within the grasp of the three independent, and competing (but now less competitive), water suppliers (Eastman 1986).

After the LFAA was signed in 1978, WSSC and Fairfax Water were free to expand and build Potomac intakes. WSSC began expanding its existing 184 mgd intake to 400 mgd. Fairfax Water followed suit and began building a Potomac intake of 200 mgd. Although the water suppliers were acting in their own interests, these intakes allowed the possibility for more flexible and regional operation. An engineer at ICPRB, Daniel Sheer, realized that the water storage in the suburban reservoirs was enough to meet the calculated shortfall in Washington's demand with the then-planned intakes (Sheer 1977; Eastman 1986). If WSSC and Fairfax Water used more Potomac water instead of reservoir water during the winter and spring, the suburban reservoirs could be kept full until the beginning of the drought season. The suburban reservoir water could then be used during the summer and fall drought period instead of Potomac water, leaving more water in the river for the most downstream water supplier, the Aqueduct. This strategy was viable because even during drought months, the winter and spring Potomac flow is more than adequate to meet water supply demands. Engineers at the time called this the "reregulation" option.

As Sheer envisioned, the suburban reservoirs could be used to meet regional water demand via raw water interconnections with the Potomac River or via finished water interconnections (Sheer and Eastman 1978; Eastman 1986). A second contribution by Sheer was the idea to not only coordinate the local reservoir releases by the suburban utilities, but to better manage releases from the newly created Bloomington Reservoir in coordination with downstream suburban reservoirs. Sheer's idea became the basis of what eventually would become a collaborative solution to

Washington's water supply problem, and was introduced in a short paper titled, "A perspective on Washington's water supply problem" (Sheer 1977).

The ideas introduced in Sheer's paper were studied extensively in the 1978 and 1979 time period (Sheer et al. 1978). It was widely assumed that major facilities to interconnect the water supply reservoirs would need to be built to implement these operations. Proposals included expensive raw water transmission mains to connect the Potomac River to the Occoquan and Patuxent reservoirs, the latter an interbasin transfer. The interconnection studies yielded a surprising result: no major new distribution system lines were necessary to implement the concept. With minor improvements in the existing systems in combination with the planned intakes, the system could be immediately implemented by adjusting the balance of withdrawals between the Potomac River and reservoir treatment plants. If river flows were low, more water could be taken through the reservoir plants, and if flows were higher than expected, river withdrawals could be increased and reservoir withdrawals reduced to save reservoir water. The difficulty with this solution was that its implementation would require the upstream water suppliers to keep their reservoirs full in the spring, in order to have adequate water to get through summer and fall droughts. It would require the water suppliers to cooperate, build trust, and overcome political and jurisdictional hurdles.

Stakeholders brought this idea to the attention to the Corps via the Metropolitan Washington Area Water Supply Study. One of the successes of this study was that planners allowed for input from the study participants, allowing the study to grow and change with the evolving thinking of the study participants. The reregulation idea was incorporated into the study and documented as a potential policy option in the August 1979 *Progress Report* (U.S. Army Corps of Engineers 1983) as the alternative "Plan 4 – Regional Plan 1." This alternative identified the collaborative solution as the lowest cost of any of the proposed plans but also identified potential shortages occurring as early as 1990 at a 1 in 50-year probability level.

While the reliability of water supply under this option was improved, it was not ideal. The work assumed fairly narrow constraints including rather inflexible rules on how to use the upstream Jennings Randolph Reservoir. The Corps did not consider forecast-based releases from the reservoir. Forecast-based releases from Jennings Randolph Reservoir (then called Bloomington Reservoir) would eventually become an integral part of the water supply solution. According to Sheer,

> Bloomington management was the biggest piece. The Corps counted the yield of Bloomington as the yield at the dam. The yield at DC if managed properly could be several times greater, BUT… managing for DC required using a forecast. In the Corps view, 7 day (travel time) forecasts were not accurate (I think they actually said "useless"). In any case, historical records of forecasts didn't exist – they were never made – so we could not simulate using them. And the Corps simply refused to consider operations to meet a target at DC

> because they did not have a way to get the required forecasts (my view). So, they needed six reservoirs….The models I wrote to test rules needed forecasts, too. So I made up a forecast technique that I could easily recreate for the historical record. The forecast technique was very complicated – the flow forecast for seven days from now would be today's flow. The rules used the local reservoirs to compensate for any errors in the forecast… (Daniel Sheer, personal communication, March 26, 2009)

The Johns Hopkins Team

As Sheer and others analyzed the so-called re-regulation option, it was also being studied at Johns Hopkins University as a part of a post-doctoral study by Richard N. Palmer at the Department of Geography and Environmental Engineering, advised by professors Charles S. ReVelle and Jared L. Cohon (Palmer et al. 1980). The study was funded in 1977 through the Office of Water Research and Technology, with matching grants from the State of Maryland, the Commonwealth of Virginia, and the Interstate Commission on the Potomac River Basin. The first year of the study was devoted to the formulation and solution of optimization models.

The Johns Hopkins team represented an innovative systems approach, as these optimization tools were just coming on-line as a practical possibility. The team cast a broader net than the optimization conducted under the Metropolitan Washington Area Water Supply Study, looking for the *maximum* possible water that could be supplied to the region during the worst droughts under a variety of management constraints and objectives. A critical difference was the use of forecasts to help manage the system. Palmer's work showed that "with optimal reservoir operation, the yield of the Washington water supply system is significantly higher, and its useful life substantially longer, than had been previously perceived" (Palmer et al. 1980). The groundbreaking study showed the possibility of meeting Washington's needs well into the future (2030) with existing resources, including Jennings Randolph Reservoir—a result almost too good to be true.

At the time, it probably would have been easy to discredit the results. Palmer's optimization study was just that, an optimal result. Releases of water from Jennings Randolph would take at least seven days to reach Washington, and Palmer's study relied on perfect forecasts of water shortages. This would be impossible in real life. No one knows what river flow will be in seven days time. The river flow can be higher or lower than predicted. Even water demand is variable and hard to predict seven days ahead as it is highly influenced by rainfall, temperature, and other factors. For example, during a hot and dry spell in 1999, Washington water demand increased from 514 to 708 mgd in seven days, an increase of 38 percent. (Sarah Ahmed, personal communication, July 31, 2009). Yet Palmer's optimization assumed a perfect forecast of river flow and water demands seven days in the future.

Palmer, in a follow-on study, showed what must have been seen at the time as an incredible result that "The yield which results from the proper joint operation of the system is significantly greater than the yield of the individual components of the system" (Palmer et al. 1982), a result that was called "conjunctive yield." This is almost like saying that two plus two equals five, but Palmer's analysis showed how, with intelligent operations, the total of the whole, managed as a system, was greater than the sum of the parts. Clearly it would take more analysis, better tools, and a creative approach to demonstrate to the water suppliers and the Corps the applicability of Palmer's results. Without an appropriate tool and approach, the water suppliers would remain skeptical of the seemingly impossible model results.

Meanwhile, Dan Sheer at the ICPRB continued to work on the water supply problem. On a parallel track with Palmer, he refined and explored the forecast problem through simulation modeling. He used the optimization results provided by Palmer's study to benchmark his results and

> …as an upper bound on the reliable supply at DC. The optimization had perfect foreknowledge of week-ahead flows. I figured that if the rules in the simulation using the no change forecast were not too far below the "optimal" from the LP studies, they were acceptable—maybe even pretty good. (Daniel Sheer, personal communication, March 26, 2009)

While an analytical solution began to seem possible through the work of Palmer and Sheer, there were significant obstacles remaining. These were model results. They looked good on paper, but the Corps and the water suppliers needed more than model results. It was not clear yet that the results could work in the real world. In the recent past, the water suppliers had fought with each other for a bigger piece of what seemed to be a very small and limited pie. Now they were being told that cooperative management could increase the available water so that all could be satisfied, with what must have seemed something akin to the wave of a magic wand.

A cooperative solution would mean coordinating not only Jennings Randolph releases, but also using the WSSC and Fairfax Water reservoirs for the benefit of the system as a whole during droughts. The timing could not have been worse. The region had just been through a serious drought in 1977. In early fall of 1977 the Occoquan Reservoir was close to empty, the hot drought seemed endless, and restrictions on water use were in place. At the time, there was no other source of water. It seemed not unlikely that a major jurisdiction in the Washington area would run out of water. Rain eventually solved the problem in the nick of time, but now Fairfax Water was asked to share this precious water in their reservoir for the benefit of other water suppliers, during droughts no less.

WSSC was in a similar position with its small and vulnerable Patuxent reservoirs, which do not always refill from year to year. WSSC had also experienced restrictions during the 1977 drought. On July 6, 1977, an electrical fire knocked out a main pump

on the Potomac Filtration Plant just as demands were near record levels. Then, the transformers for the whole plant blew and a large part of WSSC's service area was without a water supply, relying on stored water in the distribution system. Montgomery and Prince George's counties imposed emergency water restrictions, businesses closed, and police cars escorted tankers to water distribution points. It was several weeks before WSSC's system would return to normal (Potomac Basin Reporter 1982).

It would take more than the results of an optimization model to get Fairfax Water and WSSC to share the water from their reservoirs with other suppliers. They needed to somehow see if these model results would really work in the real world, but also to come to agreement on how to operate this system. Who could be trusted to run this system? These practical and institutional obstacles seemed insurmountable. But several engineers, certain in the convictions of their modeling results, worked on an approach to bring the adversarial players together to test the models and to see if the solution was viable. The work of these engineering teams to implement a solution would resolve these obstacles, solve the Washington area water supply problem, and result in the birth of Shared Vision Planning.

Frustration with the Available Tools

Key issues remained unresolved and none of these issues could be easily addressed by the optimization models. There was a question as to how much flow should be kept in the river for environmental protection— and no one knew what an appropriate level should be. Without this information, there was no way to determine the reliability of the water supply system. This issue was dubbed the "flowby" issue by the study participants. Too high of a flowby would lead to quickly depleted reservoirs and unreliable supply.[3] Another issue was the Little Seneca reservoir site being studied by WSSC (Henningson, Durham & Associates 1978), originally proposed as one of the 418 smaller "headwater" reservoirs in the Corps basin plan for the Potomac in 1963 (U.S. Army Corps of Engineers 1963). Should it be included as a joint resource for the benefit of all three Washington metro suppliers? If so, what would be the operating rules? Another outstanding issue related to the LFAA Freeze provision, which allocated

3. It is worth noting that the flowby issue was studied in great depth in a 1979 study (Maryland Department of Natural Resources 1979), but some claim the scientific results were inconclusive. Simply put, the river did not flow at a low enough level during the study period for study participants to get a good idea of what was going on in the river. And at medium to high flow rates, this stretch of river is impossible to survey because it is so treacherous. Consequently, critics believed that the flow recommendations of the study were not supported by science. The study recommended minimum flow rates for two stretches of the river, yet provided no clear rationale for the low flow numbers. Perhaps the numbers reflected that a similar flow rate had been experienced in prior droughts for a short time, with no obvious problems in the river. The issue was re-examined during the droughts of 1999 and 2002 (Maryland Department of Natural Resources 2003), with no change to the minimum flow recommendations. The river downstream of the last intake is a very short stretch of quite rocky river bottom—attendant conclusions about biological significance of infrequent and extreme low flow continue to be a point of debate for this stretch of river. Questions remain, such as whether there are any endangered clams or other immobile creatures at risk, whether and how such populations might recover after a drought, and for how extended a period can the river maintain the current minimum low flow without harm. Informal surveys done by the Maryland Department of Natural Resources and by ICPRB revealed no endangered shellfish in 1999 and again in 2002. Rod-and-reel sampling during very low flows by ICPRB showed highly concentrated but healthy populations of larger fish in the deep pools.

shortages in the Potomac based on 1978 levels of water demand. Decision makers were keen to negotiate how to divvy up the Potomac water more equitably given future growth in the event of a shortage, a question that became known as the "allocation percentage." The optimization models were not flexible enough to easily answer these and other changing assumptions that decision makers wanted to examine. The members of the key FISRAC committee, composed of the key decision makers for the metropolitan Washington water supply matters, were frustrated with the ability of the existing optimization models to quickly answer these questions.

Frustration peaked at a critical meeting of the FISRAC committee in December of 1979. While there were promising ideas developed through the optimization models, no one could make sense of the big picture, and the models themselves were seen as "black boxes" and so were not trusted. (James W. Haines, personal communication, September 9, 2008). There were too many questions left unanswered by the unwieldy models, particularly the role of the flowby and allocation percentages. The optimization models were simply too cumbersome to quickly answer questions for the committee about the system and management choices. It was not only a question of lag time, but of the structure of the model itself. An optimization model has inputs of weighted objective functions, which can be described as a non-intuitive way to quantify user-priorities. Furthermore, optimization models at the time were run by experts, and did not allow access by the study participants nor enhance their understanding of the system. The study lead for the Corps, James W. (Bill) Haines, recalls presenting the initial and promising preliminary results of the optimization work done by the U.S. Army Corps of Engineers at the December 1979 meeting and describes the reaction of the committee to the results: "We felt that the FISRAC group asked questions we couldn't answer and basically handed our heads back to us—I remember asking, what just happened?'" (James W. Haines, personal communication, September 9, 2008).

Development of the Interactive Model

At this time, in the second year of the study at Johns Hopkins, the Hopkins team led by Rick Palmer introduced a new interactive computer modeling tool that allowed the decision makers unprecedented access and understanding of the system. The Hopkins team was aware of the use of interactive water models by Pete Loucks, a professor of engineering at Cornell University. Palmer writes about why the group moved from an optimization model to a simulation model:

> We were increasingly confronted with the problem of getting local planners and decision makers representing competing jurisdictions involved in a cooperative, or at least common, management process. We intended to create a tool to facilitate dialogue among planners and decision makers, providing insight into their own problems as well as those of other jurisdictions. This meant an interactive model; a hands-on planning tool. This in turn argues against optimization, a structured, inflexible approach, and for interactive simulation which would allow users to ask a range of questions and to test many possible management approaches. (Palmer et al. 1980)

Demonstrating foresight, the Hopkins team built the Potomac River Interactive Model, called PRISM in 1979, even before the December 1979 FISRAC meeting in which the attendees expressed so much frustration with the optimization model. Palmer's simulation model allowed for preferences and tradeoffs to be discovered through interactive modeling. The study designers were aware of the inherent limitation of the optimization models used at the time, such as lack of user understanding, and difficulty in translating value judgments into the non-intuitive objective functions required by the optimization modeling as inputs.

The interactive model was developed to address these shortcomings. The decision variables such as flowby amounts and allocation percentages could be entered by users directly, and changed to see how they would affect the model results. The resulting tradeoffs could then be discovered and solutions negotiated directly. The introduction screen of the PRISM interface rather poetically introduces the concept of the simulation model as an alternative to the "black box" modeling approach: "As an optical prism is able to disperse light, it is the purpose of the PRISM model to indicate a wide spectrum of management policies and to synthesize them into a single, coherent management strategy" (Palmer et al. 1980).

The optimization model developed in the first year of the Hopkins study provided insight as to what was feasible, albeit in a very prescriptive way and subject to narrowly defined constraints. In contrast, the simulation model could be used to illustrate changes to the water supply system given changes to user-defined inputs. In this way, the model was used to answer a series of "what if" questions to show what *could* be done. "Simulation models of the type can be 'exercised' in a systematic and iterative manner to converge on an optimal operating policy. While optimality cannot be guaranteed, fluctuations in the parameters of the system can be viewed by decision makers and hence the operation of the system can be more readily understood" (Palmer et al. 1980). Palmer's model effectively modeled the decision-making process itself, allowing for preferences and trade-offs to be discovered through the operation of the model while negotiating.

Palmer writes of the importance of understanding and communicating to the decision makers the assumptions on which the model is built and what to expect from its use. "The absence of an effective way of teaching the users of the model its logic and structure is a major impediment for its use as an aid in decision making" (Palmer et al. 1980). The lack of understanding of the "black box" optimization model was a major factor impeding the participants' use of the optimization tool to aid in decisions.

The PRISM model was designed to investigate how to better operate the reservoirs in the system as an alternative to structural solutions to the water supply problem. The Johns Hopkins team was in close contact with ICPRB's Daniel Sheer. At the time, Sheer had another version of a simulation model running and was working to refine the operating rules of the system. The Johns Hopkins study team took PRISM to the

water suppliers and on the road in a series of workshops, demonstrating the regional solution to the system operators and managers. These groups included:

- Washington Suburban Sanitary Commission
- Fairfax County Water Authority (now Fairfax Water)
- Washington Aqueduct Division (Baltimore District, U.S. Army Corps of Engineers)
- Office of Water Research and Technology, U.S. Department of the Interior
- Metropolitan Washington Council of Governments

The Johns Hopkins team used the workshops to share the PRISM model assumptions, and responded to the input of regional water managers and others in cases where the model assumptions could be improved. By responding to their concerns, water managers gained trust in the experts and in the model itself. The give and take between expert modelers and users with native knowledge of the water supply system was a great help in building a better PRRISM model, and one that could be trusted by the water managers.

Ultimately, water managers began to understand the model and use it to begin exploring how coordination in the water supply system might solve Washington's water supply problem. But the solution was not yet fully demonstrated to all the participants, including the most senior water managers. For that, the Hopkins and ICPRB teams needed to assemble the water suppliers in what would be a virtual drought demonstration. They brought the three utilities together for the first collective "Drought Exercise." The Drought Exercise would become of critical importance to the regional managers, who for the first time came together to test the operating strategies using the model interactively, together trying to manage their way through a terrible simulated drought.

The First Drought Exercise

A major goal of the Hopkins study was to build a model that could be used in a drought simulation, thereby simulating the process by which policy is made. Policy makers may have different objectives, some of which may be poorly understand or defined. The Hopkins team recognized that as such, decision making can be described as perhaps the most important system variable (Palmer et al. 1980). Palmer and his team knew that typical simulation models of the time failed to provide a forum in which decision makers could articulate the reasons behind specific actions, so they designed their model in such a way that it could be used interactively by the actual decision makers as it was being executed, so as to simulate the actual decisions being made during a drought in Washington. In this way, the Hopkins

team, in close collaboration with ICPRB, hoped to force the active participants in an exercise to incorporate non-quantitative factors into the simulation process, thereby increasing awareness and understanding of the motivations behind decisions.

The Hopkins team believed that the interactive feature of PRISM made it an efficient way to involve the decision makers in the model building and modification process. The team designed PRISM to enhance the exchange of ideas and information, facilitating the identification of key issues, and allowing for faster connection between the decision process and access to modeling results. They felt that the interactive feature of PRISM greatly increased its utility as a planning tool:

> Placed in the roles of regional decision makers (often not corresponding to their actual roles), participants respond to recommendations made by PRISM for the release of water among user jurisdictions. Options for changing model parameters are also offered by PRISM during a session. To aid decisions, graphical displays of the condition of the system are available throughout the simulation. Upon completion of each iteration (drought management period) of the model, PRISM presents a summary showing the effectiveness of decisions made during that period, providing an immediate feedback of information to be used in the evaluation of previous management decisions. At the end of the simulation, a complete record of the exercise is available for further analysis… Individuals who are knowledgeable in the operation of the system gain insight into the planning and management process as they interact with the model. This insight, which is crucial to the implementation of new policy alternatives, would be difficult to create with more conventional simulation models. (Palmer et al. 1980)

The Hopkins team and ICPRB decided to use PRISM to hold a role playing game, or Drought Exercise, with the three utilities. The utility managers were asked to use PRISM to manage their water supply system during the worst simulated droughts. The managers could see the recommendation provided by the PRISM model, but were free to override the recommendations with their preferred operating policies. At the conclusion of each weekly timestep, the model would pause and solicit new instructions from the participants. The organizers of the Drought Exercise provided different "hats" with names on them, and the managers were asked to wear different hats—that is, to operate someone else's system during a drought. The managers gained a new understanding of the system, and a new sympathy for the challenges and positions of the other utilities. Daniel Sheer recalls that

> …the first game involved both of us [Sheer and Palmer], Harry Ways [Chief, Washington Aqueduct], Bob McGarry [General Manager, WSSC and previous Baltimore District Colonel] and Jay Corbalis [General Manager, Fairfax Water, and ICPRB Commissioner]. I do remember calling in my chits to get them to go. Many of those chits originated with the work on the Occoquan in 1977, about the time of the LFAA… the first session was very interesting. In the first iteration where the "forecast" indicated a release might be needed to meet demands 7 days hence, all three said words to the effect

> of "that's a week out, why do we have to decide now....Oh, it takes a week to get there... What do we do?" The game forced them to face the issue of using forecasts in a real way. By the end of the game, they jointly realized they didn't know how they'd operate the water supply storage in Randolph, and asked us to figure that out... The first game was very, very, important, and a success due to the JHU [Johns Hopkins University] groups preparation. (Daniel Sheer, personal communication, March 26, 2009)

The Drought Exercise marked a turning point for the Washington Metropolitan area water suppliers, who for the first time began to understand how the system might be better operated using regional operating rules and to begin to understand the other issues such as flowby. This groundbreaking work set the stage for water suppliers to understand that they would be better off working together on a regional solution, and motivated the water suppliers to begin working together for a cooperative local solution. Robert McGarry spoke about the exercise at a meeting of the ICPRB in 1981, describing how the PRISM model transformed the understanding of policy makers about how to operate the system via a collaborative and interactive modeling exercise:

> Dan Sheer has just mentioned the work that was being done by the CO-OP [ICPRB Section for Cooperative Water Supply Operations] ...examining the possibility of operating the systems regionally—a new concept that hadn't even been possible before. In assessing the current capacity, we discovered that by operating cooperatively...as proposed, we could meet our needs through the year 2000, and probably through the year 2020...it is very difficult for many of us to announce that, after preaching the need for 13 reservoirs—6 reservoirs—2 reservoirs—a reservoir and interconnections—to now say, "Lo and behold, we have what we need under construction." The key was that we got smarter by: 1) using CO-OP; 2) considering operating this system as a regional facility. We recommended, and the task force has approved, that ... the total system should be operated regionally...I expect that the final recommendation will be made ...so that we can give to the task force, the elected leaders of the region, a plan that within our jurisdictions will solve our water supply problem forever. It is exciting that we are able to do this through cooperation in operating what are actually three very independent Washington Metropolitan Area water supply systems... as one system. This comes as a result of the very sophisticated work that CO-OP has developed which enables us to meet a need at a minimal cost. (McGarry 1981)

Support for a Local Solution

There were several additional, and positive, outcomes of the critical December 1979 FISRAC meeting. Probably the most important outcome of these was that the regional water suppliers decided to take control and develop a local solution to the problem:

> The local water suppliers finally faced up to the fact that water supply was ultimately a non-federal responsibility. They were going to have to pay for a solution anyway (no dollars from the federal government for water supply),

> so why not take charge and create a system themselves that they were all comfortable with. To me, this was the most important decision—not flowby, not allocation percentages, not Little Seneca, not anything else. They didn't want Uncle Sam telling them how to solve their problem. (James W. Haines, personal communication, September 9, 2008)

A second important outcome of the December 1979 FISRAC meeting was the decision by the locals to form an independent committee to see if a local, cooperative solution could be developed. The committee was called the Metropolitan Washington Regional Water Supply Task Force (Regional Task Force), composed of top elected representatives from each jurisdiction and supported by technical and citizens advisory committees.

Trust in the technical abilities of the ICPRB and in the people themselves was a part of what made the water suppliers amenable to working on a collaborative solution, and work closely with ICPRB. Sheer writes:

> The Corps had proposed big interconnection pipelines. It turned out that not only were 5 additional reservoirs not necessary, the big pipes weren't either. The Corps analyses were —how shall I say—no longer considered the be all and end all—and ICPRB's credibility was on the rise—both the interconnection analysis and the initial joint ops analysis were done at ICPRB, and Eastman and my credibility was rising. I'm pretty sure that had something to do with the move by the water utilities to take things over—remember that Corbalis was an ICPRB Commissioner and that the Commission had helped him substantially in 1977. McGarry was one of McNamara's (Defense Secretary under Kennedy) w[h]iz kids, and knew what computers were about. He personally reviewed the ICPRB model output and found round off errors and questioned me—forcefully—about them. (Daniel Sheer, personal communication, March 26, 2009)

Strong personalities were instrumental in the development of this committee. Robert McGarry, a retired Brigadier General who was a former District Engineer (Baltimore) of the Corps and the current General Manager of WSSC took charge early on, eliciting the membership of elected officials from each jurisdiction and becoming the non-voting Executive Director of the Regional Task Force.

> The Water Supply Task Force was convened with the general consensus that we couldn't make progress until we as a group and/or region sit down and agree to agree, and we need to work on this ourselves. They [the members of the FISRAC group] felt they had the technical pieces in place or studied, so they needed to develop a plan they were all satisfied with. It kind of took on a life of its own. [Robert] McGarry and others said that they need to work out this agreement—a gentlemen's agreement to agree—and the result of that agreement was the signing ceremony 2 years later. It was the people—McGarry had stature as former District Engineer and now General Manager at WSSC, and James Corbalis [General Manager at Fairfax Water], a tall slender man over 6 feet and around 60 years old—low key, knowledgeable, he

> wanted the intake but knew he had to compromise and cooperate. And you had Harry Ways [Chief of the Washington Aqueduct]. All three were very much respected, all were very knowledgeable and all were gentleman. Based on the strength of their personalities, they basically said they were going to do it. They developed this set of agreements. (James W. Haines, personal communication, September 9, 2008)

The purpose of the Regional Task Force, formed in 1980, was to formulate a water supply plan which would be acceptable to the entire region and to prepare the necessary contracts and agreements so the plan could be quickly implemented. Robert McGarry explains to the ICPRB commissioners that the key to the formation of the committee was the understanding "for the first time that the solution to our water supply problem was within our jurisdictions. We no longer had to go to Frederick, Maryland, or Staunton, Virginia or Sixes Bridge, or the 'six pack' that Colonel James Peck mentioned. [Here, McGarry is referring to reservoir locations and plans outside the metro area.] The solution was available within our own jurisdictions—it only required a decision on our part to do something" (McGarry 1981).

While the work of the Johns Hopkins study was finished, the PRISM model would continue to be used by the water suppliers to find and polish a regional solution. As the water suppliers developed an understanding that the water supply system would be best managed regionally, they turned to the ICPRB for help. In response, the ICPRB created its Section for Cooperative Water Supply Operations (CO-OP) to help the water suppliers manage the Potomac resource using the operating rules developed collaboratively. This was possible because under its compact the role of the ICPRB could be broadened to create special sections to address issues of concern within the watershed.

Dan Sheer was using a modification of the original weekly PRISM model converted to a daily model.

> What we were running were simulations, not optimizations or games. We had to demonstrate that the simulations followed the desired rules. The sessions were CAN [computer-aided negotiation] sessions, not exercises. When it came time for the second [drought] exercise, ICPRB modified the daily model to support the exercise, and I believe that the interface and the outputs were quite different. It is worth noting that the WSSC game had the parties in separate rooms (the Corps room had a T table) and the participants had to use telephones to contact each other and hold meetings. We even had a reporter write inflammatory articles for the "Washington Pest." It took a while for some of the targets of his attacks to forgive him. The exercise was as real as we could make it, and the realism was one of the reasons for its success. (Daniel Sheer, personal communication, March 26, 2009)

The second Drought Exercise was held at WSSC. "In July 13th of this year (1981), we put together a drought simulation to test the operating rules that we have been developing and to look for flaws in the system. We hope to find what was wrong and

Daniel Sheer presents to several graduate students from Johns Hopkins University, Professor John Boland, ICPRB's Jim Smith and an administrative assistant, representatives from WSSC, Metropolitan Washington Council of Governments, and the state of Virginia.

to correct it. We put together an equivalent of a "war game" which was held at the Washington Suburban Sanitary Commission. It was quite successful. The utilities and the Corps managed the system extraordinarily well, using the forecasts and weather information for the drought. I am confident the work we are doing with CO-OP on water supply will be successful" (Sheer 1981).

Once the Regional Task Force had a working solution, it was time to convince the Baltimore District of the Corps of the solution. The strength of the technical work was emphasized by the strong leadership of Robert McGarry. Sheer writes,

> …once the RTF [Regional Task Force] had found a set of operating rules we thought would work, we had to present them to the Baltimore District. Peck was the Colonel. Imagine a T shaped table, Peck at the head, 25 Corps staffers around the T, McGarry and me at the bottom. Just the two of us. McGarry, West Point trained and former Colonel, had the stature necessary to tell the Corps staff that he'd personally reviewed the ICPRB work (and he had, in detail) and that it worked. On that day I realized that West Point was not your average Ivy League school and what leadership training could do. (Daniel Sheer, personal communication, March 26, 2009)

Further institutional support for PRISM came about when the Corps incorporated it in to the Metropolitan Washington Area Water Supply Study. The Corps revised and modified PRISM to reflect the programs and projects being considered by the Regional Task Force, and named the model PRISM/USACE. The Corps study managers used PRISM/USACE to evaluate different assumptions and input values relatively quickly and inexpensively, to determine how to use Jennings Randolph Reservoir (then Bloomington Reservoir) and the overall system's response to various management strategies. (Bloomington Reservoir was authorized for purposes of flood control, water quality, and water supply, with a provision for non-federal cost sharing of the water supply storage.) PRISM/USACE was also used to affirm that the collaborative solution eventually endorsed by the Regional Task Force could meet water supply demands through the year 2030, while meeting a minimum environmental flow of 100 mgd. Ultimately, the Corps' final report for the Metropolitan Washington Area Water Supply Study concluded that:

> In light of the significant advances in regional cooperation among the major users, the region's recent commitment to act on high priority water supply programs, and the creation of local institutional mechanisms to implement these water supply programs, the District Engineer recommends that no additional projects or programs be undertaken by the Corps of Engineers at this time…(U.S. Army Corps of Engineers 1983)

The lessons learned through the drought exercises, combined with trust in the technical competence of the study team, strong leadership of key people making policy, and a well-crafted study plan allowing for input from the study participants allowed for collaborative support for a regional operating plan. The Washington metropolitan area water suppliers institutionalized cooperative management through series of eight separate legal documents and signed on July 22, 1982. Of the eight agreements of 1982, perhaps the most comprehensive is the Water Supply Coordination Agreement that is signed by the federal government, water supply agencies, and the ICPRB. The Water Supply Coordination Agreement provides for the coordination of all the major facilities in the region so as to minimize the potential for water shortages.

The water suppliers looked to the ICPRB to manage the system and institutionalized this relationship through the Water Supply Coordination Agreement. The flexibility of the ICPRB's compact allowed for the creation of a special section of the ICPRB—the Section for Cooperative Water Supply Operation. CO-OP maintains the regional operating rules and manages and coordinates operations for the three Washington area water suppliers during periods of low flows. CO-OP directs the water supply withdrawals and releases from reservoirs and Potomac sources in accordance with the regional operating rules. Arguably, the creation and designation of CO-OP to manage water supply would be one of the most important long-term outcomes of the agreements.

In coordination with the three water suppliers and regional institutions, CO-OP has conducted drought exercises in every year since 1981, except for those years in

which actual drought operations occurred. CO-OP's active role in conducting annual drought exercises has ensured that the cooperative management agreements and operating procedures required to function smoothly are not forgotten. CO-OP would not be needed to actively manage the water supply system until the droughts of 1999 and 2002, after what would be nearly two decades of adequate water supply and long after the 1982 agreements were signed. With the benefit of the prior drought exercises, the water suppliers sailed smoothly through the droughts of 1999 and 2002.

The regional solution garnered recognition as a nominee for the American Society of Civil Engineers' annual Outstanding Civil Engineering Achievement in 1982, and the Potomac example has become a well-known case study of excellent water resources planning and management (U.S. Army Corps of Engineers 1995).

If Shared Vision Planning can be compared to a river with multiple headwaters, then the Potomac case study can be thought of as a major tributary providing much of what would eventually become Shared Vision Planning. However, Shared Vision Planning would not become recognizable as a disciplined approach to water resources planning until Palmer's collaborative modeling element joined with Shared Vision Planning's two other major tributaries, a structured approach to planning and a strategy for stakeholder involvement. Shared Vision Planning became what it is through the collaboration of Palmer with William (Bill) Werick on a national drought study conducted through the Corps. The development of Shared Vision Planning is the story of a long and productive partnership between Palmer and Werick beginning in the early 1990s. Highlights from the drought study pertinent to the further development of SVP are presented below.

The National Study of Water Management During Drought and the Development of Shared Vision Planning

After the droughts of 1988, Congress funded a four-year National Study of Water Management During Drought (Drought Study) led by the Corps' Institute for Water Resources (IWR). The primary objective of the study was to find a better way to manage water during drought in the United States. Water resources management at the time was seen as inefficient, often failing to involve stakeholders in the decision making process. The Drought Study aimed to address these problems by developing "an innovative, integrated, and collaborative approach to drought management" (U.S. Army Corps of Engineers 1995). The goal was to develop a synthesis of the best practices in the field. These best practices included two powerful elements that would combine with collaborative modeling to become SVP. These two elements were: 1) a structured approach to water resources planning that has its roots in multi-purpose planning first developed from the Harvard Water Project of the 1950s and early 1960s, modified and implemented in federal water studies, and codified in "Principles and Guidelines" for federal water planning; and 2) a strategy for involving stakeholders in water resources planning that had its roots in the Viet Cong.

Much credit is due to Dr. Eugene Z. Stakhiv, formerly Chief of IWR's Policy and Special Studies Division, for emphasizing and incorporating the first element. Stakhiv, a forceful personality and vocal advocate of a structured approach to water resources planning, recognized that long history of water resources planning was thoroughly tested by myriad researchers and practitioners and needed to be included in the Drought Study. Consequently, the resulting guidance and approach is derived from this history and reflects the lessons learned over decades of experience in water resources planning.

Dr. Robert Waldman of IWR developed a "state of the practice" approach towards stakeholder involvement, drawing on his own experience as a former community organizer in Baltimore and his brother's experience in psychological operations at Da Nang, who told him about the way the Viet Cong organized. This approach became known as the "circles of influence" method.

The study manager of the Drought Study, William Werick, developed the "Drought Preparedness Method" after the first year of the study. This method was based on Stakhiv's federal planning approach and Waldman's stakeholder involvement methods. While these are two key elements of what would eventually become Shared Vision Planning (SVP), there was still a missing, and critical, third element. This third element, the interactive computer model, would transform Werick's "Drought Preparedness Method" into something unique in the field of water resources. This missing piece was first introduced at a public meeting for the Drought Study by one of the creators of the collaborative model used so successfully in the Potomac, Dr. Richard Palmer.

The Drought Study budget included $2.5 million to apply Werick's Drought Preparedness Method to case studies. Werick and Palmer met, appropriately enough, at a public meeting for one of the case studies. Werick writes about the meeting:

> In each case study, we held public meetings asking what the problems and opportunities were, and at the Cedar-Green meeting, Rick Palmer showed up… I had done computer programming for the Corps in the late 1970s and had dealt with modelers as a planner in the 1980s and found the models were money sinks that often didn't address problems, a direct result not just of the "secret language" of computer coding, but of the modelers being uncomfortable with people. I did not want to build more models with the $450,000 we gave each of the four big studies. I distinctly remember Rick being in the audience of maybe 2-3 dozen people, raising his hand to say he had something we should consider for this case, and the Seattle district manager leaning over to whisper in my ear that Rick was a "professor looking for money for modeling." But as a facilitator, I had been trained to be open, so I had to let Rick talk, even though I had my answer (NO!) ready. Rick argued that models such as PRISM, which he had designed for the Potomac case study a decade earlier, had the power to allow stakeholders and decision makers to understand and accept new solutions, and further, that there was a new software that allowed you to build

> much better versions of these sorts of models much more easily, and he showed an example done with STELLA [a new modeling platform]. I was immediately impressed and converted – I had never heard of STELLA; this was such a leap I hadn't even imagined it was possible. (I knew about the Potomac solution from reading a paper Dan Sheer had written, but didn't know that Rick had been the modeler who initiated the resolution). I asked Rick to hold a workshop in which he presented this approach to all four case studies, and he did that. (William Werick, e-mail communication, October 3, 2008)

Study participants were impressed by what they saw, and wanted to involve Palmer and his modeling approach. Werick found funds to involve Palmer and his graduate students in each of the four case studies and worked to integrate the collaborative modeling approach into the Drought Preparedness Method. Werick writes that, "during the 3 years of these four Drought Preparedness Studies, we managed to refine other aspects of the approach, like the Circles of Influence approach to public involvement, but the star power of the STELLA models overwhelmed the other elements, and it became the signature piece of the work. When I used to give talks on the DPS [Drought Preparedness Studies] method, I would tell people …about the models last because once they saw them, they'd lose interest in the planning and public involvement methods, which were important, but not as attractive" (William Werick, e-mail communication, October 3, 2008).

Werick writes that not only was Palmer's contribution inestimable, but also that "… without him, there would be no shared vision models, and the systemic planning process we present here, no matter how sound, would be more difficult to use, and thus, less effective. His scholarship, enthusiasm, and inventiveness motivated the rest of the Drought Study team" (U.S. Army Corps of Engineers 1995).

The personality and skillset of the SVP study lead are important. Personal charm and enthusiasm can help, as can natural abilities at engineering coupled with strong communication skills, in both writing and speaking. Training in system engineering is helpful for incorporating the modeling elements. A flair for creative problem solving and liberal arts backgrounds does not hurt. While these characteristics are difficult to find in a single person, they are important characteristics of a successful SVP study lead.

The quality of the planners and modelers involved in the study itself are also critical to the success of a SVP approach. In the four case studies in which SVP was applied in the Drought Study, the Huntington (West Virginia) District of the Corps ran the most successful study. In that case, the study lead produced a new, better solution that had not been identified in a 1986 district study of the same issues. "Richard Punnett, the modeler and hydrologist on that case study, exemplified most of what we looked for—he was technically capable, open to new ideas, and had the trust of the people he worked with. He came up with two new alternatives in the Kanawha River STELLA model, and we used a simple decision making process with stakeholders voting to arrive at a new plan. We estimated the new operating plan would

save about $10 million in lost rafting-related tourism expenditures during the next drought, twice the cost of the entire National Drought Study" (William J. Werick, e-mail communication, October 3, 2008).

The Cedar-Green basin case study of the Drought Study was also very successful. In this case, it reduced the time and tension associated with developing refill strategies for the reservoirs each year. The other case studies were less successful, mainly because some of the people charged with leading the planning and modeling work were less skilled or could not sustain their participation due to budget problems. One of the central conclusions from the Drought Study, in which the same methods and same funding were applied simultaneously in four case studies with very different results, is that the quality of the people determines more than anything else whether a collaborative study will be successful (William J. Werick, e-mail communication, October 3, 2008).

The refinements in collaborative modeling approaches in the Drought Study led to the first documented definition of Shared Vision models: "Shared vision models are computer simulation models of water systems built, reviewed, and tested collaboratively with all stakeholders. The models represent not only the water infrastructure and operation, but the most important effects of that system on society and the environment. Shared vision models take advantage of new, user-friendly, graphical simulation software to bridge the gap between specialized water models and the human decision making processes. Shared vision models helped the Drought Study team members overcome differences in backgrounds, values, and agency traditions" (U.S. Army Corps of Engineers 1995).

The collaborative and interactive modeling approach used in the Potomac was the incubator for further collaborative modeling in water resources. Dan Sheer has since applied the techniques in various water resources studies around the world and calls his work "computer-aided negotiation." Interactive modeling became a main focus of academic work by Dr. Richard Palmer, becoming SVP during the collaboration between Palmer and Werick on the Drought Study. Palmer has continued to apply SVP to academic studies, most recently at the University of Washington although he is now Chair of the Civil Engineering Department at the University of Massachusetts Amherst. Werick and IWR have continued to apply SVP to different basins throughout the country. The role of SVP in the broader field of Computer-Aided Dispute Resolution, or CADRe, is still being resolved.

Summary of Factors Contributing to the Success of the Collaborative Approach

Early obstacles to the collaborative solution included a lack of understanding of an obvious road map for how to proceed through the complex technical questions, a lack of a connection between modeling results and decision makers, a lack of trust and understanding by the stakeholders of the model itself, an inability of decision makers to see their concerns reflected in model runs, and a lack of trust between stakeholders.

Several factors contributed to the solution to the problem. First, the Metropolitan Washington Area Water Supply Study set the stage for a collaborative solution because it allowed for:

- Superior planning and public involvement method at the begin of the study
- Well-crafted and non-prescriptive planning objectives
- Adaptability, as study participants could influence and change the study alternatives through the public involvement process

Secondly, the tools developed in response to early problems were conducive to developing a solution. The transparent and user friendly simulation model allowed the user groups to:

- Explore the model allowing for increased understanding of what the model represented
- Change the model to better represent user interests and the physical system, thereby building trust in the model and in the modelers
- Incorporate non-quantitative factors (such as actual decision making) into the simulation process allowing for understanding of other points of view and negotiating positions
- Understand the motivations behind the decisions of their competitors, thus building trust

Thirdly, other factors contributed and were equally important. These include:

- The dynamic leadership and stature of the decision makers involved and of those convening critical meetings
- Modelers with strong people and technical skills, using the latest available technology
- Motivated users with native knowledge of the water supply system
- A desire on the part of all the participants to find a solution

Lastly, the success of the plan is ensured through far-sighted agreements which provision an agency, CO-OP, with the responsibility of keeping the regional agreements fresh through a series of annual drought exercise and quarterly meetings of the water suppliers.

Chapter 5

Reflections of Computer-Aided Dispute Resolution (CADRe) on the Roanoke

by Brian J. McCrodden

Introduction

This is a case study in which a model was used to help settle a hydropower re-operation decision in the context of a federal proceeding antecedent to the issuance of a new operating license. Key participants in the process were asked a series of questions focused on the use of the model in the process. The chapter is organized by first describing the setting and the process. Next, the answers to the questions asked of participants are reported followed by a set of reflections by the author.

The Setting

In 1992 Dominion Generation (then Virginia Electric Power Company) embarked on what would become a 12-year effort to obtain a new operating license for its Roanoke Rapids and Gaston hydroelectric plants on the Roanoke River. As shown in Figure 2, the plants sit astride the Virginia-North Carolina border just downstream of John H. Kerr Reservoir, a multipurpose[1] federal project owned and operated by the U.S. Army Corps of Engineers.

Operating licenses for hydroelectric projects are issued by the Federal Energy Regulatory Commission (FERC). Until fairly recently, most licenses were issued for terms of 50 years. To issue a new license, FERC must determine that operation of a project is in the "public interest." Thus, the "relicensing" process is a thorough reevaluation of a project's impact, both positive and negative, on both the human and natural environments. Because of the rapid rate of dam construction in the middle of the last century, dozens of projects have come up for relicensing in the past 15 years. In the vast majority of cases, the modified operating conditions of the new license have adversely affected the profitability of dams for their owners. Generally, operators were required to scale back or modify hydropower generation and/or schedules to provide additional benefits for other purposes, most commonly for recreation and for preservation or enhancement of the aquatic environment via improved fish passage and/or the partial restoration of the pre-dam hydrology and geomorphology of the river. Recreation usually occurs both in the lake and downstream. Likewise, there are aquatic environments that are valued both in the lake and downstream. Thus, it is not uncommon for the upstream and downstream interests to be in conflict. If there are significant development or commercial interests involved, either upstream or downstream, the conflicts over the re-distribution of social and

1. The authorized purposes of John H. Kerr Reservoir are flood control, hydropower, recreation, water supply, fish and wildlife, and low flow augmentation.

economic benefits associated with altered operations can be much higher. Thus, the relicensing process is a major exercise in balancing multiple, often competing, interests conducted under the rules associated with the National Environmental Policy Act and other environmental laws and regulations. The traditional re-licensing process is widely known to be time-consuming and expensive, and most operators begin the process some ten years before the expiration of the old license.

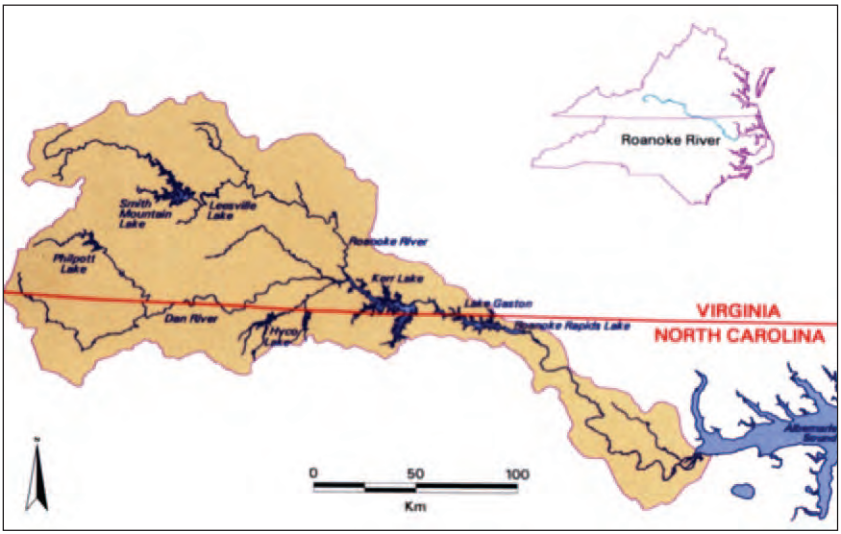


Figure 2: Roanoke Basin map

The traditional relicensing process involves numerous economic and scientific studies conducted and paid for by the applicant, from which FERC prepares the environmental documentation upon which to base a public-interest decision. In 1997, FERC issued rules allowing what became known as the Alternative Licensing Process, the objective of which was to put FERC in a position of being able to endorse the agreements reached through negotiations among all the parties affected by the re-operation decision (Stephenson 2000). The process was structured so that if the parties could reach agreement on the terms of the re-operation, that agreement would be recorded in the Environmental Impact Statement (EIS) and would, therefore, be less likely to be challenged administratively or legally. Dominion chose to use this new process. This chapter reports on that process, the role of the collaborative model used in that process, and the settlement that was reached.

Representatives of all of the interests that are typically involved in a relicensing were involved here: the state and federal fishery and wildlife agencies, lakeshore property owners' associations, local economic development interests, and non-governmental conservation interests, in this case represented principally by The

Nature Conservancy. The upstream/downstream tension noted above also existed as manifest in the deeply held believe on the part of lakeshore property owners that any change in the operation of the project to benefit downstream interests could only result in less desirable lake levels.

Two other factors made the potential for disagreement and conflict even more intense. First, the three lakes (Kerr, Gaston, and Roanoke Rapids) are "head-to-toe," and, to some degree, must be operated as a system. In addition to generating hydropower, the much larger Kerr Reservoir is a flood control project. This means that the Corps, which is not subject to FERC jurisdiction, to a very large degree controls the river. Dominion simply passes through whatever water the Corps releases, subject to some re-regulation as it tries to generate in the hours that are most valuable to its system. This meant that the downstream interests had to tease apart the effects of the Corps' operation, which could not be addressed in the relicensing process[2], from those of Dominion, which could. Resolving this issue consumed a major part of the first few years of the process. (The eventual resolution was to undertake a Section 216 Study[3] to address the Corps' contribution to impacts downstream.)

The second unusual factor was that one of the areas of ecological significance was the floodplain 75 to 100 miles below the dam, where there was a desire to enhance the viability of a bottomland hardwood community by restoring, to some extent, portions of the natural hydrograph. Typically, the impacts of hydropower operations that are addressed in re-licensing are restricted to the main channel in the reach immediately below the dam. In this case, however, the conservation community was able to demonstrate that there were impacts that far downstream and, to the extent that Dominion (as separate from the Corps' operation of Kerr) was responsible for the impacts, it was a legitimate matter for negotiation.

The Modeling Process

HydroLogics was retained by The Nature Conservancy (TNC) in 1992 to develop a mass balance simulation model of the basin with which TNC could investigate operational alternatives available to Dominion and to the Corps. The model became known as the Roanoke River Reservoir Operations Model, or RRBROM. The North Carolina Department of Environment and Natural Resources (DENR) provided additional funding for the effort in 1994. In the late 1990s, before the negotiations were concluded, the model was converted to HydroLogics' then-new OASIS modeling platform. It was only several years later after the utility and

2. Because the Corps' and FERC's responsibilities and jurisdiction arise from different federal statutes, the Corps cannot make operational changes to its projects without undertaking its own studies and preparing its own environmental documentation. Thus, the Corps did not participate in the negotiations in any formal way.

3. A Section 216 Study is so-named because such studies are authorized under Section 216 of the River and Harbor and Flood Control Act of 1970. The purpose of a Section 216 Study is to juxtapose current needs and the Congressionally-authorized purposes of a project and to recommend to Congress whether any modification to the list of authorized purposes would be in the public interest.

accuracy of the model had been demonstrated, that Dominion agreed to participate in funding additional model development efforts.

For years, HydroLogics (then Water Resources Management, Inc.) had been promoting a dispute resolution process referred to as Computer-Aided Negotiation, or CAN (Sheer, Baeck, and Wright 1989). In many ways it was a predecessor of CADRe. The CAN process consisted of five major elements:

- Development of Performance Measures
- Agreement on modeling data and methods
- Joint development of the models in an open and transparent process
- Agreement on the initial alternatives to be modeled
- Mediator-assisted evaluation of alternatives and development of additional alternatives

Performance Measures are metrics developed for each stakeholder that reflect whether a particular alternative is better or worse *from the perspective of that stakeholder*. Performance Measures take many forms, but the most common are time series of elevations and flows at various points in the system, quantities of total energy generated and revenue produced, and counts of attributes such as the number of days available for different types of recreation, the days of flow below some threshold, the number of successful breeding seasons in the record for different species of interest, and the number of successive poor breeding seasons for the same species.

In the CAN process, joint development of the models requires that participants convene periodically to review: 1) the long-term hydrologic record, which often must be assembled from numerous, discontinuous, USGS gages using statistical techniques or back-calculated from reservoir operating data; 2) the algorithms used to represent various functions, e.g., hydropower generation and flood control operations; and 3) the results of verification runs in which simulated results are compared with historical data. Getting agreement on these aspects of the model before any alternatives are run lessens the likelihood that they will be challenged later when model results do not square with a participant's wishes or intuition. Joint development of the models not only ensures that it has the trust of all users but also helps build relationships that are vital to successful negotiations. In addition to being developed in the open, the completed models are offered to all stakeholders and others working on their behalf. The combination of these activities imbues both the model and the process with credibility and promotes trust among the stakeholders.

In this relicensing, most, but not all, of the CAN process elements were followed. Performance measures were developed, although not in advance of developing the model. And while the offer was extended to all parties to participate in the

development of the model, initially only a few participated. Eventually, however, following the presentation of model results by TNC and DENR, it became apparent that the model was providing information that was available through no other source and was, therefore, helpful to the negotiations. At that point, other parties[4] conducted extensive reviews of the model and underlying data and came to accept its validity and utility. In the end, the desired objectives of openness and credibility were achieved.

The model was offered to all stakeholders on condition that they attend a one-day training session on its use. Approximately 20 individuals initially expressed interest, and a significant number were trained. In the end, however, only five parties actually chose to receive a no-cost license to use the model and even fewer actually ran it.

The reason the CAN process provides for mediator-assisted sessions is to allow for real-time, interactive, sessions with all stakeholders. Because the model was designed so that an alternative could be run and results presented within a matter of a few minutes, the expectation was that many alternatives could be evaluated in one session thereby accelerating the pace of the negotiations. However, the stakeholders felt more comfortable seeing the results privately prior to engaging other stakeholders. The result was that HydroLogics became the modeler/advisor for all parties. In this role, HydroLogics ran alternatives, interpreted results, and made suggestions to individual parties about operational changes that would benefit their interest. It served as the honest broker who advised individual stakeholders and presented trade-offs but did not participate in the actual negotiations. Although at one point early in the process a facilitator was retained, his services did not prove to be helpful in large part because he did not understand the technical and scientific issues involved in the negotiations. Consequently, the substantive negotiations were conducted without any formal facilitation. This points to the need for technically savvy facilitators who can advise participants in addition to promoting communications.

The Settlement

After ten years of negotiation, a settlement was submitted to the Federal Energy Regulatory Commission on July 15, 2003. The final license congruent with the terms of the settlement was issued in March 2005. In addition to standard requirements for spawning releases and minimum release schedules, it includes provisions to adaptively manage flows in the bypassed reach; fish passage for migratory species; water quality; drought operations; and hydrologic alteration, specifically addressing both long- and short-term impacts both in and outside the river channel. To support hydrological restoration, five-year monitoring programs for tree seedlings, crayfish, woody debris, resident fish, bank erosion, bank vegetation, and overall vegetation

4. The City of Virginia Beach, VA, has a water supply withdrawal on Lake Gaston. This withdrawal was permitted in the 1980s after a very contentious interstate dispute. To protect its interests, Virginia Beach was an active participant in the re-licensing process and paid to have an outside consultant conduct a comprehensive review of the model.

change were mandated. The stakeholders meet with Dominion on a quarterly basis to manage these studies and to implement the adaptive management provisions of the license.

Perspectives on the Process

Four of the key participants who shaped the final settlement were asked to independently respond to a set of questions. They represented Dominion, The U.S. Fish and Wildlife Service (FWS), The N.C. Wildlife Resources Commission (WRC), and The Nature Conservancy (TNC). The participants and their titles at the time of relicensing are:

- Jim Thornton, Technical Consultant, Dominion Generation (formerly Relicensing Manager)
- Jean Richter, Wildlife Biologist, Roanoke River National Wildlife Refuge, U.S. Fish and Wildlife Service
- James W. (Pete) Kornegay, Coastal Region Supervisor, Division of Inland Fisheries, N.C. Wildlife Resources Commission (formerly Anadromous Fisheries Coordinator)
- Sam Pearsall, SE Manager, Land, Water and Wildlife, Environmental Defense Fund, (formerly Director of Science, The Nature Conservancy, N.C. Chapter)

The questions were phrased to elicit responses from different perspectives but also to see if there had been any attempt to use the model and its results to gain a negotiating advantage. As to the first purpose, the responses were very consistent and positive even though the participants represented very different interests. As to the latter, it does not appear that there was any attempt to use the model to gain any advantage. Rather, it seems that the model was viewed by all as a means to bring unbiased information to the negotiating table where it could be discussed on its merits.

Dominion's interests are the easiest to describe—namely to retain as much flexibility as possible with which to generate power during the hours when it is of most value in their system. WRC was mainly interested in the migratory fishery in the river below the most downstream dam at Roanoke Rapids. TNC was concerned about the degradation of the floodplain ecosystem approximately 100 miles downstream from Roanoke Rapids. FWS had two main interests, the 21,000-acre Roanoke River National Wildlife Refuge, and fish passage through or around the system of three dams. Because the Refuge is in the floodplain that was the principal interest of TNC, the USFWS focused largely on fisheries issues.

Because the responses were consistent, they are summarized here rather than including each author's complete response, but the summaries are supplemented with original text where the comments are particularly enlightening.

1. Did you consider the use of a model such as RRBROM (OASIS) before the relicensing process began?

In general, at least in the mid-1990s, the participants to this process were not familiar with models such as OASIS and the information that could be obtained from them. Not surprisingly, Dominion had a bit of a head start in that they (and their consultant) had used mathematical models in other contexts and other FERC proceedings under the traditional licensing process. For example, Jim Thornton noted:

> The licensing consultant advising Dominion supported the use of modeling to best understand the river basin operation. His experience indicated to Dominion that when empirical data is not available, modeling was a suitable means to answer difficult questions. Dominion also uses models for many of its environmental issues including fossil fuel air emissions and thermal power station cooling water discharges.

For the others, the concept was somewhat foreign. Pete Kornegay observed, "My understanding of the utility of such models evolved as the relicensing process proceeded. I had had no training in the use of such models before my involvement in the relicensing process."

Jean Richter came to appreciate the contribution of the model as the means to integrate the many disparate studies of relationships and different aspects of the situation:

> The outcome of the studies alone could not bring resolution to the issues; instead, they only led to suggestions of what would need to be changed in order to minimize impacts. The challenge put forth to Dominion Power was coming up with a settlement agreement that would adequately address all the pertinent issues. One powerful tool that had the ability to consider multiple issues and helped generate flow release alternatives was the RRBROM. The RRBROM was not a tool that the FWS considered using going into the relicensing process. The infrastructure within the FWS is designed to provide technical expertise on fish and wildlife and their habitats and does not have the capacity to develop such a tool.

But for TNC and the NC Department of Environment and Natural Resources, who were somewhat familiar with such models by virtue of earlier interaction with HydroLogics, this type of modeling would likely not have been part of the process. While it may be somewhat less true today than in the 1990s, it appears that further education and exposure to the use of these models as negotiating tools would be beneficial.

2. Did the availability of the model (a) enhance your understanding of the system or (b) help advance your agenda?

To a person, the participants answered that their understanding of system operations and operational impacts was enhanced through the use of RRBROM. It is certainly true that such models are of value when, as here, the system is complex and consists of multiple reservoirs, but even in simple systems, educating the participants about the full extent of the operating envelope is often required. As important as what the models show is what they don't show. That is, by demonstrating what is operationally possible, models tend to disprove many strongly held, but untested, convictions of what is possible and what is not, thereby sharpening the focus of and speeding up the time it takes to reach agreement. The following reflections on the process were offered:

> In fact, the model and data served TNC's purposes extremely well. Almost immediately, TNC was able to narrow its concerns about altered hydrology to the fact that the dams cause extended warm-season inundation in the bottomland hardwood forest systems (including levees and banks). Robust hypotheses were drafted to state the relationship between this phenomenon and organism mortality (especially for tree seedlings), mass wasting of the banks, and hypoxic events following periods of extended inundation. These hypotheses became the bases for strong adaptive management sections in the final settlement and the resulting license. Other potential relations between altered hydrology and ecological stresses could be tabled as either non-existent or low priority. TNC's willingness to narrow the range of its concerns and then to commit very strongly to the remaining issues supportable by strong hypotheses definitely strengthened TNC's negotiating position. (Sam Pearsall)

> The output enabled FWS biologists to see how constrained they would be in meeting their objectives and also identified where there was room for negotiation without significant compromise to the resources they were entrusted to protect. The RRBROM allowed FWS biologists to ask "what if" questions and get realistic outcomes instead of wondering how a given release scenario would address their concerns. Most importantly, the model helped all stakeholders realize the complexity of the system by identifying and quantifying those constraints within the system that were outside of Dominion Power's influence. (Jean Richter)

> Definitely—the use of RRBROM began to break down the hypothesis of Dominion that their hydropower peaking effects were irrelevant in downstream areas… The RRBROM and the digital elevation model gave graphic representation that hydropower peaking under a given set of circumstances could cause and exacerbate aseasonal swamp flooding. (Pete Kornegay)

> As someone walking in stone cold to the collaborative relicensing process, I was open to most any tool that would quickly bring me up to speed in river system knowledge and contentious issues. Since downstream flows, flooding and lake level control were all key issues in the negotiations and resultant settlement agreement, the RRBROM was a great learning tool for me personally. Several

> key river system components were critical for me that the model illustrated. Among them were (1) the ability to compare a non-regulated system with a regulated one, particularly related to downstream flooding impacts; (2) the ability to understand the reservoir impacts for providing various fish / spawning flow requirements and (3) illustration of required minimum flows impact on reservoir levels during droughts. (Jim Thornton)

3. Did you use RRBROM or have HydroLogics use it on your behalf? [In the context of this question, the word "use" was intended to mean running the model and interpreting results. In other chapters "using the model" has been used to mean using model results in negotiations. It seems clear that the participants interpreted the question as intended.]

As noted above, as a part of HydroLogics' CAN process, models such as RRBROM are offered to participants in a process such as the Dominion relicensing. In this case, even though a number of parties were trained and five actually received the model, only TNC actually ran it. TNC used the model to inform the development of its principal hypothesis, namely that growing season floods were the cause of significant ecological damage in the backswamps. Following that, TNC asked HydroLogics to confirm the conclusions of its modeling efforts, which were then presented to stakeholder group. HydroLogics ran the model on behalf of Dominion and on behalf of the N.C. Department of Environment and Natural Resources (DENR). Dominion sought to evaluate the revenue impacts of potential operating alternatives suggested by stakeholders. DENR used the model's simulated flows from the Roanoke Rapids dam in conjunction with an aquatic habitat model (PHABSIM) to assess the impacts of alternative operations on habitat downstream of the dam.

4. Did the model help other parties more than it helped you?

> From Dominion's perspective, the model was advantage neutral; that is, it provided no information that gave any party a particular advantage. What the model provided was information that parties then used to help make their point or find out that their hypothesis was not supported by fact. (Jim Thornton)

This and Questions 7 and 8 were intended to address the question of whether the model was used to gain a negotiating advantage. Perhaps this question should have been phrased differently. Mr. Thornton's response does not address whether the simple availability of the model, as opposed to its objectivity, afforded opportunities to other parties that they might not have had otherwise. One could argue that in a full, open, and good faith negotiating process it would have been disingenuous for Dominion not to make available all relevant information whether it came from a model or not. By virtue of its operating experience, Dominion certainly had a better understanding of the system dynamics than the other participants, at least at the beginning of the process. In that sense, the model certainly enlightened others more than Dominion, so it is to Dominion's great credit that it was willing to embrace the model and lay out the results for all to see. This has certainly not always been

the case in relicensing proceedings where it has often been difficult for participants other than the applicant to get information relevant to their particular interest in a form that was useful to them. Whether intentional or not, the disparity in relevant data often puts the applicant in an advantageous negotiating position.

5. Did the model help drive (inform?) the negotiations?

> Tools like the RRBROM are normally not available for relicensing negotiations, and having it available proved to be pivotal in moving the almost-stalled negotiations forward. (Jean Richter)

> Yes—the model results along with the downstream flood model strongly indicated that the current operating procedures of Dominion might be causing adverse impacts downstream and these results served as the impetus for designing post-license studies to investigate these procedures and their impacts. (Pete Kornegay)

> The model was a good source of information. It provided many visual aids for grasping water balance concepts. However, it did not drive the negotiations in that it did not force the negotiations to go any particular direction. (Jim Thornton)

6. Was the lack of interactive negotiating sessions with the model a help or a hindrance to the process?

HydroLogics encouraged interactive negotiating sessions, which never occurred, at least not as envisioned in the stylized CAN process. This was possibly the result of being in a tense negotiation in which parties can be reluctant to disclose their views and interests when they are not certain that the negotiation process will be the forum in which the final outcome is determined. Real-time sessions require a level of trust among the parties and a view that there are few acceptable alternatives to seeking agreement through a negotiation process. Another explanation was the time it took for the model to solve and for participants to understand the implications. Pete Kornegay opined that:

> The negotiating sessions were often driven by many things other than fact-finding. I suppose that real-time sessions running different reservoir operation scenarios may have been helpful but in reality, the stakeholders probably needed time to digest the results of various model runs."

In the same vein, Sam Pearsall noted, "…many parties (including TNC) preferred to have time to comprehend the results of any given model run before using them as a basis for negotiations."

Jim Thornton noted that at the time of the negotiations, the run-time for RRBROM was long enough such that delaying a meeting to wait for results would not have been productive. Subsequently, as the model was refined and greater computational power became available, run times improved significantly. Thus, in a different context, by the mid-2000s, RRBROM was used in the relicensing of Appalachian

Power Company's Smith Mountain/Leesville pump-storage project in the upper part of the Roanoke River basin. In that process the model was used interactively to develop and refine alternatives. (Since that relicensing did not use the Alternative Licensing Protocol, a formal negotiation and agreement was not an expected outcome.) As a stakeholder, in this case representing a downstream interest, Mr. Thornton was involved in that relicensing as well and offered the following comment about interactive negotiations:

> Later, during the Smith Mountain – Leesville relicensing ….the model worked well to get information relatively quickly to answer specific questions or visualize minor changes in flow release patterns."

7. In terms of the settlement and from the perspective of your interests, did you get more than expected to get (or, conversely, did you lose less than you expected to lose)?

> The availability of the RRBROM in the FERC relicensing was a unique opportunity for all involved. The model revealed avenues where conflicting stakeholders could negotiate and come to some sort of resolution. In the end, there was probably no stakeholder that walked away with everything they wanted as there was compromise on all sides. Even though the final settlement agreement did not meet all of the FWS's objectives, the agency felt like it broke even. (Jean Richter)

> I probably got more than expected. My nature is to not trust modeling, particularly in a complex system. However, I can say I was satisfied and recommended to Dominion's Market Operations Department to utilize the model to improve water scheduling in the Kerr–Gaston–Roanoke Rapids reservoir system. (Jim Thornton)

8. For Dominion, since TNC and NC came to the table with the model, did you feel that you were forced into using it?

> Although Dominion was not forced into using specific tools during relicensing, it was often forced to make choices between available tools. Dominion perhaps was forced into evaluating RRBROM, but not forced into using it. I do not think TNC or NCDENR gained any sort of upper hand in negotiations by using the model. (Jim Thornton)

Conclusions

Although the Roanoke experience occurred mainly in the 1990s, the following conclusions still seem relevant in today's environment.

1. Many stakeholders to complex disputes are not aware of how mathematical models can be used to explain the interaction of variables in a system. Not having that information puts these stakeholders at a disadvantage compared to others who have access to such tools.

2. Models such as the RRBROM can be very useful in narrowing the focus of negotiations to alternatives that can actually be implemented and which will have a high likelihood of achieving the desired benefit.

Where, as here, there are multiple hydropower owners/operators in the basin, such models are virtually indispensable in order to ascertain what impacts are associated with what project. In this case there likely would not have been a settlement had the participants not been able to assure themselves that some of the impacts they saw were the result of the Corps' operation of Kerr Reservoir rather than Dominion's re-regulation of the Kerr releases. Having the possibility of addressing these impacts via a Section 216 study was also helpful. In cases where there are multiple private operators in a basin, getting the data necessary to build a model can be very difficult. Whereas the Corps' data are publicly available, absent compulsion by a federal or state agency with regulatory authority, private data are not. Building basin-scale rather than localized models can be helpful because the process of their development tends to promote a "we're in this together" attitude, which, in turn, fosters cooperation and openness among stakeholders.

3. The model need not be run in interactive sessions to inform negotiations. If sufficient trust can be developed among the parties, someone outside the process can run the model on a confidential basis for different participants. However, this requires some sort of review process to confirm for the group that neither the model nor its underlying data had been altered inappropriately. In this case, because HydroLogics ran the model for and had the confidence of all participants, there was no need for a separate review process.

Chapter 6

The Lake Ontario-St. Lawrence River Study

by William Werick

Introduction

The Lake Ontario-St. Lawrence River case study was the most technically ambitious application of Shared Vision Planning (SVP)[1] heretofore attempted. It was grandly sized—a $20 million, five-year bi-national effort to examine alternative ways of releasing flows through an existing dam. The decision process was more deliberately designed and the decisions were more transparent than any SVP study undertaken or known of by its highly experienced modeler-mediator. The Lake Ontario Shared Vision Model (SVM) was the most sophisticated of its kind ever built, using a system of models dynamically interconnected that evaluated alternative regulation plans using over five dozen performance metrics. As sophisticated as the SVM was, it was used routinely by stakeholders and debates about study outcomes typically used SVM results at face value (although with real differences about how to value one outcome as opposed to another). The impact of the natural variability of water supplies under the current climate and the effect of climate change were both quantitatively modeled, using climate change and stochastically-generated water supplies to evaluate regulation plans. The stochastic results were used to discount the value of future erosion and shore protection damage, recognizing that these damages would occur with all regulation plans but that part of the benefit in some plans would be the delaying of the impact, a benefit measured by the reduced present worth of the damage.

Despite this muscular effort, it is not clear how Lake Ontario and the St. Lawrence River will be regulated in the future. A working group was recommended in 2008 and established in 2009 to explore a regulation plan acceptable to the United States, Canada, Ontario, New York, and Quebec. Such a working group would likely use the SVM to evaluate alternatives.

Historical Background

The International Joint Commission (IJC) is a joint U.S.-Canadian organization created by the Boundary Waters Treaty of 1909. The IJC issued an Order of Approval in 1952 to build the St. Lawrence River Hydropower Project, including a dam across the St. Lawrence River between Cornwall, Ontario, and Massena, New York, that allows the regulation of Lake Ontario water surface elevations and of flows and water surface elevations in the St. Lawrence River. The IJC has used a written set of

1 Shared Vision Planning (SVP) integrates planning principles with systems modeling and collaboration to provide a practical forum for making water resources management decisions. See Chapter 4 for an early case study exploring the origins of SVP.

Figure 3: Lake Ontario and St. Lawrence River study area

regulation rules called "Plan 1958-D" since 1963 to determine how much water to let out of Lake Ontario each week, but about half of those weekly releases now are permissible "deviations" from the plan (deliberate small changes in outflows from those determined by the plan). These deviations have been necessary for many reasons, most importantly because the written plan was designed around 1860-1954 water supplies and supplies have been both drier and wetter than that since 1962.

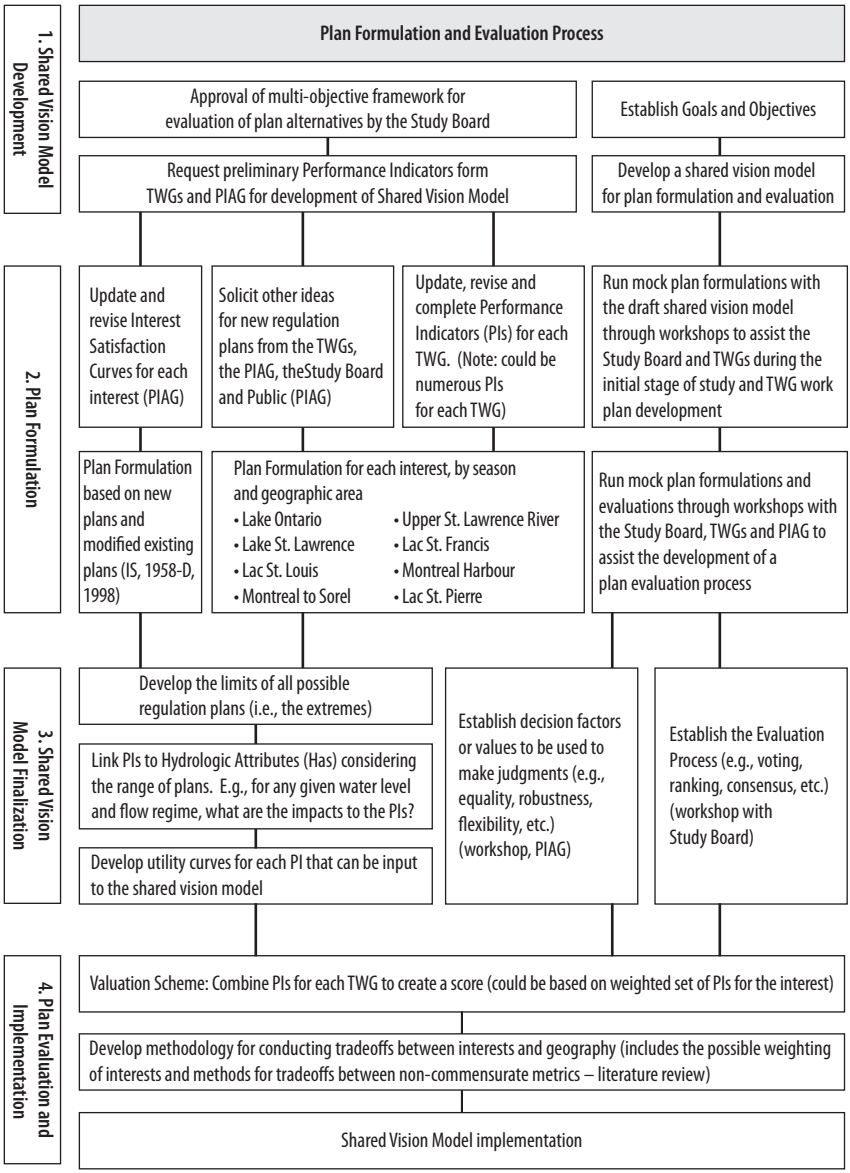
A previous multi-year IJC study, the Levels Reference Study (Levels Reference Study Board 1993), recommended that the "Orders of Approval for the regulation of Lake Ontario be revised to better reflect the current needs of the users and interests of the system." That study did not address environmental impacts, a use of water not identified or explicitly protected in the treaty, nor did it precipitate a consensus on how the current needs could be addressed while protecting traditional uses. The Levels Reference Study helped launch development of a new regulation plan called "Plan 1998" that was not implemented because the IJC did not have sufficient information on the environmental impacts associated with the proposed plan and because the plan would not constitute sufficient improvement over the existing situation. In April 1999, the IJC informed the U.S. and Canadian governments that it was becoming increasingly urgent to review the regulation of Lake Ontario levels and outflows. A plan of study was accepted in 1999 and the five-year, $20 million Lake Ontario-St. Lawrence River (LOSL) study began in 2000. The IJC appointed a ten-member Study Board to conduct the study and recommend options for changed operations.

Excerpts from the IJC directive (2007) for the study made it clear that IJC commissioners wanted broad public involvement and openness in a study that considered multiple objectives, including some that had not been addressed in previous regulation rules:

- "In carrying out this mandate, the Study Board is encouraged to integrate as many relevant considerations and perspectives into its work as possible, including those that have not been incorporated to date in assessments of Lake Ontario-St Lawrence River regulation, to assure that all significant issues are adequately addressed."
- "The Study Board and the study teams, committees, work groups and other advisory bodies shall endeavour to conduct all their work by consensus."
- "The Commission emphasizes the importance of public outreach, consultation, and participation. The Commission expects the Study Board to involve the public in its work to the fullest extent possible."
- "To facilitate public outreach and consultation, the Study Board shall make information related to the study as widely available as practicable, including white papers, data, reports of the Study Board or any of its subgroups, and other materials, as appropriate. The Study Board shall develop and maintain a web-site as a means for disseminating information related to implementation of the Plan of Study, and will use the web-site to encourage public discussion of such information. To the extent practicable, the Study Board shall make available on the web-site all documents that are available for public information under the Commission's Rules of Procedure, including public comment and other information made available by decision pursuant to the Rules of Procedure."

The IJC had specified what it wanted but the Study Board had the responsibility for finding an approach that would produce those characteristics. The original plan of study did not define how plans would be formulated, evaluated and ranked, how the public would participate in plan formulation or evaluation, or how researchers would design their work to fit into an overall evaluation scheme. Several months into the first year of the study, Dr. Eugene Stakhiv, the U.S. study manager, asked Bill Werick to explain to the Board how SVP could be used on this study. The presentation included a Microsoft Excel model based on an existing dynamic STELLA®[2] model developed for the five Great Lakes by Phil Chow and Hal Cardwell of the U.S. Army Corps of Engineers' Institute for Water Resources. Thereafter, the Study Board agreed that all its subsequent planning work would be done using SVP. The Study Board formed a Plan Formulation and Evaluation Group (PFEG) soon after, and PFEG began to restructure the study with the aim of linking research, public input, and decision making. PFEG helped shape new research and, in some cases, had to realign research that had already begun.

2 STELLA is a registered trademark of isee systems. The name is an acronym (System Thinking and Experiment Learning Laboratory). STELLA software allows users to build simulation models using four basic iconic tools in such a way that the structure of the system is easy to understand and the model is easy to use.



PIAG = Public Interest Advisory Group; PI = Performance Indicator; TWG = Technical Work Group
From "Year 1 Report to the International Joint Commission," submitted to the IJC on May 31, 2002.

Figure 4: Planning process adopted by the study board the first year of the LOSL Study

Figure 4 shows a diagram of the planning process that was approved by the Study Board. The "shared vision" dynamically bridged geographic regions, stakeholder groups and types of expertise, and its informed consent decision process connected the end of the study to its beginning.

The Mock Model—Integration of Preliminary and Final Products

A mock SVM was built even before the Study Board approved the SVP process so that all participants could collectively envision how research and decision making would come together in the end, and use that vision to improve the definition of planning objectives, metrics and decision criteria as well as the design of the research program. It was called a mock model because there was no pretense that the model included reliable functions or study results – its inputs and outputs were meant as an easy-to-understand inventory checklist, not a preliminary evaluation. The mock model included assumptions about decision criteria that provoked the multiple decision makers to begin the definition of the criteria that they would use and the information they would need. The mock model used performance indicators such as hydropower energy or recreational boating benefits that were explicitly, mathematically linked to water levels, a presumption that study managers and researchers compared to planned research, asking, "Will this research produce these water-to-outcome functions, or should it?" Stakeholders looked at the mock model to see if the issues they were concerned about were dealt with and if so, whether the modelers' version of a good outcome was what the stakeholders wanted.

How the Mock Model Reshaped Research, Stakeholder Expectations, and Decision-Making Framework

Figure 5 shows how the study research (contained within the dashed border) was programmed into SVM elements. Research was conducted by seven technical working groups (TWGs), managing water information (the Hydrology and Hydraulics TWG) and six impact areas (coastal, navigation, hydropower, municipal and industrial water, recreational boating, and the environment). A STELLA® model simulated water levels and produced most of the economic evaluation. The Control Panel was an Excel spreadsheet used to select which water supplies and alternatives the STELLA® model would run, and the Data Warehouse was another Excel model that included all the water supply and ice and weed retardation data used in the STELLA® model. The Control Panel and Data Warehouse were linked through Dynamic Data Exchange (DDE) to the STELLA® model, so changes in the Excel sheet led to automatic updates in the STELLA® model. The Board Room was a large Excel file structured like a dynamic internet site. Results from the STELLA® model runs were pasted into alternative worksheets in the Board Room, allowing users to see how alternatives compared to one another in a wide variety of dynamic presentations. FEPS (Flood Erosion and Protection System), SRM (Shoreline Response Model) and IERM (Integrated Ecological Response Model) were separate programming codes launched from the Board Room that calculated Lake Ontario coastal

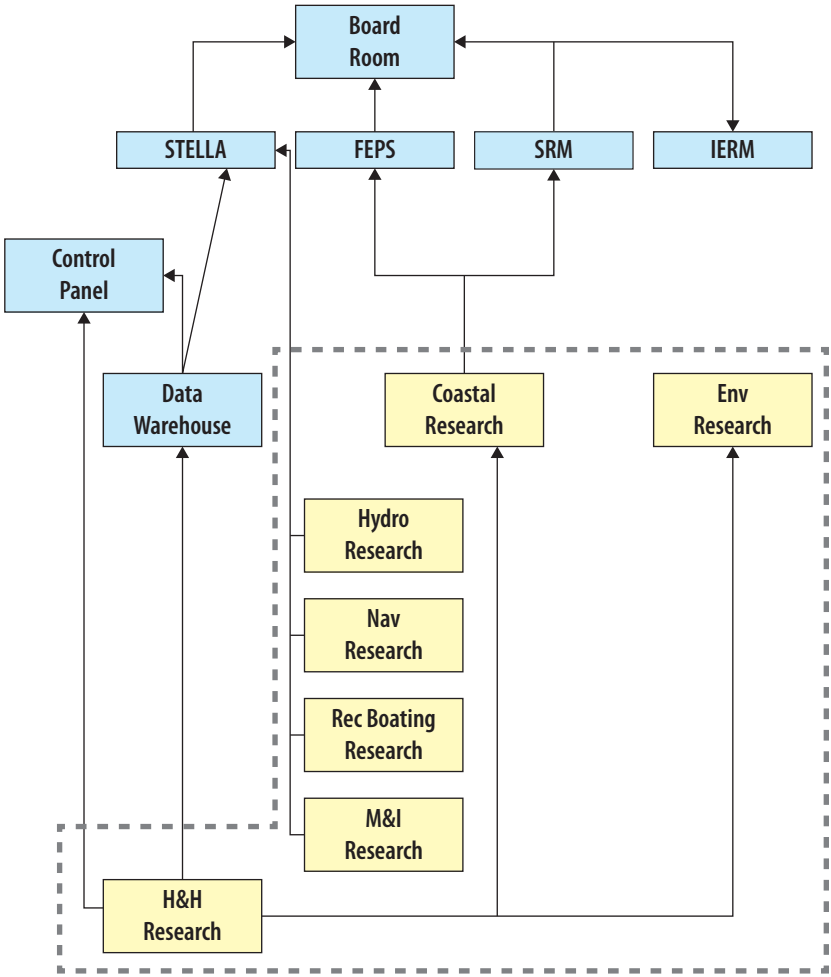


Figure 5: Schematic of LOSL Shared Vision Model and research

impacts, St. Lawrence River coastal impacts, and environmental impacts, respectively. The impacts were automatically returned to the Board Room and became part of the overall comparison.

Connecting Experts and Decision Makers

Because the SVP process was approved nearly a year after the study began, much of the research had already begun. In some cases, the mock model showed that the research underway was appropriate but some research programs had to be substantially redirected. The Hydropower TWG had intended to calculate quarter-monthly energy production as shown in the mock model, but challenged the mock

model's use of dependable capacity—a measure of the minimum amount of power that would be generated over time. The TWG eventually agreed to use the forecasted marginal market value of energy produced as the primary economic metric. However, it also designed non-economic metrics applicable only to Hydro-Quebec, a hydropower organization that operated facilities downstream of the dam being considered, because Hydro-Quebec representatives made it clear that the predictability of energy production at this one part of their system was as important to them as the amount and value of energy. The performance indicators for recreation boating were about what that TWG had imagined, but building the mock model raised issues not debated before about how many segments would have to be used in the river to faithfully capture marina water depths as the slope of the water surface profile changed. The mock model itself did little to influence the research or decision criteria for municipal and industrial water uses, but it began a long process of refining the definition of coastal performance indicators.

The Coastal TWG clearly was interested in flooding, erosion, and shore protection damage, but had not settled on the sequence of functions that would translate high water and cumulative erosion to net benefits or disbenefits for a particular alternative regulation plan. Three coastal issues, the subject of months of debate, are simply noted here.

First, the FEPS model used to calculate flooding, erosion, and shore protection costs was originally a standalone model run by one coastal contractor. That meant that plan formulators could not evaluate coastal impacts of alternative regulation plans unless they could run the model. It also made FEPS less transparent, because most study participants saw only summary FEPS modeling results. A year into the use of the model, study participants discovered that a modeling assumption in FEPS was not economically correct, and that led to a discussion of how the FEPS model, admired for its sophisticated analysis of coastal damages, could be made more user friendly and transparent. The answer was to integrate FEPS into the SVM, with executable code triggered by an Excel macro. The executable FEPS could be tailored to use different assumptions and produce different kinds of output, and that made it much simpler and less costly to evaluate new alternative regulation plans.

Second, once plan formulators could easily run the FEPS model, they asked for geographic sub-area outcomes so that they could better refine their design parameters. This made the FEPS model more transparent and led to the discovery of another error, this one related to the GIS data incorporated in the model. Modeled flooding damages in one sub-reach seemed too large and occurred at moderate water levels, yet there had been no reports of actual flood damage there. Field measurements revealed the region had been filled since the aerial topography had been flown and before a new housing complex had been built.

Third, the widespread use of the FEPS model as opposed to review of summary outputs facilitated a change in the way coastal benefits were calculated. Initially, the

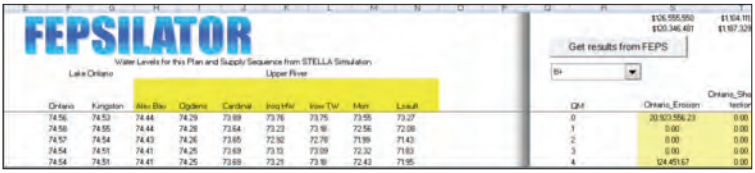


Figure 6: Screen capture from Board Room showing the macro button to launch and retrieve FEPS model results

average or total erosion costs for a 101-year simulation were reported, but debate in and outside the Coastal TWG created a consensus that these impacts had to be discounted; erosion damage happened sooner or later, and the benefit provided by an alternative was in how long it delayed the damage. The discounting approach used is described later in this chapter.

The biggest changes occurred within the Environmental TWG. PFEG worked with the two Environmental TWG chairs to review more than two dozen environmental research scopes of work and help establish mathematical relationships between water levels and a biological result. Dr. Joseph Depinto and Mr. Todd Redder of Limno-Tech, Inc., then developed a dynamic model relating water levels to the potential environmental impacts as identified in the existing body of research. Although environmental researchers initially opposed the Integrated Ecological Response Model (IERM), they eventually embraced it as their own and, in workshop exercises, began to question their intuition when it differed from model results, rather than vice versa.

Stakeholder Participation

The Public Interest Advisory Group (PIAG) contained about 30 members and was the formal body representing stakeholders in the study. Some members came and went, but many stayed on PIAG for the entire duration of the five-year study. The U.S. and Canadian PIAG leads were also Study Board members, with the same decision-making rights as agency staff or experts. In addition, some Study Board members who were not PIAG members were widely perceived as representing geographical interests such as U.S. coastal homeowners or the variety of interests in Montreal. PIAG had a five-year budget of about $3 million, roughly 15% of the overall study costs. PIAG members were reimbursed for travel expenses, but not for their time. IJC and Study Board communications experts supported PIAG with Web sites, newsletters, and presentations. PIAG took a lead role in many of the study presentations to the broader public, using traditional town hall meetings scheduled around the basin, featuring a formal presentation followed by a question-and-answer period.

SVP supplemented the already-intensive public involvement program with "Circles of Influence" workshops. Sociologist Robert Waldman developed this approach for SVP to supplement the typical PowerPoint broadcast of information to all

Table 1: Five Year PIAG Budget in LOSL Plan of Study

Estimated costs (per year)	U.S. ($K)	Cdn ($K)
2 staff at $100,000 each including overhead	100	100
Newsletters (2 per year)	18	18
Public Meetings / Open Houses (at least 8)	50	75
Workshops (2 per year)	25	38
Web site, per year	10	15
Out of pocket costs for IAG members (20 members, 4 meetings, airfare, hotel, etc.)	40	60
Contingency	27	34
Total per year	**270**	**340**
Symposium (last year)	50	75
Total for the Studies (over 5 years)	**1400**	**1775**

(St. Lawrence River – Lake Ontario Plan of Study Team 1999)

stakeholders at arranged meetings. The inner circle is made up mostly of people paid to work on the study; the outer circles include stakeholders and the general public. In between are stakeholders who are respected advocates and educators—the stakeholders other stakeholders trust. Circles of Influence workshops were held with small numbers (typically three to six) of expert stakeholders at a time and place convenient for them, often tied to a meeting of their own citizens groups, to elicit their ideas for new regulation plans, and to work with them to build parts of the SVM they would then use to rank alternatives. Any particular circle might be composed of stakeholders representing one interest (a shipping group, for example) or many interests from one region. In the end, seven sections of SVM evaluated alternative plans using metrics and displays developed with Circles of Influence groups, as well as three sections reflecting geographically grouped interests also stemming from the Circles of Influence workshops.

The graphs shown in Figure 7 were built in workshops with boaters in Brockville, Ontario. One of the concerns they had was with low water levels in the boating season. Initially, engineers published non-exceedance frequency plots of water levels and listed the percentage of time water levels fell below water levels boaters in the Brockport circle of influence identified as preferable for boating in the Upper St. Lawrence River (see Figure 3) and on Lake St. Lawrence. But boaters cared about water levels only during the boating season, and these data presentations did not reveal the seasonality of water levels, so SVM designers built a graph in the SVM that showed all the Lake St. Lawrence water levels generated in a 101-year simulation by quarter-month for whichever regulation plan alternative the model user wanted to see. Brockville stakeholders became familiar with the graph and could tell at a glance that one alternative regulation plan (Plan 2007, Figure 7a) was better for them

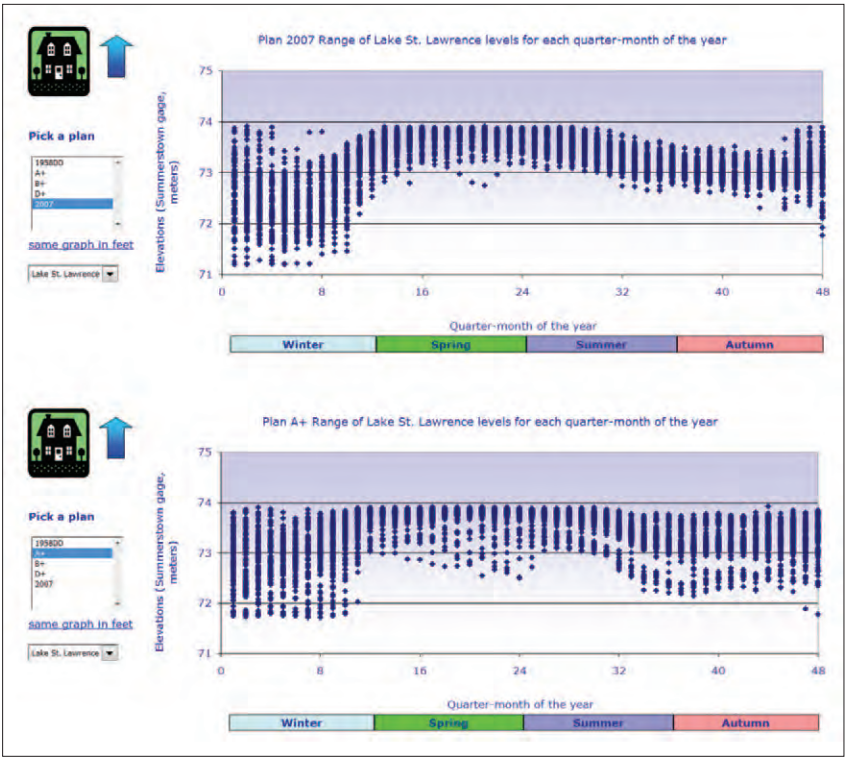


Figure 7 (A&B): Brockville, Ontario, water level graphs under Plan 2007 and Plan A+

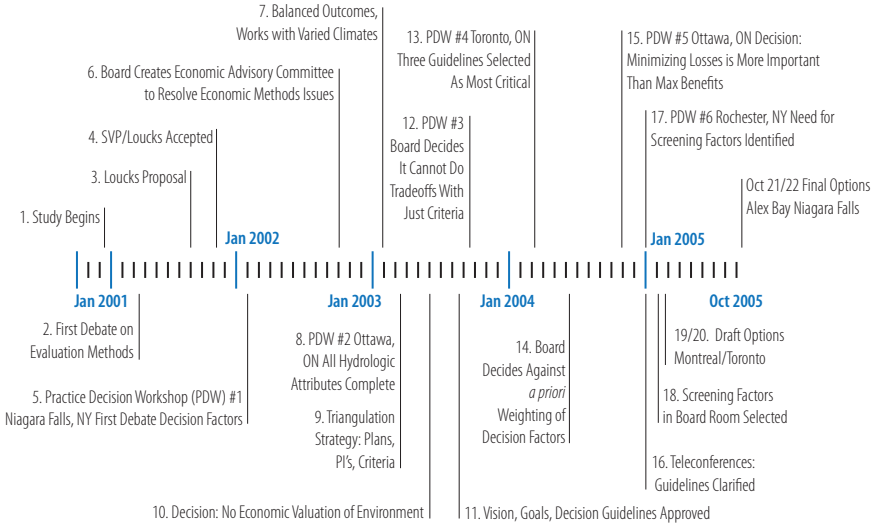
7A (top): Brockville, Ontario stakeholders graph of water level ranges throughout the year, Plan 2007

7B (bottom): Same graph showing Lake St Lawrence levels under Plan A+

than another alternative regulation plan (Plan A+, Figure 7b) because although it produced many low water levels (below 73.0 meters) most were not during the boating season. The seasonality of water levels became a key issue for trading benefits, as higher spring and fall Lake Ontario levels were more natural and better for the environment but bad for shoreline property owners who were most vulnerable to damage in the spring and fall when storms were more likely. The Circle of Influence approach allowed local subject experts to refine the definition of what was important for them, both ensuring that their concerns were addressed and providing additional flexibility for addressing others' concerns.

Connecting Stakeholders and Decision Makers

The PFEG co-chairs asked the Study Board to hold six "practice" decision workshops (see Figure 8) to iteratively refine the criteria the Study Board would use to select the final options. Those workshops were conducted with stakeholders and



The Study Board thought about the final decision almost from the beginning of the study. Late in 2001 Pete Loucks, one of the Study Board members, proposed that the alternative regulation plans would be ranked based on a combination of water metrics and performance indicators such as economic benefits. The Board accepted that approach and refined it over time in iterative decisions.

Figure 8: Decision milestones including six practice decisions in the LOSL Study

often with IJC commissioners (the anticipated final decision makers) present. These "fire drills" helped make sure that the Study Board understood what stakeholders wanted and helped stakeholders understand why the decisions were made the way they were. The iterative nature of the decision-making sessions allowed for increased understanding and refinement over time

Connecting Experts and Stakeholders

Stakeholders were participating in TWGs even before the SVP process began. The SVP process, especially the collaborative model building, added three primary elements to the expert-stakeholder connection. First, it allowed experts to make sure they understood how stakeholders were impacted. Working with experts and stakeholders, planners developed over 100 hydraulic attributes such as seasonal water level ranges that were used to evaluate plans (especially in the early part of the study, before economic or environmental impact functions were complete). PFEG leads met with groups of stakeholders around the study area and worked with them to design their own section of the SVM that contained the information they said they would use to rank alternative regulation plans, with tables and graphs they helped design. Second, it gave stakeholders a better understanding of how economic and environmental impact measurements were linked to water levels, not just in their own areas of interest but also for issues that stakeholders with conflicting interests

supported. Finally, stakeholders got to know each other, too, and understand each other's perspectives better because they now participated in the Circles of Influence workshops, which sometimes brought key stakeholders representing conflicting interests together in small groups.

The Model

The final SVM was a system of models (Figure 5), not just one software or file, but all the results were captured in a sophisticated Excel spreadsheet that became the face of the SVM for most study participants. That spreadsheet came to be known as the Board Room. There was considerable debate about what software to use to build the SVM. The final structure was a compromise that (in retrospective judgment) worked well, but was bent a little too much in the direction of researchers' preferences.

The PFEG led the development of the model, with STELLA® and Excel coding being done primarily by Bill Werick and Mark Lorie of the U.S. Army Corps of Engineers' Institute for Water Resources, and David Fay and Yin Fan of Environment Canada. A few other agency experts added elements to the STELLA® and Excel models. In the original experiments with SVP in the early 1990s, stakeholders were invited to help code the models, an attempt to increase their knowledge and trust of the model. In the LOSL study, stakeholders sometimes were engaged in modeling workshops, but by their choice none did any coding. Stakeholders trusted the models because they were very familiar with the modeling effort, not because they performed it, and because they knew there was no censoring or significant time delay in reporting modeling news. When modelers found a significant modeling mistake, everyone knew about it the next day. Nearly 20 years of SVP confirms that stakeholders generally do not want to code models and can come to trust and understand the SVM if they observe the model development in an open forum.

The planning process percolated through various models in this fashion:

- Researchers developed algorithms connecting impacts to water levels or flows using field data and their own analytic procedures. For instance, stage-damage relationships in the lower St. Lawrence River were developed using geographic information systems that estimated the level of flooding on individual parcels at a range of water levels (this information was aggregated within the FEPS model as damage by reach and generally reported as damage over the entire lake or by county). Information from these models was then used to develop damage functions in the SVM system.

- Board members, stakeholders, experts in various fields other than regulation plan development and paid plan formulators would propose new regulation plans in conceptual terms and then the plan formulation team members would code the concepts. There were four formulation teams that experimented in four categories of regulation plans: modifying the existing

rules, optimization schemes, "natural" regulation, and coding of plan concepts offered by others. Each team would use whatever software it wanted to code the rules. The output, a 4,848 quarter-month time series of flow releases, was then pasted into the Control Panel, an Excel model that was part of the SVM. That release set defined a unique alternative regulation plan.

- "Fence post" plans were developed, with each fencepost defining a regulation plan that was designed to serve one interest no matter the effect on other interests. These fence posts defined the decision space, and showed the limits of the ability to control water level-related impacts. Most importantly, the freedom to design "unfair" fencepost plans showed residents along the south shore of Lake Ontario that regulation of Lake Ontario could not reduce damages to Lake Ontario shoreline properties much more than the current regulation plan already had, even if regulators cared nothing about environmental impacts, hydropower, or Montreal area shoreline effects. In a similar fashion, planners formulated "perfect forecast" versions of alternative regulation plans so that the potential benefits of better forecasts could be measured in dollars and environmental performance improvements.

- Water levels and most impacts would then be calculated in a STELLA® model dynamically linked to two spreadsheet input models, the Control Panel and Data Warehouse, which housed water supply and channel roughness datasets. After the STELLA® model was run, tables from that model would then be copied and pasted into a third Excel model called the Post Processor.. The post processor included macros and tables that could be used to call external models that did the rest of the impact evaluations, including Lake Ontario coastal impacts (FEPS), St. Lawrence River shore protection damages (SRM), and the environmental impacts (IERM). Those three models are described very briefly below.

    - FEPS (Flood and Erosion Prediction System) is a proprietary C++ model developed by Baird Engineering during previous investigations into Great Lakes erosion and flooding research. FEPS uses water-level erosion relationships developed using a very data-intensive erosion model at several representative cross-sections around the lake and then applies the results over and over using reach-specific parameters around the entire Lake Ontario coastline. Flooding damages are based on water levels and wave heights, capturing both inundation and wave impact damages, and shore protection structure damages are assessed using erosion and flooding models. Erosion at any moment in time is serially dependent on the water levels experienced in the years preceding that moment. Hence, a shore protection structure becomes more

vulnerable to damage as erosion eliminates protective beachfront, and it may fail in the eighteenth year of simulation under one plan and in the twenty-fifth year under a different plan. Run time for the FEPS model was about three minutes.

- SRM (Shoreline Response Model) was a proprietary model developed by Pacific International Engineering to assess the effects of different flow releases on shore protection built along the banks of the St. Lawrence River. Evaluations showed that all alternative regulation plans being seriously considered had about the same amount of river shoreline damage. Run time was about a minute.

- IERM (Integrated Environmental Response Model), a Visual Basic model, was itself a collection of sub-models developed to assess environmental effects of various alternative regulation plans. When called from the post processor, the IERM would present a window announcing which sub-model was running. Run time was about 80 minutes on a 2005-era laptop.

Several people had this model suite on their computers and used it to evaluate models and to check the evaluations other people had done. All these evaluations were designed around a 101-year simulation using 4,848 quarter-month time steps. Twenty-nine year climate change datasets had been developed using the 29 years of historic data for which there was enough collateral information, such as precipitation and evaporation, to downscale and interpret global circulation model outputs. Planners repeated these 29-year datasets to create 101-year input datasets to match the format of the historic water supplies. The study developed a 50,000-year stochastic hydrology. For sensitivity analysis, four 101-year "centuries" from this large data file were extracted to form four alternatives to the historic water supplies, representing extremes possible under the current climate. This allowed a quick screening of new alternatives to see how they would work in very dry or very wet centuries. Later, a full stochastic analysis using 495 101-year sequences was also done using FORTRAN code translated from STELLA® equations and a variation of the FEPS code. Figure 9 shows a graph of the range of Lake Ontario levels generated in these 495 sequences. The design of the graph was worked out with stakeholders, some of whom preferred metric and some English units of measurement.

The four plan formulation teams compared results and benchmarked each others' plans, both over the Internet and in face-to-face workshops. This developed a rich understanding of how the system worked, and allowed teams to share breakthroughs wherever they were made. Stakeholders had complete access to these sessions, and while few took part in them, stakeholders who did take part helped spread news of plan formulation, and this helped people trust the process. Hundreds of alternatives were tested with the historic evaluations, which could take from two

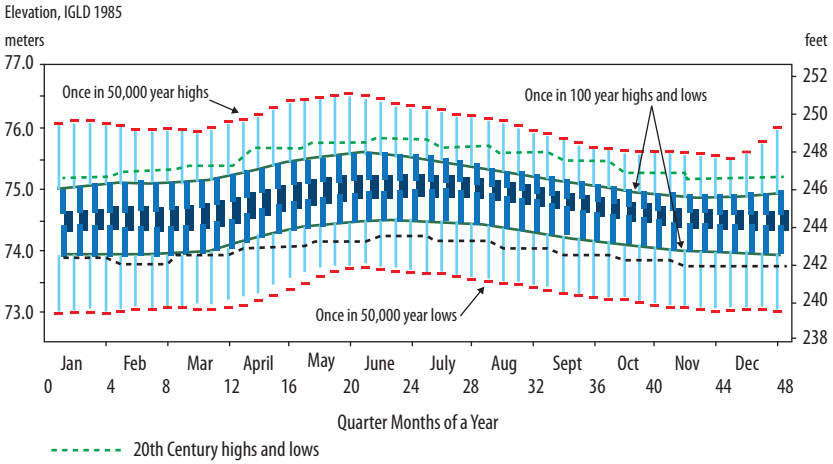


Figure 9: Range of possible Lake Ontario levels through the year under the current regulation rules

minutes (STELLA® only) to 90 minutes (STELLA®, FEPS, SRM, and IERM). The full stochastic analyses took over a day of computing time to run and these runs were done only for plans that were of particular interest.

The final economic benefit analyses were based on discounted values using the full stochastic evaluations. The discounting captured the reality that erosion happens no matter the regulation plan, so the only difference was how fast it happened (plans that slowed erosion down had positive economic benefits). The stochastic version of the model recorded damages for each quarter-month of the 4,848 quarter-months in each of 495 101-year "centuries" and so was able to produce an average expected damage for each quarter-month into the future. These average damages were then discounted. A sensitivity analysis allowed various planning horizons and interest rates, but the final report was based on a four percent discount rate and 30-year evaluation period. Figure shows that Lake Ontario water levels could be nearly three feet higher and lower than recorded levels even under the current regulation plan, which seeks to compress lake level variation.

The Essential Conflicts

The Study Board's decision would have to resolve interest, cognitive, and value disputes; there were no disputes over authority during the study because the IJC was assumed to have clear authority under the 1909 Treaty. It should be noted that after the study was over it became clear that the IJC would not implement a regulation plan that did not have the support of U.S. and Canadian governments. The federal governments, in turn, were very interested in the opinions of the state (New York) and provinces (Ontario and Quebec) most directly affected by the new plan.

This had the effect of making Quebec, Ontario, and New York State final arbiters of the decision.

As is often the case, the interest, cognitive, and value disputes were enmeshed with one another—those with self-interest in reducing coastal damages sometimes dismissed the value of restoring wetlands and were critical of any research that suggested the two interests were in conflict. Those who saw themselves as environmental champions often said publicly that coastal homeowners should not have chosen to live so near the coast, and that society should not protect those properties at the expense of the environment.

The regulation decision would affect many interests, but ultimately hinged on a trade-off between the Lake Ontario coastal environment and Lake Ontario coastal damage. There were many problems that could be much improved through regulation. As is true in most places, people have built along the coast based on recent water levels, not on the higher and lower levels that will inevitably come after building. There are a few hundred homes along the Lake Ontario and St. Lawrence River coast that will receive at least nuisance flooding no matter how Lake Ontario is regulated. Similarly, there are a few hundred boat slips that will not offer enough draft even at average water levels. The latter was probably exacerbated by the generally high levels in the last few decades, which coincided with the increase in boating ownership and use. On the other hand, some conflicts that might have been expected were not an issue. During a drought, water released from Lake Ontario can help Montreal and other river communities, but it lowers the amount of water on Lake Ontario. However, drought management plans that held water on Lake Ontario as long as possible worked both for people around the lake and along the river; large short-term releases to create normal depths in the river in the shorter term often hurt people along the river in the longer term because those releases lowered Lake Ontario water levels, resulting in drastically lower river levels later if the drought persisted.

There were real conflicts, though. Compressing lake level variations helped property owners but narrowed the band of transition between submerged and upland species, reducing wetland plant diversity, especially the meadow marsh communities. There is also a conflict between coastal damage above and below the dam. The damage risk on the river is by far the greatest when winter ice and snow in Quebec melts. If Lake Ontario is high at the same time, the release decision must balance the near certain river damage from higher releases against much larger potential damages along the lake if wind storms occur while lake levels are high. And it was a challenge to keep enough water in Montreal Harbor in the fall while emulating the naturally higher fall levels of Lake Ontario, although Deborah Lee of the U.S. Army Corps of Engineers was able to formulate a variation on one alternative regulation plan (Plan B+) after the study was over that could do this, although at the expense of Lake Ontario shore damage.

The Results

The IJC asked the Study Board to provide options, not one recommendation for a new regulation plan. In its final report, the Board gave the IJC three regulation plans labeled A+, B+ and D+. All the plans met the Study Board requirements, but Plan A+ maximized economic benefits, B+ maximized environmental benefits, and D+ minimized sectoral losses. No plan was found that improved on the current plan in every sector; trade-offs, sometimes fairly small, seemed unavoidable. The Plan B formulation team tried but could not reduce coastal damages from the B+ plan. It would cause an average of about $2.5 million per year in damages, an average created by no damage in most years but tens or hundreds of millions of dollars of damage every 20-30 years. PFEG showed that these damages could be eliminated with perfect forecasting in the fall of local spring runoff into Lake Ontario (that is, not the flow from the Upper Lakes, which is fairly predictable). That creates hope that better forecasting, even if not perfect, would allow the development of a risk management strategy for fall levels that would keep most of the environmental benefits and not cause more coastal damage than would be expected under the current regulation plan.

Current Status

As of this writing, a new plan has not been selected. A draft selection (a variation on Plan D+) was rejected by New York, Ontario, and Quebec. There was greater, but not unanimous support after the study for a plan similar to B+. In a letter to the governments of Canada and the United States (International Joint Commission 2008), the IJC proposed a one-year process with Canada, the United States, New York, Quebec, and Ontario to resolve the outstanding issues and obtain the concurrence of the two federal governments on the future of regulation. Subsequently, a Lake Ontario-St. Lawrence River Working Group was established to provide advice to the IJC. The working group held its first meeting on December 4, 2009, and was continuing to meet in 2011.

Lessons Learned

The Lake Ontario study was ambitious and well executed. Almost every element of it could be held up as an example of how to do a study well (although climate change evaluation has progressed since 2005). But it was not perfect. The study was the subject of some criticism from a National Academy peer review. While the Study Board concluded that most of the criticisms were the result of a lack of communication and the limited time the reviewers had to engage with this work, the Study Board did agree that the study had failed to do some traditional documentation and had not communicated its risk and uncertainty analysis well. The Study Board took steps to address both issues.

There have been several "emulations" of black box models by SVMs throughout the history of shared vision modeling. In each case, the black box has been held up as the standard for the validation of the shared vision model. In almost every one of those

cases, the SVM emulation revealed errors in the black box model. Self-interested modeling technicians are quick to condemn the admittedly limited ability of software such STELLA® and Excel that is easy for stakeholders to use; neither is well suited to performing iterative "do-loop" logic. But these technical limitations have to be balanced against the fact that most black box models rarely get one good peer review, while the typical SVM is closely scrutinized by dozens of people and is used so often that mistakes are more prone to show up and get cleared up.

In retrospect, a good argument could be made for coding the FEPS and IERM algorithms in Excel or STELLA®. Subtle misunderstandings and deeply buried errors in the FEPS modeling—an otherwise impressive modeling effort—caused a complete mid-study shift in plan evaluation, as the study team found that alternatives that seemed promising were not. And while there were iterative models in the IERM that could not have been done efficiently in STELLA® or Excel, these sub-models did not play a significant role in decision making. The wetland plant diversity model, which was crucial in decision making, had been modeled successfully in STELLA® and Excel. At study's end, discrepancies were found between the IERM and the original model created by the biologist who had developed the algorithm linking water level sequences to plant diversity. The differences were small, caused by subtly different interpretations in code of concepts like "the highest three quarter-month elevations during the summer." After the study was completed, shared vision modelers developed Excel coding that was faithful to the concept, but it has not had the broad review and endorsement it would have had if it had been done during the study.

Finally, the Lake Ontario study marked the first full scale use of the "informed consent" decision process, a formalization of decision steps that grew out of experimentation with decision processes in SVP studies over the last dozen years. The Lake Ontario informed consent process will serve as a model for future studies, although it might need to be scaled down for shorter studies with more modest budgets. The informed consent process is premised on the notion that decision makers, experts, and stakeholders must practice the decision from about mid-study, using available information. Each practice decision on this study was observed and criticized both by the Study Board itself and by a consultant, Frank Lupi of Michigan State University.

The Study Board summarized its experience with Shared Vision Planning in its final report (Lake Ontario-St. Lawrence River Study Board 2006).

> This approach combines scientific and public input in an interactive analytical framework that has helped the Study Team and public interest groups explore numerous plan formulation opportunities, operating nuances and performance impacts in an organized fashion. (page iv)
>
> As used in this Study, the general planning approach, termed "Shared Vision Modeling," has proven to be very successful. The Commission should consider applying these same techniques in subsequent International Joint Commission studies. (page vi)

> Reviews in progress are built into the Shared Vision Planning process. The act of building one model that encompasses all other models requires an in-depth analysis and review of the underlying models. Because Shared Vision modelers need to understand the workings of the underlying models so thoroughly and because they remold the underlying models into a format that hundreds of people can access, this in-progress review proved to be much more thorough and effective than traditional quality control methods. (page 10)
>
> By dynamically integrating all the models into a Shared Vision Model from the outset, incompatibilities in the models, and even in the conceptual research frameworks have been discovered and corrected. (page 23)
>
> In this Study, the Shared Vision Model allowed planners to change plans and re-evaluate them within about an hour. That means there is a practical alternative to making trade-offs, which is to create a new plan that reduces the need for trade-offs. (page 26)
>
> In summary, this Study has produced more and better data and information by which to evaluate plans than has ever been available before. With the information integrated into a Shared Vision Model, it has allowed for numerous iterations of plan development in attempts to reach the best balance between interests and locations. While there will always be gaps in understanding, the Study Board is confident that the information developed and analyzed is sufficient to ensure the best selection of regulation plans for managing the Lake Ontario-St. Lawrence River system. (page 28)

The Ultimate Measures of Success

The Lake Ontario study was the most sophisticated and fully realized SVP study ever conducted. But there are two areas where critical judgments still have to be made. First, will the final plan selection be made using the SVM? The Alabama-Coosa-Tallapoosa Apalachicola-Chattahoochee-Flint shared vision study in the mid-1990s was the most sophisticated SVP study before the Lake Ontario study. The study partners agreed to use SVP out of desperation— everything else had failed, and it appeared the conflict was headed towards resolution in the courts. Three years into the SVP effort the states had agreed to the first interstate water compact in the Southeast, and compact went into effect after being ratified by the U.S. Congress and signed by President Clinton. The compact had a sunset clause that could be extended if the three states (Alabama, Florida, and Georgia) all believed that plan selection negotiations should be extended, and it was extended for several years as the states worked with the models to develop new plans. But the governors who had been involved in the study eventually all left office and negotiations were led by governors who were not familiar with the study tools. Those negotiations failed, causing the end of an interstate water compact. The first test for the Lake Ontario SVP study will be the degree to which the SVM influences the choice of a regulation plan by the governments involved.

The second test is even more difficult. At the end of the Lake Ontario study, a brief adaptive management strategy was designed that called for monitoring in two areas that were both uncertain and important in the choice of plans. According to the study, more natural Lake Ontario levels would be good for wetlands and occasionally very damaging to existing shore protection structures. The adaptive management strategy called for continued low-level funding of a handful of research and monitoring efforts that could lead to plan modifications that reduced this apparent conflict. Some avenues of potential funding were put forward, but to date there is no funding for this effort.

These "ultimate" measures are tests for planning in general, not just SVP. Important strategic water management decisions are always and appropriately political decisions and are part of a larger tableau than a water planning study. Governments may agree to a water decision that water resources experts see as sub-optimal if it is part of a larger intergovernmental negotiation that covers non-water issues. Other processes, including the operations of markets, court rulings, and legislation and lobbying, will influence future water management and these processes may also lead to water decisions that water specialists see as sub-optimal. The test will not be whether planning by a handful of people can trump these large democratic processes (it cannot and should not) but whether it can inform them. Among "sub-optimal" decisions, some will rank higher after a SVM evaluation than others. The potential for planning to influence real-world decisions may be linked to our ability to fund adaptive management efforts, for it is this sort of post-planning use of planning tools that will keep study results in our field of vision when the time comes to make the big decisions long after the planning study is completed.

Chapter 7

Use of Modeling to Facilitate Interstate Collaboration on the Lower Susquehanna River

by Andrew D. Dehoff and Thomas W. Beauduy

Introduction

In 2002, the Susquehanna River Basin Commission (the Commission) convened the Conowingo Pond Workgroup (the Workgroup) to recommend a management plan for the Conowingo Pond, a 14-mile-long interstate water body created by construction of the Conowingo Dam on the Lower Susquehanna River (see Figure 10). The pond, which straddles the Pennsylvania-Maryland border, serves multiple manmade and natural needs. During low-flow conditions on the Susquehanna River in the 1990s, the pond demonstrated an inability to meet all existing uses, and the Commission determined that a more comprehensive management scheme was needed to avoid future conflicts. As a regional, interstate agency with basin-wide water allocation and consumptive water use regulatory authority, the Commission was uniquely qualified to initiate and lead the Workgroup effort.

The Workgroup undertook a four-year planning effort to evaluate operational alternatives for the pond and to recommend to the Commission a management plan that best meets the water use needs identified by the Workgroup. Additionally, the Workgroup was tasked with identifying management actions that the Commission should incorporate into its regulatory and water resource management programs.

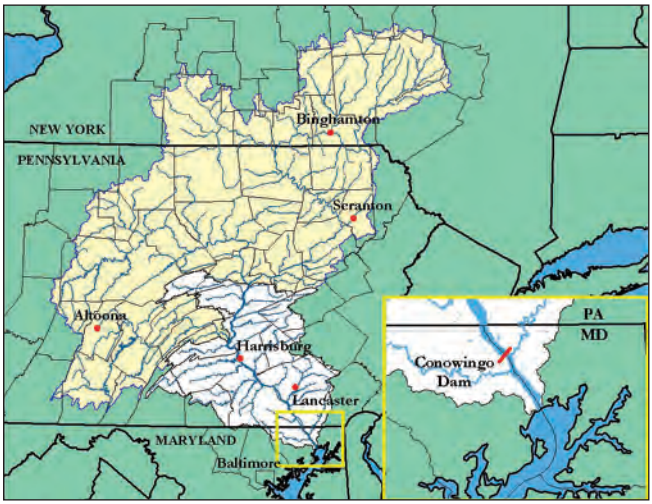


Figure 10: Location of the Conowingo Dam on the Susquehanna River in Maryland

The Workgroup completed its report in March 2006, which served as the basis for the Conowingo Pond Management Plan adopted by the Commission.

Photograph of Conowingo Dam, courtesy of Exelon Corp.

Background

The Conowingo Pond was created by the construction of the Conowingo Dam in 1928 to provide hydroelectric power generation for the Conowingo Hydroelectric Station. Operation of the dam by Exelon Generation, Inc. (Exelon) is subject to the requirements of the Federal Energy Regulatory Commission (FERC). These requirements include provisions related to minimum flow releases and maintenance of recreational pond levels. Seasonal minimum flow requirements were established to provide protection for fishery resources, with highest minimum flows required during the anadromous fish migratory period in spring, and intermittent flows permitted only during the winter, when fish populations are limited. The minimum flows resulted from a multi-party settlement reached in 1988 after a prolonged, contentious legal battle during the last FERC relicensing of Conowingo Dam.

By virtue of the pond, a stable source of water storage for other purposes was also provided (see Figure 11). The Muddy Run Pumped Storage Hydroelectric Facility, built in 1968, cycles water back and forth from the pond for additional power generation. The water in the Conowingo Pond is also used for public water supply by the City of Baltimore and Chester Water Authority, and for industrial cooling by the Peach Bottom Atomic Power Station. Finally, the pond provides a valuable recreational, fish, and wildlife resource.

Under normal and slightly below average flow conditions, there is generally ample water in the lower Susquehanna River to maintain hydroelectric operations; support water supply demands; sustain recreational, fish, and wildlife activities; and meet required flows to downstream river reaches and the upper Chesapeake Bay. However, during more severe low-flow conditions, the available water becomes insufficient to meet all prescribed uses and required needs. During such periods, as Exelon operates the Conowingo Dam in accordance with its FERC license requirements, storage levels in the Conowingo and Muddy Run facilities begin to decline. Declining pond levels pose a threat to Peach Bottom's cooling water intake, Muddy Run's intake, the use of recreation facilities, shore habitat, and maintenance of downstream flows (see Figure 12). In response to declining pond levels and worsening conditions, FERC has authorized Exelon on five occasions to temporarily include water leaking

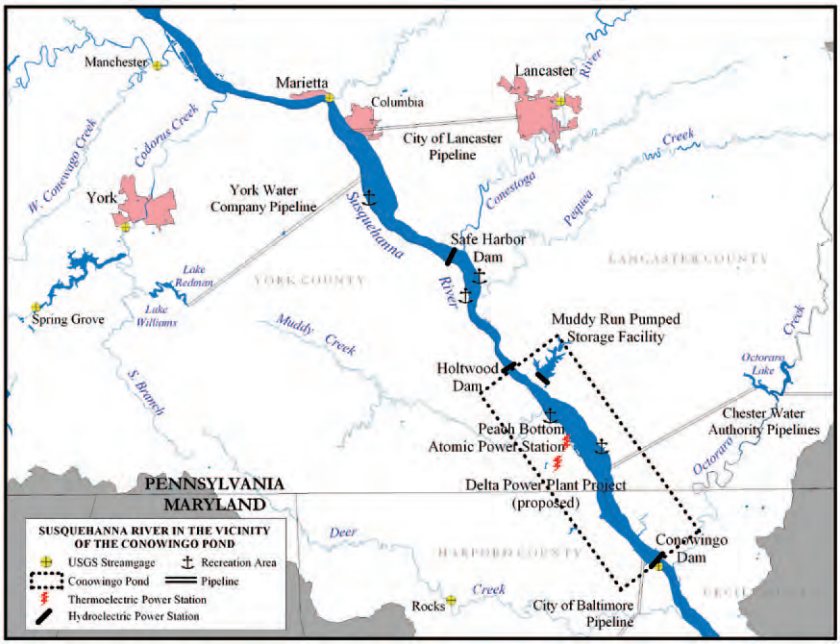


Figure 11: Water use features in the vicinity of Conowingo Pond

through closed wicket gates toward meeting the dam's daily minimum flow release requirement. The 1988 settlement agreement specifically excludes that water from the minimum release calculation, but FERC has overridden the exclusion during the five events.

Use of CADRe in the Lower Susquehanna River

The various uses and potential conflicts surrounding the Conowingo Pond touched on elements of both Interest Disputes and Value Disputes. In considering whether the water flowing to Conowingo dam is allocated to withdrawals from the pond, for hydroelectric operations, or to sustain ecological conditions downstream, there is conflict over how various stakeholders are positively or negatively impacted by the movement of limited quantities of water during drought. Likewise, in arguing for one allocation over another, there is disagreement in the value derived by the recipients of the water. In establishing a Workgroup of stakeholders, the Commission's goal was for resolution of the perceived conflicts and to receive recommendations for sustainable and mutually beneficial operation of the Conowingo hydroelectric facility.

The composition of the Workgroup was intended to represent the interests of the key stakeholders in the operation and use of the pond. Participation remained open to any interested party throughout the process, but invitations to participate

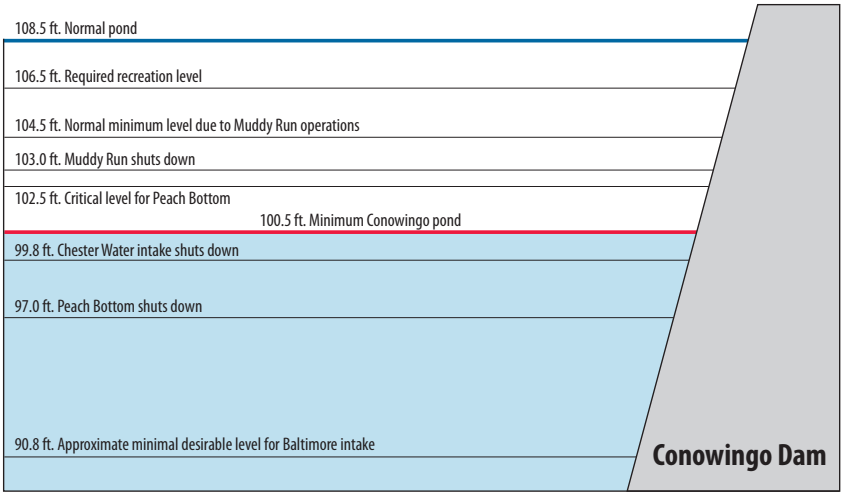


Figure 12: Critical levels of Conowingo Pond

were extended directly to targeted representatives from federal and state planning and resource management agencies, local jurisdictions, operators of the lower Susquehanna hydroelectric facilities and Peach Bottom Atomic Power Station, local water utilities, and the Commission. The Workgroup met several times a year and provided direction, oversight, input, and review for the planning effort and its results. Other interested parties that did not directly participate were kept apprised of the Workgroup's progress. Importantly, all targeted parties were encouraged to be active in Workgroup activities, and the Commission endeavored to include whatever output and performance measures that would help achieve full participation.

The first year of Workgroup deliberations was spent sharing information and developing working relationships among stakeholders with different—and often conflicting—objectives. In order to investigate and recommend a management plan for the Conowingo Pond, it was important that the members of the Workgroup provide insights to the diverse interests related to the pond's resources. The Workgroup collectively assessed the interests and identified problems and conflicts that needed to be addressed. They were:

1. Maintaining FERC-mandated minimum flow releases from the Conowingo Pond can lead to disruption in power production, water supply withdrawal limitations, and diminished recreational opportunities during significant low-flow events, and depletes storage that might otherwise be available for release during low-flow events of extended duration.
2. Temporary waivers to allow inclusion of gate leakage towards meeting minimum flow releases have been authorized by FERC five times (1999, 2001, 2002, 2005, and 2007) during recent droughts, but only under

emergency or near-emergency conditions when time is critical and serious impacts are developing with no projected improvement.

3. Increased salinity levels in the Susquehanna River downstream of the Conowingo dam during low-flow conditions can negatively impact the water supply for the city of Havre de Grace, Maryland, located at the mouth of the river.
4. Consumptive water use in the Susquehanna River Basin, from and upstream of the Conowingo Pond, is increasing and could eventually impact negatively on the pond and those who rely on its water.
5. Commission-owned water supply storage at two federal reservoirs in the upper basin is managed under operating rules that were developed for water supply users elsewhere in the Susquehanna River Basin. Releases from these reservoirs are not mandated by FERC license requirements and may not provide optimum and timely benefits to the Conowingo Pond during low-flow conditions.
6. Increasing public water supply needs for Baltimore City, Harford County, Chester Water Authority, and the areas of Pennsylvania and Maryland surrounding the Conowingo Pond are expected to lead to requests for greater withdrawals from the pond or the Susquehanna River just upstream.
7. Increased consumptive water use needs (i.e., cooling water for a new thermoelectric power plant) could require additional withdrawals from the pond.

In order to assess these problems and conflicts, the Commission retained the services of HydroLogics, Inc., to guide it through CADRe and develop a daily flow model of the Conowingo Pond area using its OASIS modeling software. CADRe and the OASIS software were chosen based on their successful application in the Delaware River basin. The Commission had in the past used other software to model certain extents of the basin, but they were not specifically designed for water resource analysis and lacked the flexibility and multi-objective capability of OASIS. The Commission had not formally used CADRe to this point, but the complexity of the conflicts and the number of stakeholders called for a structured approach. Following development of the model, HydroLogics continued to serve in a consulting role, providing guidance in the use of the model and in the CADRe process.

The OASIS daily flow model comprised more than 70 years of hydrologic record, incorporated estimates of existing and future consumptive water uses, and included representations of the operation of public water supply withdrawals, power plants, and reservoirs throughout the basin. The model was developed with the ability to measure the impacts of various operation parameters on the pond and flow conditions downstream.

The stakeholders were as directly involved in development of the model as possible, from providing operating data to reviewing and verifying modeled operations. Commission staff and HydroLogics met individually with any stakeholder that desired a detailed review of the information and operating parameters included in the model, and all modifications were reported to the entire group. When issues with complex modeling ramifications arose, such as the interest in tracking salinity at the juncture of the Susquehanna River and Chesapeake Bay, Commission staff were committed to providing a suitable substitute. In the case of the salinity at the river's mouth, stakeholders were able to provide anecdotal information and data that allowed creation of a surrogate indicator for salinity levels. Recognizing the complexity of modeling salinity, Workgroup members came to consensus on an effective substitute.

As originally conceived, the model's extent was limited to the immediate vicinity of the Conowingo Pond. However, discussions with stakeholders revealed several justifications for expanding the scope of the model to include the entire Susquehanna basin and the City of Baltimore's water supply system (see Figure 13). The stakeholders correctly identified that hydrologic conditions and water use outside the pond area play significant roles in conditions in the pond and can serve as the basis for certain operations. Without specific modeling of the additional influences, the alternatives analyses would have been more hypothetical in nature, and perhaps less indicative of the potential for real-world conditions. In addition to that obvious benefit, the stakeholder input resulted in a more complete and comprehensive model with the capability of assessing more alternatives and answering more questions than were originally contemplated.

Once all stakeholders were satisfied with the contents and extent of the model, a verification scenario was developed for the 2002 drought to allow direct comparison of model results to actual conditions observed during that summer and fall. Examples of the comparisons prepared for review are shown in Figure 14.

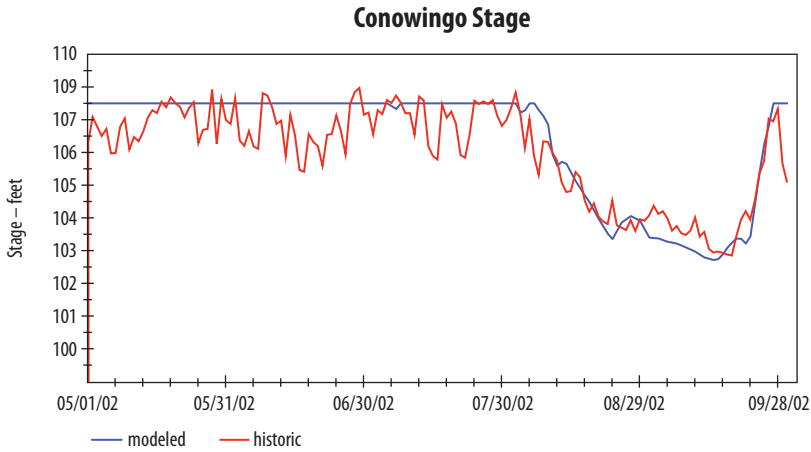
In order to achieve resolution of the hydrologic disputes on the Conowingo Pond, Commission staff considered it necessary to achieve complete participation of the Workgroup in CADRe. That goal was met by building critical knowledge of the lower Susquehanna system through collaborative model construction and development of performance measures. Model results of various alternatives were then used to develop consensus-based recommendations for action by the Commission and others to address issues discovered during CADRe. Without full participation, any recommendations would have run the risk of not having full support by key stakeholders.

Using the model, baseline conditions (i.e., existing operations) were established and a series of 32 initial alternatives was evaluated. Key parameters identified for the evaluation included minimum downstream flow requirements, credit for leakage of water at the dam, water supply withdrawals under normal and low-flow conditions, consumptive water use in the basin above the Conowingo Pond, and the use of

Figure 13: Schematic of the components of the OASIS model

Commission-owned storage at two upstream reservoirs to augment low flows. The Workgroup participated in computer-aided negotiations (CANs) to perform efficient evaluations of the long-term implications of changes in operating policies and facility configurations. Comparative output displays of Conowingo Pond levels and dam releases allowed the Workgroup to evaluate the numerous operation alternatives and make recommendations for the management of the pond. The iterative process embodied in the CAN sessions served to inform the Workgroup members about the pros and cons of many alternatives on a consistent and balanced basis. Over time, the CAN sessions were also valuable in further building the credibility of the model with Workgroup members.

After review of the initial 32 alternatives, the Workgroup developed six final alternatives for closer analysis leading up to the selection of a preferred operating plan. The alternatives differed mainly in operating rules for release requirements from the Conowingo Dam during times of low flow. Parameters such as demand for water



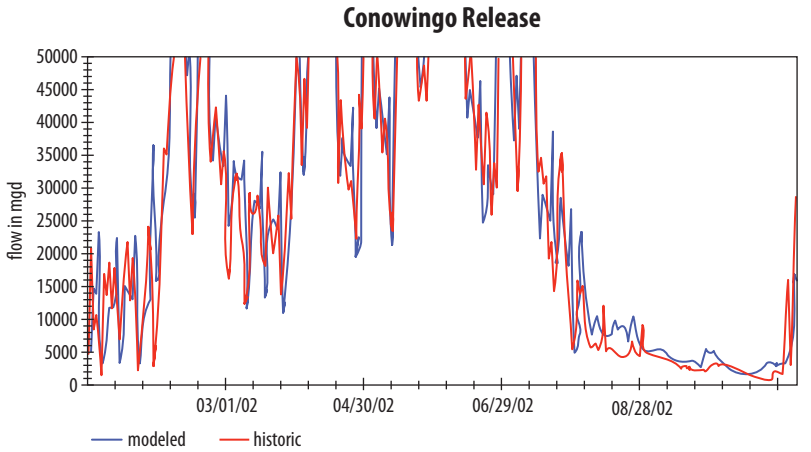


Figure 14: Sample model verification output

supply, water withdrawal operations, and upstream consumptive use were kept constant to allow for direct comparison between alternatives. A thorough evaluation of the six preferred alternatives using the OASIS model led to the selected plan, which contains favorable elements of several of the final alternatives.

Based on results of the modeled alternatives, the Workgroup identified the leakage and the minimum release requirement as the most critical parameters in managing low flows and enabling the Conowingo Pond to remain viable during droughts. While water conservation measures and the release of augmenting flow from upstream reservoir storage were deemed reasonable measures worthy of consideration, the supplemental volume of water they provide was found to be small relative to the

daily fluctuations of the pond, and simply did not offer substantial drought mitigation. Therefore, the selected Conowingo Pond Management Plan was based on establishing a formal protocol to implement a credit for leakage, and specifying the hydrologic conditions under which the credit is warranted.

The selected plan includes initiation of an automatic credit for leakage of up to 800 cubic feet per second (cfs), when the flow conditions at the upstream Marietta gage decline to a flow of 1,000 cfs greater than the seasonal flow thresholds ("QFERC") established by FERC for that gage. The Marietta flow threshold is 5,000 cfs between June 1 and September 14, and decreases to 3,500 cfs on September 15 through the end of November.

Modeled simulation runs of operating the resource under the recommended guideline produced favorable results. They demonstrated the most favorable balance for preserving adequate levels in the pond, ensuring reliable multi-purpose use of the pond, and meeting the requirements for the quantity of water released to the downstream reaches of the Susquehanna River and the Chesapeake Bay. To further avoid potential negative impacts, the Workgroup conditioned its recommendation with restrictions that prohibit Exelon from automatically taking a credit for leakage during the spring fish spawning and migration season (April 1 – June 30) and limiting the credit to only the portion of the 800 cfs that is absolutely necessary to maintain viable pond levels.

Arrival at the consensus recommendation is attributable entirely to the lessons learned from using the model. The exercise provided new insights that helped to dispel preconceived ideas of how best to solve the low flow problems of the Conowingo Pond. For example, as mentioned above, use of upstream reservoir storage did not address the problem as well as some Workgroup members anticipated. Likewise, most members were surprised to find that the system—including downstream releases—as a whole functioned better under scenarios implementing a credit for leakage earlier in a drought rather than later.

Implementation of the selected plan will require that Exelon successfully petition FERC for an amendment to the existing license to include the altered disposition of the gate leakage during drought conditions. A draft license amendment request was prepared by Exelon in late 2008. The thorough four-year planning effort of the Workgroup and formal support of the proposed license amendment by the agencies involved are expected to be positive input to the FERC review process. If FERC approves the amendment request, the flow credit for leakage will be implemented five years before the next earliest opportunity in 2014, at the culmination of Conowingo's license renewal process.

The Workgroup members agreed to convene annually to review project operations, assess the potential for hydrologic conditions to develop into drought, and conduct a drought operations exercise. The hydrologic model used to develop the management plan is being kept up-to-date by the Commission for the Workgroup's use,

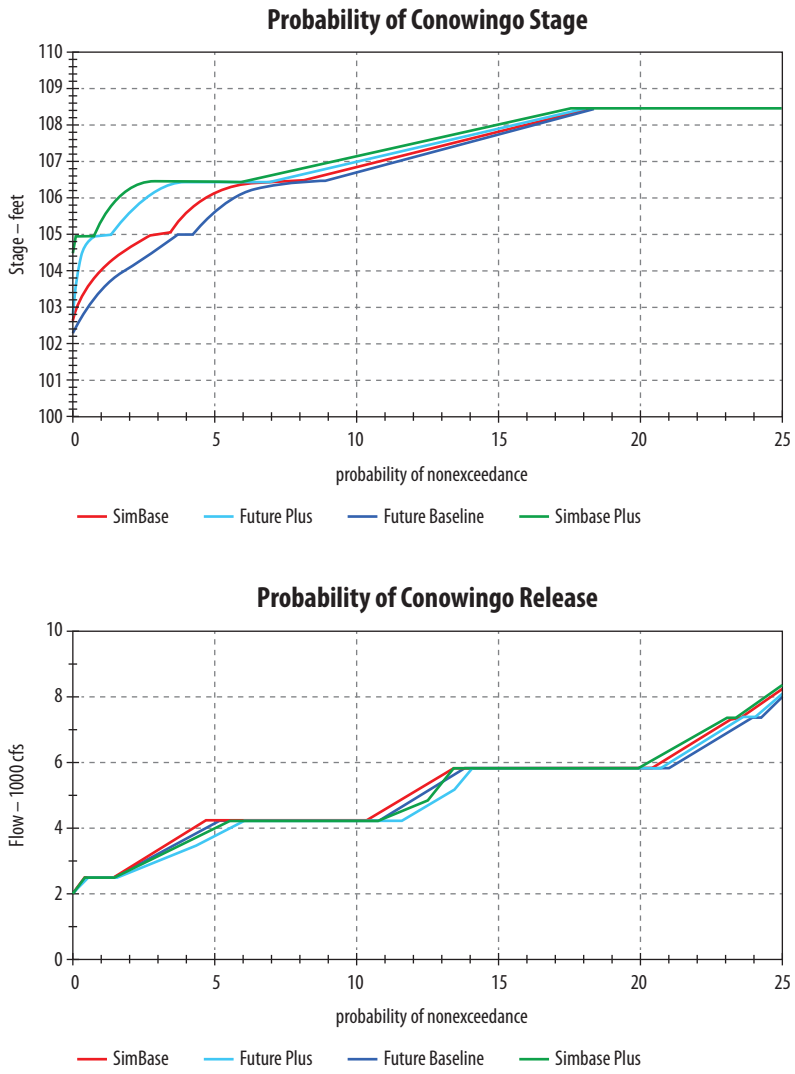


Figure 15: Sample model output

and continues to accurately reflect water withdrawals in both the pond and the Susquehanna River Basin, as well as current policies and operation protocols. The Workgroup will also be responsible for reviewing and updating, as necessary, the selected management plan on a periodic basis not to exceed five years. Workgroup members, although no more bound to continue participation than they were during the initial process, seem committed to extending their roles through the follow-up activities, and drought exercises held in 2007 and 2008 enjoyed broad participation.

The need for the Conowingo facility to undergo relicensing by FERC in 2014 is no doubt an incentive; much of the work conducted thus far by the Workgroup will be revisited in that process and play a role in the development of new license conditions. The relicensing process will also likely cause additional stakeholders to become interested in Conowingo operations. Any with a direct stake in the operation of Conowingo Dam during low flows will be invited to join the Workgroup.

The planning study also identified three related actions beneficial to managing the Conowingo Pond that the Commission supports including in its regulatory and water resource management programs. They are:

1. Consideration of the impacts of increasing consumptive water use in the basin on the Conowingo Pond and determination of what measures, if any, are necessary to mitigate the impacts.
2. Investigation of the water supply storage owned by the Commission at the federal Cowanesque and Curwensville Lakes projects for alternative operational strategies to provide more effective low flow augmentation, including benefits to the Conowingo Pond and instream resources below the dam.
3. Incorporation of key management principles and tools described in the study report, including the use of the annually updated hydrologic model, into the Commission's regulatory and water resource management programs.

The Commission demonstrated its support for implementing the above recommendations by formally adopting the Conowingo Pond Management Plan in March 2006. Subsequent to adoption of the recommendations, Commission staff completed an analysis of current consumptive water use in the basin and projections for future use, and identified mitigation needs. Following that effort, the Commission entered into an agreement with the U.S. Army Corps of Engineers to reassess the water supply storage owned by the Commission at the Cowanesque and Curwensville Lakes for the potential to revise release operations. The two-year study was begun in October 2008.

The Workgroup's report, with its documented and thorough analysis, provides valuable information for the Commission, public water suppliers, power companies, and environmental resource agencies in making regulatory and management decisions involving the resources of the lower Susquehanna River. The Commission's OASIS model developed during the Workgroup's deliberations will continue to serve this same community in the years ahead.

Given the potential for increased water use and future withdrawals in the upstream basin and from the Conowingo Pond, the adoption of the Conowingo Pond Management Plan and related actions is intended to ensure sustainable operations and a reliable water source for all needs, from public water supply and power generation to recreation and aquatic habitat, for many years to come. However, the resource is still not without limitations, and it is just one part of a much larger

system. There exist many potential conflicts and future unknowns, ranging from large diversions to impacts of climate change, which cannot necessarily be accommodated under the recommended management plan. The recommended related actions by SRBC and others will serve to acknowledge the limitations of the resource and be important in planning for the ongoing management of the Susquehanna River basin.

Conclusion

The Commission's first foray into CADRe resulted in successful resolution of a long-standing and worsening problem, and clearly demonstrated the benefits of shared decision making and collaboration through model building. In fact, the act of cooperatively compiling and verifying the model was arguably the most essential element in forming a catalyst for promoting trust and the notion of shared decision making. Ultimately, the process facilitated the Workgroup's ability to find consensus-based solutions.

In addition to promoting shared decision making, direct involvement of stakeholders served to benefit problem solving in other ways. Input from the stakeholders greatly influenced proceedings, and brought to light issues initially unforeseen by the Commission. These issues would have inevitably become apparent, and the process benefited from the early introduction of all issues, eliminating the need for costly and time-consuming revisions. This result is, perhaps, not unexpected. Water management and planning are integral to the day-to-day tasks and long-term outlook of each stakeholder, and it became apparent that the Commission was not the only party giving consideration to conditions in the Conowingo Pond.

Benefits of the CADRe model did not end with its construction. Use of the model in Workgroup sessions demonstrated that it had value equally as a learning tool and a negotiating tool. As a learning tool serving to inform stakeholders of how the system's components interact, the model provided easy-to-see demonstrations of what parameters truly drive conditions in the pond, which helped provide focus for the group's efforts. Then, during negotiations, the model offered valuable comparisons of trade-offs and various operations the stakeholders wanted (or thought they wanted) to see implemented. Display of performance measures was critical in demonstrating system relationships, and preconceived notions of relations were in some cases proven to be unfounded, or not truly representative of actual conditions. Workgroup members were responsive to what the performance measures displayed, and were amenable to evaluating new management approaches they might not have initially thought to be possible, important, or necessary.

Commission staff learned as much from the use of CADRe as the Workgroup members did. The collaborative process itself was extremely effective in building trust in the model and in CADRe, and that credibility enhanced the use of the model in negotiating and reaching consensus-based solutions.

Chapter 8

Drought Preparedness in Northern California: People, Practices, Principles and Perceptions

by Ane D. Deister

Introduction – Setting the Stage

California is known for many things: sunshine, agriculture, Hollywood, aerospace, Silicon Valley, beaches, kayaking, cars, music, fancy homes, snow-boarding, racial conflicts, fishing, electronic devices, political dynamics, educational institutions, and communities that provide the backdrop for television shows viewed across the country. These California icons and many more are seemingly different, but they are united by one thing—they all need water. Yet, many of the folks at the top of their game in most of the state's commercial and industrial enterprises are probably not aware that the state's water supply is riddled with many challenges and uncertainties. Not unlike many other parts of the country, most of the water-rich areas are located some distance from the largest population centers. And, not unlike many other areas in the West and throughout the country, California's water supplies are subject to naturally-occurring droughts that can extend close to a decade in duration.

Northern Californians are intensely interested in water supply and may comprise some of the most interested and engaged members of the general public. While the days of "we" and "they" are beginning to mellow slightly, there is still a sense of entitlement by Northern Californians regarding the water supplies that originate in their back and front yards and flow downstream to the high-population centers in Southern California. El Dorado County covers the area between Sacramento, the state capital, and South Lake Tahoe. It is a strikingly beautiful area that still sports vast areas of forest land, supporting rich wildlife and fish populations, and serves as a key bedroom community for people working in California's state capital. In the past, El Dorado County was known as the site of California's gold discovery and today the gold has been replaced with acres of tree crops, burgeoning vineyards and wine production, water-based recreation, and systematic residential and commercial growth.

In 1976-77 the phrase "if it's yellow let it mellow; if it's brown flush it down" descriptively pronounced the conservation measures northern Californians were taking to cope with the worst drought of historical record. In the late 1980s and into the 1990s, over the course of about seven years, California experienced a daunting prolonged drought that heightened the water supply awareness for many water users. In 1998 and again in 2005 California's Department of Water Resources modified the requirements for water utilities regarding the legislatively mandated Urban Water Management Plans. The plans must be updated at least every five years and, since 2005, must include a chapter on water shortage contingency plans and address a 50 percent water reduction situation.

Today, California's governor has elevated water supply issues substantially with his direct involvement in climate change issues and global warming regulations. With the experiences of Northern California, and now coupled with the statewide spotlight of the governor, it was certain that a comprehensive drought preparedness program for El Dorado County had to be something that relied on intensive collaborative dialogues, data sharing, and significant scenario planning.

In 2004, the El Dorado Irrigation District and El Dorado County Water Agency joined together to update previous drought and conservation plans, and to develop and fund a comprehensive drought preparedness program. A key part of this program has been development of a Shared Vision Model and collaborative dialogues with many interested parties, or stakeholders, and both local and national experts.

Shared Vision Planning – Using Diverse Views to Strengthen the Whole

One of the characteristics of an engaged and highly interested community is the view by many participants that they are as knowledgeable and informed as practicing experts in the fields of climatology, water resource engineering, computer modeling, and other similar "ologies." Some may see that as a challenge; others as an opportunity. El Dorado chose to see it is as an opportunity, and worked to find a way to capture public input, incorporate scientific information, and develop "what if's" to generate discussion on preferences and expectations. Developing a Shared Vision Model in a Shared Vision Planning (SVP) process—a specific application of Computer-Aided Dispute Resolution process—allows diverse participants to weigh in early in the process, buy in at each stage, and ultimately support the products and implementation when completed.

The Shared Vision Model, also called SVM for short, takes advantage of new, user-friendly, graphical simulation software to bridge the gap between specialized water models and human decision making. It is an effective way to integrate multiple factors into the process including potential economic, environmental and social impacts associated with droughts and contingency measures. It provides an integrated framework upon which sound drought preparedness decisions may reside.

Figure 16 graphically depicts the manner in which the drought preparedness participants developed a "shared vision." This vision considered the past drought experiences and economic impacts to El Dorado County residents and businesses, coupled with their concerns for future impacts considering climate change and the increasing demands for water throughout the state.

The key to acceptance by the diverse interest groups was an iterative, interactive process of data presentation, discussion of the data, sharing of personal experiences and rigorous scientific perspectives provided by several key experts. Having a stable of solid, well-respected, nationally recognized practitioners to help guide the process resulted in serious, lively, and well-versed communications. The expert team El

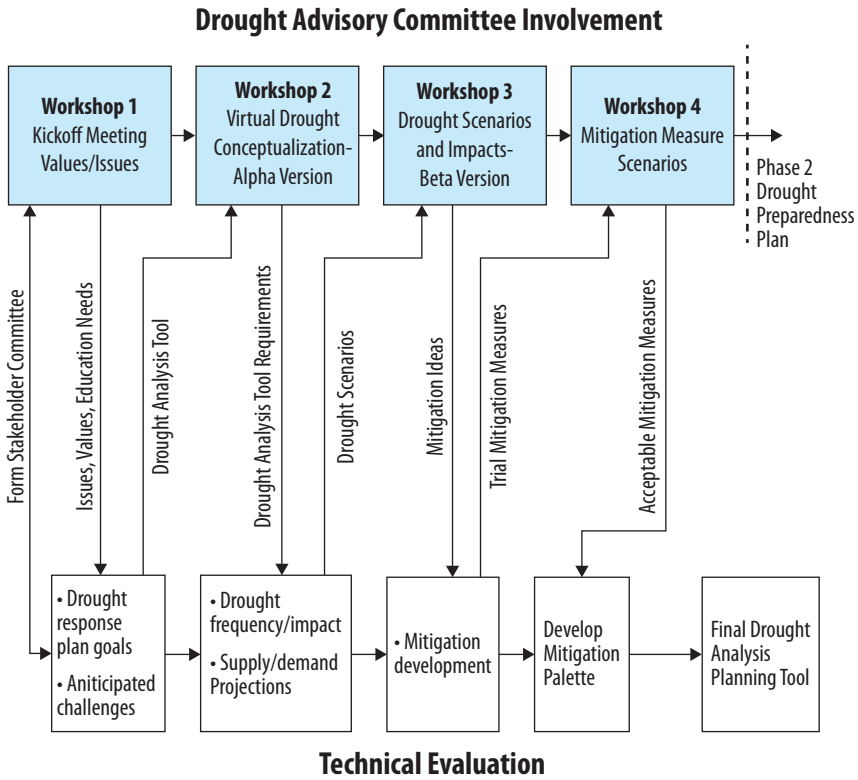


Figure 16: Shared Vision development process, El Dorado County, California

Dorado used included: the late Dr. David Jones, former University of California at Berkeley professor, USGS state hydrologist, and local winery owner; Dr. Jay Lund, University of California at Davis climate change and environmental engineering and systems professor; John Olaf Nelson, former water utility general manager and current water resource consultant; Bill Werick, former long-time water resource expert with the U.S. Army Corps of Engineers and present Shared Vision Planning consulting expert; and Dr. Donald Wilhite, who served as Director of the National Drought Mitigation Center at the University of Nebraska at Lincoln during this project, and presently consults as a drought planning expert.

The data loaded into the SVM used a graphical depiction (Figure 17) called a "dashboard" using green, yellow, and red indicators to clearly display if the activity was within acceptable levels of performance. If the water supply and demand data and prediction of the future fell within the green zone then it indicated acceptable performance; if the measurement fell within the yellow zone it indicated a level of concern regarding performance and that steps needed to be considered to improve

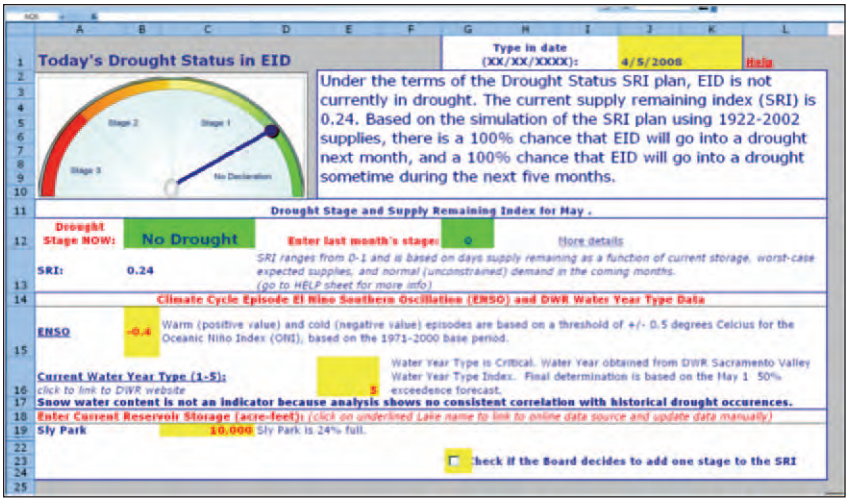


Figure 17: Dashboard depiction of drought status, illustrating green zone or acceptable situation

the situation; if the measurement fell within the red zone, it indicated that immediate action was required to improve performance. Some adjustments in setting where the green, yellow, and red zones would be triggered helped resolve trade-offs between model complexity and model transparency and accessibility. Data being monitored included such things as flows in the American River, storage levels in Jenkinson Lake, water levels in various storage basins, pressure levels in the distribution system, and a variety of regulatory measurements required as part of the hydroelectric plant operating license.

The primary development process tapped into several key external and internal forcing functions that affect the acquisition, storage, management, distribution, and conservation of water throughout the county. Model development required communication, facilitation, and two-way dialogues to reach consensus on such things as: the data, the analytical tools used to assess the trends from the data, description of drought preparedness tools, identification of potential levels of drought based on historical and predictive trends, potential actions that might be taken to reduce vulnerabilities of drought, and potential response actions to augment the preventive measures.

Shared Vision Model Overview – Clear, Open Technical Applications

Moving from a conceptual shared vision into practical application involved the use of a Microsoft Excel-based model. It allowed users to review information and assumptions that may be embedded in the model, and provided flexibility to separate inputs and impacts for each water provider in a given area. Figure 18 graphically depicts the steps used in developing the SVM.

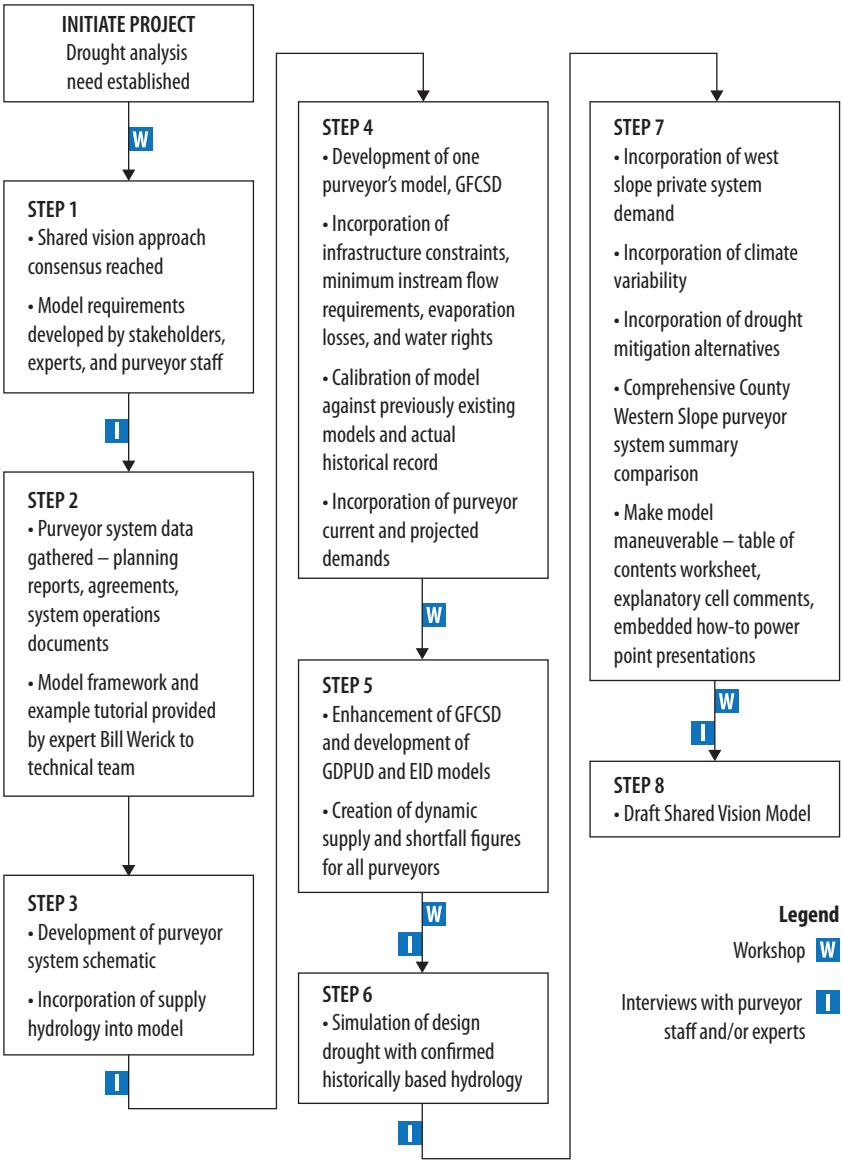


Figure 18: Shared Vision Model development process, El Dorado County, California

The "W" and "I" indicators in the model, as shown in Figure 18, depict the key forms of communication and facilitation occurring with the project. At times there was a need for a full participant level workshop—where all the stakeholders participating on the Drought Advisory Committee received information, discussed it, and

engaged in a facilitated two-way dialogue to reach consensus. Other times it was necessary to interview stakeholder participants one-on-one to identify where a key point of conflict might exist in order to develop alternative approaches to resolve the dispute. Other times the use of caucuses or small groups would be used in an interview style, to better understand a particular interest or view point, as a way to develop alternative dispute opportunities and dialogues.

Additionally, the public workshops with the elected members of four boards of directors were advertised and made open to the public, and provided another opportunity for involvement and transparency.

The array of involvement opportunities—including Drought Advisory Committee meetings, small group caucuses, one-on-one interviews, and public workshops with elected officials—were effective and allowed stakeholders to participate where they felt most comfortable, and to have more than one venue in which to participate.

The stakeholders included local agricultural growers, rafting/water recreational interests, land developers, community interest groups, environmental groups, Chambers of Commerce, local planners, former elected and appointed officials, Resource Conservation District members, County Agricultural Council members, a former state hydrologist, a, climatologist, a former U.S. Forest Service District Administrator, and members of the general public.

The computer model was developed iteratively initially with the Drought Advisory Committee participants at the table. The stages of model development were shared in open, public workshops to provide additional transparency and viewing of the model development. Once parameters were agreed upon they would be implemented at the next Drought Advisory Committee meeting and then presented at subsequent public workshops to ensure there was still agreement.

Applying the Model – Success through Simulations and Transparency

The process of working with the stakeholders, developing the model and reaching consensus on the model and its inputs occurred over a two-year time frame. The reason for that length of time was because the process had to be vetted periodically with the elected boards of directors of three public agencies, based on their meeting schedules and taking into account requirements for public notice for those meetings. With multiple elected decision-making boards there was a need to ensure each utility board and the county board of supervisors were comfortable with the model and its implications when viewed from their "home" agency's perspective as well as the county-wide view. As a result, the model results were presented in a full participatory workshop in late October 2007 after each agency had sufficient time to conduct its own review and provide appropriate public notice.

Representative stakeholders, implementers, and experts. Back row left to right: Bill George (El Dorado Irrigation District (EID) elected board member), Don Wilhite (National Drought Mitigation Center), Lisa Maddaus (Brown and Caldwell), George Wheeldon and Harry Norris (EID elected board members), John Olaf Nelson (independent consultant). Front row left to right: Bill Hetland (Executive. Director, El Dorado County Water Agency), Bill Werick (independent consultant), Ane Deister (Former General Manager of EID, current Vice President of Brown and Caldwell), Jay Lund (University of California at Davis)

Interestingly, these same agencies were involved in another collaborative effort during the same time period as the drought preparedness project and they did not use Shared Vision Planning, choosing instead to use interest-based bargaining and negotiation. That other process continues today, without agreement on the outcomes, and is at risk of falling apart due to lack of trust and non-aligned priorities.

Once the model was developed, the participants worked collaboratively to apply the results of the intensive data analysis phase of the project and translate the science of drought into practical drought preparedness solutions. Through the use of "virtual drought" simulations the group of experts and other participants tested the vulnerabilities of each water entity's supply management and delivery systems. Identifying predictable outcomes provides an objective basis upon which the group developed contingencies and mitigation measures to lessen and/or better manage the adverse impacts of drought on various community components. The model provided the shared framework upon which each of the legally-constituted entities could develop their own regulatory and administrative procedures.

The transparency of the model was especially useful to facilitating stakeholder agreement on and learning about modeled system relationships. The transparency allowed for numerous "what-if" testing, which was an important learning tool. The SVM was equally useful as a way to inform stakeholders of how the system works

and as a part of active negotiation. For participants who had been around a while and were familiar with the system, it was a way to "brush up" on their knowledge. For others, it was a chance to learn how the whole system works. The scenario runs, however, brought everyone together and were useful to the negotiation process.

Each of the water entities are in the process of drafting implementing regulations to be adopted by the various elected boards of directors and county supervisors. Each of the agencies will adopt its own implementing regulations, as they have different jurisdictions, legal authorities and mandates. Presently El Dorado Irrigation District has adopted the program.

The SVP and SVM development processes provided two key ingredients to the success of this project. First, the model development included a graphical tool that was used to incorporate key data and information into the model, making the model easy to understand and easy to modify. Using an Excel spreadsheet approach with the Stella® model made information accessible to participants, in part because many of them were familiar with at least the Excel part of that approach. That ease in model management made the advisory committee and public workshops active and meaningful. Second, the transparency of the dashboard graphics in depicting the outcome of the SVM was important to developing trust, building consensus, and achieving widespread acceptance. Without that acceptance by the diverse stakeholders, the elected officials would have had some difficulty in adopting the plan and implementing strategies. And the dashboard graphics allowed decision makers, who may not be modelers, to become comfortable with the data and process. As a result, these two key features were foundational to the project's success.

The most challenging aspect did not relate to the process of SVP or SVM development. Instead, it related to integrating climate change input into the model. Some participants felt strongly that climate change should be considered, while others felt it was a distraction at best and a hoax at worst. However, after participants agreed to look at a diversity of scenarios and of likely resource constraints, it was possible to consider the impacts of possible climate change scenarios without either endorsing or debunking climate change.

The following qualities, results, and experiences were realized through the SVP and SVM processes:

- Transparency of diverse information, assumptions and decision factors
- Ease of use for both model experts and non-experts
- Ability to quantitatively predict shortfalls
- Clear depiction of the water utilities and providers in the area
- Ability to demonstrate the manner in which shortfalls would occur
- Ability to evaluate effectiveness of various drought responses

- Ease in updating the model tool
- Ability to test existing drought plans against proposed, improved plans
- Ability to integrate climate change scenario influences

The overall success of the drought preparedness project, beginning with an intensive drought analysis project and development of the SVM for El Dorado County, was due in large part to the enthusiastic, informed stakeholder participation process. Consensus was reached through facilitated dialogues and workshops that iteratively and systematically integrated financial, environmental, and scientific information; water use histories for commercial, agricultural, and residential users; and social equity concerns shared by some of the stakeholders. A great deal of the integration work occurred in facilitated sessions with the Drought Advisory Committee, which worked collaboratively with project and agency staff members prior to presentations in the public workshops with the elected officials. Although initially the group had significant differences, participants stuck with the process and were vocal in their support at the end.

The close attention to detail, which was time-consuming, led to enhanced public confidence and buy-in. Compared with the other interest-based negotiation currently ongoing in the same geographical area with the same elected officials, the time dedicated to working with an advisory committee and public involvement was well spent. The end result is El Dorado County is better prepared for the next inevitable drought and will be able to serve the public with assurance that their expectations and concerns were valued and integrated into the agencies' business operations.

There was careful consideration in making sure the various committees and groups that worked together on this project reflected the diversity of interests, tapped into the wealth of informed members and resources available, and included people who could serve as "liaisons" with both supporters and critics who were interested in the outcomes. The Drought Advisory Committee was composed of representatives of many if not all of the stakeholder groups. The experts noted previously gave presentations at each of the workshops, served as facilitators and assisted the group in identifying the problems, potential solutions, and priorities for actions. The host of experts also provided depth and different perspectives to illustrate that there may be alternative ways to approach and solve resource management problems. Sometimes the technical and expert participants represented their technical area of expertise, other times they served as facilitators and small group leaders to ensure the various stakeholder comments were voiced and understood. The people who participated in the virtual drought simulations included the stakeholder members of the Drought Advisory Committee, elected officials from El Dorado Irrigation District, the County Board of Supervisors, the County Water Agency, Grizzly Flats Community Service District, Georgetown Divide Water District, staff from each of the agencies, and the drought/model experts.

Implementation

Recent work with El Dorado Irrigation District on this project has included a very successful drought model training and update session. This effort included:

- Phase III model training session notes
- Updated Drought Status Supply Remaining Index (SRI) model
- Model reference guide
- Updated SVM
- Video passed along by the U.S. Army Corps of Engineers (Water08) based on a Western Governors' Association report regarding water needs and strategies for a sustainable future

The training effort included some specific tasks regarding use of the model. By getting everyone up to speed through training, participants saw how they could contribute data and how they could use and apply the data in the model, which expanded the detail and clarity of the data. In addition, the training effort addressed how to update the model and develop new triggers, and provided the following:

- A commentary to guide how to incorporate snowpack updates based on the state's Department of Water Resources inputs
- Ways to incorporate elected board decisions, such as drought declarations, to reflect the political environment
- Revisions to annual ditch water (the amount of water available to be released into the ditches that year, based on the runoff in the streams)
- Integration of recycled water supplies

Beyond the model updates, Brown and Caldwell continues to provide on-call support as the utility staff proceeds in using the model, making updates, and discovering new applications. Participants and implementers, both elected and staff, have come to see the model and dashboard depiction as a "living" tool, and are continuing to work together as needed to update and implement it for effective, informed decision making.

Conclusion

The SVM process was instrumental in bringing together many perspectives in a way that allowed participants to understand how the system worked and then find workable approaches. Having a neutral facilitator in each modeling session was important to ensure that all viewpoints were voiced and considered. Having both general session and individual interviews with participants was helpful in revealing different kinds of information, concerns, and attitudes that ultimately helped reach a strongly-supported agreement. Having an "outside, non-aligned" team of experts able to function well with local experts was key. It was also important to have the whole team and the ultimate decision makers at the same meetings periodically; this

enabled briefings to inform elected officials, where an individual view or presentation might come from a certain perspective, to be tempered by the balancing views of the group. The process required patience and much communication—even to the point, perhaps, of what some might consider over-communication. However, this patience and communication paid off, with the ultimate result being an outcome with great support, as reflected in unsolicited testimonials.

Chapter 9

CADRe in an Evolving Planning Environment – Rio Grande, New Mexico

by Vincent Tidwell, Howard Passell, and Jesse Roach

Abstract

Computer-assisted dispute resolution (CADRe) is a process whereby stakeholders are engaged in the conceptualization, specification, and synthesis of knowledge and experience into useable information (i.e., model) for the express purpose of addressing a complex problem. Rather than re-birthing the CADRe process with every emerging planning problem, a culture should be cultivated in which one CADRe process spawns new processes that learn from and extend the work of the previous effort. Here we explore the adaptation of a CADRe process within an evolving planning environment for the Rio Grande located in north-central New Mexico. Specifically, we investigate changes to the collaborative process and modeling and the factors that induced the change as the planning process evolved from one of regional water planning to one of water operations planning. Our purpose here is to convey lessons learned in the context of an evolving CADRe process.

Introduction

The solution of environmental problems is no longer seen as the exclusive responsibility of government; rather, quasi-governmental organizations, the business community, civic organizations, and citizens are demanding a greater voice in resource planning (e.g., Driessen and Glasbergen 2002). Emergent forms of direct participation (e.g., interactive governance) by interested citizens and other stakeholders in processes of collective decision making are reducing the distance between government and their citizenry. The value of collaboration, whereby various stakeholders work with policy makers to address a particular issue, has been well documented (Spash 2001; Claussen 2001; Susskind, Jain, and Martyniuk 2001; Connick and Innes 2003). Such collaboration has increasingly included model building to inform the decision process. In fact, the use of models in open decision-making processes is not a new concept, as there are case studies dating back to at least 1961 (Rouwette, Vennix, and Mullekom 2002). Although known by a variety of names, the process of computer-assisted dispute resolution (CADRe) is one of engaging stakeholders in the conceptualization, specification, and synthesis of knowledge and experience into useable information (i.e., a numerical computer model) for the express purpose of addressing a complex problem.

Rather than treating environmental planning as a one-off process with each emerging issue, a more sustainable model might consider a basin-wide culture where one CADRe process spawns new processes that learn from and extend the work of the

previous effort. In this way, the relationships, group learning, social networks, and collective voice developed in each successive CADRe process are woven into the fabric of the planning community. Thus, an important aspect of CADRe is the establishment of a flexible and adaptable process so as not to die once a particular project comes to an end, but rather to respond to evolving planning demands within a basin or watershed.

Here we track the adaptation of a CADRe process within an evolving planning environment. The setting for our study is a reach of the Rio Grande located in north-central New Mexico. In this case study we explore changes to both the collaborative process and the model necessitated by the transition from one planning project to the next. Our story begins with a collaborative modeling process designed to support regional water planning that was part of a broader state-wide endeavor. Aspects of the planning model and collaborative modeling process were later adopted by federal/state water managers to aid in water operations decisions as well as to prepare for future water planning exercises.

This chapter is organized according to two broad water planning efforts: regional water planning and water operations planning. Within each section we describe the planning drivers, collaborative process, model, and results of the planning effort. We end the chapter with a discussion of key lessons learned toward adaptation of a CADRe process in an evolving planning environment.

CADRe Applied to Regional Water Planning

Planning Driver

A statewide water planning process was initiated in New Mexico in the mid-1990s in response to mounting concern over water issues. The New Mexico Interstate Stream Commission (ISC) divided the state into 16 planning regions, and each was tasked with defining its water supply and demand, and preparing a 50-year water plan that would balance the two. The planning process in each region

Figure 19: Rio Grande Basin in northern New Mexico. Shown are key tributaries, gages, and reservoirs.

was structured around a partnership between local governments and volunteer organizations. In the Middle Rio Grande (MRG) Planning Region (Figure 19) this partnership principally existed between the Mid Region Council of Governments (MRCOG) and the MRG Water Assembly (MRGWA) and other stakeholders. The MRGWA, established by volunteers drawn from the MRG Planning Region, grew to include water scientists and managers, academics, lawyers, economists, real estate developers, agriculturalists, environmentalists, business people, and others. To accommodate the broad range of views, the MRGWA organized itself around five constituency groups focused on agriculture, environment, urban development, water management, and special technical issues.

The MRGWA began a methodical, rigorous, and often contentious effort to define the terms of water supply and demand for the region, citizens' preferences for water uses, and publicly-supported water conservation measures. Progress was achieved through regular meetings of the Water Assembly, punctuated with public meetings aimed at gauging public concerns and providing updates on project progress.

Model Development Process

It became clear as the planning project grew in complexity that a model could assist in the planning process. A modeling project was initiated to: 1) provide a quantitative basis for comparing alternative water conservation strategies in terms of water savings and cost; 2) help the public understand the complexity inherent to the regional water system; and 3) engage the public in the decision process. Construction of the model began in January 2002 and working versions of the model were released and applied to the regional planning process in spring and summer of 2003. In efforts to build acceptance and confidence in the planning model, a community-based, participatory process was adopted. Model development involved direct collaboration between Sandia National Laboratories (SNL), the MRGWA, the MRCOG, and the Utton Transboundary Resources Center of the University of New Mexico School of Law (Figure 20). SNL was responsible for model formulation and implementation within a system dynamics framework. The MRGWA was responsible for system conceptualization, identifying sources of subject expertise and data, model review, and most importantly, representing the views of the public and key constituency groups (team members had expert knowledge through direct engagement, e.g., farming or land development, and in many cases served on boards/action groups that collectively represented the views of a particular interest). The MRCOG represented the interests of the local governments that have ultimate responsibility for implementing the plan, while the Utton Center provided expertise in group facilitation.

Individuals from each institution were organized into a "Collaborative Modeling Team" (CMT); specifically, two modelers from SNL, one facilitator from the Utton Center, one MRCOG representative, and 10 participants from the various constituency groups composing the MRGWA. The team met roughly every other week throughout 2002 and early 2003 to develop the model. Starting in spring 2003, after

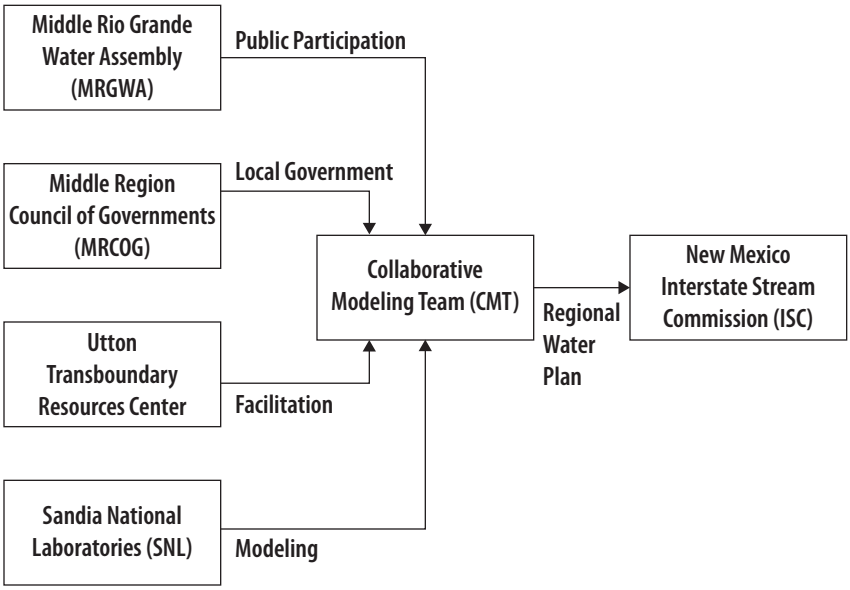


Figure 20: Schematic depicting the relations between collaborating entities participating in the regional water planning for the Middle Rio Grande.

the bulk of the modeling work was completed, the CMT began meeting monthly to review and update the model and to monitor use of the model in the planning process.

The model development process benefited from extensive contact not only with members of the CMT but also with professionals and scientists from regional, state, and federal agencies, including formal reviews. Public feedback was gathered in public meetings in which draft versions of the model were previewed, and in outreach activities targeting such venues as public meetings, water forums, children's water fairs, state and county fairs, civic and professional groups, and various schools and universities.

Decision Support Model

The developed model is structured according to a dynamic water budget within a system dynamics architecture (Passell et al. 2003; Tidwell et al. 2004). The spatial extent of the model is defined by the boundaries of Bernalillo, Sandoval, and Valencia counties. The various water supply, demand, and conservation terms are generally aggregated over the three-county region; however, in some instances features outside the planning region were simulated to accomplish required calculations (e.g., Elephant Butte Reservoir downstream of the three-county region). Temporally, the model operates on an annual time step encompassing the period 1960–2050. This includes a 39year calibration period (1960–1998) and a 52-year planning horizon (1999–2050).

Basic model elements include surface water and groundwater supplies balanced against municipal, agricultural, evaporative, and riparian demand. Specifically, the surface water system is composed of the Rio Grande and three area reservoirs. Inflows include the main stem of the Rio Grande, tributary flows, interbasin transfers from the Colorado River (each of which is subject to drought) and wastewater returns. Losses from the surface water system include evaporation from the river and reservoirs, agricultural consumption, transpiration from the riparian corridor along the Rio Grande, and pumping-induced river leakage. Groundwater inflows include mountain-front recharge, interbasin flows, and river leakage, while withdrawals include groundwater pumping and discharge to the river/shallow aquifer system. Municipal demand is driven by population growth and per capita demand disaggregated by residential, commercial, industrial, and institutional uses. Evaporative losses are a function of climatic conditions and reservoir surface area, while transpiration losses depend on the climate, acreage and vegetation type.

Also built into the model were 24 of 42 different water management strategies that the public suggested through community meetings held as part of the planning effort. The alternatives included in the model were those most conducive to modeling, subject to the resources available for this project. The model allows users to simulate many of the most important large-scale, long-term hydrological, ecological, and economic consequences of various water resource management alternatives (see Table 2).

The model operates on a personal computer and takes less than 10 seconds to complete a simulation. The model interface was designed to be user-friendly and accessible to a wide range of users. It was developed collaboratively and iteratively within the CMT. The interface spans approximately 80 computerized pages that include pictures, explanatory text, 66 slider bars and buttons for programming water resource alternatives in the region, and graphs and tables for describing model simulation output (Figure 21). The slider bars and buttons allow users to simulate different management strategies. Performance measures reported by the model include the Rio Grande Compact balance (key legal institution for the basin), groundwater depletions, water savings, and costs (construction, operation and maintenance).

Planning Outcome

In the spring of 2003 the MRGWA began the process of balancing the water budget by drafting a series of five "scenarios," or water plans. The model described in this paper was an integral part of this scenario-development process. Each scenario was developed from the point of view of the various constituency groups. These scenarios integrated various combinations of 42 water conservation alternatives identified by the public in early phases of the planning process. About half of these alternatives were quantifiable, and included such measures as low-flow appliance conversion programs, xeriscaping, elimination of exotic phreatophytes from the riparian forest, and changes to agricultural use and reservoir operations. The other half were

Table 2: Selected button and slider bar settings for the preferred scenario[1]

Category	Action	Setting
Residential	Conversion of existing homes to low flow appliances	80%
	Low flow appliances installed in all new homes	yes
	Conversion of existing homes to xeriscaping	30%
	Xeriscaping for all new homes	yes
	Reduction in size of irrigated yards in new homes	40%
	Reduction in consumptino by xeriscaping	50%
	Conversion of existing homes to water harvesting	25%
	Roof top harvesting in all new homes	yes
	Conversion of existing homes to on-site gray water use	5%
	On-site gray water use for all new homes	yes
Non-Residential	Conversion of existing properties to low appliances	80%
	Low flow appliances in new construction	yes
	Conversion of existing properties to xeriscaping	30%
	Xeriscaping for all new construction	yes
	Reduction in landscaping for new construction	5%
	Reduction in future per capita growth rate for parks and golf courses	80%
San Juan–Chama Bosque Ariculture	Annual average delivery, from total contracted amount of 76,000 af	60,000 af
	Remove non-native phreatophytes from all public bosque acreage	yes
	Miles of lined public conveyances, from a total of 750 miles	150 miles
	Laser leveling of farmland, from a total of 50,000 acres	25,000 acres
	Installation of drip irrigation	2,500 acres
	Change crop type distribution	no
	Reduce agricultural acreage	no
Reservoirs	Increase storage capacity in Abiquiu Reservoir	yes
	Maximize upstream storage/minimize Elephant Butte Reservoir storage	yes
	Minimum Elephant Butte Reservoir storage volume	40,000 af
	Build a new northern reservoir	no
	Implement artificial recharge	yes
Desalination	Desired quantity of desalinated water	22,000 af
	Water source	Turlarosa
	Year desalinated water becomes available	2010

[1] Table does not include all options available in the model

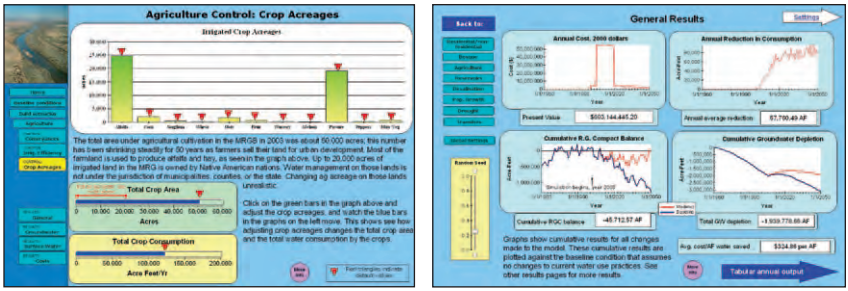


Figure 21: Example interface pages for the MRG regional water planning model. Left-hand page controls acreage and crop type in planning region, while right-hand page displays the resulting impact on the performance measures.

less amenable to quantification, and included such measures as expanding public awareness campaigns, centralization of regional water management authority, coordination of regional planning, and adjudication of water rights. During the summer and fall of 2003 the MRGWA worked closely with the MRCOG to combine the individual scenarios into a single "preferred scenario." This process strove to identify and preserve key framework elements from each of the constituency plans, while equitably distributing the responsibility for balancing the water budget (e.g., between city conservation and improved irrigation efficiency). Ultimately the preferred scenario became the basis for the water plan submitted by the MRGWA and the MRGCOG to the ISC later in 2003, and which was accepted by the ISC in 2004 (Middle Rio Grande Water Assembly 2004).

Three studies of the modeling process followed. In the first two, the authors document results from post-project interviews designed to identify strengths and weaknesses of collaborative modeling, to determine if and how the model facilitated the planning process, and to solicit advice for others considering model-aided planning (Cockerill, Tidwell, and Passell 2005, 2006). Interviews with CMT members revealed that collaborative modeling did indeed facilitate the water planning process, especially by helping stakeholders better understand the complexities associated with water and related systems. Interviewees suggested that other groups wishing to use collaborative modeling approaches try to reach consensus on a guiding vision or philosophy for their project early in the project, and that they acknowledge early on that collaborative modeling will be time-intensive. The authors also note that using collaborative modeling as a tool to build bridges between science and the public requires consistent and ongoing dialogue between technical experts and stakeholders about both the collaborative modeling process and the models that are produced.

In the third study, the authors compare the project described in this paper with three others and document some of the "lessons learned" from the experiences (Cockerill et al. 2007). Two of these projects were largely academic and team

members were all professionals who agreed to work together to build a model. The other two teams were convened to contribute to water management processes. One of these emanated from a regional planning exercise and the team included professionals and volunteers from the public. The final project team presented included professionals, members of the public, and government agency personnel. Like any multidisciplinary effort, the teams encountered communication challenges. The overarching lessons derived from these efforts are that teams can never pay too much attention to group dynamics, and that the proximity to a "real" management decision and involvement by real decision makers (as opposed to those with a more academic interest) does have its influences, for better or worse, in the collaborative modeling process. Recommendations from this study to others embarking on a collaborative modeling effort included reviewing the literature regarding previous projects, establishing clear guidelines for team interaction early in the project, and remaining flexible so that the project can evolve.

At the very close of the project an unexpected lesson was learned. Tensions flared over perceived ownership of the jointly developed model. By the rules of the institution in which the modelers worked, a copyright was necessary to allow broad distribution of the model, and authorship for copyright purposes was limited to those who were physically engaged in the coding of the model. Thus, the copyright was granted solely to the modeling institution, and this created the tension. Although full use rights were granted to all participating institutions, this issue challenged the trust developed over the course of the project. Understanding and communicating the nuances of the copyrighting process early in the CADRe process would have helped alleviate much of this trouble. This problem underlines the importance of addressing potentially divisive issues early in the professional relationship, even when those divisive issues have not yet arisen–much like pre-nuptial agreements can be important in other kinds of relationships.

CADRe Applied to Water Operations Planning

Planning Driver

As discussed in the previous section, the annual time step, spatially lumped model of the Middle Rio Grande served a specific role as a foundation for stakeholder dialogue, learning, and decision making in support of regional water planning. A secondary outcome of this initial effort was a demonstration to the wider water management community of the power of the CADRe approach and the systems-level analysis employed therein. Due to limited resources and the nature of the first model-building effort, the temporal and spatial resolution of the first model were fairly coarse. As the technical community in the basin became aware of the model-building process and model results, an interest in a more focused CADRe effort was born. Certain systems-level insights developed with the annual time-step, spatially-lumped model called for a more detailed analysis. In particular, the relations among population growth, conservation practices, reservoir storage, and

compact compliance when evaluated in a single model yielded system behavior that was initially unintuitive (such as water conservation hurting compact compliance) but when realized was completely logical. The next step in the evolution of the CADRe water planning effort was the formulation of a more spatially- and temporally-detailed model, developed under the guidance of a more technical group of stakeholders, namely the Upper Rio Grande Water Operations Model (URGWOM) technical team.

In 1996, many of the major public agencies associated with management of the Rio Grande in New Mexico, including the U.S. Army Corps of Engineers, the U.S. Geological Survey, the U.S. Bureau of Reclamation, and the New Mexico Interstate Stream Commission (ISC) signed a memorandum of understanding to embark on a collaborative surface water model building effort. This process led to the development of URGWOM, a daily time-step surface water routing and operations model built in RiverWare (U.S. Army Corps of Engineers et al. 2002). URGWOM is the state-of-the-art operations model for the Upper Rio Grande in New Mexico; however, due to its complexity and focus, it is not well suited to longer-term systems-evel analysis of dynamically changing human demand, groundwater, and surface water systems, nor is it well suited for public outreach. The next phase in the evolving CADRe approach was designed to develop a rapid scenario and stakeholder outreach tool with the URGWOM agencies and technical team as the principal stakeholders in this step.

Model Development Process

Beginning in 2005, modelers from SNL established a collaborative modeling team and CADRe process with members of the URGWOM technical team. In regular meetings (monthly meetings over a roughly eight-month period), the role of a systems-level model that could incorporate real-time analysis of dynamically changing groundwater, human demand, and surface water systems while still capturing the salient behavior of URGWOM was discussed. The stakeholders were introduced to the software used to develop the systems-level model and pieces of the model underwent systematic technical evaluation. The most important analysis for the stakeholders was direct comparisons of systems-level model behavior to that of the more temporally detailed URGWOM model. The outcome of this process is a screening and public outreach model that is trusted by the technical water management community in the Upper Rio Grande Basin that is complementary with the higher-resolution URGWOM model.

Decision Support Model

The model developed in this second phase was built in the commercial software package, Powersim Studio 2007, and operates at a monthly time step ("monthly model"). The monthly model calibration period is 1975-1999, which is the same as for the URGWOM model. The model validation period is 2000-2004, followed by a scenario period from 2005 forward. Typically, runs of 40 to 100 years are considered.

The spatial extent and resolution of the surface water portion of the model is almost identical to URGWOM for the surface water system. Specifically, there are 17 reaches describing flow in the Rio Grande, Rio Chama, and Jemez Rivers in New Mexico north of Caballo Reservoir. The reaches are defined by USGS stream gage locations. In addition to the river reaches, mass balance is also calculated in seven reservoirs: Heron, El Vado, Abiquiu, Cochiti, Jemez, Elephant Butte, and Caballo. Unlike URGWOM, which is primarily a surface water routing and operations model, the monthly model includes a modeled groundwater system that is regional in extent. The modeled groundwater area includes spatially distributed models of the Espanola, Albuquerque, and San Acacia groundwater basins based on more spatially resolved MODFLOW (McDonald and Harbaugh 1988) groundwater models (Frenzel 1995; McAda and Barroll 2002; Shafike 2005). These basins underlie and communicate with the Rio Grande surface system from the confluence of the Rio Grande and Rio Chama to Elephant Butte reservoir. The spatial extent of the surface and groundwater components of the monthly model is shown in Figure 19. In addition to the surface and groundwater components, the model also tracks agricultural use, and human populations and municipal and industrial indoor and outdoor water demands in major cities and in lumped rural areas. The model does not include a rainfall runoff component, so major inputs to the model from the supply side are gaged inflows at headwater and tributary locations. On the demand side, climate data, reservoir storage, agricultural area, and riparian vegetation area are used to calculate evaporative demand, which dominates model demands. Municipal and industrial demands are driven by population levels and per capita usage all of which are user inputs to the model. A more comprehensive description of the model can be found in Roach (2007).

Planning Outcome

The monthly model of the Rio Grande hydrologic system in New Mexico described above has been used to screen thousands of potential climate sequences in order to generate probability distributions of future system behavior. Results suggest a future with significantly less water in storage in reservoirs than has been seen in the recent past, a finding with ramifications for water management planning in the basin. This analysis was also used to select a limited number of 10-year sequences as representative for detailed analysis with the URGWOM model, thus providing a probabilistic context for water operations planning in New Mexico. Currently, attempts are being made to combine hydrologic understanding of the type provided by the monthly model, with models of endangered species population dynamics to assess implications for water management in the basin. The monthly model has not yet been called upon to facilitate public outreach and education, but that is a role that it has been designed to play, and it will be an important tool in any such future efforts undertaken by URGWOM.

Significant planning challenges lie ahead for the Rio Grande basin in New Mexico. The surface and groundwater resources of the basin are challenged to support endangered species, traditional agricultural uses, and growing human populations in the face of normal variability that may be exacerbated by changing climate

conditions. In addition to the realities of supply and demand, the legal institutions set up to handle these conflicts are nascent. A formal adjudication of the basin in order to legally define water rights has yet to occur. Potential for conflict is rife, yet in the midst of this classic resource management problem, a tool developed with the CADRe approach is poised to assist in charting a path forward.

Discussion and Conclusion

From the aforementioned projects several insights and lessons learned were gleaned. Many of these lessons are documented in the papers cited above. Our intent here is to highlight the lessons learned that pertain directly to the evolution of the CADRe process from one aimed at regional water planning to one focused on water operations.

One lesson learned and which is still unfolding, involves the dynamics that gave rise to the distinctly different participant compositions for the two collaborative modeling teams. Regional water planning was an issue of particular public concern, hence the regional water planning effort benefitted from heavy participation by the lay public, while by design lacked involvement of state or federal water managers/planners Alternatively, as daily water operations are the responsibility of state and federal water managers, they were the obvious stakeholders for our second project. However, involving the public in this effort would have been next to impossible given the lack of a contested planning driver. In this way the degree of public awareness and concern goes a long way to defining public participation, while project funding often defines the level of agency participation.

This participation dynamic makes it difficult to create generic planning models, in preparation for future challenges. We can only wait and see if stakeholders and the public outside the URGWOM technical team are willing to adopt the developed model in future planning exercises. In a perfect world, a collaborative modeling team would be developed that includes a permanent set of core participants (cross-project participation) as well as project-specific participants. Establishing such a team is problematic, as demonstrated here, due to the considerable time commitment required from the volunteer public.

An important consideration early in any collaborative program is who will "own" the developed model at the end of a given project. Complications are exaggerated when these tools are adopted by subsequent projects. At the beginning of any project it is important to explore potential copyright constraints across the participating institutions and agencies. Transparency and open communication is necessary to define expectations relative to ownership, use, and access to the developed models, while also protecting the team and planning process from the model being used in ways that might undermine the efforts of the collaborative planning process. Such planning should also include provisions for how the model might be used in the future by an "evolving" CADRe effort.

From the cases cited above, as well as other related CADRe efforts, we have found a real preference in the way a collaboratively developed model is exercised. Specifically, exercising of the model is predominately accomplished in the context of meetings with the lead modeler operating the tool. It was very unusual for anyone outside the CMT to operate the model to test scenarios on their own. CMT members were also hesitant to begin working off-line with the model; only after seeing the model in operation numerous times (usually requiring workshops aimed at teaching members how to use the model) do they feel confident enough to play with the model alone. These findings are important as to how one might engineer a model interface and likewise plan to make it available to the public. These findings in no way undermine the utility of models as a means of outreach to the community and a means of grounding planning in good science. Rather, the results tend to suggest this is generally best achieved through workshops, as opposed to off-line personal analysis.

Evolution of the models, collaborative networks, and trust achieved in a CADRe process is necessary to maintain relevancy with the planning community. Without active maintenance the path of natural progression is one of marginalization and eventual death of the CADRe process. Alternatively, a CADRe process that learns, adapts, and evolves is better equipped to meet the next resource planning/management challenge. Specifically, each evolving CADRe process builds on the growing stock of intellectual capital available for tackling progressively complex and contentious issues.

Acknowledgements

We sincerely thank participants from the Middle Rio Grande Water Assembly and the URGWOM technical team for without their contribution there would be no collaborative modeling. Support for this effort came from the New Mexico Small Business Assistance Program, Sandia Campus Executive Laboratory Research and Development program, and Senator Pete Domenici. Sandia is a multi-program laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.

Chapter 10

Bringing CADRe to Contemporary Water Policy – Some Challenges

by Kurt Stephenson and Leonard Shabman[1]

The premise of this emerging field is that the integration of a collaborative process with computer-based models offers new opportunities to build mutual knowledge and effectively manage water resources disputes. This chapter highlights some of the challenges in making CADRe effective within contemporary water resources planning and decision making, with some themes explored further in subsequent chapters. The rich literature on managing environmental disputes emphasizes ways to design collaborative processes to assure representation, honest communication and consensus building (Raiffa 1982; Fisher and Ury 1983; Lewicki and Litterer 1985; Bingham 1986; Ozawa 1991; Field et al. 1996; Ayres et al. 1996; National Research Council 1996; Susskind, McKearnan, and Thomas-Larmer 1999; Wondolleck and Yaffee 2000; O'Leary and Bingham 2003; Office of Management and Budget and Council on Environmental Quality 2005; Federal Interagency Alternative Dispute Resolution Working Group Sections 2007; Council on Environmental Quality 2007; National Research Council 2008). This chapter emphasizes its authors' own observations and commentary on the challenges of employing CADRe processes, including resistance from possible decision participants, barriers embedded in the structure of specific regulatory and decision processes, and opposition at a conceptual level on the appropriate role of analysis and expertise in collective decision making. Recognizing these challenges will enable better choices about when to undertake CADRe processes and when conditions may not be ripe, allow reflection on opportunities for lessening concerns, and highlight adjustments that may improve chances for success within a CADRe process.

The Contemporary Structure of Water Resource Decision Making

Agencies of governments have responsibilities to make decisions on specific issues within their authority. Often these agencies have constituencies that work with, and support, their responsibilities. Several challenges to the use of CADRe arise when there are multiple agencies in a CADRe process that are expected to share decision-making authority.

Conflicting Roles and Responsibilities

One challenge is to establish the relationship between the decisions made in a CADRe process and the agencies' own decision-making responsibilities. CADRe processes are based on the premise that decision participants will be provided real responsibilities and influence in reaching a decision on a particular water resource

1 Senior authorship shared equally.

issue. Yet, agencies may be reluctant to sanction or participate in a CADRe because of a perception that they are ceding their delegated responsibilities for decision making to a process they cannot control. Such participation may also be seen or interpreted as a specific endorsement of any subsequent collaborative decision.

Such challenges can be addressed. Agencies may sanction a CADRe-like process with an understanding that any decision collectively agreed upon by stakeholders will be supported subject to predefined conditions. For example, in the late 1980s and 1990s, the Federal Energy Regulatory Commission (FERC) faced an increasingly costly and time-consuming process for relicensing non-federal hydropower dams. In a series of reforms beginning in the 1990s, the FERC instituted a new licensing process (called the "alternative" and "integrated" licensing processes) that placed greater burden and responsibility on the hydropower operator to work with other stakeholders to produce studies, dam operating alternatives, and a proposal for an operational license (Swiger and Grant 2004). The underlying presumption is that if the licensee produces a proposed license that is acceptable to the multiple interests involved, the FERC will accept these conditions in the new operating license. The alternative/integrated licensing processes yield recommendations that the FERC commissioners can review, endorse, and then implement, while still exercising the congressionally-mandated mission contained in the FERC organic legislation.

Regulatory agency involvement can also create a series of process challenges. Agencies reluctant to cede some control over the collaborative process may insist on assuming primary responsibility for conducting the technical analysis or facilitating the collaborative negotiation. Such direct involvement may create distrust among particular participants in the CADRe process and may even discourage any participation. Regulatory agencies may find it difficult to maintain perceived neutrality in the negotiations. Agency involvement may also entail strong preferences to use specific models or requirements to perform specific analyses not wanted or deemed counterproductive by some parties. If agency leadership and direct management of the negotiation process diminish stakeholder participation, limit development of credible models, and limit development of alternatives, the benefits of CADRe processes are greatly diminished.

Also, in contemporary water resource decision making there are often multiple decision points and regulatory layers of approval. These multiple decision points compound the challenges described above. One agency may wish to take the lead in promoting the collaborative model or encouraging the integration and negotiation process, prompting other agencies to step back from participating in or supporting such a process. For example, a municipal water utility might want to initiate a CADRe process for securing a permit for a water supply reservoir, but the regulatory authorities who will need to judge the adequacy of the permit application by their own criteria may want to remain outside the CADRe process. Thus, if multiple agencies are among the disputing parties, then an outside entity may need to be the convener, facilitator, and financial supporter of a CADRe process.

Narrow and Conflicting Decision Rules

Another challenge is to find the legal and organizational flexibility to engage in the integrative bargaining process envisioned by CADRe. Today numerous separate agencies (or parts of agencies) are asked to make decisions based on a "bright line decision rule"—a statute or regulation that sets an explicit standard dividing what is an acceptable alternative from what is not. These might be called agencies in the regulatory tradition—for example, the Environmental Protection Agency in its implementation of various environmental laws such as the Clean Air Act, or that portion of the Corps of Engineers issuing permits under Section 404 of the Clean Water Act. Other agencies (or parts of agencies) have missions guided more by general principles or frameworks than bright-line decision rules and build on a resource management tradition of making choices and trade-offs. Agencies in this resources management tradition include the Bureau of Reclamation in its implementation of water development, the Federal Energy Regulatory Commission's regulatory and permitting program for hydroelectric power generation under the Federal Power Act, or the portion of the Corps of Engineers pursuing water development programs under multiple authorities (Hayes 1998).

Agencies with narrower regulatory responsibilities and bright-line decision rules may be more limited in their ability to participate in a CADRe-like process based on satisfaction of competing stakeholders' values and interests and on securing agreement as opposed to meeting legislative or regulatory requirements (Maguire 2003). Consider, for example, strict adherence to the "avoid and minimize" regulatory language under the Corps and EPA fill permitting program under Section 404 of the Clean Water Act. Imagine a permit applicant has two reservoir options. The first option is expensive to construct, adversely impacts downstream fisheries, and results in 20 acres of wetland fill. A second, less-costly option can enhance downstream fisheries through low-flow augmentation, but results in 30 acres of wetland fills. Strict adherence to single objective of minimizing wetland losses could downplay the incorporation and consideration of fisheries impacts or preclude the possible acceptance of the second, less-costly alternative.

This narrowing of choice is compounded if multiple agencies are involved, and each has a single requirement to be met. It is also compounded when agencies expect to use their own analytic procedures to evaluate how any water management alternative might or might not meet its responsibilities; agencies may carry their own particular analytical, reporting, and decision-making rules that follow from the original legislation governing the program and its subsequent interpretation by administrative rules and court rulings. In these cases, agencies and their supporting constituency groups may enter into a negotiation with a necessarily constrained—or possibly even predetermined—position. If an agency enters a negotiation with a fixed position based on authorizing law, its own analysis, and constituency support, opportunities for negotiations will be more limited.

In short, the narrower the focus of an agency's legislation—particularly if an agency is governed by bright-line decision rules—and the more such agencies involved, the smaller the potential decision space for negotiation among stakeholders. While such situations do not preclude a CADRe process, they can make it more difficult or more constrained. Such situations should be identified up-front and considered in determining whether, and if so how, a CADRe process will proceed.

Resistance from Decision Participants

In addition to the structure of contemporary decision making and organizational challenges, implementing CADRe-like processes requires the support of and commitment by the participants themselves. Decision participants include not only agency staff, but also the corresponding technical modelers, scientific experts, and interest-group leaders who support and participate in the decision-making process. The attitudes, incentives, and beliefs of these participants can, and do, present real challenges to successful implementation of CADRe processes.

Disincentives for Participation

CADRe requires an up-front investment in time, money, and personnel to develop collaborative models and discuss/negotiate alternatives. An often-heard comment in discussions of the concept is that CADRe processes can shorten the time to reach a decision, but increase the time to develop the analytical models and output necessary to make a decision. There appears to be some support for that general observation. For example, the traditional FERC hydropower licensing process relied heavily on the owner of the hydropower facility (the licensee) to develop the technical analysis for the relicense application and FERC staff to decide over contested conditions. The recent licensing reforms emphasized joint study determination and more structured negotiations over license conditions between the licensee, resource agencies, and interested stakeholders, all increasing up-front investments in the licensing process. Such reforms have lengthened the time for the licensee to prepare a license application, but shortened the process of obtaining a license (Federal Energy Regulatory Commission 2001).

However, another possibility is that CADRe will increase the up-front costs *and* extend the time for a decision to be made. By front-loading the decision process, the risk of failure may increase for parties bearing the cost of the collaboratively-supported technical models and negotiations (the up-front costs are immediate and certain, but the promised payoff is not). Unless there is some way to establish reasonable expectations for how a final outcome or end to the process will occur (for example, establishing the primacy of particular decision makers that will support the CADRe process and results as in the case of the FERC processes) then the possibility that some entity will go outside the CADRe process and overturn its results means that CADRe may be viewed as nothing more than an added burden and source of delay.

Furthermore, CADRe processes are premised on development of jointly constructed models and technical analyses. This involves an upfront development and sharing of technical expertise. Some decision participants may not feel such a sharing of information and analyses is in their best interests, particularly if the decision-context is already highly charged and dispute-ridden (Werick and Palmer 2004).

The open-ended nature of the collaborative modeling process may also create disincentives for participation. As noted throughout this book, the advantages of CADRe processes, for example, allows decision participants to expand their search for alternatives and may offer a way out of costly trade-offs. For example, a theme of CADRe is taking a system (watershed) approach to problem solving. This system perspective is beneficial partly to identify more alternatives and increase the chance of identifying more mutually satisfactory alternatives. Yet, a regulated party may have reasonable fears that such an up-front and expansive examination of the issue may result in higher costs in order to secure the support of opposing stakeholders. For example, a municipality wishing to construct an off-stream water supply facility may also be asked to improve downstream water quality, provide recreational facilities, and enhance fish populations, in order to secure agreement with their plan from others.

Lack of Support for CADRe Modeling

CADRe processes obviously require technical modelers to work in support of the negotiation process. Challenges can arise in locating technical professionals able and willing to work within this specific setting. In many CADRe applications analysts/modelers are also mediators who have a mind set of expanding the gains from agreement to all parties and helping to analyze complex trade-offs in terms agreeable to participants. Professionals with modeling and mediation expertise are in a unique position to conduct successful CADRe processes, but the number of people with both skill sets is limited. In other situations, the analysts/modelers who contribute to the collaboration and the specialized mediators who manage the process are different people. In either case, for a successful collaboration effort, analysts' skills should include not only technical modeling expertise, but skills that enhance productive engagement in collaborative processes, including ability to probe assumptions, keep many threads of argument in hand, and to communicate effectively. These are learned skills, often acquired and refined only by practice and experience. As professional training becomes increasingly specialized, there may be a future challenge to train and expand the collection of professionals capable of conducting CADRe processes. Chapter 13 discusses the skills needed and the training and educational programs that might be necessary for effective leadership of CADRe processes.

Equally important, personnel with technical modeling expertise must be willing participants and supporters the CADRe approach. Expectations and professional training may create false expectations for the complexity and validation of technical models in CADRe processes. Models can take many forms, but whatever the form, models all begin with a conceptual representation of the multiple relationships

affecting one or more aspects of a water management decision (a conceptual model) and then proceed to mechanistic and/or empirical equations (a mathematical model), followed by measurements and/or scientific judgment to empiricize the mathematical model so that it can be solved for prediction and/or explanation. Models in CADRe are built on existing scientific understanding, but may simplify many relationships in order to be tractable and useful for policy and management decisions. Such models may not fully incorporate or reflect complex relationships and processes or utilize the state-of-the-science modeling techniques that are often the focus of one or more scientific disciplines. Within the modeling community, computer models designed to support collaborative negotiations for policy (management) decisions may not always (nor should) reflect state-of-the-art modeling capabilities (Korfmacher 1998; Reckow 1994). Indeed, in certain settings, many CADRe models may be, by design, simplified (low resolution) models intended to quickly link major system elements and demonstrate directional changes.

If technical and scientific participants in a CADRe process do not fully appreciate the different uses and roles of computer models for collaborative processes, then soliciting the cooperation and effective participation of technical modelers may be difficult. Of particular note, technical and scientific experts within agencies frequently have some decision-making responsibilities. These technical staff may not always understand or appreciate the modeling needs of the collaborative process. Furthermore, lack of technical analyst support may produce active criticism of the technical models developed in a CADRe process. For example, a recent review of the studies conducted to support a collaborative modeling process for lake levels on Lake Ontario (see Chapter 6) focused its criticisms on the technical sophistication of some of the technical models produced and downplayed the necessity of having models that were transparent and readily useful for the process (National Research Council 2008). Such sophistication may or may not be warranted, depending on the specific needs of the decision process and nature of the water resources system. While all collaborative models have internal and professional systems of model validation, outside criticism of the models may erode or undermine stakeholder confidence in using the models (Chapter 12 addresses considerations associated with peer reviews and model certifications in a collaborative modeling process).

Perceptions of Role of Scientific Authority and Expertise

Water resource decision making is often populated with people having specific and high-level technical and scientific training. These people might be biologists, chemists, economists, or engineers within the agencies, regulated parties, and non-governmental organizations. Perceived roles of these technical experts may, at times, work against support for CADRe processes.

Agency staff and scientific experts may be reluctant to participate in, or support, CADRe efforts because of perceptions that stakeholders (often non-technical stakeholders) are too uninformed or biased to reach the "right" decisions. CADRe

processes require that some decision-making authority be vested with the negotiating groups. CADRe processes also require involvement and participation at multiple levels of the decision process (including the technical analysis) and from multiple stakeholder groups. Scientists (within and supporting the agencies) may perceive that such participation would compromise the technical credibility of the analysis. A recent survey of scientists in the northwest United States found that scientists support public involvement in the form of review and comment but do not believe they should be "equal partners" in making natural resource decisions (Lach, Steele, and Shindler 2005).

Such disagreements have roots in deeply held differences about the role of science and the efficacy of interest group based negotiation in environmental policy. The participation of stakeholders with clear and narrow political or economic interests may be viewed as simply a "power struggle" between opposing interests. Some science or technical experts may view a collaborative process as diametrically opposed to the rational, objective decision making that "science" is purported to represent. Indeed, agency staff may perceive that disinterested scientific expertise produces better decisions than negotiations with self-interested stakeholder groups (Weible, Sabatier and Lubell 2004). Daniels and Walker (2001) sum up the challenge as follows:

> [T]he juxtaposition between technical competence and open process is a defining characteristic of American policy formulation.... Finding ways to increase the quality of technical expertise, while simultaneously increasing the inclusively the decision processes, is perhaps the fundamental challenge of effective policy formation. (page 4)

Discovering the Public Interest: Collaboration and Computation?

Finally, opposition or distrust of CADRe-like processes may be rooted in philosophical differences about the how the "public interest" can be represented in public choice processes. Skeptics of a collaborative process might ask the following questions:

- How do we know that all interests are served?
- Are certain groups under-represented in a negotiation process?
- How do we know that the potential net gains of different alternatives are exhausted or maximized?
- How do we know the preferences and desires of those not "at the negotiating table" are adequately or accurately reflected?

Critics of negotiation and collaboration often advocate for the use of "objective" analysis to estimate people's preferences for different water resource outcomes and then weigh them with a quantifiable decision rule. For example, benefit-cost analysis would require the maximization of net benefits. Such critics might also argue that water resource decisions must be supported by evidence that gains (net benefits) to

society are being maximized (national economic development) and that evidence must come from analysis to quantify preferences for different outcomes.

Stokey and Zeckhuser (1978) reflect the underlying belief that benefit-cost analysis can more comprehensively and completely reflect individual preferences than the negotiation processes when they write:

> One of the great virtues of the benefit-cost approach is that the interests of individuals who are poorly organized or less closely involved are counted. Even when pushed by powerful interest groups, projects whose benefits do not outweigh their costs will be shown to be undesirable. The benefits and costs accruing to all—to the highway builders, the environmentalists, the "little" people," the users and providers of services, the taxpaying public—will be counted on a dollar-for-dollar basis. Benefit-cost analysis is a methodology with which we pursue efficiency and which has the effect of limiting the vagaries of the political process (151).

Similar reservations and suspicions on the efficacy of representative democratic processes remain 30 years after these authors expressed this concern (Loomis 1997; Portney 2002).

As noted in previous chapters, the efficacy and operation of CADRe is based on a different set of behavioral and perhaps conceptual premises. Advocates of CADRe stress that people's preferences are revised, created, and discovered through collaborative learning and the process of choosing. Measuring the preferences of people distant or removed from the process through non-market valuation techniques sometimes used in benefit-cost analysis assumes informed and stable preferences. Yet, the act of participation in CADRe process is an expression of an active personal commitment and responsibility to discover and refine preferences and interests that is different than a passive opinion (Sagoff 1994). Analytical models cannot replace or replicate such attributes. Rather, collaborative models are constructed to facilitate and support negotiating participants in their process of choosing.

The collaborative environmental negotiation literature addresses many concerns expressed above. For example, procedures and formats can be implemented to ensure broad-based participation and negotiation guidelines developed to prevent cost-shifting to unrepresented parties. If such conditions hold, the premise is that if negotiation parties (presumably those impacted by the decision) agree on a particular alternative, then the mutual gains (benefits) of each consenting party must have been large enough to outweigh any costs. If this is the case, the larger public interest is also served.

This purpose of this discussion is not to resolve these tensions or defend the criticism that interest-based negotiations cannot, or may not, produce decisions that are in the public interest. Differences in opinion on the efficacy of collaborative approaches to water resource decision making are ultimately deeply rooted in

differences in beliefs in how people form and express preferences, the efficacy and operation of representative democratic processes in reflecting these preferences, and the ability and limits of analysts to know individually-held preferences (Shabman and Stephenson 2000). The purpose is simply to point out that some critics of CADRe may object to or criticize the concept on larger grounds than simply practical or pragmatic concerns (e.g., models are not sophisticated enough to adequately model the water resource system or there are too many organizational barriers to implementing CADRe in our current institutional situation).

Conclusions

CADRe processes do not pretend to eliminate disputes, but rather seek to create a setting in which disputes can more effectively be managed and perhaps mediated toward agreement on an alternative that if implemented would satisfy all the CADRe decision participants. Agreement is never assured but the prospects are increased if CADRe processes facilitate joint learning while also building social trust and understanding among participants in the process. In turn, this joint learning and social trust creates both the motivation and opportunity to discover alternatives that are more acceptable to a broader range of stakeholders.

Clearly, a successful CADRe process will require more than competent people to run the negotiations and construct the technical models. As this chapter argues, constructing and effectively using collaborative models demands a broad-based commitment to participate in a CADRe process. The lack of incentives to making such a commitment may be professional (lack of professional reward and recognition for technical modelers), financial (high costs, uncertain payoffs), organizational (limiting regulatory decision rules that remain outside the process and can veto the agreements made) and even philosophical (CADRe cannot represent the public interest). Recognition of incentives, or lack of incentives, for such committed participation should be recognized when a CADRe process is being considered. Such recognition may help to tailor the design of the process to address these challenges in order to provide the best possible chance of success. At a minimum, recognition of these potential challenges will help form realistic expectations of the opportunities for success during implementation.

Chapter 11

Differences in How Modelers and Facilitators Approach Computer-Aided Dispute Resolution

by James L. Creighton and Mark Lorie

By its very nature, computer-aided dispute resolution (CADRe) requires at least two different skill sets. First, it requires the skills of the modeler, who must possess the analytic skills needed to understand and portray how relevant pieces of the natural and man-made system fit together. Then it requires the facilitator, a person who knows how to help groups of people work together effectively to achieve agreements.

This chapter reports on an effort to determine if people with these two different skill sets approach CADRe differently. If so, what are those differences? What implications does this have for the field? What implications does this have for people entering the field?

The authors of this chapter represent the two different skill sets. Creighton is an experienced facilitator, while Lorie is an experienced modeler. Together they identified four senior modelers and four senior facilitators, all of them experienced with CADRe, and arranged to conduct in-depth interviews with each of them. Brief biographies of the people interviewed are provided at the end of this chapter.

The fact that the people being interviewed were all highly experienced with CADRe may have been an important determinant of the results. Each of the participants had either worked extensively with someone from the other discipline or had personally played both roles. Presumably some of the attributes of the other discipline had "rubbed off" on them, and, in fact, some of the modelers had become rather proficient as facilitators and the facilitators had become increasingly knowledgeable about modeling.

As a result, the interviewers observed greater variations between people within each class (i.e., within modelers, or within facilitators) than between classes. There were only subtle differences between the modelers' and the facilitators' descriptions of how they each approach CADRe. The interviewers observed that had they not known in advance which were modelers and which were facilitators they might have been unable to identify which they were based on the interviews.

The clear exception was when the questions focused on the interviewees' *perceptions* of each other's fields. Then the differences were clear. The modelers and facilitators we interviewed see clear attitudinal differences between the two fields. Those perceptions are described below.

Differences between Modelers and Facilitators

What is the primary purpose of a CADRe process? What are you trying to achieve?
Our first interview questions were designed to assess whether modelers and facilitators approach CADRe with the same or different goals.

The responses show that modelers' primary concern is for outcomes, particularly implementable decisions. All other factors, they believe, should be in support of identifying good solutions to the problem on which they are working.

Facilitators do not disagree on the need for implementable decisions. But that is only one of the dimensions on which they evaluate a process. They also place emphasis on process goals that support decision making, such as:

- Increasing the range of solutions people know about
- Building confidence in tools that can also be used in future decisions
- Building confidence/trust/relationships so that people can talk about the big problems
- Shared learning

As one interviewee expressed it: "Facilitators and engineers just value things differently—engineers value finding concrete answers, facilitators value effective process." This perhaps overstates the position of facilitators—they also want concrete answers—but they can see a process as having positive attributes even if full agreement is not reached.

Paraphrases of comments received during the interviews are shown in Table 3.

What are the strengths and weaknesses of modelers/facilitators? How prepared are modelers/facilitators to conduct CADRe processes? What additional skills do they need to acquire to be effective at CADRe?
The interviewees were asked a series of questions that were designed both to clarify differences between people in the two fields, but more importantly, to identify what additional training and skills are needed for people who want to work in the CADRe field, beyond their initial professional training. This goes directly to the issue of what kinds of people need to be recruited into the field, and what training/skills will they need.

Perhaps because the people interviewed had all worked extensively with people in the other field, modelers' perceptions of modelers were actually quite similar to facilitators' perceptions of modelers. People from both fields also had similar perceptions of facilitators' strengths and weaknesses.

Table 3: Comments regarding the purpose of CADRe

Here are paraphrased comments from the interviewees about the goals of CADRe:

Modeler	To improve outcomes of water management, make decisions that lead to more benefits
Modeler	To arrive at a solution that improves the current state and which is sustainable and implementable. Change the way water is managed.
Modeler	To identify and describe non-inferior solutions given stakeholder objectives and priorities
Modeler	Influence the long-term "social conversation" about a water management problem; "reduce friction" in that conversation; introduce new ideas that those in the middle of the conversation can't introduce for one reason or another.
Facilitator	To help people learn about solutions they may not have been aware of. Tactically, to make sure an interdisciplinary team can work together effectively, to make sure the disciplinary differences don't get in the way. Develop a tool that can be used for subsequent decisions.
Facilitator	Depends on situation, but usually the goal is to develop tools/information in which stakeholders have confidence, as a basis for decision making and management.
Facilitator	In one case, the goal was simply to get conflicting parties to talk and work together, to begin building relationships so they could eventually deal with the big problems. In general, CADRe may be the answer when neither modeling nor mediation alone will work. I remain very focused on outcomes for these processes. This is a positive thing I received from engineering training*.
Facilitator	Shared learning. Give people the tools to go through a planning process together, despite their different perspectives. Help people work together effectively so they can learn more about the technical and non-technical aspects of the problem.

* This individual received a degree in engineering before undergoing training to become a facilitator.

Strengths and Weaknesses of Modelers

Based on the comments from the interviews, both modelers and facilitators perceived the strengths of modelers as:

- Providing accurate and useful information
- Providing an understanding of the system (the natural resource system)
- Identifying alternatives that address problems/opportunities
- Helping with ranking/trade-off

On the other hand, both modelers and facilitators saw modelers as:

- Too introverted, not comfortable being "at the front of the room"
- Too data-focused, too concrete
- Not good listeners
- Failing to value "perceptions" as being important information
- Ignorant of politics and human behavior
- Uncomfortable with open-ended problems

The weaknesses of modelers were identified as often, and as forcefully, by the modelers as by the facilitators we interviewed. This was particularly clear when interviewees were asked "How prepared are modelers to conduct CADRe processes?" These comments are shown in Table 4.

The interviewees suggested that the skills modelers need to acquire if they want to be effective at conducting CADRe are:

- A willingness to engage in intellectual debate
- Asking appropriate questions
- Ability to help define the problem, particularly in a broader context
- Coping with perceptions/emotions
- Translating ideas between different disciplinary languages (e.g., between biologists, hydrologists, and economists) and translating technical language into terms understandable to the public
- Summarizing/listening/reframing skills
- Recognizing when other kinds of professionals are needed

Strengths and Weaknesses of Facilitators
Based on the interviews, facilitators are perceived by both modelers and facilitators as providing added value in the following areas:

- Ensuring that all potentially affected parties are involved
- Helping structure an effective decision making process
- Visualizing the incremental decisions that need to be made
- Identifying coalitions that need to be formed for implementable decisions

But they are also perceived as:

- Undervaluing technical knowledge—"they seem to think that being neutral means they can't be knowledgeable about the subject matter"
- Having insufficient knowledge about the technical subject to be a good translator of technical knowledge to the public
- Missing significant issues because they didn't understand their technical significance
- Sometimes using warm-up techniques that technical people see as silly and demeaning

According to the interviewees, facilitators need the following skills to be effective at facilitating CADRe processes:

- The ability to translate between different disciplines
- Reframing skills

Table 4: How prepared are modelers to conduct CADRe processes?	
Modeler	Engineering training* pre-selects for people who will do badly with CADRe. They're taught to reduce a real world problem to something that will work mathematically and they're taught to work alone; otherwise they're cheating. They don't learn to work collaboratively. Engineers are uncomfortable with intellectual debate. Any true intellectual will always engage in debate, always ask questions. It's a cultural thing with engineers—they're introverts. The engineering method selects out the people who are predisposed to Shared Vision Planning. Not always, but most of the time. Modelers are plagued by shyness, inwardness, resistance to conflict.
Modeler	As an engineering educator, I see the field self-selecting for people "who don't want to be in the front of the room." And they don't want to deal with open-ended questions. They want to deal with concrete stuff. This is changing these days, but engineers in the past were rarely trained to be good communicators. And they don't often have much respect for facilitators because facilitators too often undervalue outcomes and results and overvalue process.
Modeler	In general, this kind of thing is not part of their training at all. They're not taught to engage in processes of determining what the objectives ought to be, they're taught to take the objectives as given and design solutions. They're not interested in psychology, politics, etc. There is a need for pure design engineers, but you need engineers who can see the big picture too. They should at least be trained to recognize overarching problems and recognize when other kinds of professionals are needed.
Modeler	Engineering self-selects for people who don't want to work with people. But this is changing. The field also attracts people who want to save the world.
Facilitator	Overall, engineers/modelers are not well equipped to do this. They are too data driven, and they can't understand that most people aren't. They struggle with the issue that, often, perception equals reality. They think that good decisions just emerge from good data.
Facilitator	Engineers are not trained on the facilitative aspects of these problems. They're not comfortable with the open-ended nature of these problems. They need more structure. They're not good at formulating problems. They're not comfortable with psychological/political aspects of problems, e.g., "I'm an engineer, I don't want to deal with this political stuff." There is a need for this attitude but it doesn't work for dealing with these big problems.
Facilitator	I wouldn't expect to find this ability in most engineers. There are some who are naturals, or some who have had the appropriate exposure to real world problems. But I get contacted by engineering students because they are interested in getting into this kind of work.
Facilitator	Experience matters most. New modelers/engineers are not well equipped for this. They need to learn more about listening, communication, and translating ideas between different conceptual or disciplinary languages. They need to know how reframe questions.

*Not all modelers are engineers; modelers may come from biology, economics, or other technical fields. But in the water resources field almost all modelers come out of civil engineering and the comments in these interviews reflect that orientation.

- Ability to synthesize what people are saying
- Intuitive sense of timing about when to do these things
- Ability to keep people on track
- Ability to learn at least the basics of relevant technical issues
- Ability to ask leading questions of technical people and stakeholders

The sharpest critique of facilitators came when people were asked "How well-prepared are facilitators to conduct CADRe processes?" The comments are shown in Table 5.

Table 5: How well-prepared are facilitators to conduct CADRe processes?

Modeler	Most facilitators are not at all prepared. They are often tone deaf to the context in which they work. They use too many techniques (e.g., making rhythmic noises with sticks) that irritate all the sensitivities of engineers, causing engineers to think they're idiots. They don't understand how engineers work, how they think, what they feel, and so they're not effective working in an environment with engineers.
Modeler	Facilitators often downplay results/outcomes. This makes it difficult to do problem solving and to work with engineers. They often don't know enough about the technical problem, which is understandable if they're working on multiple cases. But it can be disruptive and limit their ability to facilitate good discussion.
Modeler	It varies. Some think that in order to remain neutral they can't know anything about the problem. That may work for purely emotional disputes but it doesn't work for technical disputes. Facilitators need to know something about the technical nature of the problem. Pragmatic facilitators will agree that they can know something about the problem and still be neutral. Some facilitators are too rigid on what it means to be neutral.
Modeler	Sometimes facilitators don't focus enough on substance. They prolong the conversation and let energy dissipate, so then there's not enough energy left when you get to issues of substance.
Facilitator	You need a facilitator who has learned how to handle technical issues, or who has some background in technical stuff. The facilitator needs to be able to translate between technical and non-technical people, helping non-technical folks understand what technical folks are saying. Much of it is about communication between people with different orientations. If people are not familiar with different orientations they will have a hard time.
Facilitator	Facilitators often focus too much on psychological/political aspects of the problem and ignore the technical aspects. It's not that they're resistant to learn it but the issues can be very complicated and difficult to learn.

Table 5: How well-prepared are facilitators to conduct CADRe processes? continued	
	One of the key roles of facilitators is to reframe questions. If they don't know enough about the technical problem then they can't do this effectively. People often underestimate the skill required to be a good facilitator or mediator. They would never underestimate the skill required for engineering but they do so for facilitation/mediation. They focus too much on the "kumbya" of it and not on the actual skill set. New facilitators are usually not ready—they need real world experience.
Facilitator	A lot of people assume that engineering is clear cut, that there's clear right and wrong. I find that a lot is subjective and uncertain [this facilitator has a degree in engineering]. I try to be very clear about this and try to understand how it might influence decisions. A lot of people assume that a mediator is some kind of a therapist. This doesn't work for these kinds of cases. There's a need to dispel that perception at the beginning of the process. There's a need to make it clear that the mediator's job is to understand the various perspectives and help a group solve the problem given their differences.
Facilitator	Again, experience matters most, so new facilitators are not ready. Their training is often focused on conducting meetings. So they may not be comfortable with helping to frame or scope big questions. There is a set of skills that engineers or facilitators will gain with experience: These include: • Ability to translate between different disciplines and speak their languages • How and when to ask questions about scope • Ability to synthesize what different people are saying • Intuitive sense of timing about when to do these things. • An ability to lead people to stay on track

One of the particular challenges facing facilitators is to have sufficient mastery of the technical subject matter so they can understand the significance of what is being said by technical people, ask appropriate questions about how an issue relates back to the ultimate decision, and translate what is being said by technical people into language that can be understood by the public. One interviewee suggested two tests for determining if a facilitator knows enough about the problem. These are:

- They should not disrupt the flow of conversation too much by asking lots of clarifying questions about technical terms; they should only do this when it will serve the larger group.
- They should know enough to ask useful leading questions of technical people and stakeholders.

Approaches to Addressing Process Issues

One of the purposes of this study was to determine whether there were significant differences between modelers and facilitators. So the authors asked several questions designed to present key process issues that can come up during a CADRe process, to see whether modelers handled those issues differently than facilitators. Specifically these questions addressed:

- The need for a convener
- Defining the scope of the process
- Handling participation from people with hidden agendas

Upon reviewing their comments, there were no clear differences between modelers and facilitators in how they handled these issues. The people interviewed were largely in agreement on how to address these issues.

How should a CADRe process be convened?
CADRe processes do not just happen. Someone has to take the lead in proposing and championing the use of a CADRe process. The interviewees are in agreement that convening of the process must be done by someone or some entity with authority and/or influence, not the facilitator or modeler. Comments are shown in Table 6.

Table 6: How should a CADRe process be convened?

Modeler	There needs to be someone precipitating it—someone with influence and authority and maybe resources to back it up. And there often needs to be a host institution who will pursue this kind of approach.
Modeler	I'm not a convener. The process must be initiated by decision makers or some organization with authority.
Modeler	Someone else has to convene the process. I'm not, and I don't see most other CADRe practitioners as being, a convener.
Modeler	Ideally, all stakeholders would realize and agree that a CADRe process is needed. But this rarely happens. Because of our positions as professors, my collaborators and I are able to be bold in our work and initiate studies that might make others uncomfortable. But I wouldn't call it convening. A CADRe-type process can be convened by a judge or other legal authority. Otherwise, there has to be some incentive for stakeholders to engage in a CADRe.
Facilitator	The best way is to find some existing group, like a planning group of some kind or another group with responsibility for the problem, and see if they are willing to serve as the focal point.
Facilitator	The first task is to ask what the problem is; convening comes from that.
Facilitator	There has to be a convener either with some authority or with enough influence to convince stakeholders that they might benefit from a CADRe process, and the convener has to have enough authority or influence to make stakeholders participate in good faith.
Facilitator	Convening must involve the ultimate decision makers; someone who is sponsoring the process. Ask them about the scope of the problem and then ask who the ultimate decision makers are.

This means that there is clearly a third role—the convener—in addition to the facilitator and modeler. This has important implications for a planning agency. In many cases, someone from the planning agency may act as the convener of the process. In such a case, the attitudes of participants towards the planning agency may color their perception of the CADRe process.

As an example, if a federal agency is the convener, and some of the participants are suspicious of that agency (believing it has an agenda), then these attitudes may influence peoples' willingness to participate in a CADRe process. They may suspect the process is a new form of manipulation. If an agency is the convener, and there is antagonism towards the agency, it is possible that modelers from that agency may not be seen as neutral parties acting on behalf of all the participants. There may be occasions when it is wise to have a local entity act as the convener, so that the federal agency is seen as the neutral, and there are fewer fears of federal agencies intruding on local planning.

How do you define the scope of the process?
There is always a tension when defining the scope of the process. If the scope is defined too narrowly, it tends to constrict the range of alternative solutions that will be considered. For example, agencies are sometimes criticized for defining the problem in such a way that the only possible answer is construction of a physical structure.

On the other hand, if the scope of the process is too broad the study can quickly become amorphous or complex, or outside the ability and authority of the stakeholders to implement any solution.

This problem exists both at the level of the scope of the process as a whole, and the scope of the model. At the study level, for example, does the study look at too large or too small a geographic area? Does the study focus only on physical solutions, not institutional solutions? Does the study address all the relevant issues?

These same questions get played out during the development of the model. In fact it is not unusual for the development of the model to be the catalyst for discussions about the scope of the study as a whole. When discussing "what needs to be measured" during the development of the model, modelers may be asked to address criteria that some participants consider relevant and some do not.

Very often, getting agreement on the scope of the process is the first major challenge of a CADRe process. Unless agreement can be reached on the scope, it can become meaningless to attempt to build a model.

There were no obvious major differences in how modelers and facilitators approach the problem. In some cases the scope is defined by legislation, administrative decisions, or is handled by the convener. But there was acknowledgment that putting limits can be a difficult problem, and sometimes an on-going problem throughout a study. The facilitators stressed that the scope flows from the problem definition. Once those are defined, then it can be determined who the stakeholders need to be.

There is general agreement that setting the scope must be done in collaboration with stakeholders as much as possible and that the scope should be clearly related to the heart of the problem and the ultimate decisions that need to be made.

Interview comments are shown in Table 7.

Table 7: How do you define the scope of the process?	
Modeler	Defining the scope of the process can be very difficult and is often an on-going problem. You have to limit the scope despite the connectedness to other issues. But it must be done in a way that everybody agrees to. Sometimes it is set by prior legislation or administrative decisions.
Modeler	By defining the problem that is being addressed in collaboration with all the stakeholders. Sometimes it is set for you, and you have to ask if the scope of the work you do relates to that broader problem.
Modeler	Since I don't see myself as a convener, I'm not usually involved in setting the scope of a CADRe process. But I always ask how the modeling work (and all its components) relates to the problem or decision being made.
Facilitator	It is really determined by the decision being made and who is affected by that decision. Setting the scope starts with those two questions.
Facilitator	First define the problem and then determine who the stakeholders are for that problem. That defines the scope of the effort (especially who needs to be involved).
Facilitator	We do a formal situation assessment of the problem by interviewing those involved. Then we ask who else is impacted and who else needs to be interviewed. From there we develop recommendations on scope.
Facilitator	I ask stakeholders (starting with those who've been identified by decision makers) how they would frame the problem and what their interest is. Ultimately they come to a description of how to frame the problem and ask if all involved can agree to it. From there they can begin asking what other stakeholders should be involved. When a convening entity is being overly restrictive about scope it is sometimes necessary for the facilitator to emphasize two values: • Inclusiveness—including all relevant stakeholders and their issues • Intellectual curiosity—willingness to explore new ideas.

How do you handle it when you suspect that some participants are trying to "game" the process by misrepresenting their interests, withholding information, or providing bad information.

On occasion leaders of CADRe process may begin to suspect that some participants are trying to manipulate the process in some manner. One tactic, they observe, is that technical folks propose studies that are irrelevant to or far too detailed for the given problem. Sometimes it seems like they have a hidden agenda.

Comments received in response to this question are provided in Table 8. It is interesting to note that the facilitators seemed far more likely to assume that technical people have good intentions, but that their egos get in the way, or they have to be reminded of fundamental values. Modelers seemed more likely to perceive behaviors in terms of intentionally trying to distract or subvert the process. Since the number of people interviewed is small, it is not known whether this is a fundamental difference in orientation, or this difference is merely an artifact of how the question was asked or interpreted.

Table 8: How do you handle it when you suspect that some participants are trying to "game" the process by misrepresenting their interests, withholding information, or providing bad information?	
Modeler	I can be fooled, but I just try to ask a lot of questions, especially about issues (objectives, data, proposed alternatives etc.) that seem like they will be important to the ultimate decision. I keep coming back to certain basic questions: • Is the planning effort likely to be subverted by lobbying or adjudication? • Is the necessary openness of Shared Vision Planning in itself contrary to the interests of a major stakeholder? • Is water the issue or the stage for other conflicts to play out on? On occasion I may ask for an assessment of the situation from a local political scientist. Increasingly I'm making use of agreed-upon rules of engagement.
Modeler	I impose a relevance test. Is the information, objective, proposed data collection relevant to the decision? Some people have pet issues and you have to let them talk about it, but not to the point that is unfair to other stakeholders. Sometimes you can diffuse it by asking that person to take on a task that is not crucial to overall progress. Often, they'll want to analyze something in great detail and that can be a delaying tactic
Modeler	Information has to be relevant to the decision and it should be measurable (in the case of performance measures).
Facilitator	This has not been much of an issue in my experience. This was partly because the technical team I worked with (Sandia National Labs) was a trusted source of modeling and data, and also because their projects were not focused on the ultimate decisions, but rather on developing a good tool that could be used for the decisions (in some cases the tools were not used). When necessary I allow for debate among the stakeholders and they have dealt with any issues on their own.
Facilitator	Credible scientists will usually not want to be wrong, and they usually respond to reasonable criticism. This is why it is important to have a facilitator who can deal with technical issues because they can ask questions and sometimes smooth over the egos that scientists have. There should also be an agreed-upon process for how the model and data gets changed. For stakeholders, they need to have someone on the technical team that they trust. There needs to be a clear definition of goals, objectives and related ideas and how they will be used and there needs to be a facilitator who is capable of understanding stakeholder's interests. "Rules for dialogue" can help.
Facilitator	I observe people's behavior to see if it's consistent with what they've told me. Sometimes it's clear they are not behaving in a way that is consistent with their stated objectives so then you know something is going on. Always keeps in mind that stakeholders are always assessing whether they can get more from being outside the process than remaining in it.

Table 8: How do you handle it when you suspect that some participants are trying to "game" the process by misrepresenting their interests, withholding information, or providing bad information? continued	
Facilitator	Usually, once people agree to a collaborative process they don't want to cheat. Overall, I start from an "aspirational place" by appealing to the basic values that engineers and scientists have such as desire for accuracy, civic service, public service, the desire to get it right. This can usually keep people from being dishonest. I do rely on some kind of rules of engagement. Overall my purpose is to help people succeed in working collaboratively, not punish them for doing bad things. So I may confront a person if necessary, or I may slow the process down to give it time to be resolved.

There was agreement on the value of some kind of rules of engagement, agreed upon by participants.

Building Expertise to Conduct CADRe Processes

One of the clear implications from the interviews is that few, if any, modelers or facilitators are equipped to conduct CADRe processes based on their academic training alone. In the short term this raises the question of whether modelers and facilitators should work in teams. It also has implications for how to prepare qualified people to conduct CADRe processes.

Should Modelers and Facilitators Work in Teams?

The interviewees were specifically asked to address the question of whether modelers and facilitators should work in teams. The interview comments suggest that:

- A team approach is appropriate.
- Both the modeler and the facilitator need to gain an understanding and some familiarity with each other's field to be successful.
- Both have to be good at what they do.
- They need to trust/like each other.
- They need to design the process and individual meetings together, because good design requires the knowledge that both bring to the process.

Put another way: It may be useful for modelers and facilitators to work together in teams but they must also have a common vision of what needs to occur, they must share decision making, and there needs to be an effective working relationship— some chemistry— between the two people.

Comments from the interviewees are shown in Table 9.

Table 9: Should modelers and facilitators work in teams?	
Modeler	There needs to be trust between the two people if they are to team up and lead a CADRe process. If they are good in their respective fields, have a good liberal arts (or otherwise broad) training, and are articulate, a teaming approach can be done. You might lose some of the immediacy you get with one multi-talented person—e.g., a facilitator leading a discussion might miss an important issue if they don't understand the technical intricacies, so it might not get dealt with until the modeler prompts the facilitator to revisit the issue. But there could be a benefit as well if each individual is better in their respective field than the one multi-talented person is in either field—i.e., you might get better modeling and better facilitation if done well.
Modeler	There's a role for both the facilitator and the modeler. The facilitator must ensure that those who will be affected by or can affect the decision are involved, that all the key players have been identified. The facilitator must have the ability to envision a process by which a relevant decision can be made which will solve or help solve the conflict at hand. The facilitator needs the ability to envision a range of solutions; visualize what incremental decisions need to be made, and what coalitions need to be formed so that you get an action at the end. A facilitator can't guarantee an action, but they can guarantee a process that makes an action more likely. They can also facilitate use of some kind of process that allows trade-offs between value systems. The modeler must be able to provide accurate and useful information at every juncture, in support of the vision that the facilitator generates. The modeler can help the facilitator with the broader issues; provide an understanding of the system; generate alternatives that address problems and opportunities, and help with help with ranking/tradeoffs. Then they step back, and the facilitator helps the group use the information.
Facilitator	I don't think modelers should facilitate. It's difficult to do both simultaneously. What you're hearing as a facilitator will affect your modeling. They need to like each other, they need to be able to operate as a team and trust each other.
Facilitator	There needs to be a teamwork approach, with the modeler and facilitator working closely on all decisions and issues. They must recognize that the interconnection goes much deeper. They would have to design the processes together.

How should people get the expertise they need to conduct a CADRe process? People need experience to gain the expertise they need to conduct a CADRe process. The interviewees also feel it is especially important that professionals in each field get exposure to the other field and exposure to real-world problems.

Suggestions for how to give people the experience they need included the possibility of apprenticeships or internships. One suggestion was that they could serve as a meeting recorder or play some other support role as a way of getting basic exposure to real world problems. For example, one facilitator commented:

> Experience is the key, so the challenge is how to provide ways of giving new people experience slowly. I start new facilitators off in basic roles of taking notes and writing meeting summaries, so that they can observe what is going on. An engineer I've partnered with does a similar thing—he starts junior engineers in smaller roles in CADRe-like processes and lets them progress to higher levels of responsibility as they learn.

Several of the people interviewed are presently conducting training courses designed to give students the skills they need to make a start in the CADRe field. One of the interviewees, a modeler, commented:

> One thing we've tried to communicate in the course is that CADRe is more art than science, so experience matters a lot. We've been conducting a training course in which we're trying to give students some exposure to how real world problems work. They work on a real water dispute case for the entire semester and have to go through each step of developing objectives, working with stakeholders, modeling, negotiating etc. The goal is to give them a sense of how complicated the problems can be so that they are aware of how modeling and analysis have to support the learning and negotiation process.

A facilitator commented:

> I'm teaching a university level course on Integrated Resource Planning for technical students. I'm giving them real management problems as part of the course. They have to work with a real stakeholder, interview that person and write up the summary of their issue. Then they go back to the stakeholders and see if they got it right. They develop goals, strategies, and alternatives. The students struggle with the open-endedness of the problem, but they're learning how to cope with that. They're also beginning to understand how/why people behave the way they do on contentious issues. This kind of a training course could be developed as workshops for active professionals.

These two courses are intended as pilots, with the potential for adapting these courses for other settings, such as training people who are already established as facilitators or modelers and want to enter the CADRe field.

Chapter 13 explores education and training for CADRe in detail.

Conclusions and Implications

As noted in the introduction, all of the interviewees were experienced with both facilitation and modeling aspects of CADRe. All of the modelers interviewed have either played a facilitator role (some quite regularly) or had worked closely with facilitators on specific projects. In addition, all of the facilitators interviewed either have direct experience with modeling (or related technical analysis) or had collaborated with engineers and/or modelers on specific projects.

There were some subtle differences between the groups in how they view and approach CADRe, but as noted above, these differences were less than might be expected. For example, modelers do tend to focus more on identifying solutions, while facilitators tend to focus more on the quality of the process. However, all interviewees noted the interdependence of process and outcomes—*to achieve good outcomes, you need good process.*

What was more striking were similarities in their views of CADRe and what is needed to successfully conduct CADRe processes. Our interviewees showed these similarities precisely because they were all experienced with CADRe-type processes. The modelers had learned a lot about facilitation and the facilitators had learned a lot about modeling. They had similar views about the purpose of CADRe, skills needed to conduct CADRe, principles that should guide CADRe, and how CADRe can be convened. This suggests that there is a finite set of skills and principles needed for successful CADRe application and that these can be learned through experience.

The interviews with modelers and facilitators showed that both the modeler and facilitator roles are crucial when conducting CADRe processes. It is clear that one person can play both roles, as several of the interviewees have been doing so in their work for some time. But all of the interviewees have also worked as part of modeler-facilitator teams. Further, they all agree that a modeler and facilitator can successfully team up to lead a CADRe process as long as they have the right mix of skills and an effective approach for managing each role.

In addition, it is clear from these interviews that the typical modeler and typical facilitator (especially those early in their careers) are not likely to have the necessary skills to play a lead role in a CADRe process, either as part of a team approach or as a single leader playing both roles. Modelers were seen as too concrete, too introverted, and unwilling to deal with the messiness of political deliberations. They were also seen as poor listeners, unable to be empathetic or to reframe comments from participants. On the other hand, facilitators were seen as lacking in technical knowledge and thus unable to interpret technical knowledge to the public and unable to identify critical technical issues. They were also seen as often resistant to gaining technical knowledge. Both were seen as lacking practical experience that is essential for addressing these kinds of issues.

Two key conclusions emerge from these interviews. First, different professionals starting from different fields arrived at similar views about how CADRe should work and the skills needed for successful application. There were some differences, but the similarities were much more obvious. This solidifies the idea that there is a clear set of skills and principles for CADRe, drawn from different disciplines. This is not necessarily a new revelation, as the Institute for Water Resources and other organizations are working to formalize and standardize these skills and principles for the first time. But the fact that experienced professionals share many views about CADRe highlights the need to continue formalizing and standardizing these methods. The efforts to formalize and standardize the needed skills and principles will make it easier to train more people in how to do CADRe, and the efforts will be aided by the knowledge of those interviewed for this chapter.

The interviewees were very clear in their discussions of the limitations of typical modelers and facilitators. This is perhaps the greatest challenge facing CADRe

becoming a standard way to address water resources problems—*there are not enough professionals around with the necessary skills to implement and lead CADRe processes.* Furthermore, formal programs to increase the number of skilled CADRe practitioners are limited.

Two of the people interviewed are currently conducting training courses to introduce students to the skills needed to conduct CADRe processes. Both of these are university courses for undergraduate and/or graduate students. In addition, the Institute for Water Resources has been developing reference and training materials on CADRe, including a primer on Shared Vision Planning and detailed process guide for Shared Vision Planning. The challenge of increasing the number of professionals skilled with CADRe highlights the importance of the conclusions and recommendations of Chapter 13 in this book.

Furthermore, all of the interviewees thought that both modelers and facilitators need practical experience with real-world problems and some familiarity with the other field to be effective in CADRe processes. Formal training programs will not be sufficient. One suggestion for giving professionals practical experience is to provide them with opportunities to "intern" in supporting roles, such as a meeting notetaker. The Institute and its collaborating organizations should continue to look for ways to develop these intern opportunities by partnering with universities, nonprofit organizations, and private firms.

Finally, there was general agreement that there is an important third role in CADRE, that of the individual or organization to convene these processes. CADRe practitioners are rarely in a position to convene and initiate a process. Political leaders and leaders within water and natural resources management organizations—such as government agencies, water utilities, and river basin commissions—need to be made aware of CADRe methods and their potential benefits. As the community of CADRe practitioners continues to improve the methods and expand the community through training, it is also important to reach out to the organizations and political leaders that might demand CADRe for water problems.

Biographies of Interviewees

Modelers

Jay Lund is Professor of Civil and Environment Engineering at the University of California, Davis. He is the principal developer of the CALVIN economic-engineering optimization model of California's inter-tied water supply system. He has had a major role in water and environmental system modeling projects, in California, the United States, and overseas.

Rick Palmer is Chairman of the Department of Civil and Environmental Engineering at the University of Massachusetts at Amherst. For many years he

taught at the University of Washington. He has received numerous professional awards including the Huber Award for research excellence from the American Society of Civil Engineers, for his innovative application of simulation and optimization techniques to issues in water resource management. He is the co-developer, with Bill Werick, of Shared Vision Planning, developed as part of the National Drought Study. He also pioneered the use of "virtual drought exercises."

Dan Sheer is the President of HydroLogics, and has over 32 years of experience in integrated management of reservoir systems, systems operations, and modeling water supply operations, especially using optimization based simulation models. He has been a pioneer in the field of computer-aided dispute resolution. He is a co-developer of OASIS, a multi-objective optimization-based simulation package designed to support computer-aided dispute resolution in water resources.

Bill Werick is an independent consultant in Culpeper, Virginia. He served with the Army Corps of Engineers from 1964 to 2004, the last 14 years as a senior planner at the Institute for Water Resources. He led the National Drought Study for the Corps, and during that study he and Rick Palmer developed Shared Vision Planning. He recently completed a shared vision planning effort for the International Joint Commission to find better ways to manage Lake Ontario levels and St. Lawrence River flows. He continues to consult on a number of shared vision planning processes around the country.

Facilitators

Gail Bingham is the owner of the Civic Dialog Group. She served as President of RESOLVE, an organization dedicated to the effective use of consensus building processes in public decision making. She is widely recognized as one of the pioneers in the use of mediation to resolve public policy disputes. She has written extensively about environmental dispute resolution.

Ann Bleed is a Senior Program Manager at CDR Associates, an internationally recognized organization of conflict resolution specialists headquartered in Boulder, Colorado. Before joining CDR, Dr. Bleed served for many years with the state of Nebraska Department of Water (now Natural) Resources. As State Hydrologist, Deputy Director and finally Director of the department, Ann played a key role in the department's water rights administration and contested case hearings, interstate compact administration and in the successful settlement of two complex interstate water disputes before the U. S. Supreme Court.

Kristan Cockerill is Coordinator for Interdisciplinary Research at Appalachian State University. Previously she was an Assistant Professor at Columbia University and a Fellow at the Army Environmental Policy Institute. Her focus is the nexus between science and public policy, especially water policy. Dr. Cockerill has facilitated several computer-aided dispute resolution processes in support of studies conducted by Sandia National Laboratories.

Diane Tate is a Program Manager at CDR Associates, an internationally recognized organization of conflict resolution specialists headquartered in Boulder, Colorado. Ms. Tate is a licensed professional civil engineer, holds an MA in Public Affairs, and received mediation training at the University of Texas School of Law. She co-facilitated a launch of a statewide committee to improve the process of trans-basin negotiations in Colorado and co-facilitated an aquifer management plan in Idaho.

Chapter 12

Considering Convener, Stakeholder, and Decision-Maker Issues

by Lisa Bourget and Gail Bingham

Introduction

Over the years, governmental agencies and others have made increasing efforts to convene members of the public to engage in dialogue or collaborative action to address public issues that affect them. Similarly, members of the public and non-governmental organizations have become more aware of opportunities to influence governmental decision making, and have become more active in ensuring that public views are known.

At the same time, strides in technology have made possible new means of communication and the possibility for participation where none was previously feasible. Technology also can provide the means to link information from different disciplines that once may have been handled separately, and to bring into consideration new knowledge about increasingly complex and inter-related issues that are part and parcel of water resources management.

The time is ripe for agencies to consider CADRe, which draws on the lessons from participatory processes and merges them with technological advances that allow modelers to link and present diverse information that is readily understandable (often graphically based), inclusive, and interactive. As agencies and others take on a leadership role in convening collaborative decision support processes such as CADRe, a clear understanding of some of the key factors in situation assessment and in process design will increase the likelihood that these processes will achieve useful results.

A well-designed CADRe process can provide better access to a diversity of information and views and can yield better decisions, in part because it allows conflicting interests and perspectives to surface. This is as important for inter-agency coordination and cooperation as it is for stakeholder engagement. Not only are various views held by different interest groups or by members of the public, government agencies themselves can have strongly held views on the same issue, each agency driven by its own particular mandate, mission, and responsibilities. This is certainly true in water resources management, where various responsibilities—ranging from environmental restoration to flood risk management to facilitating navigation—are spread among numerous agencies at the federal level as well as between federal, state, and local entities across the country.

The costs of not dealing with conflict proactively, particularly as reflected in agencies' dealings with litigation, are well recognized. Alternative Dispute Resolution (ADR), a range of processes that provide alternatives to traditional litigation, is being embraced and institutionalized throughout the federal government to reduce cost, increase workforce productivity and accountability, ensure timely achievement of agency goals, and deliver reliable, efficient, and high-quality service (Federal Interagency Alternative Dispute Resolution Working Group Sections et al 2007). Although federal use of ADR was still in its infancy in 2000, there has been major expansion since, including in enforcement and regulatory areas (Federal Interagency Alternative Dispute Resolution Working Group Sections et al. 2007). Others are urging collaborative approaches in other venues, such as evidenced by the Council on Environmental Quality's 2007 handbook to guide agencies' collaborative undertakings with respect to work conducted under the National Environmental Policy Act (2007). Agencies are working to increase the effective use of environmental conflict resolution and build institutional capacity for collaborative problem solving, as directed by the Office of Management and Budget and the Council on Environmental Quality (2005), and are required to report annually on their progress in the use of environmental conflict resolution and other collaborative problem-solving approaches and in tracking cost savings and performance outcomes (Office of Management and Budget and Council on Environmental Quality 2005, Section 4(g) of Memorandum).

As shown by recent case studies, CADRe has begun to be used as a collaborative decision-support tool in water resources management. While still relatively unknown generally, there appears to be both interest in its potential as well as some lessons learned and perspectives to consider, particularly given the relative newness of these approaches. This chapter discusses some of the factors that conveners of collaborative processes should take into account and explores issues facing conveners, stakeholders, and decision makers. Agencies often find themselves acting as decision makers and/or conveners in such collaborative approaches, and the chapter also provides specific comments regarding agency considerations.

Time and Cost Considerations

Agencies have limited budgets. They are responsible for spending resources wisely and delivering sound results expeditiously. Stakeholders also have limited time and budgets for participation—particularly interests represented by citizen volunteers whose time is not compensated or where technical experts representing stakeholder perspectives may be needed for participatory model development. CADRe, with its emphasis on group learning through participatory model-building, loads the front end of the overall process but offers the promise of more robust results—results that can shorten the back end of the overall process and help avoid litigation. However, these long-term benefits do not change the short-term budget implications of the up-front investment, either by the agency or its stakeholders. What types of modeling

and/or facilitation assistance will be needed? Given the range of options for framing the scope of issues and defining the objective of the process (e.g., asking for input or seeking agreement), what might be the anticipated duration of the process and number of meetings? Will financial assistance for travel expenses be needed to get the right people to the table?

Particularly for volunteers who may not be able to count their participation as part of their "day job," support may be critical. In addition to considering direct expenses, such as for travel, providing a modest stipend for major time commitments or contracting for expert technical assistance can ease the burden for them. If this is not possible, agency recognition of stakeholders' contributions, perhaps in multiple forms and forums, becomes even more critical.

An assessment of both agency and participant costs should be undertaken, and objectives set for the process in light of a realistic match between objectives that will motivate participation, what the needs are in each circumstance, and the amount of resources available. Involving stakeholders in this discussion can pay significant dividends in trust-building, transparency, ensuring the process offers sufficient incentives for participation and, even possibly, in initiatives to raise funds from private sources.

Framing the Issues and Creating Incentives to Participate

A broader group of participants is typically identified very early, and then collaborates in ways that can influence the process itself. Identifying, engaging, and supporting the larger group is a management issue that requires early and continued agency attention. The case studies presented earlier illustrate that this broader group will often have members with different understandings of the problem being tackled, along with pre-conceived notions of how best to fix the problem as they understand it. Thus, time is required on the front end to delve into defining the problem itself. Months can be spent separating the "why" from the "how": defining and understanding the values and issues each member brings to the table, sharing information, and developing a common understanding of the problem(s) to be solved. As it works through these basic questions, the group is also establishing important working relationships. Defining the problem sounds straightforward, but delving into different understandings to appreciate issues of importance requires sufficient time and interaction, which an agency needs to accommodate in its initial planning and budgeting (larger groups require greater support.) With the clearer initial focus based on a deeper appreciation of interests and perspectives, however, the group runs less risk of pursuing less relevant paths, and the agency runs less risk of being challenged later for missing important elements. Furthermore, ironing out these differences up front can lead to quicker analysis and resolution on the back end, with an outcome more likely to be accepted and supported by a large, diverse group.

Agency and Stakeholder Roles and Expectations

Agencies work within the bounds of the authorities and budgets given to them. Inviting a broader group to help define and then recommend solution(s) to a problem opens the possibility of issues being raised that may be beyond an agency's purview or capability to address, or of solutions that may be beyond an agency's ability to fund or implement. However, this is a manageable concern. When establishing a group, an agency needs to be clear about the scope of its authority, consulting stakeholders in advance to shape the scope of a discussion and clarify expectations in a mutually-acceptable way. Many times, all involved agree to limit the questions to be addressed to those within the agency's purview. In other situations, the discussion can be expanded to include multiple agencies when stakeholders feel strongly about a broader range of issues and the affected agencies agree.

When establishing a group, a convening agency also needs to clearly identify the purpose of the process, roles, and operating assumptions. Who has a "seat at the table," and are participants speaking as individuals or as formal representatives of an interest group? What are the pros and cons of allowing alternates? Are agency representatives members of the group? Who will represent the agency and what authority do those representatives have? Will the products of the group be advisory or is it an agreement-seeking process? How much independence does the group have to establish its own objectives, membership, approach, and decision-making protocols? How will the group interact with the public and with the agency? How does the group's work fit into an overall agency process, and how will the final decision be made? What are the anticipated timeframe, budget, and support? Are there requirements (statutory, policy, etc.) by which an agency must abide? These questions do not have one right answer. An agency must define a process consistent with its mandate that reflects the unique circumstances of each situation, and needs to ensure a common understanding and acceptance of starting expectations with its stakeholders. In many processes, these expectations are put in writing as terms of reference or operating procedures approved by the group.

From this common initial framework, then, the agency and the group can consider how to address substantive concerns and suggestions that may arise about the issues themselves. It may be that a concern is so strongly held that, although it may be tenuously linked to the outcome, it may be prudent and feasible to answer the question. It may be that an initially-appealing option is suggested that would require action by others to implement; in that case, judgments can be made about whether or not efforts are worthwhile to explore it further. Overly restricting the group can limit potential creative solutions, but constraints must be recognized.

Inherent in the approach outlined above is the premise that, when collaborating with stakeholders, the agency needs to consider challenges from the stakeholders' perspectives. Having a clear concept at the outset of the expected role and influence, time commitments (both intensity and longevity), expected operating procedures,

and available support will help stakeholders determine whether they can and whether they want to commit.

Different stakeholders may prefer differing levels of involvement; in fact, this is to be expected. For example, some stakeholders may simply want to be kept informed, some may want to roll up their sleeves and delve into detailed aspects under consideration, while others may want to participate in guiding the overall conduct of the study. The institutional structure of the group can be structured to accommodate this, which can also facilitate the more focused work by smaller subgroups often required. The case studies provide examples of differing ways of structuring the group to accommodate various stakeholder preferences.

Some stakeholders may be a public leader or spokesperson within a broader interest group. If so, that stakeholder can be helpful in serving as a trusted source for updating those less directly involved. Keeping these lines of communication open can help maintain the study's transparency, provide an avenue for raising concerns back to the group, and increase overall understanding within the broader interest group as work proceeds. However, the stakeholder fulfilling such a role also faces the challenge any representative (including agency representatives) must confront: that others they represent do not experience the shared learning that those more directly involved go through, with the consequent risk of more widely diverging views as the process continues. Agencies can help groups manage this challenge by discussing it explicitly, keeping lines of communication open, encouraging an iterative process, planning time for representatives to consult constituencies and bring concerns into the deliberations, and providing tools for participants to use to share information along the way (Web sites open to the public, newsletters, presentation materials, meeting summaries, etc). Such steps will help reduce the risk of representatives losing credibility with the broader interest group if the decisions and direction taken either are not understood or are perceived as antithetical to their original positions (even if it may achieve some of their underlying interests).

Agencies build certain relationships with stakeholders as work progresses, and stakeholders with each other. Heightened shared understanding and increased trust can be powerful, useful to study outcomes and gratifying to the participants. Stakeholders often ask for a continued role after the decision has been made, particularly if they feel they contributed to something worthwhile. This desire may dovetail with the group's recognition that issues are rarely static: new information and knowledge will become available, changes to models will be made, and new or unforeseen circumstances will test current assumptions and raise new concerns. Figuring out whether and how to continue opportunities for stakeholders' further interaction, learning, and contribution will likely be an important aspect for an agency to consider.

Modeling Considerations

Agencies often have highly-trained experts who have worked with issues and models for years, developing a detailed understanding within their area of expertise. These experts may have developed models, some very sophisticated, to show the workings of the problem at hand, understand and are comfortable with the models they use, and can readily apply and explain them. The agency itself has invested in training, development, and application for the specific models it uses. So there can be both agency and expert reluctance to embark on the participatory model development that is central to CADRe. Why incur the additional cost? Why put aside the work already done? Won't a new model "dumb down" the finely-tuned relationships in the current model, which have been refined over years? What is gained, and is it really necessary?

The earlier case studies show that it is possible to design a process that makes good use of modeling work already done, when that exists, or to bring valued expertise to bear in situations where no models may yet have been created. In addition, key features of (and benefits from) participatory modeling are to achieve a greater degree of transparency and trust in model outputs as well as to facilitate group learning. Experts outside the agency, either in some stakeholder groups or who are trusted by those groups, often have their own perspectives and models; different agency model preferences may also need to be addressed. Unless attempts are made to understand alternative modeling assumptions and, in some cases, link or integrate different models, effective collaboration can be impeded by technical disagreements. In some cases, different models, such as biologic and physical, may need to be interlinked. On-the-ground and diverse experience may need to be incorporated. More fundamentally, the group needs to understand what it is working with, and the modelers need to understand—and be able to reflect—the specific results of importance to the group in ways that are accessible to all.

Participatory modeling can be particularly useful when there are significant differences among stakeholder interests or where public confidence in agency decisions is low. Transparency and a shared understanding of the assumptions and relationships inherent in a model, or in linked models, can build public trust and acceptance of the results. The case studies show that building the models together allows members of the group to focus on, understand, and help shape the each piece of the puzzle, and to help determine how the pieces fit together and how the results are presented. CADRe often places heavy emphasis on graphics, because that is one useful way to grasp results quickly, but the graphics may need to be tailored to the group, or to change over time as the group's work proceeds. While expertise and existing work cannot be discarded, opening the "black box" with the group uncovers and tests assumptions, finds and addresses errors, and significantly increases the overall understanding of the complexities of the system, the realm of the possible, and the realities of limitations. This heightened shared understanding cannot be underestimated, and can change the dialogue from arguments over whose model is right, or which information

is more important, to a discussion founded on common accepted assumptions and information about what the results actually show and what it means.

Peer Review and Model Certification Considerations

Agency processes often include peer review, particularly for larger and more controversial studies. Agencies may also require certification of models to ensure appropriate technical grounding. Developing a model collaboratively does not change the responsibility of all involved that decisions be based on technically sound information and approaches. Attention should be given to how a peer review or model certification process fits with a collaborative process, however, to gain the best results from both.

Careful thought to the charge to any peer review panel is essential for its success. Where the product to be reviewed is the result of participatory modeling, some additional considerations may be important. For example, a CADRe group may consider modeling options or decision-making approaches and choose one that is suited for that issue or is understandable by participants with different kinds of expertise, but which may not be cutting-edge practice. A subsequent peer review may produce different results depending on whether the question posed has to do with the adequacy of the model for the intended purpose versus asking the reviewers to comment generally on the choice of models. Unless the choice of questions has been well thought through and explained, the peer reviewers may perceive that the study is heading in a less-desirable direction, while participants may perceive that the peer reviewers do not understand because they were not part of the discussions leading to the decision. Furthermore, as can happen with any peer-review process, once a decision is reached (or a proposed decision announced), those with a strong interest in a different outcome may use the criticisms from the peer review to try to discredit the study. In some situations, agency conveners may want to invite stakeholders—both those actively engaged and those observing the process—to suggest questions for a peer review.

Peer reviews have an important role in collaborative processes, just as in any other agency decision process. Good peer reviews can raise the right questions at the right times and either confirm direction or allow course corrections where needed. The challenge is to frame up-front an institutional structure and a process that provide opportunity for outside review when and where needed (perhaps iteratively), respect the value that can be added by independent review, ensure that reviewers maintain sufficient distance and do not become co-opted by the study, provide information to peer reviewers about group thinking and decisions, and allow for group consideration of questions raised. Documentation can help this iterative process; while the group has a collective memory of its evolution, peer reviewers will not unless the group's progress and direction is explained.

Model certification processes and requirements need to fit seamlessly with the overall collaborative process. Collaborative processes necessarily require some flexibility in choosing the model(s) to use, as discussed previously. An overly restrictive list of certified models available for use can hamper that flexibility or thwart resolution of difficult stakeholder and/or agency model preference issues, particularly if the group perceives that one agency (rightly or wrongly) is pushing its own models on the group through certification requirements. Some agencies provide the ability to certify newly developed models or applications of those models; this can be helpful if certification time and costs are reasonable and fit well within the overall collaborative process. Similar to peer reviews, advance (and perhaps iterative) coordination, and care in documenting approaches and group decisions, can be helpful to smoothing a certification process. It is critical for agency participants in the group to be open and honest about model certification requirements and processes up front, so that limitations and opportunities are fully understood at the outset and group decisions can be made accordingly.

Decision Making

Ultimately, the decision matters. Agencies and their stakeholders care about the decision itself and how well it addresses their concerns. However, the way in which the decision is made matters as well—both to provide sufficient opportunities for input so that the eventual outcome satisfies as many concerns as possible, and also to provide the transparency and legitimacy needed for stakeholders to accept that the decision made was the best that could be achieved given all the interests and concerns involved. That is why it is so important for agencies to consult with stakeholders to define up front who will make the decision, the constraints or guidelines under which the decision will be made (including regulatory requirements or agency policy), and, if possible, the way in which the decision will be taken—including whether and how agency representatives participate in the group and how the group's work will factor into the agency's formal decision-making process. Agencies (or other conveners) may consider using a facilitator, who can help all sides assess their unique circumstances, provide process advice, and keep the group cognizant of differing roles as needed.

Different agencies, and people within the same agency, may have different perspectives on how much their agency should be engaged in a CADRe process. There is no one right approach, but in considering the options it is important to consider both the role of the agency as an entity and the role of the individual decision makers within that agency.

No agency can fully delegate its organizational decision making responsibilities to a group. However, agency staff (and sometimes decision makers within the agency) can participate fully in a process that leads to recommendations for agency action. Agencies often make distinctions between the roles of decision makers and staff, with decision makers receiving recommendations generated by a group in which staff has

participated. The nature of the role played by staff also can vary. Agencies have the option of having staff participate as a member of the group or of serving as a technical resource but not being part of the group's decisions. An agency also can step back and receive recommendations from a CADRe group on which it has not participated. There are many variations—and pros and cons—to each of these options.

The biggest advantages to an agency (and the process as a whole) when staff participate directly in a CADRe process in some manner is that the agency has a voice in the conversation and that staff can establish or strengthen their relationships with agency stakeholders. Staff can explain the agency's goals and constraints and help shape the process accordingly, and they can learn about the concerns of others. Staff also can raise questions that the agency needs to see addressed, share information it has gathered, offer its staff's expertise in developing and analyzing options, learn first-hand about the nuances of how recommendations evolve, and ensure that the agency's concerns are considered in recommendations made. Stakeholders wish to do the same, and doing so together helps all involved create an effective, problem-solving relationship. In some cases, an observer role can achieve some of these objectives, but unless the agency joins discussions, it runs the risk that agency views and concerns will not be included in the group's deliberations. It can also put a damper on overall discussions, as the group may feel it is being watched and/or that the agency does not value having a direct relationship with them.

Modified degrees of agency participation could include deliberate provision of information throughout the process, but still remaining reserved from the discussions. This is a fine line for agency personnel to walk and can require considerable judgment, but has nevertheless been undertaken in some instances with apparent group acceptance and comfort.

Planning ahead and being transparent about who has formal decision-making authority within the agency, along with the timing, criteria, and the eventual rationale for the decision when it is made, are critical factors in the credibility of collaborative processes. Again, there are several options.

In some circumstances, a regulatory agency such as the Federal Energy Regulatory Commission may decide that its final decision makers—in this case, the commissioners—should play an impartial role and, thus, should not be involved in a collaborative process. However, the agency contributes to the success of these processes by establishing clear procedures for use of a collaborative approach and often encourages staff participation. If the process has been followed, recommendations are generally accepted unless there has been a serious omission. This approach can work well when the agency's concerns are addressed through the procedures and by staff involvement.

In other situations, the agency and its stakeholders agree that agency decision makers will be engaged through periodic briefings. Staff representatives then bring the

questions and perspectives of decision makers into the process, in much the same way as a stakeholder representative would share the views of his or her constituency. The product of the collaborative process is a recommendation, but one that the agency has confidence in using as the basis for any required formal public comments. The engagement of decision makers in this fashion also creates more incentives for stakeholder participation than would a process in which the eventual decision maker is more distant and, thus, more likely to have perspectives or concerns that would need to be taken into account later and might cause the group's recommendation to be changed in a substantial way.

Agency decision makers do need to take public comments into account in a final decision. The degree to which new information is considered after the group completes its work increases the likelihood that the group will not understand, and potentially not support, the direction taken. However, stakeholders generally accept the legitimacy of doing so in response to public comment more readily than when senior management in an agency makes changes that could have been discussed within the process.

The case studies highlight the use of an iterative and interactive decision-making process. This is consistent with recent reports of the National Academy of Sciences, including both *Understanding Risk: Informing Decisions in a Democratic Society* (1996) and *Public Participation in Environmental Assessment and Decision Making* (2008). Decisions improve over time with practice. An iterative process gives the group the opportunity to reflect on and deepen its understanding of how its members, and the group as a whole, reach decisions. It builds credibility for the supporting model within the group, as members not only see how results are used but can also refine how results are presented and delve into results that differ from what was expected. It also allows the group to gain experience with the decision-making process itself, and to explore how modifications to alternatives being considered might (or might not) address specific concerns.

CADRe can help a group get beyond the information struggle. By building a common understanding with common data (input), a jointly-built transparent model, and an agreed-upon presentation of relevant impacts (output), the group can focus on alternatives, trade-offs, and values. Establishing a shared information base and an accepted model for decision making does not mean, however, that the group will necessarily agree on a single recommended outcome. Even ideal tools and processes, while significantly increasing the likelihood of bridging differences, do not always guarantee that people will come up with a mutually acceptable option. In some situations, an agency may ask the group for options as opposed to a single recommendation, perhaps as one means of reserving ultimate decision making to itself. Individual group members will almost invariably develop preferences for one option over another, as well as a sense of other members' preferences. If a decision is required and the group does not arrive at a common preference, the agency will need to make its best judgment. But this judgment can be immensely informed by

the evolution of the group's thinking, and the group (and the public, to the degree the two are intertwined) can have an increased understanding of the agency decision taken. In these circumstances, agencies and their stakeholders also almost always report that the process was helpful in clarifying issues and preferences—and creating the basis for future work together.

A more difficult situation is when the group does arrive at a commonly-held preference or recommendation, but the agency does not implement it. Similarly, if the group was asked to develop options, it can be difficult if the agency does not implement one of the group's offered alternatives. Certainly there will be reasons for the agency making a different decision, such as taking required public comments into account or the emergence of new information. Thus, it is important for agencies to be clear about their responsibilities in advance and to report back to the group about the rationale for decisions when they are made; the degree to which the group knows and accepts these reasons will smooth the path. Timing is important. For example, if the group believes the reasons should have been anticipated and provided to the group for consideration in its process, it may feel undercut and there may be considerable loss of trust between the group and the agency. If new information recently came to light, there may be greater acceptance—although there may still be questions as to why the process established would not anticipate such an occurrence and provide for it within the group itself.

It may be that the group prefers an outcome outside the agency's ability (or willingness) to implement, whether because of lack of funds, lack of authority, or lack of complementary actions by others. Sometimes the energy behind strongly-held common views can prompt actions by others, enabling an outcome that otherwise would not have been possible. Such situations may offer unexpected opportunities, but seizing those opportunities may require building unaccustomed partnerships with uncertain outcomes and timeframes, perhaps in a highly charged atmosphere with the public calling for a decision.

Deadlines, say from a pending decision, focus attention in ways that ongoing processes do not. Rarely do things stand still. These two truisms argue for the shortest process reasonably possible. Personnel changes in agency or stakeholder organizations, particularly at the leadership level, can introduce new thinking that may be difficult to reconcile with group understandings and agreements. Furthermore, organizations' leadership is most likely to engage when a concrete decision is pending.

Even when personnel remains unchanged, it also is important to maintain deliberate ties between group participants and their leadership throughout the group's process to avoid the introduction of late surprises. Again, transparency is helpful but does not replace ongoing management throughout the process.

Evaluating Results

CADRe allows participants to weigh in early in the process, buy in at each stage, and ultimately support the products and implementation when complete. It can yield richer understanding by a wide cross-section of affected parties and a respect for others' views. It requires sufficient time up-front to frame a commonly-held view of the problem and desired approach, but once accomplished can yield quicker, more creative and more accepted solutions. The nature of the process and resulting solutions can limit, but not eliminate, the risk of protracted back-end conflict. Sounds great, but does it work? How do you know? Is the benefit of undertaking CADRe worth the risk?

The various uses of CADRe, some of which have been presented as case studies, form a compendium of experiences. They provide both a qualitative assessment of its uses and outcomes, and a resource for current practitioners. CADRe's ability to improve common understanding and focus discussion on values rather than technical questions recurs again and again, and energizes its practitioners. Those trained in modeling see models being used in new, exciting, and fruitful ways. Those trained in dispute resolution processes see a new tool for addressing conflict. There is real excitement on both sides, fueled in part by real results under real circumstances.

A more systematic evaluation of CADRe will require a larger sampling of applications. The Institute for Water Resources undertook work to develop a suite of performance measures that can address this need (Michaud and Langsdale 2009). Those measures will need to be applied to an appropriately-sized sampling of case studies to provide meaningful results. Meanwhile, an empirical study of environmental conflict resolution (ECR) suggests that ECR performance can be enhanced by providing access to relevant, high-quality and trusted information (Emerson et al. 2009). Not only does such access contribute to effective engagement of parties, it also contributes directly to the quality of agreements reached by the group. CADRe promises to improve this access and further increase the performance of collaborative water resource management.

Acknowledgment

Kirk Emerson's willing reviews, thoughtful suggestions, and kind encouragement during the early development of this chapter is much appreciated and deserves special mention. Kirk Emerson serves as Senior Policy Associate at the School of Government and Public Policy, Institute of the Environment, University of Arizona, and is the former director of the U.S. Institute for Environmental Conflict Resolution of the Morris K. Udall Foundation.

Chapter 13

Training and Education

by Megan Wiley Rivera

Introduction

Preparing its workforce is a challenge for any field. In the case of Computer-Aided Dispute Resolution (CADRe), the typical challenges are compounded by the uncommon but essential combination of knowledge, skills, and characteristics required of its practitioners. In addition, appropriate educational experiences vary with who is being trained and to what end.

Figure 22 provides an overview organized by the target outcome of the education and training. On one end of the outcome spectrum are CADRe mediators: individuals skilled at all aspects of CADRe processes. At the other extreme is the general water resources community and beyond, for which single educational experiences can promote awareness of and interest in CADRe. Between these two groups are individuals who will participate in CADRe processes as part of a team: these individuals would not be responsible for all aspects of the process.

The first section of this chapter focuses on the goals of CADRe education and training—the "Whys" in Figure 22. The second section then considers the "Whats"—what knowledge and skills should be included in CADRe education—by surveying the backgrounds of leading CADRe practitioners. Section three examines the "Hows"—how can the desired knowledge and skills be cultivated in both students and post-graduate professionals to prepare CADRe practitioners and promote awareness and understanding of CADRe? This question is addressed mainly by presenting educational opportunities already available. The final section lists recommended next steps in improving CADRe education and training.

This chapter draws heavily on information gathered through interviews with CADRe pioneers James Creighton, Daniel Sheer, and William Werick. Creighton's firm Creighton & Creighton specializes in public participation including CADRe facilitation, and he serves as a "process consultant" to the U.S. Army Corps of Engineers Institute for Water Resources Shared Vision Planning program. Sheer is president of HydroLogics, Inc. and the driving force behind Computer-Aided Negotiations, a CADRe process practiced by his firm for the past 20 years. Werick developed Shared Vision Planning along with Richard Palmer while a senior planner at the U.S. Army Corps of Engineers Institute for Water Resources (see Chapter 4 for further detail). They were asked the following three questions by the author:

- What about your education/experience best prepared you to develop and participate in CADRe processes?

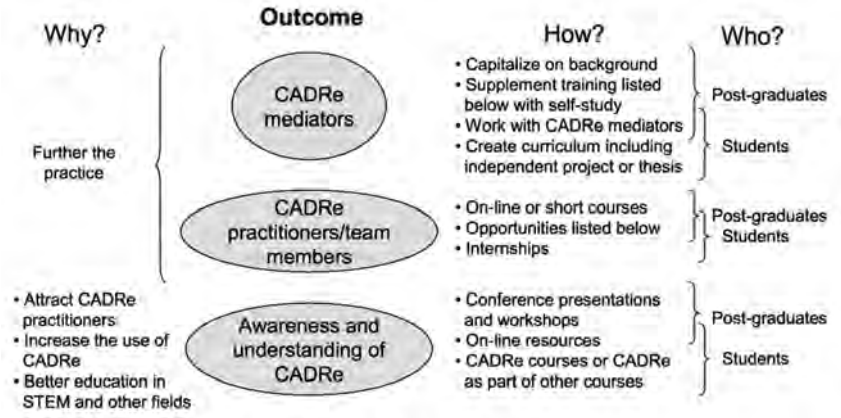


Figure 22: Overview of CADRe educational goals and methods

- Do you think it's important for the facilitator to be facile with the models being used? Should this be a goal of CADRe education?
- What advice would you give a high school student interested in practicing CADRe?

Goals of CADRe Education

The primary goal of CADRe training and education is to prepare individuals to further the practice. Specifically, the field requires people who can convene, design, facilitate, and guide CADRe processes and help identify, build, and use appropriate tools. In discussing educational requirements, it is helpful to separate CADRe mediators, single individuals proficient in both "computer-aided" and "dispute resolution," from CADRe team members. The separation is somewhat artificial, as CADRe mediators work on teams. The key distinction for this discussion is that CADRe mediators are capable of navigating both the modeling and process aspects of CADRe, while team members rely strongly on the expertise of others. For simplicity, consider a CADRe team of one facilitator and one modeler.

While there are pros and cons of using a mediator or a team, here we consider the educational needs of both. The substantial preparation required of CADRe mediators is addressed in the next two sections. Each member of a CADRe team must be capable in their respective roles of facilitation and modeling, but how much understanding of and skills in the other role and CADRe overall is necessary?

When CADRe pioneers were asked what modeling skills CADRe facilitators need, both Sheer and Werick characterized the facilitator as a translator between the participants and the model. In this role, he or she must understand the model, but does not need to be proficient in modeling. The better the understanding of the model,

the more guidance the facilitator can provide in molding stakeholder ideas into a form that can be tested with the modeling tool. This understanding can also serve the facilitator in eliciting and formulating creative approaches to problems that arise (Sheer, personal communication, February 2, 2009; Werick, personal communication, January 28, 2009). Creighton added that experience with complex decision making is perhaps even more vital than comfort with the modeling tools (Creighton, personal communication, January 25, 2009), suggesting that facilitators benefit from engineering and science education beyond computer modeling.

Just as the facilitator benefits from an understanding of the model but does not need to build or use the model directly, the modeler benefits from an understanding of the negotiations process even if that person is not the primary facilitator. Perhaps the most important lesson for the modeler is the need for tools that serve the process. Traditional training for engineers and computer scientists tends to emphasize the accuracy and precision of models. While these are important, they must be balanced with the goals of the process. Often, improved precision and accuracy comes at the price of a number of factors, including: simplicity, which is key to collaborative model building and buy-in from stakeholders; run time; errors in the code (Werick 2007); and alternative uses of time and money.

Exposure to the fields of mediation and negotiation may also help modelers widen their purview from the details of the model to the big picture and end results. According to Werick, the ability to focus on the big picture and end results is the most vital characteristic of CADRe practitioners, and what is frequently lacking in water resources professionals, who tend to view public policy decisions through the lens of their own specialties (Werick, personal communication, January 28, 2009). Undergraduates in particular, who have not yet become personally invested in a specialty or modeling approach, may be the most receptive to such a shift. Students and professionals who already have such a worldview may have it strengthened and may be encouraged to become more involved in CADRe and CADRe-related fields through CADRe educational opportunities.

Preparing individuals to practice CADRe is certainly the primary, though not the only goal of CADRe education. Extending CADRe educational opportunities to the general water resources community and beyond may attract talented, well-suited individuals to the field, promote the use of CADRe, and improve education in science, technology, engineering, and mathematics (STEM) and other fields primarily at the undergraduate and graduate levels (see Figure 22).

With regard to the last goal—improving education—courses designed to teach CADRe are likely to use pedagogically-sound methods due to the nature of CADRe itself. Some background in educational theory is helpful in understanding why this is the case. First, "meaningful" learning is characterized by the ability to apply the knowledge appropriately in new situations. Frequently, the learner's level of

motivation to engage with the new material determines the possibility of meaningful learning (Dole and Sinatra 1998). Motivation is influenced by a number of factors, including the perceived relevance and plausibility of the new material (Posner et al. 1982). These two are connected but distinct. Relevance refers to how useful the information is judged to be by the learner to him- or herself or the world more generally. Plausibility refers to the extent to which the learner believes the information to be true (Posner et al. 1982). Information must be plausible to be relevant, but plausible information need not be relevant.

In traditional lecture and textbook based courses, the relevance and plausibility of the material are not always clear for at least two reasons. First, much of the complexity and disciplinary overlaps are removed to target a specific lesson. Without this culling, the desired lesson may be obfuscated by other information that the student may or may not understand. In doing so, however, the context that would demonstrate relevance is lost, and attempts to supply a simplified context may appear contrived.

Second, students have experiences in which information provided in classroom settings appears at odds with their personal observations of the world. An extreme example of this disconnect is Newtonian mechanics (Champagne, Gunstone and Klopfer 1985; Gil-Perez and Carrascosa 1990; Dykstra 1992; Vosniadou and Saljo 1994), but minor contradictions occur as a byproduct of the simplifications previously discussed. As a result, the plausibility of all classroom-derived information suffers.

CADRe cannot be taught using a traditional lecture and textbook-based approach. Not only do the textbooks not exist, but the context and interdisciplinary connections are as important as the discipline-specific content. CADRe courses would likely draw heavily on case studies, a teaching method that directly addresses relevance and plausibility criteria and has been demonstrated to promote meaningful learning (Carlson and Schodt 1995; Chinowsky and Robinson 1997; Volpe 2002). Further, the two CADRe courses described in the educational opportunities section rely heavily on student-directed team projects. Such projects provide an opportunity for students to integrate new information into relevant existing conceptions derived from previous course and non-course experiences. This conceptual connectivity is another hallmark of meaningful learning (Dreyfus, Jungwirth, and Eliovitch 1990).

By employing case studies and student projects around complex, real-world, interdisciplinary resource disputes, students may learn the disciplinary pieces of CADRe better than they would in a discipline-specific course. Experiencing a CADRe course *before* the discipline-specific course would likely increase the plausibility and relevance of the disciplinary material. This approach has been used in engineering programs that provide freshman-year design experiences as motivation for the rest of the curriculum (Calabro et al. 2008; Hanesian and Perna 2000; Sheppard and Jenison 1997).

This increased motivation to engage in discipline-specific courses may also serve to attract and retain traditionally under-represented groups to STEM careers. There is evidence that some students with an interest and aptitude for STEM fields leave or do not pursue them based on the impression that these fields are isolating and do not provide opportunities to help people or better the world (Seymour and Hewitt 1997; Margolis, Fisher and Miller 2000).

The educational benefits are not limited to STEM fields. The inherently interdisciplinary nature of CADRe processes benefit students and professionals across the board. Some potential benefits of a CADRe role-playing course, for example, include providing students with first-hand experience in balancing multiple objectives, negotiating disputes, and facilitating understanding of and appreciation for the role of science and technology in solving complex problems in public policy (and vice-versa). Arming the next generation with the ability to utilize scientific knowledge and technological tools, function effectively on interdisciplinary teams, and successfully negotiate with disparate interests can only enhance society in both foreseeable and unexpected ways. CADRe education could help produce policy makers who understand the potential of cutting-edge science and technological tools to inform decision making, lawyers who have a new model for negotiation of long-standing disputes, and scientists who can design studies to focus on pressing societal issues.

In summary, the following are four goals, or in some cases, byproducts, of CADRe education:

- Preparing individuals to practice CADRe
- Attracting talented, well-suited individuals to the field
- Increasing the use of CADRe by greater awareness
- Improving education

Skill Set for CADRe Practitioners

In this section, the backgrounds of leading CADRe practitioners are used to identify what knowledge and skills are likely important in CADRe education. When asked what experiences prepared him for developing and practicing CADRe, Sheer responded "everything" (Sheer, personal communication, February 2, 2009). Some of these experiences are discussed below.

Acting. Crieghton, Sheer, and Werick all share a sense of humor and rapport with people that helps put them at ease, strong communication skills, and the confidence to lead a group, even when tensions are high. This combination of technical and "people" skills has been pointed to as central to their success as facilitators in CADRe processes. While some of this talent is likely innate, acting courses and experiences may, in fact, prove effective at developing these abilities in others.

According to Sheer, for example, acting taught him to put himself in the shoes of others, to read an audience, and to recognize effective communication.

Operations Research and Systems Analysis in Water Resources Planning. Operations research (OR) or management research, and systems analysis were identified by both Sheer and Werick as essential pieces of their background. Werick learned systems analysis as part of his training at the Army Corps of Engineers, which used the ideas developed during the Harvard Water Program in the drought of the 1960s (Werick, personal communication, January 28, 2009). For Sheer and Richard Palmer, another CADRE pioneer, this training came from Johns Hopkins University's Department of Geography and Environmental Engineering (DOGEE), where faculty built on the ideas developed during the Harvard Water Program.

The Harvard Water Program began in 1955 as a seminar in the Harvard Graduate School of Public Administration, in part, to develop an approach for maximizing net benefits in water resource systems (Reuss 2003). Much has changed in water resources planning since the Harvard Water Project, but these steps that emerged from this seminar:

1. Specifying the *objectives* of the design
2. Translating the objectives into *design criteria*
3. Using the design criteria to formulate *specific designs* for development and management of water-resource systems that fulfill the objectives to the highest degree
4. Evaluating the *consequences* of these designs (Hufschmidt and Fiering 1966)

These steps have been adopted by and adapted in Shared Vision Planning, Computer-Aided Negotiations, and other CADRe processes. For example, the primary steps in Computer-Aided Negotiations are:

1. Develop performance measures for all stakeholders
2. Reach consensus on the nature of the alternatives to consider and how to structure the evaluations
3. Create and evaluate alternatives in a collaborative setting with other stakeholders

One of the participants in the Harvard Water Program, Robert Dorfman, brought principles of operations research, especially linear programming, to the seminar (Reuss 2003). These methods, in particular, have been influential in Sheer's thinking, teaching him how to frame and solve problems, the importance of clear objectives, and multi-objective theory and non-inferior concepts.

CADRe practitioners have drawn from thinkers outside the Harvard Water Program as well. For example, John Krutilla, an environmental economist at Resources For the Future, paved the way for ecological performance measures in multi-objective analysis and CADRe generally through groundbreaking work in the valuing of undisturbed natural resources. Roland McKean of the RAND Corporation helped shift the framework for the selection of water resource alternatives by, for example, requiring system-wide evaluations and considering the present value of net benefits rather than the cost-benefit ratio alone.

Operations research is one field that can demonstrate the use of a big picture, ends-oriented view of water resource problems. The importance of such a view was discussed in the previous section.

Biology/Natural Sciences. Biological and ecologic issues are part of, if not central to, all contemporary water resource negotiations. The content knowledge and methods learned from biology and other natural sciences will aid in meaningful participation around these issues. In addition, these fields may serve to increase comfort with both the "messiness" of CADRe problems and an ends-oriented approach to CADRe processes, particularly for engineering and computer science students and professionals. Biologists generally deal with a higher level of uncertainty and more confounding factors in their problems than engineers and computer scientists. Many biological studies, particularly field studies, demonstrate that even under non-ideal conditions, significant information can still be gleaned. Note that Sheer's undergraduate degree is in natural sciences, focused on biology.

Political Science. Like systems analysis and OR, political science was identified by Creighton, Sheer and Werick as central to their efficacy in CADRe. None of the three learned political science in a classroom. Sheer, for example, learned how government works initially as a graduate student through mentoring by Mel Shite at Johns Hopkins University, while Creighton and Werick learned the essential role of politics by experience alone. Werick suggested water-specific case studies as a possible means of sensitizing students to the role of politics in a negotiation process. In addition, coursework in political science offers preparation in this area for students.

Psychology. From his freshman-year psychology course, Sheer learned how people think and react. He uses this knowledge in displaying information effectively to stakeholders, down to the color schemes chosen. This background also helps him understand the role of incentives within both group processes and water management plans.

Creighton, who has both a B.A. and Ph.D. in psychology, does not consider a full degree in this area as necessary. Some background in group dynamics and facilitation, however, are important. For Creighton, this training did not come from his academic programs; at the time he was undergraduate, the field of psychology was focused on behaviorism. Instead, parent effectiveness training taught him the core skills he has

used as a CADRe facilitator, including active listening and mutual problem solving. His approach to public participation was then developed by experience (Creighton, personal communication, January 25, 2009).

In addition to "how" to do CADRe, the field of psychology offers insight into "why" CADRe is needed and effective. These topics include collective decision making, social psychology, preference formation, and cognitive limitations. Coursework and self-study are the primary means of acquiring this knowledge.

Mediation. The role of mediation is central to CADRe processes. CADRe mediators often bring parties together, help design consensus-building processes, establish a constructive atmosphere for negotiation, clarify issues to be addressed, help parties obtain data they need to make decisions, facilitate joint sessions and call caucuses, clarify interests and priorities, help parties explore ideas for creative solutions and criteria to evaluate solutions, record agreements as they develop and help parties anticipate implementation problems and address future conflicts.

While Creighton had to draw from non-academic sources to develop his mediation philosophies and techniques, there are now well-established programs and institutions. For example, both the U.S. Institute for Environmental Dispute Resolution and the Association for Conflict Resolution offer conferences, workshops, and trainings. RESOLVE, a dispute resolution non-profit organization, offers various capacity-building opportunities, including individual coaching. All three produce publications and newsletters for self-study. For students, many programs in negotiations and conflict resolution now exist at both the undergraduate and graduate level. See, for example, a list of conflict resolution programs world-wide at http://www.conflict-resolution.org/sitebody/education/international.htm.

Computer Programming. From computer programming, Sheer learned orderly logical structure, which would serve CADRe practitioners who do not work directly with the models as well as those who do. In addition, he learned the capabilities of computers. This background aids in distinguishing between problems that can and cannot be solved on computers and in formulating those that can.

Economics. Economics, particularly resource economics, also helped Sheer understand motivations and human behavior. In addition, this coursework introduced him to marginal cost, cost-benefit analysis, and Pareto optimality (when economic resources and output have been allocated in such a way that no one can be made better off without sacrificing the well-being of at least one person.)

Hydrology. CADRe practitioners would likely draw on much of the content of an introductory hydrology course, but the lesson Sheer identified as most valuable was how to describe uncertainty.

Chemistry and Physics. These physical science courses provide a foundation for how the world works.

English. The importance of strong communication skills, which Sheer gained in part through English literature coursework, was highlighted by both Creighton and Sheer.

Environmental Law. A graduate-level course in environmental law has proved useful to Sheer on a number of his CADRe projects. Technically and politically feasible water resource management plans must also conform to the law, and many CADRe processes occur in places with prior or active litigation that must be considered.

Comparative Religion. Sheer's Sunday school education helped him appreciate different belief structures, and how these structures function when a person does and does not have a rational reason for his or her belief. This education also highlighted the value of knowledge. One of the central goals of bringing the computer models into the dispute resolution process is to test beliefs and arm the participants with knowledge about the system.

Boating. From boating and sailing, Sheer learned self-reliance: when something breaks on a boat, you are the one to fix it. This confidence with problem-solving could aid CADRe practitioners in offering creative solutions to the participants. Also, boating or other outdoor activities can help instill an appreciation of the natural world.

Figure 23 provides a summary of the educational experiences described above. On top of this preparation, Sheer also cites his general curiosity—learning as much as possible about everything—as serving him in developing and practicing CADRe. As an example, his leisure reading of *Getting to Yes* (Fisher and Ury 1983) allowed these principles to inform the Computer-Aided Negotiations process.

Much of the information these pioneers learned by experience or self-study, such as negotiation principles and political science, is now readily available in the classroom. The next section reviews educational opportunities currently available to students and professionals, and then discusses how these opportunities can best be mobilized by the populations for the training outcomes summarized in Figure 22.

Examples of CADRe Educational Opportunities

In this section, a number of CADRe educational experiences currently available are discussed, including CADRe-specific courses, CADRe programs, student projects and research, individualized plans of study, and experience in CADRe processes. The section ends with recommendations on using these opportunities to design an appropriate education.

Courses. For many years, Richard Palmer, one of the developers of Shared Vision Planning, has offered a graduate course in Water Resources Management. Students

Figure 23: Summary of formative educational experiences cited by leading CADRe practitioners

Training/Experience	Operations Research/ Systems Analysis	Biology/Natural Sciences	Computer Programming	Chemistry and Physics
Importance to CADRe	Systematic approach to maximizing net benefits Multi-objective theory Big picture, ends-oriented view	"Messy" problems Biology and ecology subject matter in water resources	Orderly logical structure Capabilities of computers	How the physical world works
Comments	Vital supplement for those with training in dispute resolution side	"Messy" = uncontrolled parameters, confounding factors, high uncertainty		

Hydrology	Psychology	Mediation	Political Science	Economics
Describing uncertainty Subject matter overall	How people think and react Displaying information effectively Role of incentives	Convening and designing processes, facilitate sessions, clarify interests priorities, record agreements, etc.	Understanding of role of politics in negotiation processes and water resources	Motivations and human behavior Marginal cost, cost-benefit analysis, and Pareto optimality
			CADRe practitioners interviewed learned by experience or through mentoring (not class)	

Environmental Law	English	Comparative Religion	Acting	Boating
Role of law in facilitating and deterring improvements in water management	Communication skills	Different belief structures Rational and irrational justifications Value of knowledge	Understand other viewpoints Read an audience Effective communication	Self-reliance Appreciation of natural world
			"People" skill development in engineers/computer scientists	Other outdoor activities could serve same purpose

Figure 24: Addressing skill set for CADRe practitioners in Computer-Aided Negotiations of Water Resources Disputes course

Training/Experience	Operations Research/ Systems Analysis	Biology/Natural Sciences	Computer Programming	Chemistry and Physics
CADRe Role-play Project	12 different performance measures (one for each student/ stakeholder) were considered during course negotiations; process-serving models were discussed and demonstrated	Focus on performance measures (PMs) for endangered mussels and oysters, providing content knowledge and demonstrating "messiness"	All students programmed operational alternatives in macro language	Salinity, estuarine dynamics, water temperature, and mass balance all part of PM and management alternative development
Guest Lectures	Linear programming	Delaware Basin Ecology	Introduction to the model	Conservation of mass

Hydrology	Psychology	Mediation	Political Science	Economics
Floodplain inundation PM based on an IHA; flooding PM; all students worked with watershed management model	Designed PM displays and written and verbal explanations to most clearly and accurately demonstrate stakeholder interests	Students participated in a series of negotiation sessions throughout the semester	Negotiations held in context of consent decree and subsequent inter-state agreements; plan that met all objectives likely to last	Value of recreation (livery and lake PMs) and fisheries (shad and oyster PMs)
Watershed hydrology, runoff, reservoir operations, etc.		Mediation principles and techniques	Discussions by mediator and lawyer for Delaware River Basin Commission	Valuation of natural resources

Environmental Law	English	Comparative Religion	Acting	Boating
History of consent decree, import of endangered dwarf wedge mussels, and litigation as alternative to negotiations discussed	Written reports document PM development and negotiated basin management plan; oral communication during negotiation sessions	Tested stakeholder beliefs against simulation model; found (e.g.) little could be done to prevent flooding and many objectives could be met simultaneously.	Students took on viewpoint of assigned stakeholder groups with fervor; also understood viewpoints of other stakeholders and thus collaborated easily	Not yet, but field trip would be a good addition
Introduction to Eastern Water Law and Delaware Basin Issues				

spend the bulk of the class applying the seven steps of the Shared Vision Planning process[1] to a case study. At the end of the course, they examine additional case studies, including the Rio Bravo Basin, the site of an international dispute. The syllabus describes the course as "a team projects-oriented learning experience in which students are taught the basics of water resources planning and then asked to apply them in a challenging case study. Fun on a lot of levels."

In 2008, Megan Wiley Rivera and Daniel Sheer of HydroLogics, Inc., partnered with Andrew Miller of the University of Maryland Baltimore County (UMBC) to develop an undergraduate course in which each student role-plays a different stakeholder interest in a multi-state water dispute, titled Computer-Aided Negotiations of Water Resources Disputes. The Delaware River Basin was used in the pilot version of the course. The students worked in teams, one for each state involved in the conflict, to develop performance measures for their stakeholder groups, and then assess alternative operating policies in terms of these measures both within their groups and during negotiation sessions with the other states.

CADRe courses such as these present the opportunity to integrate much of the skill set outlined in the previous section while demonstrating the steps and potential of CADRe processes. In the Computer-Aided Negotiations course, for example, all of the topic areas shown in Figure 23 were covered, with the exception of "boating." While the course centered on the role-playing project, during the first half of the semester, practitioners in a range of CADRe-related fields provided guest lectures (all of which are available for download). Figure 24 summarizes how each of these subject areas was addressed by both the guest speakers/lectures and the course project.

Materials from both courses, including the models, are available on-line. In addition to the case studies contained in this book, a bibliography of case studies is available on the Shared Vision Planning Web site (http://www.sharedvisionplanning.us/), and case studies with models can also be obtained from HydroLogics (http://hydrologics.net/). These materials could be adapted to courses at various levels with various focal points for various student groups, depending on the course goals.

The pilot version of the Computer-Aided Negotiations course, for example, drew undergraduates from a wide range of disciplines, including chemical engineering, history, psychology, and environmental science. While most of these students will never practice CADRe professionally, the experience of working with people of varying backgrounds will benefit those who do. In addition, offering the course to this group of students targets two of the other goals of CADRe education: attracting talented, well-suited individuals to the field and improving education in CADRe-related fields.

1 See http://www.svp.iwr.usace.army.mil/trnDemoFair.cfm for a demonstration project using the seven steps of the Shared Vision Planning process.

By advertising the CADRe course across the university, students from a variety of backgrounds whose interest were piqued by the course description gained the experience of role-playing a CADRe process. Any students who were "turned on" to the field based on the course would have ample opportunities to supplement their education at the graduate level. Thus, the goal to attract talented, well-suited individuals to the field was served. With regard to improving education in CADRe-related fields, the course employed sound pedagogy, as discussed in the previous section, through the role-play of an actual water resources dispute, along with details of course implementation.

Abridged courses for professionals could draw on the same materials used in the courses described above. In fact, Palmer has offered a one-day version of his Water Resources Management course to practicing engineers. According to Werick, who has served as a co-instructor for these courses, the level of interest of the course participants is the most important factor in determining success of the course (Werick, personal communication, January 18, 2009). This suggests that courses should be developed as needed rather than advertising widely and attracting individuals who need training credit but have mild interest in the field. For professionals who will not play a central role in the process, short, virtual courses through professional organizations such as the American Society of Civil Engineers, the Association for Conflict Resolution, and the U.S. Institute for Environmental Conflict Resolution may provide sufficient background to help them understand, appreciate, and better-participate in the process.

Programs. A number of graduate programs include CADRe beyond a single course. For example, the MIT-USGS Science Impact Collaborative (MUSIC) (http://web.mit.edu/dusp/epp/music/) includes "a Science Impact Coordinator curriculum to help teach graduate students in a range of professional degree programs about the best ways of handling scientific and technical controversies surrounding public policy decisions of various kinds." (http://web.mit.edu/dusp/epp/music/wwd/index.html, accessed 2/12/09) Coursework includes negotiation and dispute resolution in the public sector. Perhaps even more valuable than the coursework are the individual projects students complete as part of the two-year Masters of City Planning degree. Identifying opportunities for these students to participate in CADRe processes can be challenging (Herman Karl, personal communication, September 14, 2007); CADRe practitioners can, therefore, significantly contribute to building capacity in the field by contacting program faculty to promote student involvement.

Student Projects and Research. Even when an academic program is not designed for CADRe training per se, many different graduate programs could provide necessary support to individual students. As an example, Diane Tate completed a Masters of Public Affairs at the LBJ School of Public Policy, University of Texas at Austin in 2002. Her thesis, *Bringing Technology to the Table: Computer Modeling, Dispute Resolution, and the Rio Grande*, studied the effectiveness of using computer models

to help manage the dispute resolution process. Her test case was the Lower Rio Grande/Rio Bravo which borders both Texas and Mexico. Policy makers, agency representatives, farmers, environmental researchers, and academics from both countries participated in a day-long drought exercise in which they attempted to manage the water resource together through a simulated drought.

What did this experience teach Tate? A master's thesis does not provide the time or money to study a full CADRe process, but this project involved a number of the essential pieces. These include working directly with stakeholders, using resource management computer models, learning background information on water resource management issues, and utilizing a modeling tool in a collaborative process with stakeholders.

First, her study involved bringing the players to the table, in this case, the *actual* stakeholders on this river. Working with these stakeholders both prior to and during the drought exercise provided many logistical and practical lessons. In fact, one of Tate's primary conclusions was that simply being together was valuable to the participants:

> Participant feedback consistently supported one positive achievement of the Operations Exercise—getting people to show up. Observation of conversations that took place during down time in the simulation corroborates this input, as many participants renewed connections with colleagues, discussed upcoming projects, and introduced themselves to individuals they did not previously know. (Tate 2002, p. 98)

In addition to working with stakeholders, Tate was introduced to a number of modeling tools and became proficient in using one of these. A chapter in her thesis is devoted to examining eight water resource management models, providing some level of familiarity with each. She then received in-depth training on the particular model used for the drought exercise. A team of three other graduate students also received this training as they assisted her with the model development and worked on different aspects of the process for their own course projects. This also gave her the experience of relying on a team and being comfortable with not having all the answers.

Along with experience in modeling and working with stakeholders, she learned about water resource management issues in Lower Rio Grande/Rio Bravo basin and, by extension, water resource management issues in general. Her thesis lays out the interests of each stakeholder group, the legal framework of both Texas and Mexico, and recent tensions caused by drought and negotiations over Mexico's water debt (Tate 2002). Her student team was also exposed to a number of these issues while preparing for the drought exercise.

A cornerstone to any CADRe process is utilizing a modeling tool in a collaborative process with stakeholders. This thesis project did just that in the form of a drought exercise. Specifically, the stakeholders were led week-by-week through a simulated

drought, and asked to make decisions about operating the system. The model helped illustrate the impact of their decisions on all the stakeholders' interests. Such an exercise can be used as part of CADRe to develop operational alternatives, educate stakeholders about the system and each others' interests, and build community among participants. While this exercise is only one potential piece of a larger dispute resolution process, many of the principles involved in its choreography are directly applicable to other steps in a full CADRe process. This single meeting therefore provided strong preparation for effective participation in CADRe more generally.

Tate not only learned how to design and facilitate a drought exercise, but also discovered that other steps in a CADRe process are essential for the success of such an exercise. For example, she reports that:

> … trust in the model is a determinant of comfort with and participation in the process' technical aspects. A process to facilitate actual negotiations would require extensive involvement on the part of all parties during model development and testing, to gain familiarity with the software, data, and results. (Tate 2002, p. 98)

Similarly, she found that participants needed more than a single exercise to develop alternatives.

Based on educational theory, it is likely that this project was an effective means of teaching Tate the skills, concepts, and knowledge described above. Elements of effective teaching and how CADRe education lends itself to meaningful learning were discussed in the previous section. One reflection of its effectiveness is the professional accomplishments Tate has achieved since earning her masters. She is currently a project manager at CDR Associates, an internationally recognized organization of conflict resolution specialists headquartered in Boulder, Colorado. Most of the public involvement and mediation projects she has worked on rely on simulation models of the systems under dispute, though these models generally exist before she gets involved, so model development is not part of the negotiation process.

Tate was able to craft and execute this study with the support of her undergraduate background, her graduate program, her faculty advisor, and a CADRe practitioner. Her undergraduate degree in Civil Engineering provided a foundation for the technical aspects of the study.

The LBJ School offers Natural Resources and the Environment as one of seven specializations for Masters of Public Affairs. According to the program's Web site, "[t]his specialization encourages graduate students to use technical, economic, and political information to be effective in policy analysis and policy making within local, regional, state, or federal arenas." Tate supplemented this coursework with courses in the School of Engineering, which were particularly valuable in the data collection and modeling pieces of her research (Tate, personal communication, January 22,

2009). Flexibility in coursework thus contributed to her ability to complete such a project through this program.

The expertise of her advisor contributed greatly to the project. While not primarily a CADRe practitioner, David Eaton has all the commonly occurring elements in his own background, including an undergraduate degree in biology and a Ph.D. in Environmental Engineering and Geography from Johns Hopkins University. He is an expert in water resource conflicts, especially international disputes. This expertise includes performance measure development through public participation in places like the Colorado River Basin (Eaton 2000) and the South Saskatchewan River Basin (Eaton 2008). Through his graduate program, he knew Daniel Sheer, a CADRe practitioner, who served as a co-advisor to Tate.

While perhaps not essential, the ingredients that made this particular thesis study possible include a student with an undergraduate background in a CADRe-related field (in this case, engineering); a graduate program in a different, complementary CADRe-related field (in this case, Natural Resources and Environmental Policy); an advisor with expertise in an aspect of CADRe (in this case, performance measure development and water conflict meditation), relevant connections, and funding; and a CADRe practitioner available for guidance on the model and the process.

Individualized Curricula. At the undergraduate level in particular, students with a developing interest in CADRe may find themselves piecing together a curriculum to prepare them for practice and/or future study. The list in the skill set section (summarized in Figure 23) provides a starting point for these students. While courses in most of these areas are generally available, programs that specialize in these fields can be easily found. For example, The Institute for Operations Research and the Management Sciences provides a list of colleges and universities offering programs in OR/Management Sciences (ORMS Educational Programs in the U.S. 2007).

Students seeking to design a curriculum would benefit from individualized guidance from CADRe practitioners.

Conferences. Including CADRe presentations, sessions, and workshops at a variety of conferences will expose professionals, and to some extent, students, to the field. This is perhaps the most appropriate venue for the two CADRe educational goals of attracting talented, well-suited individuals to the field and increasing the use of CADRe through greater awareness.

Direct Experience. Courses and projects can provide a foundation for effective CADRe participation, but there is no substitute for direct experience. Education via direct experience occurs during every CADRe process. Practitioners should consider ways to involve interested students and professionals that will enhance their projects and the students' education.

Self Study. Post-graduate professionals, in particular, will likely need to include self-study in their preparation. Conference papers, journal publications, this book, case study databases, and project reports all provide valuable information for aspiring CADRe practitioners. The Shared Vision Planning Web site (http://www.svp.iwr.usace.army.mil/) provides a database of such resources.

Designing a CADRe Education/Training Program. As always, different educational opportunities are appropriate for different purposes; in the case of CADRe, some of these opportunities and purposes are illustrated in Figure 22. To attract talented, well-suited individuals to the field of CADRe, promote the use of CADRe, and improve education in CADRe-related fields requires expanding awareness of CADRe in the water resources community and beyond. Conferences provide a clear opportunity to reach a large audience. Conference workshops can expand these opportunities from exposure to meaningful training. The expanding collection of Web-based resources also provides a means of CADRe exposure. The impact of these resources will be magnified by targeted and extensive linking with other sites.

In addition to conferences and Internet sites, CADRe courses, especially at the undergraduate level, will promote CADRe exposure. The pilot version of the Computer-Aided Negotiations of Water Resources Disputes course demonstrated the appeal of such a class to students with a wide range of majors. CADRe principles and case studies can also be integrated into courses in many departments. Disseminating educational materials, such as those used in CADRe courses and those cited under "self-study" above, will facilitate their use in the classroom.

Moving beyond CADRe awareness to preparing CADRe practitioners, aspiring CADRe team members must first be skilled in their role as facilitator or modeler. The more training in and understanding of the others' role and CADRe generally, the better prepared they will be. Conference presentations and workshops, Web-based resources, and coursework discussed above can provide some of this expansion. In addition, students can take courses in the fields listed in Figure 23. Similarly, postgraduates can benefit from on-line and short courses provided by professional societies.

The most potent educational experiences for aspiring CADRe team members, however, are CADRe-specific internships and courses. Currently, student internships with CADRe practitioners and university and professional CADRe courses are in short supply. Expanding and advertising these opportunities should be a priority.

Some combination of the educational experiences listed in the previous two paragraphs would provide sufficient preparation for many people to participate effectively in CADRe processes as a member of a team. Fulfilling both the roles of facilitator and modeler as a CADRe mediator, however, requires even more.

From a practical standpoint, post-graduate professionals need some background in many of the fields listed in Figure 23. An exceptional aptitude in areas where experience or training is lacking may also suffice. It may not be obvious that knowledge of physics, for example, is needed to mediate CADRe processes, and in some cases, it may not be. However, when physics-based issues do arise, in reference to energy generation, for example, a mediator who has some understanding of the issue will be more effective than one who does not.

A post-graduate professional can then supplement this background with the educational opportunities already described. Whatever gaps still remain can be filled with self-study.

Students can create an individualized curriculum, which should include a CADRe-based independent project or thesis if possible. The specifics of the curriculum will vary depending on student interest and available opportunities. The information provided in this chapter along with input from an academic advisor and CADRe practitioner should provide sufficient guidance to develop an effective course of study.

The art of CADRe mediation, however, must then be honed through experience. This is true for both professionals and students. Working with a CADRe mediator is one way to gain this experience; apprenticeship is arguably the most effective means of CADRe education. At some point, with or without the benefit of apprenticing, practicing CADRe becomes part of the educational experience.

Recommended Next Steps

At the 2007 CADRe Workshop in Albuquerque (Education and Training in CADRe group) the following list of action items was developed in the education breakout session, some of which have been undertaken:

1. Use the CADRe Wiki as a common information source for materials, programs, course information, contacts, and internships.
2. Create more internship opportunities for graduate students.
3. Develop and post a list of the desired skill set for CADRe practitioners to guide students and others who wish to expand into this field.
4. Create a Best Practices Manual of CADRe techniques (underway through a Task Committee of the American Society of Civil Engineers' Environment and Water Resources Institute) and/or revive a version of the Harvard Water Program.
5. Expand Shared Vision Planning's bibliography.
6. Develop training opportunities in cooperation with professional organizations.
7. Include CADRe in undergraduate and graduate courses as possible.

Chapter 14

Conclusion

by Lisa Bourget and Hal Cardwell

The Collaborative Modeling for Decision Support / CADRe concept

CADRe is an approach to decision making where parties negotiate agreements by communicating through a mutually developed and accepted computer simulation model. The umbrella term for this approach is evolving to "Collaborative Modeling for Decision Support." The approach integrates collaboratively-built computer modeling with participatory processes in ways that support decision making, promote group learning, improve dialogue among technical and political actors, encourage competing interests to identify trade-offs, and encourage negotiations among interests. Political and technical participants bring their information and values to the table and together build a computer simulation model that describes their collective understanding of "what is," allows for exploration of a multitude of scenarios that provide factual information about "what could be," and supports a group decision on "what should be." CADRe promotes dialogue over tough issues and clearly illustrates trade-offs. It uses the advances of technology and software in the service of accountable decision making by helping interests negotiate, construct possible solutions jointly, and illustrate the consequences of possible decisions. The use of the computer simulation model is analogous to single-text negotiation tool; it is a way for participants to organize their information and deliberations, and its usefulness is enhanced by the collaborative development that ensures the model is understandable, transparent, and relevant for decision making. The model provides a common framework, but the process gives the authority for planning decisions—from criteria development and the formulation of alternatives, to evaluating the trade-offs and making a selection for implementation—to the process participants. The process yields increasing trust in the models and increasing willingness by participants to explore new trade-offs that can lead to unexpected solutions and lasting decisions.

From Lake Ontario to the Rio Grande to the Roanoke River and to Northern California, the preceding chapters demonstrate how CADRe has been useful in addressing complex water problems in situations that require multiple levels of decision making and multiple stakeholders holding a variety of objectives which they want to maximize. With willing participants, CADRe provides a multi-party learning and negotiation process that can generate agreement on a preferred alternative, and thus a supportable decision for sustainable implementation. CADRe produces accountable participation by appropriate parties and results in a decision that can be defended as being in the public interest.

The participatory and joint modeling brings relevant scientific and technical information and data to the table, prompts consideration about the appropriate scale and

level of detail for decision making, and ties ideas on possible alternatives to their anticipated consequences. The process builds understanding of the system and of participants' views, provides a means for diverse participants to work together in seeking an outcome that makes each participant better off, and strengthens relationships as trust grows among participants and their organizations. Through deliberate collaboration in the technical analysis, CADRe provides a "real time" peer review process that helps move beyond "group think" or lowest-common-denominator solutions, and allows technical knowledge to iteratively and continuously inform negotiation by political interests.

CADRe is distinguished from other public processes that use computer models by its high level of integration with participatory processes. It does not presume a particular model at the outset. CADRe seeks to create joint models that best meet the needs of participants and decision makers, in essence a "picture" of the situation at hand and how that might change. It does not assume computer modelers and technical experts will be solely responsible for the model's form and content. Rather, it involves participants in ways that reflect their issues and concerns as well as how their interests affect the interests of others. It does not presume that participants come to the table with unchanging views, but acknowledges that information exchange through model development and assessment of alternatives can lead to changed understandings and collaborative learning that may, in turn, need to be incorporated into the model itself. It does not identify the "best" or "optimized" outcome for participants, but seeks to provide information meaningful to participants about the consequences of various alternatives, supporting a decision but ultimately leaving that decision to participants themselves. The resulting model provides the level of detail and technical sophistication appropriate to the needed decision. As such, the resulting model is a direct product of the participatory process, serving the individual and collective needs of the participants, and the interests they represent.

CADRe requires attention to both process and substance. It tries to help parties identify implementable solutions that will work. Often these will be solutions that no one party thought of before engaging in CADRe processes. They should be good technical solutions, even if not optimum in the eyes of every stakeholder. However, they will be implementable and they will work to manage problems in cost-effective ways. Technically elegant solutions alone do not resolve conflicts, especially if they are not understood or if they do not address some concerns. The process for assessing the situation, bringing participants together, helping them to see that collaborative decision making may provide the best opportunity for a sustainable solution, and supporting their participation is critical. Models resulting from CADRe processes must be supportable, by technical experts and participants alike. The participatory process enhances model credibility. The way in which the model is built and tested also promotes shared learning and understanding, thus paving the way for buy-in and support of the resulting decision.

Earlier chapters provide numerous successful applications of CADRe processes that led to shared visions for planning purposes, shared understandings, and supportable decisions that resolved complex water resource management conflicts. The case studies emphasized repeatedly the focus and understanding offered by a collaboratively-built model, the opportunities to build trust through working together and addressing varied views, and the often-unexpected ease in implementing commonly-developed and supported solutions. However, CADRe is neither a panacea for all water problems nor a guarantee of success. Water resources management is complicated. It may be difficult to identify alternatives that make all participants better off, without which a lasting solution may be elusive. Decisions take place within a broader sphere than solely the water resources management issues considered, so it may be difficult to find a lasting solution by focusing solely or even primarily on water issues. If the convener does not see the value in shared decision making, if participants have options more likely to achieve their goals than shared decision making, or if a climate of openness and trust cannot be nurtured, then chances of a successful conclusion are diminished.

CADRe provides a path to success where other approaches may fail. The availability of a model that describes the problem/situation, that is accountable to stakeholders, and that stakeholders feel they own, fosters the ability to cast a broad net exploring many creative alternatives and their resultant trade-offs. This broad net increases the likelihood of finding supportable solutions. Politically, the CADRe process provides legitimacy because the structured participatory process allows affected parties a seat at the table to evaluate trade-offs and impacts, build a shared understanding, and reach a more broadly supportable solution. The shared model provides a vetted technical underpinning and a common framework for visualizing and understanding the impacts of the decision. Addressing both political and technical aspects provides for increased accountability and implementability.

Future Directions

The increasing demands on water resources, climate change impacts, insufficient infrastructure budgets, and aging infrastructure mean that water resources management challenges will become more complex and solutions more pressing. These challenges demand a systems perspective, require broad inclusion, and mandate both technical excellence and creativity. Recognizing that the CADRe approach is relatively new and the number of practitioners relatively limited, various efforts are underway improve and expand its use.

This book seeks to document efforts already undertaken, and expand on them, but by no means will this be the final word. Indeed, it is meant as a touchstone, to synthesize what has happened and to provoke debate and learning. Groups of committed individuals are continuing to clarify and improve practice of the newly-termed Collaborative Modeling for Decision Support (to replace CADRe), and the quality and quantity of its practitioners, striving to be inclusive while ensuring that basic underlying principles are maintained. Issues being addressed include: how to

better define and document methods; whether certain approaches are better suited to certain problems and, if so, how one would know; and considering the appropriate roles for modelers and facilitators in the process.

Learning through interchange is another useful way to improve use. Those interested in Collaborative Modeling for Decision Support are developing an on-line space for collaboration and engagement for a community of practice and to distill key principles and illustrate them with best practices. Efforts are also underway to link with practitioners of Collaborative Modeling for Decision Support internationally and with Integrated Water Resources Management. The ability to measure success is also an important guide to improving use, and work is underway to develop and implement evaluation criteria for assessing processes.

Advocates of Collaborative Modeling for Decision Support are reaching out to leaders in federal agencies to inform them about the approach, its potential benefits, its relation to relevant collaboration directives and policies, apprenticeship/internship programs with practitioners and growing formal courses being offered in universities.

Many decision makers are excited about Collaborative Modeling for Decision Support and ask how to expand its use. This excitement is driven not only by the promise of achieving resolution of complex issues through application of its processes, but also by a sense that that the time is ripe for these processes. Recent federal emphasis on transparency, public participation, and collaboration—including a 2007 recommendation by the White House's Subcommittee on Water Availability and Quality and a January 21, 2009, memorandum from President Obama—underscores that this is an opportune time to spread the word on the concepts and insights offered by Collaborative Modeling for Decision Support, and the promise it offers for finding better answers together.

Summary

Collaborative Modeling for Decision Support / CADRe is a process that allows interests to "jointly diagnose" problems, "jointly create" options, and "jointly work" to implement a plan. It offers new means to more effectively manage and mediate tough water resources disputes. Agreement is never assured but the prospects are increased if processes facilitate joint learning while also building social trust and understanding among participants in the process. In turn, this joint learning and social trust creates both the motivation and opportunity to discover alternatives that are more acceptable to a broader range of stakeholders. Collaborative Modeling for Decision Support can be a useful tool for water managers facing complex decisions with multiple often-conflicting interests and divided powers. As the community of practitioners better define and measure successes using Collaborative Modeling for Decision Support, and as the community grows and develops, there will be greater opportunity for water managers to avail themselves of this powerful approach for the complex technical and political water challenges that confront us all.

Glossary

Alternative Dispute Resolution (ADR) – a range of dispute resolution procedures that provide for the settlement of disputes outside the traditional court procedures and structure.

Analytic dispute – disputes over the data, analysis, and models used to characterize problems and the consequences of different alternatives that address the problem.

Authority dispute – the diffusion of formal and informal authority to decide or to review (and possibly veto) decision making and implementation.

Bargaining – a competitive and positional form of distributive negotiation, in which two or more people or groups seek exchanges for individual advantage.

Baseline alternative – an alternative against which other possible alternatives are measured, often the status quo.

CADRe – an approach to decision making where parties negotiate agreements by communicating through a mutually developed and accepted computer simulation model (now becoming known as Computer Modeling for Decision Support).

CADRe model construction – the process by which to organize data, stakeholder knowledge, and scientific knowledge into a framework credible to all.

Collaborate – to work in partnership toward a common goal.

Compensation – payment for the value of induced damages or losses. Payment can be economic (cash compensation) or non-economic.

Computer model – a computer program, or network of programs, that simulates relationships that occur in the real world, often showing the expected effects of changes over time.

Computer Modeling for Decision Support – integrating collaborative modeling with participatory processes to inform natural resource management decisions; new general name for Computer Aided Dispute Resolution (CADRe) being adopted by those in the field.

Conflict – the underlying reasons for differences about what should be done, arising from competing interests, differing values, lack of common understanding and/or competing rights or procedural rules, which often remain as constants that get expressed in specific disputes at a particular time or over a specific decision.

Consensus – agreement among all parties to a decision that an approach or solution is acceptable; i.e., that none of the parties will attempt to thwart implementation. This is often described as all sides can "live with" the decision.

Convener – the person or organization with sufficient credibility to invite stakeholders to address a problem collectively.

Cooperate – to align individual efforts so they are complementary.

Decision maker – the person or persons with ultimate responsibility and authority for selecting an alternative for implementation.

Decision making – selecting an alternative for implementation.

Decision participants – those people (and, through them, organizations) directly involved in a collaborative decision-making process.

Dispute – disagreement on what should be done in a particular situation.

Dispute resolution – processes of negotiation and bargaining as a means for making decisions where parties initially disagree, sometimes in situations with high conflict and low trust.

Facilitator – someone who moderates a meeting. Facilitators often perform some of the tasks associated with mediation.

Inferior alternatives – alternatives that do not improve the desired outcome of any performance metrics compared to a baseline alternative.

Interest dispute – when an alternative will influence different decision participants' socio-economic well being.

Joint fact finding – integrating technical expertise into negotiation processes.

Mediator – a person or persons who, in an impartial manner, assist all parties to negotiate with one another. Mediators bring parties together, help design consensus building processes, establish a constructive atmosphere for negotiation, clarify issues to be addressed, help parties obtain data they need to make decisions, facilitate joint sessions and call caucuses, clarify interests and priorities, help parties explore (sometimes in private) ideas for creative solutions and criteria to evaluate solutions, record agreements as they develop and help parties anticipate implementation problems and address future conflicts.

Mitigation – measures that lessen or offset induced damages or losses.

Model – a way to show or describe relationships that occur in the real world.

Modeler-Mediator – a person with broad-based skills who takes on a leading role in both the modeling and mediation aspects of a CADRe process.

Negotiation – a dialogue involving two or more people or groups seeking to produce an agreement that satisfies the interests of the parties through a combination of bargaining for individual advantage and creative and collaborative problem solving.

Optimization – a means of seeking a solution by defining specific desired criteria and then minimizing or maximizing among them using weighted values that address the trade-offs between conflicting criteria.

Performance metrics – indicators of outcomes of interest and concern to decision participants that are included in a computer model to allow measurement of how outcomes will change under various alternatives (including future scenarios, differing management choices, etc.)

Problem solving – determining what is causing either a dispute or an undesirable result, generating and evaluating options to understand and/or fix the undesirable situation, and selecting an option acceptable to all.

Public engagement – public participation characterized by greater participation, ongoing two-way communication, and greater public impact on the ultimate decision.

Public involvement – public participation characterized by relatively limited participation, including information sharing, occasional workshops or other forms of two-way communication, and less public impact on the ultimate decision than public engagement.

Public participation – a general term describing involvement by citizens in a decision-making process. There are varying degrees of participation possible, ranging from one-way receipt of information, to opportunities to provide comment, to two-way discussions, to ongoing structured engagement including joint action to implement decisions.

Public relations – managing a process's interactions with the general public.

Shared Vision Model – the computer model developed during a Shared Vision Planning process.

Shared Vision Planning – a particular application of CADRe that integrates planning principles with systems modeling and collaboration to provide a practical forum for making water resources management decisions.

Simulation – a representation of key elements and interactions over time, often in a computer model. Water resources simulations typically represent the physical, chemical, and/or biological system and how it will change over time under varying circumstances.

Sponsor – the person(s) or organization(s) who provides the financial and other support necessary to enable the overall decision-making process and stakeholder participation in that process. This may or may not be the same as the convener.

Stakeholder – an organization or person who may be directly affected by the decision in question, whose participation may be needed in the implementation of agreements reached, and/or who has a keen interest in the outcome of the decision.

Value dispute – when different opinions arise about whether an alternative is good for a community (as opposed to the individual decision participant.)

Bibliography

Adler, P.S., R.C. Barrett, M.C. Bean, J.E. Birkhoff, C.P. Ozawa, and E.B. Rubin. *Managing Scientific and Technical Information in Environmental Cases*. Publication date unknown. Accessed on 8/10/07 at http://www.resolv.org/about/pubs.html.

Andersen, D.F. and G.P. Richardson. "Scripts for Group Model Building." *System Dynamics Review* 13(2) (1997): 107-129.

Ayres, Donna, Frank Carr, James Creighton, Jerome Delli Priscoli, Lester Deleman, Trudie Wetherall. Overview of Alternative Dispute Reoslution (ADR): A Handbook for Corps Managers: Pamphlet #5, Laternative Dispute Resolution Series. Institute for Water Resources, U.S. Army Corps of Engineers, IWR Report 96-ADR-P-5. Alexandria, Virginia (July 1996).

Bauer, Michael R. and John Randolph. "Characteristics of Collaborative Environmental Planning and Decision-Making Processes." *Environmental Practice* 2 (2000) 2: 156-165.

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

Bingham, Gail. *Resolving Environmental Disputes: A Decade of Experience*. Washington, DC: Conservation Foundation, 1986.

Bingham, Gail. *When the Sparks Fly: Building Consensus When the Science is Contested*. Washington, DC: RESOLVE, 2003.

Borton, Thomas E., Katherine P. Warner and J. William Werick. "'Influential' Identification: Research Methods and Socioeconomic Characteristics" in *Public Involvement Techniques: A Reader of Ten Years Experience at the Institute for Water Resources*. Institute for Water Resources, U.S. Army Corps of Engineers, IWR Report 82-R-1. Alexandria, Virginia (September 1998).

Busenberg, George J. "Collaborative and Adversarial Analysis in Environmental Policy." *Policy Sciences* 32 (1999): 1-11.

Calabro, K.M., K.T. Kiger, W. Lawson, and G. Zhang. "New Directions in Freshman Engineering Design at the University of Maryland." Conference proceedings for the 38th ASEE/IEEE Frontiers in Education Conference (Saratoga Springs, New York, October 22-25, 2008.)

Call, C.H. "Framework for Effective Stakeholder Policy Making For Water Resources and Environmental Issues." Paper presented at the World Water Congress 2001, American Society of Civil Engineers.

Cardwell, H., S. Langsdale, L. Shabman, and K. Stephenson. *Computer-Aided Dispute Resolution: Proceedings from the CADRe Workshop – Albuquerque, New Mexico, September 13-14, 2007.* Institute for Water Resources, U.S. Army Corps of Engineers, IWR Report 07-R-06. Alexandria, Virginia (December 2007).

Cardwell, H., S. Langsdale, and K.Stephenson. The Shared Vision Planning Primer: How to incorporate computer-aided dispute resolution in water resources planning. Institute for Water Resources, U.S. Army Corps of Engineers. IWR Report 08-R-02. Alexandria, Virginia (January 2009).

Carlson, J.A. and D.W. Schodt. "Beyond the Lecture: Case Teaching and the Learning of Economic Theory." *Journal of Economic Education* 26(1) (1995): 17-28.

Carmichael, Jeff, James Tansey, and John Robinson. "An Integrated Assessment Modelling Tool." *Global Environmental Change* 14 (2004): 171-183.

Chinowsky, P.S. and J. Robinson, J. "Enhancing Civil Engineering Education Through Case Studies." *Journal of Engineering Education* 86 (1997): 45-49.

Champagne, A., R. Gunstone, and L. Klopfer. "Instruction Consequences of Students' Knowledge and Physical Phenomena." *Cognitive Structure and Conceptual Change*. L. West and A. Pines, eds. Orlando, FL: Academic Press, Inc. (1985): 163-187.

Claussen, E. "Making Collaboration a Matter of Course: A New Approach to Environmental Policy Making." *Environmental Practice* 3, no. 4 (2001): 202-205.

Cockerill, K., V.C. Tidwell, and H. Passell. "Assessing public perceptions of computer-based models." *Environmental Management* 34, no. 5 (2005): 609-619.

Cockerill, K.C., H. Passell, and V.C. Tidwell. "Cooperative modeling: Building bridges between science and the public." *Journal of American Water Resources Association* 42, no. 2 (2006): 457-471.

Cockerill, K.C., V.C. Tidwell, H. Passell, and L. Malczynski. "Collaborative Modeling Lessons for Environmental Management." *Environmental Practice* 9(1) (2007): 28-41.

Conglianese, Cary and Laurie K. Allen. "Does Consensus Make Common Sense?" *Environment* 46 (2004) 1:8-25.

Connick, S. and J. E. Innes. "Outcomes of Collaborative Water Policy Making: Applying Complexity Thinking to Evaluation." *Journal of Environmental Planning and Management* 46, no.2 (2003): 177-197.

Council on Environmental Quality. "Collaboration in NEPA: A Handbook for Practitioners." October 2007.

Creighton, James L. *Public Involvement & Teaming in Planning, A Core Training Program for U.S. Army Corps of Engineers Planners*. Institute for Water Resources, U.S. Army Corps of Engineers, IWR Report 02-TRN-01. Alexandria, Virginia (July 2002).

Creighton, James L. "Identifying Influentials in the Community Power Structure" in *Public Involvement Techniques: A Reader of Ten Years Experience at the Institute for Water Resources*. Institute for Water Resources, U.S. Army Corps of Engineers, IWR Report 82-R-1. Alexandria, Virginia (September 1998).

Creighton, James L. "The Use of Values: Public Participation in the Planning Process." In *Public Involvement Techniques: A Reader of Ten Years Experience at the Institute for Water Resources* (Creighton, J. Delli Priscoli, and M. Dunning). Institute for Water Resources, U.S. Army Corps of Engineers, IWR Report 82-R-1. Alexandria, Virginia (September 1998).

Crenson, M.A. and B. Ginsberg. *Downsizing Democracy: How America Sidelined Its Citizens and Privatized Its Public*. Baltimore: Johns Hopkins University Press, 2002.

Daniels, S.E. and G. B. Walker. *Working Through Environmental Conflict: The Collaborative Learning Approach.* Westport, Connecticut: Praeger, 2001.

Dahinden, U., C. Querol, J. Jager, and M. Nilsson. "Exploring the Use of Computer Models in Participatory Integrated Assessment – Experiences and Recommendations for Further Steps." *Integrated Assessment* 1 (2000): 253-266.

Delli Priscoli, Jerome. "Evolution of Public Involvement in Water Planning" in *Evolution of Water Resource Planning and Decision Making* (Russell and Baumann). Institute for Water Resources Maas-White Series. Edward Elgar Publishing, Inc. Northampton, Massachusetts, 2009.

Delli Priscoli, Jerome. "What is Public Participation in Water Resources Management and Why Is It Important?" *Water International* 29:2 (June 2004.)

Delli Priscoli, Jerome. "Conflict Resolution, Collaboration and Management in International Water Resource Issues: Working Paper #6, Alternative Dispute Resolution Series." Institute for Water Resources, U.S. Army Corps of Engineers, IWR Report 96-ADR-WP-6. Alexandria, Virginia (May 1996.)

Delli Priscoli, Jerome. "Public Involvement; Conflict Management; and Dispute Resolution in Water Resources and Environmental Decision Making: Working Paper #2, Alternative Dispute Resolution Series." Institute for Water Resources, U.S. Army Corps of Engineers, IWR Report 90-ADR-W-02. Alexandria, Virginia (March 1990).

Delli Priscoli, Jerome, and Wolf, Aaron T. *Managing and Transforming Water Conflicts*. New York, New York: Cambridge University Press, 2009.

Deutsch, Morton. *The Resolution of Dispute: Constructive and Destructive Processes*. Yale University Press: 1973.

Disaster Information Task Force. *Harnessing Information and Technology for Disaster Management: The Global Disaster Information Network*. Report to Vice President Al Gore, November 1997.

Dole, J. and G. Sinatra. "Reconceptualizing Change in the Cognitive Construction of Knowledge." *Ed. Psych.* 33(2/3) (1998): 109-128.

Dreyfus, A., E. Jungwirth, and R. Eliovitch. "Applying the 'Cognitive Conflict' Strategy for Conceptual Change—Some Implications, Difficulties, and Problems." *Sci. Ed.* 74(5) (1990): 555-569.

Driessen, P.P.J. and P. Glasbergen. "New directions in environmental politics – concluding remarks", in: Driessen, P.P.J., P. Glasbergen (eds), Greening Society. *The paradigm shift in Dutch environmental politics*. Kluwer Academic Publishers, (2002): 245-262.

Dykstra, D.I. "Studying Conceptual Change in Learning Physics." *Sci. Ed.* 76(6) (1992): 615-52.

Eastman, P.W. "Social and Environmental Objectives in Water Resources Planning and Management." Proceedings of an Engineering Foundation Conference, ASCE. Santa Barbara, California. May 11-16, 1986. Edited by Warren Viessman, Jr., and Kyle E. Schilling. New York, NY: ASCE, (1986): 57-71.

Eaton, D. "Evaluating State and Regional Water Plans: Performance Measures for Assessing Water Plan Effectiveness." *LBJ School Policy Paper* Series No.5, University of Texas at Austin, 2000.

Eaton, D. "The Future of the South Saskatchewan River Basin: Stakeholder Perspectives." Lyndon B. Johnson School of Public Affairs Policy Research Project Report Number 162, University of Texas at Austin, 2008.

Eaton, D., S. Schwartz, and J. Sharp. "What Do Groundwater Users Want? Desired Future Conditions for Groundwater in the Texas Hill Country." *Lyndon B. Johnson School of Public Affairs Policy Research Project Report* Number 161, University of Texas at Austin, 2008.

Education and Training in CADRe group. *Computer-Aided Dispute Resolution: Proceedings from the CADRe Workshop*. September 13-14 2007, Albuquerque, NM. pp. 7.3-7.5. 2007-R-06.

Ehrmann, J.R. and B. L. Stinson. "Joint Fact-Finding and the Use of Technical Experts." In *Consensus Building Handbook*, Suskind, McKearnan, and Thomas-Larmer, Eds, Thousand Oaks, California: Sage Publications, 1999.

Emerson, Kirk, Patricia J. Orr, Dale L. Keyes, and Katherine M. McKnight. "Environmental Conflict Resolution: Evaluating Performance Outcomes and Contributing Factors." *Conflict Resolution Quarterly* 27(1) (2009): 27-64.

Federal Energy Regulatory Commission (FERC). *Report on Hydroelectric Licensing Policies Procedures, and Regulations: Comprehensive Review and Recommendations Pursuant to Section 603 of the Energy Act of 2000*. Docket No. PL01-1-000. Washington, DC, 2001.

Federal Interagency Alternative Dispute Resolution Working Group Sections, Federal Interagency Alternative Dispute Resolution Working Group Steering Committee, Agencies in the Executive Branch of the Federal Government. *Report for the President on the Use and Results of Alternative Dispute Resolution in the Executive Branch of the Federal Government*." April 2007.

Field, Patrick; Antonia Handler Chayes, Sarah McKearnan, and Lawrence E. Susskind. *Partnering, Consensus Building and Laternative Dispute Resolution: Current Uses and Opportunities in the U.S. Army Corps of Engineers*. Institute for Water Resources, U.S. Army Corps of Engineers, IWR Report 96-ADR-WP-8. Alexandria, Virginia (May 1996).

Fisher, Robert and William Ury. *Getting to Yes: Negotiating Agreement Without Giving In*. New York, NY: Penguin Books, 1983.

Fredericks, Jeffrey W., John W. Labadie, and Jon M. Altenhofen. "Decision Support System for Conjunctive Stream-Aquifer Management." *Journal of Water Resources Planning and Management* (March/April 1998): 69-78.

Frenzel, P. F. *Geohydrology and Simulation of Groundwater Flow near Los Alamos, North-Central New Mexico*. Albuquerque, New Mexico: United States Geological Survey Water Resources Investigations Report 95-4091, 1995.

Gil-Perez, D. and Carrascosa, J. "What To Do About Science Misconceptions." *Sci. Ed*. 74(5) (1990): 531-540.

Grayson, R. B., J.M. Doolan, and T. Blake. "Application of AEAM (Adaptive Environmental Assessment and Management) to water quality in the Latrobe River Catchment." *Journal of Environmental Management*. 41 (1994): 245-258.

Gregory, R., B. Fischhoff, S. Thorne, and G. Butte. "A Multi-Channel Stakeholder Consultation Process for Transmission Deregulation." *Energy Policy* 31 (2003): 1291-1299.

Gregory, R. and L. Failing. "Using Decision Analysis to Encourage Sound Deliberation: Water Use Planning in British Columbia, Canada. *Professional Practice* (2004): 492-499.

Hanesian, D., and A.J. Perna. "A Change in the Freshman Engineering Education Paradigm: Bringing Engineering Design Up-Front in the Curriculum." Proceedings of the International Conference on Engineering Education (ICEE 2000), August 14-16, 2000, Taipei, Taiwan.

Hayes, D.J. "Cross Pollination." *Environmental Forum* 16 (July/Aug 1998): 4.

Henningson, Durham & Associates. Bi-County Water Supply Evaluation of Alternatives prepared for WSSC. Chevy Chase, Maryland, 1978.

Holmes, K.J. and Wolman, M.G. "Early Development of Systems Analysis in Natural Resources Management from Man and Nature to the Miami Conservancy District." *Environmental Management* 27 (2001): 177-193.

Hufschmidt, M.A, and M.B. Fiering. *Simulating techniques for design of water-resource systems*. Cambridge, Massachusetts: Harvard University Press, 1966.

Ingram, H. and A. Schneider. "Science, Democracy, and Water Policy." *Water Resources Update* 133 (Autumn 1998): 21-28.

International Joint Commission. Directive to International Upper Great Lakes Study Board, February 7, 2007. http://www.iugls.org/en/mandate/Mandate_directive.htm

International Joint Commission. Letter to the United States Department of State and the Canadian Ministry of Foreign Affairs, September 4, 2007. http://www.ijc.org/en/activities/losl/index.php

Jamieson, D.G., and K. Fedra. "The 'WaterWater' Decision-Support System for River-Basin Planning Conceptual Design." *Journal of Hydrology* 177 (1996): 163-175.

Keyes, A. M., and R.N. Palmer. "An assessment of shared vision model effectiveness in water resources planning." *Proceedings of the 22nd Annual National Conference, Water Resources Planning and Management Division of ASCE*. Cambridge, Massachusetts (May 1995): 532:535.

Koontz, Tomas M., T.A. Steelman, J. Carmin, K.S. Korfmacher, C. Moseley, and C.W. Thomas. *Collaborative Environmental Management: What Roles for Government?* Washington, DC: Resources for the Future, 2004.

Korfmacher, K.S. "Water Quality Modeling for Environmental Management: Lessons from the Policy Sciences." *Policy Science* (1998) 31: 35-54.

Lach, D., S. Rayner, and H. Ingram. "Taming the Waters: Strategies to Domesticate the Wicked Problems of Water Resource Management." *International Journal of Water* 3 (2005) 1: 1-17.

Lach, D., B. Steele, and B. Shindler. "The Role of Science in Natural Resource Decision-Making: A Survey of LTER Scientists." Preliminary Results, Oregon State University, April 2005.

Lackey, R. T. "Science, Scientists, and Policy Advocacy." *Conservation Biology* 21 (2007) 1: 12-17.

Lake Ontario-St. Lawrence River (LOSL) Study Board. *Options for Managing Lake Ontario and St. Lawrence River Water Levels and Flows – Final Report by the International Lake Ontario-St. Lawrence River Study Board to the International Joint Commission*. March 2006. http://www.losl.org/reports/finalreport-e.html

Landy, M. and C. Rubin. "Civic Environmentalism: A New Approach to Policy." Washington DC: George C. Marshall Institute, 2001.

Levels Reference Study Board. *Levels Reference Study: Great Lakes-St. Lawrence River Basin*. Submitted to the International Joint Commission by the Levels Reference Study Board, March 31, 1993.

Lewicki, Roy J. and Joseph A. Litterer. *Negotiation*. Irwin Professional Publishing, 1985.

Lewis, F. "Decision-aiding Software for group decision-making." In S. Nagel (ed). *Computer-Aided Decision Analysis: Theory and Applications*. Westport, Connecticut: Quorum Books, 1993.

Lindblom, C. *Inquiry and Change*. New Haven, Connecticut: Yale University Press, 1990.

Loomis, J. "Use of Nonmarket Valuation Studies in Water Resource Management Assessments." *Water Resources Update* (109) (1997): 5-9.

Lord, W. B. "Conflict in Federal Water Resource Planning." *Water Resources Bulletin* 15 (October 1979) 5: 1226-1235.

Lorie, M. *Computer-Aided Dispute Resolution 2nd Workshop Summary and Strategic Plan*. Institute for Water Resources, U.S. Army Corps of Engineers, IWR Report 10-R-5. Alexandria, Virginia (April 2010).

Loucks, Daniel P. "Developing and Implementing Decision Support Systems: A Critique and Challenge." *Water Resources Bulletin*. 1995.

Loucks, D.P., J. Kindler, and K. Fedra. "Interactive Water Resources Modeling and Model Use: An Overview." *Water Resources Research* 21 (1985) 2: 95-102.

Lund, J.R. and R.N. Palmer. "Water Resource System Modeling for Conflict Resolution." *Water Resources Update*, 108 (Summer 1997).

Maguire, L. "Interplay of Science and Stakeholder Values in Neuse River Total Maximum Daily Load Process." *Journal of Water Resources Planning and Management* (July/August 2003): 261-270.

Majone, G. *Evidence, Argument, and Persuasion in the Policy Process*. New Haven, Connecticut: Yale University Press, 1989.

March, J.G. "Theories of Choice and Making Decisions." *Society* (November/December 1982): 29-39.

Margolis, J., A. Fisher, and F. Miller. "The Anatomy of Interest: Women in Undergraduate Computer Science." *Women's Studies Quarterly* 28(1/2) (2000): 104-127.

Maryland Department of Natural Resources. Potomac River environmental flow-by study, prepared by Maryland Department of Natural Resources Water Resources Administration, Water Supply Division, Water Supply Planning Section. Annapolis, Maryland, 1979. (Copy in ICPRB library, Rockville MD, ICPRB POmw-13.)

Maryland Department of Natural Resources. Draft Habitat Assessment of the Potomac River from Little Falls to Seneca Pool. Maryland Power Plant Research Program, PPAD 03-01. Annapolis, Maryland, 2003.

McAda, D. P., and P. Barroll. *Simulation of Ground-Water Flow in the Middle Rio Grande Basin Between Cochiti and San Acacia, New Mexico*. Albuquerque, New Mexico: U.S. Geological Survey Water-Resources Investigations Report 02-4200, 2002.

McDonald, M. G., and A.W. Harbaugh. *A modular three-dimensional finite-difference ground-water flow model: U.S. Geological Survey Techniques of Water Resources Investigations*, Book 6, Chapter A1, 14 ch., 1988.

McGarry, R. S. *Washington Area Benefits*. The Challenge of the North Branch. The 1981 ICPRB Fall Public Meeting, September 19, 1981. ICPRB Public Papers. Interstate Commission on the Potomac River Basin. Rockville, MD. ICP 365 (c). 1981.

Michaud, W. and S. Langsdale. *Performance Measures to Assess the Benefits of Shared Vision Planning and Other Collaborative Modeling*. Institute for Water Resources, U.S. Army Corps of Engineers, IWR Report 09-R-07. Alexandria, Virginia (2009).

Middle Rio Grande Water Assembly, 2004. Middle Rio Grande Regional Water Plan 2000-2050: Volume I. *Available at* http://www.waterassembly.org/5theplan.html. *Accessed* February 2006.

MIT-USGS Science Impact Collaborative: What We Do. Available at http://web.mit.edu/dusp/epp/music/wwd/index.html. Accessed February 12, 2009.

Mostashari, A. and J. Sussman. "Engaging Stakeholders in Engineering System Representation and Modeling." Massachusetts Institute of Technology, Unpublished manuscript.

National Policy Consensus Center. *Watershed Solutions: Collaborative Problem-Solving for States and Communities*. Portland State University, 2002.

National Research Council. *Understanding Risk: Informing Decisions in a Democratic Society.* Washington, D.C.: National Academies Press, 1996.

National Research Council. *U.S. Army Corps of Engineers Water Resources Planning: A New Opportunity for Service*. Washington, D.C.: National Academies Press, 2004.

National Research Council. *Decision Making for the Environment.* Washington D.C.: National Academies Press, 2005.

National Research Council. Thomas Dietz and Paul Stern, eds. *Public Participation in Environmental Assessment and Decision Making*. National Academy of Sciences, 2008.

"Navigating the Politics of Water: Eaton Brings International Water Policy Expertise to Local Level." *LBJ School of Public Affairs Newsletter*, Summer 2004. http://www.utexas.edu/lbj/news/summer2004/eaton.html

Obama, Barack. Transparency and Open Government, Memorandum for the Heads of Executive Departments and Agencies. The White House, January 21, 2009.

Office of Management and Budget and Council on Environmental Quality. "Memorandum on Environmental Conflict Resolution." Letter to agency Secretaries/Administrators, November 2005.

Office of Science and Technology Policy. *A Strategy for Federal Science and Technology to Support Water Availability and Quality in the United States*. Report of the National Science and Technology Council, Committee on Environment and Natural Resources, Subcommittee on Water Availability and Quality, Executive Office of the President of the United States, September 2007.

O'Leary, Rosemary and Lisa B. Bingham, eds. *The Promise and Performance of Environmental Dispute Resolution*. Resources for the Future, 2003.

Oreskes, N., K. Shrader-Frechette, and K. Belitz. "Verification, Validation, and Confirmation of Numerical Models in the Earth Sciences." *Science* 263 (February 1994) 5147: 641-646.

ORMS Educational Programs in the U.S. Institute for Operations Research and the Management Sciences Student Union. Last modified: January 18, 2007, accessed May 11, 2009. http://www2.informs.org/Edu/Programs/edprogs_us_bycat.html.

Ozawa, C.P. *Recasting Science: Consensual Procedures in Public Policy Making.* Boulder, Colorado: Westview Press, 1991.

Ozawa, C.P. "Science in Environmental Conflicts." *Sociological Perspectives* 39 (1996): 219-230.

Palmer, Richard. "A history of shared vision modeling in the ACT-ACF comprehensive study: A modeler's perspective." *Proceedings of Special Session of ASCE's 25th Annual Conference on Water Resources Planning and Management and the 1998 Annual Conference on Environmental Engineering*, W. Whipple, Jr., ed. Chicago, Illinois (June 1998): 221-226.

Palmer, Richard. "The Confluence of a Career: Virtual Droughts, Shared-Vision Planning, and Climate Change." *Journal of Water Resources Planning and Management* (July/August 2007): 287-8.

Palmer, R.N., J.R. Wright, J.A. Smith, J.L. Cohon, and C.R. ReVelle. Policy Analysis of Reservoir Operations in the Potomac River Basin. Volume I. Executive Summary; Volume III, Potomac River Interactive Simulation Model. Draft final report. Water Resources Series Technical Report No. 59, College Park, Maryland: University of Maryland, 1980.

Palmer, R.N., J.A. Smith, J.L. Cohon, and C.R. ReVelle. "Reservoir management in the Potomac River Basin." *Journal of Water Resources Planning and Management* Vol. 108, No. 1 (1982): 47-55.

Palmer, Richard, A.M. Keyes, and S. Fisher. "Empowering stakeholders through simulation of water resources planning." In K. Hon (ed) Water Management for the '90s. New York: American Society of Civil Engineers (1993): 451-454.

Palmer, R.N., W.J. Werick, A. MacEwan, and A.W. Woods. "Modeling water resources opportunities, challenges, and trade-offs: The use of shared vision modeling for negotiation and conflict resolution." *Proceedings of the ASCE's 26th Annual Conference on Water Resources Planning and Management.* Tempe, Arizona (June 1999.)

Palmer, R.N., A. Mohammadi, M.A. Hahn, J. Dvorak, and D. Kessler. "Computer assisted decision support system for high level infrastructure master planning: Case of the City of Portland Supply and Transmission Model (STM)." *Proceedings of the*

ASCE's 2000 Joint Conference on Water Resources Engineering and Water Resources Planning and Management. Minneapolis, Minnesota. (August 2000.)

Passell, H.D., V.C. Tidwell, S.H. Conrad, R.P Thomas, and J. Roach. "*Cooperative water resources modeling in the Middle Rio Grande Basin*." SAND Report 2003-1330. Albuquerque, New Mexico: Sandia National Laboratories, 2003.

Portney, P. R.. "Benefit-Cost Analysis." in *Concise Encyclopedia of Economics*, 2002. On-line resource at: http://www.econlib.org/library/Enc/BenefitCostAnalysis.html. Accessed April 2008.

Posner, G.J., K.A. Strike, P.W. Hewson, and W.A. Gertzog. "Accommodation of a Scientific Conception: Toward a Theory of Conceptual Change." *Sci. Ed*. 66(2) (1982): 211-217.

Potomac Basin Reporter. Interstate Commission on the Potomac River Basin. Vol. 38, No. 4. April-May, 1982.

Potomac Planning Task Force. *The Potomac–The Report of the Potomac Planning Task Force*. Washington, DC: American Institutes of Architects, 1967. (Available in the library of the Interstate Commission on the Potomac River Basin, Rockville, Maryland; report no. PO-41.)

Raiffa, Howard. *The Art and Science of Negotiation*. Cambridge, Massachusetts: Belknap Press of Harvard University Press, 1982.

Reckhow, K. "Water Quality Simulation Modeling and Uncertainty Analysis for Risk Assessment and Decision-making." *Ecological Modeling* (1994) 72: 1-20.

Reitsma, R., I. Zigurs, C. Lewis, V. Wilson, and A. Sloane. "Experiment with Simulation Models in Water-Resource Negotiations." *Journal of Water Resources Planning and Management* (January/February 1996): 64-70.

Reuss, M. "Is It Time to Resurrect the Harvard Water Program?" *Journal of Water Resources Planning and Management*. Vol. 129, No. 5 (September/October 2003): 357-360.

Roach, J. D. *Integrated Surface Water Groundwater Modeling in the Upper Rio Grande in Support of Scenario Analysis*. PhD dissertation. Department of Hydrology and Water Resources, University of Arizona, 2007. Available in electronic form by request to the author at jesse_roach@stanforadalumni.org.

Roach, J.D. and V.C. Tidwell. "Multi-Agency Cooperative Modeling on the Upper Rio Grande." World Environmental and Water Resources Congress: Restoring Our Natural Habitat. American Society of Civil Engineers, 2007.

Rodrigo, D. "Solving Urban Watershed Problems in Los Angeles Through the Use of Collaborative Planning." Presented paper to the Computer-Aided Dispute Resolution Workshop, Albuquerque, New Mexico, September 13, 2007.

Rogers, P.P. *America's Water: Federal Roles and Responsibilities*. Cambridge, Massachusetts: MIT Press, 1993.

Rouwette, E. A, J.A.M. Vennix and T.van Mullekom. "Group Model Building Effectiveness: A Review of Assessment Studies." *System Dynamics Review* 18, No.1 (2002): 5-45.

Russell, Clifford S. and Duane D. Baumann, Eds. The Evolution of Water Resource Planning and Decision Making. Institute for Water Resources Maas-White Series. Edward Elgar Publishing, Inc. Northampton, Massachusetts, 2009.

Sabatier, P. and H. Jenkins-Smith. *Policy Change and Learning: An Advocacy Coalition Approach*. Boulder, Colorado: Westview, 1993.

Sagoff, Mark. "Should Preferences Count?" *Land Economics* 70 (May 1994): 127-44.

Schelling, Thomas C. *The Strategy of Conflict*. Cambridge, Massachusetts: Harvard University Press, 1960.

Seymour, E. and N.M. Hewitt. *Talking About Leaving: Why Undergraduates Leave the Sciences*. Boulder, Colorado: Westview Press, 1997.

Shabman, Leonard. "The Nation's Water Resources and the Challenge of Sustainability." *Perspectives on Sustainable Resources in America*, Roger Sedjo, ed. RFF Press (2008): 104-132.

Shabman, Leonard and Kurt Stephenson. "Environmental valuation and its economic critics." *Journal of Water Resources Planning and Management* 126 (November/December 2000) 6: 382 – 88.

Shabman, L. and W.E. Cox. "Urban Water Supply and the Environment: Extending the Reach of Section 404 of the Clean Water Act." *Virginia Environmental Law Journal* 23 (2004): 75-108.

Shafike, N.G. *Linked Surface Water and Groundwater Model for Socorro and San Marcial Basins between San Acacia and Elephant Butte Reservoir*. Appendix J in Upper Rio Grande Water Operations Review DEIS, pp. J-59 to J-94, 2005.

Sheer, Daniel P. Staff Members of the Water Resources Planning Board, Metropolitan Washington Council of Governments, 1977. A Perspective on the Washington Metropolitan Area Water Supply Problem. Interstate Commission on the Potomac River Basin. Rockville, MD. ICP 139. May 1977.

Sheer, D.P. *ICPRB Section on Water Supply Operations*. The Challenge of the North Branch. The 1981 ICPRB Fall Public Meeting, September 19, 1981. ICPRB Public Papers. Interstate Commission on the Potomac River Basin. Rockville, MD. ICPRB ICP 365. 1981.

Sheer, D.P. Assured Water Supply for the Washington Metropolitan Area, Interstate Commission on the Potomac River Basin, Rockville, MD. ICP 363 g. 1981. 1982.

Sheer, Daniel. "A Process for CADRe and Requirements for Tools to Support CADRe." Presentation to the Computer-Aided Dispute Resolution Workshop, Albuquerque, New Mexico, September 13, 2007.

Sheer, D.P., and P.W. Eastman. More Water for Less Cost in the Washington Metropolitan Area. Interstate Commission on the Potomac River Basin. Rockville, MD. ICP 150. April 1978.

Sheer, D.P., K. Brooks, K. Warner, and D. Hooker. *Metropolitan Washington Area Finished Water Interconnection Study, Draft Report*. Submitted to U.S. Army Corps of Engineers, Baltimore District. Interstate Commission on the Potomac River Basin. Rockville, MD. ICP-199. July 1978.

Sheer, Daniel P., Mary Lynn Baeck and Jeff R. Wright. "The Computer as Negotiator." *Journal of the American Waterworks Association* (Feb 1989): 68-73.

Sheppard, S. and R. Jenison. "Examples of Freshman Design Education." *International Journal of Engineering Education* 13(4) (1997): 248-261.

Simonovic, S. P. and M.J. Bender. "Collaborative Planning-support System: An Approach for Determining Evaluation Criteria." *Journal of Hydrology* 177 (1996): 237-251.

Slovic, Paul. "The Construction of Preference." *American Psychologist* 50 (5) (1995): 365-371.

Smith, J. A. "Yield analysis for the Washington D. C. Metropolitan Area water supply system." *Journal of Water Resources Planning and Management* 115(2) (1989): 230-242.

Spash, C. L. "Broadening Democracy in Environmental Policy Processes." *Environment and Planning C: Government and Policy* 19, No.4 (2001): 475-481.

Sprague, R.H. and E.D. Carlson. *Building Effective Decision-Support Systems*. Englewood Cliffs, New Jersey: Prentice-Hall, 1982.

St. Lawrence River – Lake Ontario Plan of Study Team. *Plan of Study for Criteria Review in the Orders of Approval for Regulation of Lake Ontario – St. Lawrence River Levels and Flows*. Submitted to the International Joint Commission, September 1999.

Stakhiv, Eugene Z. "Disintegrated Water Resources Management in the U.S.: Union of Sisyphus and Pandora." *Journal of Water Resources Planning and Management* 129 (May/June 2003) 3:151-154.

Stephenson, K. "Taking Nature into Account: Observations about the Changing Role of Analysis and Negotiation in Hydropower Relicensing." *William and Mary Environmental Law and Policy Review* 25:2 (Winter 2000): 473-498.

Stokey, Edith and Richard Zeckhuser. *A Primer for Policy Analysis*. New York: W.W. Norton, 1978.

Strike, K.A. and G.J. Posner, G.J. "A Conceptual Change View of Learning and Understanding." In *Cognitive Structure and Conceptual Change*. L. West and A. Pines, eds. Orlando, Florida: Academic Press, Inc. (1985): 211-231.

Susskind, L., S. McKearnan, and J. Thomas-Larmer, Eds. *Consensus Building Handbook*, Thousand Oaks, California: Sage Publications, 1999.

Susskind, L.E., R.K. Jain and A.O. Martyniuk. *Better Environmental Policy Studies: How to Design and Conduct More Effective Analyses*. Washington: Island Press, 2001.

Swiger, M. A. and M. M. Grant. "Creating a New FERC Licensing Process." *Hydro Review* (May 2004): 20-25.

Tarlock, D. "Who Owns Science?" *Penn State Environmental Law Review* 135 (2002): 10.

Tate, Diane. *Bringing Technology to the Table: Computer Modeling, Dispute Resolution and the Rio Grande*. M.S. Thesis, University of Texas-Austin, 2002.

Thiessen, Ernest M., Daniel P. Loucks, and Jerry R. Stedinger. "Computer-Assisted Negotiations of Water Resources Conflicts." *Group Decision and Negotiation Journal* 7 (1998): 109-129.

Tidwell, V.C., H.D. Passell, S.H. Conrad, and R.P. Thomas. "System dynamics modeling for community-based water planning: An application to the Middle Rio Grande." *Journal of Aquatic Sciences* 66, No. 4 (2004): 357-372.

Tidwell, Vince, Amy Sun, Geoff Klise, and Jim Brainard. "Collaborative Modeling to Support the 2004 Arizona Water Settlements Act." World Environmental and Water Resources Congress: Restoring Our Natural Habitat. American Society of Civil Engineers, 2007.

Turnhout, Esther, Matthijs Misschoemoller, and Herman Eijsackers. "Ecological Indicators: Between the Two Fires of Science and Policy." *Ecological Indicators* 7 (2007): 215-228.

U.S. Army Corps of Engineers. *Potomac River Basin Report*. Dept. of the Army, U.S. Army Engineer Division, North Atlantic, Baltimore Basin Studies Branch. Baltimore, Maryland, 1963.

U.S. Army Corps of Engineers. *Northeastern U.S. Water Supply Study, Summary Report*. U.S. Department of the Army, Corps of Engineers, Washington, D.C. July 1977.

U.S. Army Corps of Engineers. *Metropolitan Washington Area Water Supply Study*. Department of the Army, Baltimore District, Corps of Engineers. Baltimore, Maryland, 1983.

U.S. Army Corps of Engineers. *Managing Water for Drought*. Institute for Water Resources, U.S. Army Corps of Engineers. Washington D.C. IWR Report 94-NDS-8. September, 1994.

U.S. Army Corps of Engineers. *National Study of Water Management during Drought: The Report to the U.S. Congress*. Institute for Water Resources, U.S. Army Corps of Engineers. Washington D.C. IWR Report 94-NDS-12. September, 1995.

U.S. Army Corps of Engineers, U.S. Geological Survey, U.S. Bureau of Reclamation, U.S. Fish and Wildlife Service, U.S. Bureau of Indian Affairs, and the International Boundary and Water Commission. *Upper Rio Grande Water Operations Model*, Model Documentation, Draft by the Technical Review Committee, 2002. Availableat http://www.spa.usace.army.mil/urgwom/docintro.asp.

Van den Belt, Marjan. *Mediated Modeling: A System Dynamics Approach to Environmental Consensus Building*. Washington DC: Island Press, 2004.

Vatn, A. and D. Bromley. "Choices without Prices without Apologies." *Journal of Environmental Economics and Management* 26 (1994) 2: 129-48.

Vennix, J.A.M. *Group Model Building*. John Wiley and Sons, 1996.

Vennix, J.A.M. "Group Model-building: Tackling Messy Problems." *System Dynamics Review* 15 (Winter 1999) 4: 379-401.

Volpe, G. Case Studies. In *The Handbook for Economics Lectures*. P. Davies, ed., 2002. Available at http://www.economicdnetwork.ac.uk/handbook/.

Vosniadou, S. and R. Saljo. Conceptual Change in the Physical Sciences. *Learn. Instruct*. 4(1) (1994): 1-121.

Ways, H.C. *The Washington Aqueduct 1852-1992*. Washington Aqueduct Division, U.S. Army Corps of Engineers. Washington, D.C. 1993.

Weible, C., P.A. Sabatier, and M. Lubell. "A Comparison of Collaborative and Top-Down Approach to the Use of Science in Policy: Establishing Marine Protected Areas in California." *Policy Studies Journal* 32 (2004) 2: 187-207.

Werick, B. "Changing the Rules for Regulating Lake Ontario Levels." Presented Paper to the Computer-Aided Dispute Resolution Workshop, Albuquerque, New Mexico, September 13, 2007.

Werick, B. and W. Whipple. *Managing Water for Drought*. U.S. Army Corps of Engineers, IWR Report 94-NDS-8, September 1994.

Werick, William and Palmer, Richard N. *When Should Shared Vision Planning Be Used?* Proceedings of ASCE's 2004 World Water and Environmental Resources Congress, Salt Lake City, Utah, June 2004.

Werick, W.J. and R.N. Palmer. "It's Time for Standards of Practice in Water Resources Planning." *ASCE Journal of Water Resources Planning and Management*, 134 (2008) 1: 1-2.

Wondolleck, Julia M and Steven Lewis Yaffee. *Making Collaboration Work: Lessons from Innovation in Natural Resource Management*. Washington, DC: Island Press, 2000.

Working Group to the National Science and Technology Council's Subcommittee on Water Availability and Quality. "Collaborative Tools and Processes for US Water Solutions." Included as Appendix 8 in *Computer-Aided Dispute Resolution: Proceedings from the CADRe Workshop*, Albuquerque, New Mexico, September 13-14, 2007. IWR Report 07-R-6.

Zagona, E.A., T.J. Fulp, R. Shane, T.M. Magee, and H.M. Goranflo. "RiverWare: A Generalized Tool for Complex Reservoir System Modeling." *Journal of the American Water Resources Association* 37 (2001) 4: 913-929.

Zigurs, I., R. Reitsma, C. Lewis, R. Hubscher, and C. Hayes. "Accessibility of Computer-based Simulation Models in Inherently Conflict-Laden Negotiations." *Group Decision and Negotiations* 8 (1999): 511-533.

Appendix A – List of Figures and Tables

List of Figures

1. Potomac River Basin, Washington D.C. Metropolitan Area water supplier service areas and reservoirs
2. Roanoke Basin Map
3. Lake Ontario and St. Lawrence River (LOSL) Study Area
4. Planning Process Adopted by the Study Board the first year of the LOSL Study
5. Schematic of LOSL Shared Vision Model and Research
6. Screen capture from Board Room showing the macro button to launch and retrieve FEPS model results
7. Brockville, Ontario, Water Level Graphs under Plan 2007 and Plan A+
8. Decision milestones including six practice decisions in the LOSL Study
9. Range of possible Lake Ontario levels through the year under the current regulation rules
10. Location of the Conowingo Dam on the Susquehanna River in Maryland
11. Water use features in the vicinity of Conowingo Pond
12. Critical levels of Conowingo Pond
13. Schematic of the components of the OASIS model [Susquehanna River Study]
14. Sample model verification output [Susquehanna River Study]
15. Sample model output [Susquehanna River Study]
16. Shared Vision Development Process, El Dorado County, California
17. Dashboard depiction of drought status, illustrating green zone or acceptable situation [El Dorado Drought Study]
18. Shared Vision Model development process, El Dorado County, California
19. Rio Grande Basin in northern New Mexico
20. Schematic depicting the relations between collaborating entities participating in the regional water planning for the Middle Rio Grande
21. Example interface pages for the MRG regional water planning model [Rio Grande Study]
22. Overview of CADRe Educational Goals and Methods
23. Summary of formative educational experiences cited by leading CADRe practitioners
24. Addressing skill set for CADRe practitioners in Computer-Aided Negotiations of Water Resources Disputes course

List of Tables

1. Five-year PIAG budget in LOSL plan of study
2. Selected button and slider bar settings for the preferred scenario [Rio Grande Study]
3. Comments regarding the purpose of CADRe
4. How prepared are modelers to conduct CADRe processes?
5. How well-prepared are facilitators to conduct CADRe processes?
6. How should a CADRe process be convened?
7. How do you define the scope of the process?
8. How do you handle it when you suspect that some participants are trying to "game" the process by misrepresenting their interests, withholding information, or providing bad information?
9. Should modelers and facilitators work in teams?

Appendix B – Abbreviations

ADR	Alternative Dispute Resolution
CADRe	Computer-Aided Dispute Resolution
CADRe07	2007 Computer-Aided Dispute Resolution workshop
CADRe09	2009 Computer-Aided Dispute Resolution workshop
CAN	Computer-Aided Negotiation
CMT	Collaborative Modeling Team
CO-OP	Section for Cooperative Water Supply Operations [ICPRB]
DDE	Dynamic Data Exchange
DENR	Department of Environmental and Natural Sciences [North Carolina]
DPS	Drought Preparedness Study
DSS	Decision Support System
EIS	Environmental Impact Study
FEPS	Flood and Erosion Prediction System
FERC	Federal Energy Regulatory Commission
FISRAC	Federal-Interstate State Regional Advisory Committee
FW	Fairfax Water
ICPRB	Interstate Commission on the Potomac River Basin
IERM	Integrated Environmental Response Model
IJC	International Joint Commission
ISC	Interstate Stream Commission [New Mexico]
IWR	Institute for Water Resources, U.S. Army Corps of Engineers
JHU	Johns Hopkins University
LFAA	Low Flow Allocation Agreement

LOSL	Lake Ontario – St. Lawrence River
ModSim	Model simulator software
MRCOG	Mid Region Council of Governments
MRG	Middle Rio Grande
MRGWA	Middle Rio Grande Water Assembly
MUSIC	MIT-USGS Science Impact Collaborative
NEWS	Northeastern United States Water Supply
NGO	Non-governmental organization
OASIS	A generalized computer simulation program
OR	Operations Research
ORMS	Operations Research and the Management Sciences
PFEG	Plan Formulation and Evaluation Group
PHABSIM	Physical Habitat Simulation System
PIAG	Public Interest Advisory Group
Powersim	Computer simulation software
PRISM	Potomac River Interactive Model
PRISM/USACE	U.S. Army Corps of Engineers' modified and revised PRISM model
RiverWare	A general river basin modeling tool
RRBROM	Roanoke River Basin Reservoir Operations Model
SNL	Sandia National Laboratories
SRM	Shoreline Response Model
STELLA	Systems Thinking software for education and research
STEM	Science, technology, engineering, and mathematics
SVM	Shared Vision Model

SVP	Shared Vision Planning
SWAQ	Subcommittee on Water Availability and Quality
TNC	The Nature Conservancy
TWG	Technical Working Group
USACE	U.S. Army Corps of Engineers
URGWOM	Upper Rio Grande Water Operations Model
WaterWare	An integrated, model-based information and decision support system
WEAP	Water Evaluation and Planning system
WRC	Wildlife Resources Commission [North Carolina]
WSSC	Washington Suburban Sanitary Commission

Appendix C – Contributors

Thomas W. Beauduy is Deputy Director & Counsel to the Susquehanna River Basin Commission (SRBC), a federal-interstate compact commission with water resource management responsibility for the Susquehanna River Basin. Prior to joining the SRBC in 1997, Beauduy was in private practice specializing in environmental law and previously served as director of a joint legislative environmental committee in the Pennsylvania General Assembly from 1980 to 1985. He also served as the Pennsylvania Director of the Chesapeake Bay Commission, a tri-state legislative advisory commission, from 1985 to 2004. He is the immediate past chair and current board member of the Interstate Council on Water Policy, a national organization of state and regional water resource management agencies based in Washington, D.C.

Gail Bingham is the owner of the Civic Dialog Group. She served as President of RESOLVE, an organization dedicated to the effective use of consensus building processes in public decision making. She is widely recognized as one of the pioneers in the use of mediation to resolve public policy disputes. She has written extensively about environmental dispute resolution.

Lisa Bourget works for the U.S. Army Corps of Engineers Institute for Water Resources, where her efforts include furthering the deliberate integration of public participation processes with adaptable computer modeling tools. Ms. Bourget previously served as Secretary of the U.S. Section of the International Joint Commission, a U.S.-Canada treaty organization responsible for helping prevent and resolve disputes primarily related to water and the environment along the Canada-U.S. border, and as Engineering Director for a private engineering and architecture firm.

Hal E. Cardwell is with the U.S. Army Corps of Engineers' Institute for Water Resources. He leads the Corps' new Conflict Resolution and Public Participation Center (www.iwr.usace.army.mil/cpc/), where he pursues conceptual development, case studies, and outreach to promote collaborative modeling approaches for water conflict resolution With the U.S. Institute for Environmental Conflict Resolution and Sandia National Laboratory, he conceptualized, organized, and chaired the first and second workshops on Computer-Aided Dispute Resolution in 2007 and 2009, chaired and organized sessions and presentations on the intersection of computer tools and collaborative processes in various fora, and served on the national steering committee on the intersection between Technology and Environmental Conflict Resolution. He teaches part-time at Johns Hopkins University. Dr. Cardwell previously worked with Oak Ridge National Laboratory's Environmental Sciences Division and did water work in Panama and other developing countries with the U.S. Agency for International Development.

James L. Creighton is President of Creighton & Creighton, Inc., Los Gatos, California, and has been involved in designing and conducting more than 300 public

participation programs. He is the author of *How to Conduct a Shared Vision Planning Process*, (in press, Institute for Water Resources) conducted an assessment of past Shared Vision Planning cases, and has assisted with Shared Vision Planning projects on the Willamette and James Rivers, and the California Water Plan.

Ane Deister has more than 30 years experience in public water resource management where she has used Shared Vision Planning techniques to solve specific resource challenges, and in executive leadership positions in Florida and California with public utilities, resource agencies, and land use organizations. She worked with the Institute of Water Resources in applying Shared Visioning Planning as a member of the President's National Drought Policy Commission. In 2006-2007 she led a first-of-its-kind two-year Shared Visioning Planning and Modeling Drought Preparedness program in northern California. In 2008, she served as Vice President at Brown and Caldwell, applying shared visioning techniques with the San Joaquin River Restoration Project, state regulators and stakeholders developing recycled water policies. She has applied the principles and practices of Shared Vision Planning with other clients requiring urban water management and facilities management assistance. She now serves as Vice President at Entrix.

Andrew Dehoff is the Director of Planning and Operations for the Susquehanna River Basin Commission. He has been involved in many aspects of water resources management, including water availability and safe yield analyses, reservoir operations, drought and flood management, and the review and approval of water withdrawals and use by industry and power generation facilities. He developed several computer models for the purpose of simulating and evaluating water management projects and oversees the Commission's effort to plan for long-term mitigation of consumptive water use and its impact on local resources and the Chesapeake Bay.

Erik Hagen has a Bachelor's Degree in Civil Engineering and a Master's Degree in Water Resources Planning and Management from the University of Washington in Seattle. He worked at the Water Management Section of the City of Seattle before moving to Washington, D.C., where he worked at the Interstate Commission on the Potomac River Basin as the Director of Operations for the Section for Cooperative Water Supply Operations. Mr. Hagen worked with Mark Lorie on a Shared Vision Planning study in the Potomac River Basin to find ways to operate Savage and Jennings Randolph reservoirs that maximizes the many uses of the river. Mr. Hagen now resides in The Hague, The Netherlands, where he is a full-time artist, and is writing papers on Shared Vision Planning and contributing to a monograph on best practices in computer-aided collaborative decision making.

Mark Lorie is an independent consultant based in Fort Collins, Colorado. Mr. Lorie helped establish the CADRe program at the Institute for Water Resources, where he also worked on the Lake Ontario-St. Lawrence River Study. He also applied the

Shared Vision Planning approach in Upper Mississippi River Basin, the Potomac River Basin, and the Cache La Poudre River in Colorado.

Brian McCrodden is Vice President and Business Manager of HydroLogics, Inc. He has long been a proponent of the use of computer models to aid in improved water resources management and conflict resolution. In his 22 years at HydroLogics, he has been involved in numerous contentious water resources issues, including the federal relicensing of four hydropower projects and the permitting of several reservoir and offstream storage projects. His Raleigh, North Carolina office has developed OASIS modeling applications for seven river basins in North Carolina. These applications are hosted on the Division of Water Resources server and are available to government, academia, and the private sector for use in the development of local water supply plans, the preparation of interbasin transfer permit applications, and the assessment of ecological flow needs. Mr. McCrodden also pioneered an integrated approach to probabilistic drought management, where his clients include a number of major cities in the Southeast.

Howard Passell is an ecologist whose work centers on water, energy, and agricultural resource management and sustainability projects. His work has involved resource monitoring, modeling, management, capacity-building, and policy-related projects at various scales in the U.S., Central Asia, the Middle East, and North Africa. He works in the Earth Systems Department at Sandia National Laboratories, in Albuquerque, New Mexico.

Jesse Roach holds Bachelor of Science degrees from Stanford University in Biology (1995) and Civil Engineering (1995), and a Master of Science degree, also from Stanford, in Civil and Environmental Engineering (1997). He received his PhD in Hydrology from the University of Arizona in 2007 with a dissertation titled "Integrated Surface Water Groundwater Modeling in the Upper Rio Grande in Support of Scenario Analysis". He works at Sandia National Laboratories on integrated, systems-level modeling of natural resource systems with the goal of informing policy and planning decisions with the best available science.

Leonard Shabman is Resident Scholar at Resources for the Future (RFF) in Washington DC. At RFF, and during a 30-year career on the faculty at Virginia Tech, he has written, lectured, and consulted extensively on United States water resources management and policy. In 2004 he was recognized as an associate member of the National Academy of Sciences.

Kurt Stephenson is a professor in the Department of Agricultural and Applied Economics at Virginia Tech. Stephenson's research interests include water resource policy, the role and contribution of technical analysis to water policy, and the application of market-based policies to environmental challenges. Stephenson's work covers a range of water resource policy issues including water supply planning, water

conservation, water quality trading, stream and wetland mitigation policy, and stormwater management.

Vincent Tidwell is a Principal Member of the Technical Staff at Sandia National Laboratories. Dr. Tidwell has 20 years experience conducting and managing research on basic and applied projects in water resource management, nuclear and hazardous waste storage/remediation, and petroleum recovery. Working with the Institute for Water Resources and the Institute for Environmental Conflict Resolution, Tidwell helped establish the CADRe program. He has also applied the collaborative modeling approach in Upper Gila and Mimbres basins in New Mexico, the Willamette River Basin in Oregon and Barton Springs in Texas.

William Werick is an independent consultant in Culpeper, Virginia. He served with the Army Corps of Engineers from 1964 to2004, the last 14 years as a senior planner at the Institute for Water Resources. He led the National Drought Study for the Corps, and during that study he and Rick Palmer developed Shared Vision Planning. He recently completed a shared vision planning effort for the International Joint Commission to find better ways to manage Lake Ontario levels and St. Lawrence River flows. He continues to consult on a number of shared vision planning processes around the country.

Megan Wiley Rivera is a senior water resources engineer at HydroLogics, Inc., a firm specializing in Computer-Aided Negotiations and other support for water resources management. She is also an adjunct professor at the University of Maryland Baltimore County where she teaches a Computer-Aided Dispute Resolution course developed with NSF support. She was previously a professor of Civil and Environmental Engineering at the City College of New York, where she developed and taught courses on Water Quality Modeling, Water Resources, and Fluid Mechanics based on innovative pedagogy. Her dissertation combined research on environmental fluid mechanics and undergraduate learning.