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Cooperative Modeling: Building Bridges Between Science And The Public

By: **Kristan Cockerill**, Howard Passell, and Vince Tidwell

Abstract

As freshwater resources become more scarce and water management becomes more contentious, new planning approaches are essential to maintain ecologic, economic, and social stability. One technique involves cooperative modeling in which scientists and stakeholders work together to develop a computer simulation model to assist in planning efforts. In the Middle Rio Grande region of New Mexico, where water management is hotly debated, a stakeholder team used a system dynamics approach to create a computer simulation model to facilitate producing a regional plan. While the model itself continues to be valuable, the process for creating the model was also valuable in helping stakeholders jointly develop understanding of and approaches to addressing complex issues. In this paper, the authors document results from post-project interviews designed to identify strengths and weaknesses of cooperative modeling; to determine if and how the model facilitated the planning process; and to solicit advice for others considering model aided planning. Modeling team members revealed that cooperative modeling did facilitate water planning. Interviewees suggested that other groups try to reach consensus on a guiding vision or philosophy for their project and recognize that cooperative modeling is time intensive. The authors also note that using cooperative modeling as a tool to build bridges between science and the public requires consistent communication about both the process and the product.

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COOPERATIVE MODELING: BUILDING BRIDGES BETWEEN SCIENCE AND THE PUBLIC[1]

Kristan Cockerill, Howard Passell, and Vince Tidwell[2]

ABSTRACT: As freshwater resources become more scarce and water management becomes more contentious, new planning approaches are essential to maintain ecologic, economic, and social stability. One technique involves cooperative modeling in which scientists and stakeholders work together to develop a computer simulation model to assist in planning efforts. In the Middle Rio Grande region of New Mexico, where water management is hotly debated, a stakeholder team used a system dynamics approach to create a computer simulation model to facilitate producing a regional plan. While the model itself continues to be valuable, the process for creating the model was also valuable in helping stakeholders jointly develop understanding of and approaches to addressing complex issues. In this paper, the authors document results from post-project interviews designed to identify strengths and weaknesses of cooperative modeling; to determine if and how the model facilitated the planning process; and to solicit advice for others considering model aided planning. Modeling team members revealed that cooperative modeling did facilitate water planning. Interviewees suggested that other groups try to reach consensus on a guiding vision or philosophy for their project and recognize that cooperative modeling is time intensive. The authors also note that using cooperative modeling as a tool to build bridges between science and the public requires consistent communication about both the process and the product.
(KEY TERMS: water resource planning; public participation; water policy; cooperative modeling; system dynamics.)

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INTRODUCTION

Like many regions around the world, the Rio Grande Basin of central New Mexico is facing difficult water management decisions. Increasing human population, reduced surface water supplies due to prolonged drought, and declining ground water supplies due to long term ground water mining are all contributing to regional water scarcity (Tidwell *et al.,* 2004). This scarcity is having immediate impacts on agriculture, the environment, and tourism and has the potential for longer term impacts on economic development (Ward, 2002; Kery *et al.,* 2003; *The Albuquerque Tribune*, 2004).

Water management in the Middle Rio Grande (MRG) has a long and lively history. Water has important agricultural, environmental, residential, industrial, and cultural uses in the region. The state of New Mexico administers legal rights to surface water under the prior appropriations doctrine. This doctrine is based on the "first in time, first in right" philosophy, in which supply to users from season to season is determined by both availability and seniority of water rights ownership (Tisdell, 2003). The most senior water rights belong to American Indian nations and Spanish land grantees, with more junior rights belonging to many farmers and urban centers. These water rights, however, have not been adjudicated, and water management decisions in the region are fraught with emotion and are often contentious. It has become increasingly clear that *status quo* will not suffice and that making difficult decisions about how to

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adjust current use patterns will be painful. New tools and methods for water resource planning are essential for continued ecologic, economic, and social stability.

One approach employed in the MRG and elsewhere is cooperative modeling. This combines the power of computer simulation models with public involvement. The value of collaboration, whereby various stakeholders work with policy makers to address a particular issue has been well documented (Selin *et al.,* 2000; Wondolleck and Yaffee, 2000; Connick and Innes, 2003). The technical literature reveals that these collaborative groups are increasingly including model building as an effective way to inform the process. This technique is labeled variously as mediated modeling, group modeling, and cooperative or collaborative modeling. More specifically, many of these efforts employ systems thinking and system dynamics models. These models can capture feedback, nonlinearities, and time lags in a particular system that are too often ignored in assessing issues and in developing management practices (Costanza and Ruth, 1998). Systems thinking coupled with developing a model allows diverse stakeholders to "see" the complexity, including feedbacks and nonlinear relationships in a system. By appreciating the complexity, the team develops a common understanding of any given issue, which improves chances that results from the collaborative effort will be implemented (Palmer *et al.,* 1993; Vennix, 1996; Rouwette *et al.,* 2002; van den Belt, 2004). Case studies of cooperative modeling for a variety of subjects show that the technique increases knowledge levels about the particular topic, and there is evidence that creating a model together is more successful in helping to resolve an issue than simply having participants use an existing model (Rouwette *et al.,* 2002). The case studies reveal that cooperative modeling often leads to increased consensus about a problem and mitigating approaches (Costanza and Ruth, 1998; Rouwette *et al.,* 2002; van den Belt, 2004). It is important to note, however, as Rouwette *et al.* (2002) do, that unsuccessful cooperative modeling efforts are not well represented in the literature, and therefore it is difficult to ascertain how widespread this approach has become and with what level of success.

To help with water planning in the MRG region, the Cooperative Modeling Team (CMT) was established. Because cooperative modeling is a relatively new technique, it is important to document all efforts to help others improve the approach. Therefore, once the MRG plan was completed, the lead author conducted in-depth interviews with the modelers and with other CMT participants. Objectives of these post-project interviews were to: identify strengths and weaknesses of cooperative modeling, particularly in building a bridge to allow nontechnical people to gain system understanding; determine if and how the model facilitated the planning process; and solicit advice to benefit others considering model aided planning efforts.

The CMT experience confirms findings in existing literature because it did increase understanding of the complexity inherent in water resources management. The CMT members also report that the model development process and the final product were key to creating a regional plan. Unlike findings of some case studies, however, this effort did not increase consensus within the modeling team or the broader public, and it remains to be seen if or how ideas that the model helped generate will actually be implemented. The CMT has several characteristics that are not documented in other case studies, including the fact that anyone could join the modeling process at any time and that there was not a policy maker driving or actively participating in the model building effort.

Using suggestions from Rouwette *et al.* (2002) on how to report results from a cooperative modeling exercise, the authors briefly describe the MRG planning region and provide an overview of the cooperative model development process and the model itself. The paper then documents feedback from those individuals who actually worked to develop the model and use it in preparing a regional plan. Finally, the authors offer additional insight into this project and its value to the growing body of knowledge about cooperative modeling and the role this approach may play in improved water management.

REGIONAL SETTING

The Middle Rio Grande Basin is defined regionally as the section of Rio Grande watershed bounded by Cochiti Reservoir upstream and Elephant Butte Reservoir downstream (see Figure 1). The basin includes much of Bernalillo, Sandoval, Valencia, Socorro, and Sierra Counties. This is a semi-arid region with an average annual precipitation of about 8.75 inches. Water sources include the Rio Grande, its tributaries, and fossil ground water resources. Passell *et al.* (2004) provide a thorough description of the topography and hydrology of the basin. The region includes one of the southwestern United States' largest remaining stands of cottonwood/willow riparian forest, as well as the endangered silvery minnow (*Hybognathus amarus*) (Crawford *et al.,* 1996; USFWS, 2002).

The Middle Rio Grande is home to American Indian and Spanish agricultural communities that date back many hundreds of years. The region also includes Albuquerque, the largest urban center in New Mexico, which is preparing to celebrate its 300th birthday. Like much of the "Sunbelt" of the southwestern United States., this region experienced tremendous growth in the 20th Century. From 1900 through 2000 the population grew from about 51,000 to about 713,000 people – an increase of 1,298 percent (Passell *et al.,* 2004). Growth is projected to continue and the population will increase to about 2.5 million people by 2050 (BBER, 2002). Also increasing throughout the 20th Century was the understanding of water supplies and climate patterns. Ground water studies showed that ground water supplies in the basin are much more limited than once thought (Bjorklund and Maxwell, 1961; Thorn *et al.,* 1993). Tree ring studies showed that regional precipitation in the last quarter of the 20th Century, during which the population in the region nearly doubled, may have been greater than anytime in the last 2,000 years (Grissino-Mayer, 1996).

PLANNING HISTORY

In the mid-1990s New Mexico initiated a statewide water planning process in response to mounting concern over water scarcity. The New Mexico Interstate Stream Commission (ISC) divided the state into 16 planning regions. Of interest here is the Middle Rio Grande planning region, which includes Bernalillo, Sandoval, and Valencia Counties (Socorro and Sierra Counties, also in the Middle Rio Grande Basin, formed their own region). The ISC tasked each region with defining its future water supply and demand, along with preparing a 50-year water management plan that balances supply with demand. The planning process in some regions was structured around a partnership among local governments with oversight responsibility and volunteer organizations that spearheaded the actual planning. In the MRG planning region the Mid Region Council of Governments (MRCOG) and the Middle Rio Grande Water Assembly (Water Assembly) signed a Memorandum of Understanding. Planning in the MRG region was one of the most participatory efforts in the state.

The Water Assembly was created in 1997 as an organization of self-selected volunteers drawn from the three-county region. Active Water Assembly members include water scientists and managers, academics, lawyers, economists, real estate developers, farmers, environmentalists, business people, and others. To accommodate the broad range of views, the Water Assembly organized itself around five constituency groups: Agricultural, Cultural, and Historic Water Use; Environmental Use; Urban Users and Economic Development; Specialists (technical experts); and Water Managers.

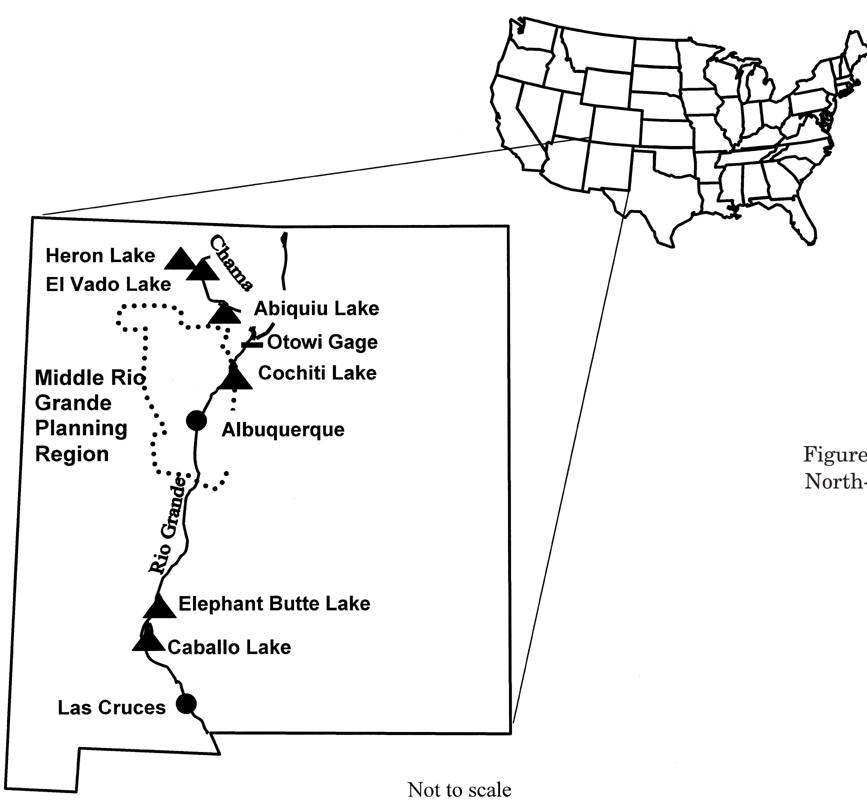

Figure 1. The Middle Rio Grande Region of North-Central New Mexico, United States.

The Water Assembly volunteers then began a methodical, rigorous, and often contentious effort to define the terms of both water supply and demand for the region and to identify citizens' preferences for water uses and their preferences for alternatives to existing water management practices. Throughout most of the planning process (1997 to 2004) the constituency groups met regularly, and the Water Assembly held broader meetings frequently to update the public on progress and to canvas their concerns, desires, and expectations concerning the regional water plan.

MODEL DEVELOPMENT

As the planning effort progressed, complexities in the regional water system and decision process became evident. This awareness led to discussions between the Water Assembly and Sandia National Laboratories (SNL) that focused on creating a model that would provide a quantitative basis for comparing alternative water conservation strategies; engage the public in the decision process; and help the public understand the complexity inherent in the regional water system.

Subsequently, SNL, the Water Assembly, MRCOG, and the Utton Transboundary Resources Center of the University of New Mexico School of Law (Utton Center) established a collaborative relationship. A community-based, participatory process for model development was adopted in an effort to build acceptance and confidence in the planning tool. The SNL was responsible for model formulation and implementation within a system dynamics framework. The Water Assembly was responsible for system conceptualization, identifying sources of subject expertise and data, model review, and representing the views of the public and key constituency groups. The MRCOG represented the interests of the local governments that have ultimate responsibility for implementing the regional plan, and the Utton Center provided expertise in group facilitation.

Individuals from each institution formed the CMT. To ensure broad stakeholder representation, each Water Assembly constituency group had a representative who attended CMT meetings. Other consistent participants included the two SNL modelers and a facilitator from the Utton Center. Additionally, other individuals from the region attended CMT meetings and provided input to model development. The CMT met twice a month from February 2002 through early 2003. Starting in the spring of 2003, after most of the modeling work was completed, the CMT began meeting monthly to review and update the model and to monitor the model's use in the planning process. The CMT members continue using the model to educate people about water resources in this region.

Funding for the project was garnered through the New Mexico Small Business Assistance Initiative. This is a collaborative effort among the state of New Mexico, SNL, and New Mexico small businesses (fewer than 500 employees). The program allows small businesses in New Mexico to receive technical assistance from the federal laboratory, either singly or in combination, with payment to the laboratory coming from a state gross receipts tax rebate system. The Water Assembly coordinated with approximately 15 small businesses that combined to receive assistance from the program.

Model development flowed through a multistage process. First, the CMT defined the problem to be solved and the scope of analysis. Next, the team developed a description of the hydrologic-ecologic-economic system. This began by conceptualizing the broad structure of the system, followed by decomposing that broad structure into a series of manageable units defined by specific system sectors. The sectors included are residential, nonresidential, bosque (riparian forest), agriculture, reservoirs, desalination, population growth, drought, and interbasin or intrabasin transfers. For each sector, the SNL modelers developed a causal loop (schematic) diagram describing the structure and feedbacks, and other CMT members reviewed and revised these. The CMT identified subject experts who were contacted to further clarify the system and to gather necessary input data. The causal loop diagrams were converted into a system dynamics context; the model sectors were populated with appropriate data and mathematical relations; the model was calibrated against historic data; and a user-friendly interface was developed. The CMT reviewed each sector of the model as a stand-alone piece and as part of the whole model. Further review both internally and by outside experts is ongoing.

Public feedback was gathered at meetings in which the modelers demonstrated draft versions of the model. Outreach targeted such venues as Water Assembly meetings; children's water fairs; state and county fairs; civic, professional and academic groups; and students in various schools and universities whose instructors requested a model demonstration.

Additionally, the modelers interacted with water professionals and scientists from local, state, and federal agencies. These meetings were often organized in response to the agencies' critical comments about the model. While these agencies had been invited to join the regional planning process and the CMT, they elected not to become active participants, either to avoid conflicts of interest or because of time and financial constraints. These agencies did provide constructive criticism and contributed to significant improvements in the model.

MODEL DESCRIPTION

The simulation model was created within a system dynamics framework (cf., Sterman, 2000). A systems approach was adopted because it allowed the CMT to take an "integrated" view of the watershed – one that coupled the complex physics governing water supply with the diverse social and environmental factors affecting water demand. This approach also allowed the team to develop a model that could be taken directly to the public for involvement in the planning process and for educational outreach. Modeling was accomplished within the object oriented modeling package of Studio Expert 2001 and 2003, produced by Powersim Inc. A full description of the model is given in Tidwell *et al.* (2004).

The model is structured as a dynamic water budget with each supply and demand component treated as a spatially aggregated, temporally dynamic variable. The spatial extent of the region 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., Rio Grande Compact balance is calculated for the entire Middle Rio Grande Basin). Temporally, the model operates on an annual time step encompassing the period 1960 to 2050. The model is calibrated using historic data from the 45-year period of 1960 through 2004 and forecasts regional dynamics for the 46-year period of 2005 through 2050.

Basically, the model balances historic and simulated annual surface water and ground water supplies against historic and simulated municipal, agricultural, evaporative, and riparian demand. The surface water system is comprised of the Rio Grande and area reservoirs. Inflows include the main stem of the Rio Grande, tributary flows, interbasin transfers from the Colorado River (each of which are 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. Ground water inflows include mountain front recharge, interbasin flows, and river leakage, while withdrawals include ground water 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 are numerous water conservation strategies that the public generated through community meetings held as part of the planning effort. The model allows users to simulate many of the most important large scale, long term hydrologic, ecologic, and economic consequences through these alternative conservation strategies. Among many others, these include the consequences of: removing nonnative, high water consuming vegetation from the riparian zone; implementing urban conservation measures such as conversion to low flow appliances; changing agricultural irrigation techniques; and modifying reservoir operations.

The model operates on a personal computer and takes less than 10 seconds to complete a simulation. Results are expressed in terms of the Rio Grande Compact balance (key legal institution for the basin), ground water depletions, water savings, and costs (construction, operation, and maintenance). 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 conservation alternatives in the region, and graphs and tables for describing model simulation output. The slider bars and buttons allow users to simulate different management strategies.

COOPERATIVE MODELING TEAM FEEDBACK

Because cooperative modeling is increasingly used in decision making processes, documenting these experiences is valuable to provide to others the lessons learned and to further the body of knowledge about the factors that contribute to a successful effort. To that end, the lead author on this paper, who was not involved with the CMT, conducted in-depth interviews with the modelers (Tidwell and Passell) as well as with other CMT participants and Utton Center personnel. All individuals who had attended multiple CMT meetings were asked to participate in this study. Those who agreed to be interviewed do represent the CMT's diverse areas of expertise including hydrology, economics, law, policy, ecology, and computer technology. They also represent levels of involvement from individuals who participated in only a few meetings to those who have remained active throughout the project. A total of 13 interviews were conducted between April and June 2003.

At the outset of the interviews each participant was asked to complete a quantitative questionnaire that consisted of 16 statements about the model development process as well as the model itself. Interviewees were asked to respond to each statement using a 1 to 10 scale with 1 meaning that they "completely disagree" with the statement and 10 meaning that they "completely agree" with the statement. As the results in Table 1 show, responses were strongly positive. Among all statements the mean of the means is 8.1, which is quite high, indicating overall satisfaction with the model development process and the model.

To gain further insight into the process, the lead author then asked each interviewee a series of open-ended questions, including the following. Did the model meet the three project objectives? What is your greatest source of satisfaction from the process and/or product (strengths in collaborative modeling)? What are you least satisfied with (weaknesses in collaborative modeling)? What role did the model play in the planning process? What advice would you give to others who were considering a cooperative modeling effort?

The following section provides the summarized responses from these interviews, organized according to the five questions above. It is important to note that these responses reflect interviewee perspectives and understanding and may not reflect what the authors believe to be true about the model or the development process. The Discussion section further analyzes results from this project.

Meeting Project Objectives

As already noted, there were three primary objectives for the model. When asked if these objectives had been met, the modelers unequivocally responded

TABLE 1. Cooperative Modeling Team Member Responses to Statements About the Model Development Process and the Model.

	Statement	Mean	Median	Lowest Response	Highest Response
1.	It was appropriate to use the model to support the regional water management plan development.	9.1	9	7	10
2.	The model is "fair" – it does not emphasize the interests of one advocacy group over another.	9	9	8	10
3.	The model helps to explain complexity in the Middle Rio Grande system.	9	9	7	10
4.	I would recommend creating a model like this to other communities (regions) that are developing water management plans.	8.7	9	5	10
5.	The data used to develop the model are appropriate.	8.3	8	7	10
6.	The model helped engage the public in the planning process. (n = 8).	8.3	8.5	4	10
7.	I would use the model to communicate with others about water management planning.	8.3	9	6	10
8.	The modeling team listened to my input concerning model design.	8.3	9	4	10
9.	Developing the regional water plan would have been more difficult without the model.	8.3	9	3	10
10.	The model was developed in an open, participatory process.	8.1	8	6	10
11.	After using the model, I recognize more connections among potential management alternatives than I did before.	7.9	8	5	10
12.	The model provides a quantitative basis for comparing management alternatives.	7.8	8	5	10
13.	Model design meetings were well-organized.	7.6	7	6	9
14.	The model is user friendly.	7.3	7	6	8
15.	I was surprised at some of the model's results.	7.1	8	1	10
16.	The model's output is realistic.	6.9	8	4	10

Notes: Each statement offered a 1 to 10 scale with 1 meaning that the respondent "completely disagreed" with the statement and 10 meaning that the respondent "completely agreed" with the statement (n = 9 except where noted).

"yes" to all three. All other CMT members hesitated before answering. Several joked that they had not realized that these were the objectives. After thinking a bit, all responses were in the affirmative but with various caveats.

As Table 1 shows, responses to the first objective, reflected in Statement 12, "The model provides a quantitative basis for comparing management alternatives," ranged from 5 to 10 on a 10-point scale, reflecting disparity in how well team members believe the model did this. In the interviews, some team members noted that not all of the publicly identified management alternatives were included in the model, and therefore not all alternatives could be compared. Others noted that the model simplified complex dynamics, and that made it difficult for those with quantitative backgrounds to fully agree with the statement.

As for the objective to engage the public (Statement 6), responses were also uneven, ranging from 4 to 10. The majority, however, said yes, the model did this. In the interviews, a key reason for hedging was that there was a belief that the general public could not just pick up the model and use it but instead needed guidance.

Interestingly, on the third objective, the quantitative responses were much more positive than the statements in interviews. The mean score for Statement 3, "The model helps to explain complexity in the Middle Rio Grande system" was a 9. Yet in the interviews, only three respondents said definitively that the model accomplished this. Others noted that the model provided this function for the modeling team itself, because they began to better understand the complexity while developing the model. They were less optimistic that the model did this for the general public unless individuals were willing to really delve into the model.

Strengths and Weaknesses in Cooperative Modeling

Because the CMT was a diverse group of individuals struggling with a complex, controversial subject, member responses to what they found most satisfying about the final outcome and what they found least satisfying were equally disparate. As is common with any diverse group, what some perceived as a positive others saw as a negative.

Most Satisfied (strengths). When asked what their greatest source of satisfaction was with the process, several team members highlighted that they were pleased that such a diverse group had, in the end, created a usable model. In the words of one interviewee, "We achieved a successful collaboration among a wide variety of people who had substantive input to offer." Several people noted that throughout the process, input was continuously sought, and it never became a "Sandia-only" effort.

A couple of team members noted that the CMT and the model development process helped focus the issues. One said, "It disciplined the [planning] process. It forced us to think quantitatively and not just in nominal terms."

As for the tool itself, many positive comments revolved around the virtues of putting excellent data into one package and thus allowing the model to show relationships and to help nontechnical people better understand impacts and to more effectively evaluate management alternatives. For example, one interviewee said, "It pointed out the coupling of attributes that the public didn't expect to be coupled, such as [how] low flow showerheads help the aquifer and hurt the Compact." The interviewee is referencing the Rio Grande Compact, which is a significant legal requirement in the region. A key attribute of the model was to reflect whether sets of management alternatives would allow the state to meet regional water demand and still meet Compact obligations. In this region, municipalities depend solely on ground water, while the resulting treated wastewater is discharged to the Rio Grande, which flows to southern New Mexico, Texas, and Mexico and helps New Mexico meet the Compact. Therefore, reductions in residential water use also reduce the amount of water discharged to the river. This was a relationship that the model helped make clear and demonstrated the complexity of water management.

Several team members noted that the graphic interface helped make the impacts visual, and this made the model a powerful planning tool. One interviewee noted that one of the most positive attributes of the model is that there were not any surprises – the model results meshed with other information available.

Least Satisfied (weaknesses). At the other end of the spectrum, CMT members also identified areas that were disappointing in the model development process. One issue raised in several interviews was that interest in the project decreased over time. Several team members noted that meeting attendance dropped from between 10 and 15 people per meeting to about six people per meeting. Interviewees gave several explanations for why this may have happened. For example, some said significant time was required for participation; people got answers they did not like, so they blamed the model and stopped participating; and some believed that special interests were driving the outcome.

This last explanation stems largely from *ex parte* meetings between SNL modelers and officials from various public agencies. As already noted, the modelers met with these agencies, which were not participating in model development, in response to negative comments about the model. Reflecting the volatile and fragile nature of any public collaboration, some CMT members viewed these "outside" meetings as necessary, while others believed that they violated the collaborative intent of model development. These outside meetings sowed seeds of mistrust that continue to affect CMT interactions.

Some interviewees expressed concern that negative comments from agencies were based on political rather technical bases. Therefore, there was concern about how these non-CMT meetings led to changes either in the data or the structure used in the model. The general sense from interviewees, however, was that the modelers were genuinely interested in obtaining the best information and were trying to address all concerns. This is revealed in the quantitative segment where most respondents said that the model was "fair" and did not favor one perspective over another and that it was developed in an open, participatory fashion (Table 1).

Another source of dissatisfaction for some members related to a concern that the team did not possess adequate expertise, particularly regarding hydrology and computer capability. Interestingly, it was often the nontechnical respondents who raised the issue of technical expertise. A couple of interviewees were unaware that one of the modelers is a hydrologist.

The CMT members also suggested that a lack of common ground impeded the group's ability to function. As one interviewee noted, "People were representing certain groups rather than trying to get together on issues." As modelers tried to balance the diversity of interests, some group members felt that their interests were ignored. Others felt that the modelers needed to "just say 'no' to some things" rather than saying, "We'll look into it."

One interviewee noted that one source of frustration was in trying to use the model to develop planning scenarios while the model was still being developed. According to this interviewee, "We'd get weird information that we knew couldn't be right."

Another source of frustration was the inability to get wider distribution for the model. An initial goal had been to have the model on the Internet relatively early in its development, but technical and financial barriers made that difficult.

Concerns raised about the model itself revolved around specific content and/or output issues, including the following. The model did not address how much water could be expected at any particular time in the river; the surface water model did not include enough spatial or temporal disaggregation. It treated the MRG basin as a single, spatially aggregated unit. Economics were treated superficially in the model. The model did not help directly answer which slider or button settings were really key in getting which results. The model provided a "sunnier picture" than really existed and could contribute to inadequate response from policy makers and the public.

In the quantitative portion, these are reflected in the low degree of agreement with Statement 16, "The model's output is realistic," which has the lowest mean at 6.9 on a 10-point scale. Most CMT members did acknowledge limitations regarding time and money. As one interviewee concluded, "I think we did well given the resources we had."

Interestingly, while some people listed the visual interface as one of the positive aspects of the model, others said the interface was a negative. Several CMT members noted that an individual could not simply sit down and run the model; instead, someone intimately familiar with the model was required to walk first-time users through it.

Some concerns also were raised about the general public's ability to glean anything meaningful from graphs as compared to photos or other types of images. As Table 1 shows, responses to Statement 14, "The model is user-friendly," were some of the lowest. This was one of two statements for which no respondent selected 10 on the 10-point scale.

Impact on Planning

The CMT was created largely to facilitate regional water management planning. When asked what role the model played in accomplishing this, responses were largely positive. As Table 1 shows, there was a median response of 9 to Statement 9, "Developing the regional water plan would have been more difficult without the model."

Comments from all interviewees who remained active throughout the project revealed that the model was instrumental in getting to a final plan. The model was the tool used by the Water Assembly to develop multiple scenarios, which were ultimately compiled into a preferred scenario, which in turn became the basis for the plan. One interviewee stated, "I think what it did was to be a reality check for the Water Assembly – the model led to the plan that we created." Some interviewees, however, commented that the model's visibility was quite limited in the actual text of the plan. This was attributed to ongoing debates about actual model output.

Several CMT members noted that playing with the model led to the emphasis on what has become known as the "urgent shortfall reality." This refers to the period of time between the initiation of conservation approaches, when water savings are still small, and the time when those approaches reach maturity and water savings are much larger. This "urgent shortfall reality" represents a period of noncompliance with the interstate compact and subsequent adverse legal consequences. One interviewee also concluded, "The model gave us considerations that we likely wouldn't have considered otherwise. It helped some people do quantitative decision making."

Others noted that using the model helped alleviate some of the advocacy positions, as all constituency groups could see the difficulties inherent in balancing supply with demand. One interviewee saw this as a potential continuing role for the model, suggesting that it could be used in the future to help identify common ground in order to reduce the emphasis on advocacy. Several CMT members also noted that the model was important in showing the public the issues and impacts inherent in managing water.

In getting to a plan that all constituencies could live with, the diversity of perspectives on what the model showed was reflected in two quotes from interviewees. One respondent said, "Without the model, I couldn't have personally come to have confidence with where we ended up – with identifying a solvable problem. It is solvable if we want to solve it – if there is will." Another respondent suggested, "In a funny way [the model] ended up discouraging us – there didn't seem to be any politically acceptable way to meet responsibilities as we defined them."

Advice to Others

When asked what advice they would give others embarking on a cooperative modeling effort, CMT member responses fit into four broad categories: guiding vision, resources, team composition, and the process used.

Guiding Vision. Numerous pieces of advice focused on the importance of obtaining "buy-in" from the stakeholders by finding common goals and interests that bridge what can otherwise be contentious and entrenched divisions. One interviewee suggested, "You have to explore how and whether these interests can be reconciled to some larger interest – [to] a collective interest that we share." This approach contradicts what some team members felt happened on the CMT (and in the larger Water Assembly), which was for particular stakeholders to remain steadfast in their "position" with little or no flexibility. A couple of interviewees noted that a project like this requires early efforts to explicitly deal with group dynamics and to gain consensus on the "larger interest," as well as setting ground rules at the outset for how the group will interact.

Resources. Several people raised the idea that funding and other types of support are crucial to a successful collaborative effort. When asked to provide advice to other cooperative modeling teams, one interviewee declared, "Get matching state funds! Lots of them!" There was some sense that the CMT would have been more successful if it had a public mandate and support (in terms of technical personnel rather than funds) from the various agencies responsible for water management. Several team members praised SNL for its level of support. One declared, "This project had two guys funded full-time to develop the model" and noted that without that support, the project would not have been feasible. While the modelers were actually only funded part-time, it was clear to the CMT members that this was a resource intensive effort.

Team Composition. There was overwhelming support for the idea that there must be technical expertise on the team, including both modeling experts and content experts to provide data, structural understanding, and "reality checks," both technical and social. The team also recognized that diversity was important and that all interests needed to participate in the model development process. Additionally, team members suggested that technical people might need "training" to fully appreciate political realities and the dynamics inherent in public participation activities.

The Process. Cooperative Modeling Team members said that transparency in the process is very important and that everyone on the team needs to be regularly apprised of what is happening in the project and why. The identity of and information about data sources needs to be open, and the strengths and weaknesses must be discussed. In any controversial issue, avoiding even the appearance that any particular interest is driving the process is paramount. Interviewees related this to the idea of establishing a "larger interest" to provide a common ground and establishing a trust-based relationship with clear guidelines for interaction at the outset.

Other suggestions included acknowledging that any collaborative effort is time consuming and may be frustrating. This is partially true because it is important in a collaborative effort that all participants be treated equally. As one interviewee eloquently stated, "You have to listen to all interests, even if you disagree with some. You can't allow that some ideas are beyond the pale and therefore can be marginalized. This isn't just a moral issue, but an instrumental issue." Respondents noted that if the cooperatively designed model is to be credible, everyone must feel vested in the process. In fact, one interviewee said that the lack of feeling vested in the model or the process was one reason he dropped out of the project.

There were several comments about the necessary time investment and the need for dedicated team members. Several interviewees questioned whether the duration of the CMT project might have contributed to waning interest. Others noted that the group seemed less productive in the later stages, and hence there was less incentive to attend meetings or stay involved. These comments often tied back to the need for a guiding vision to keep the team focused as well as to reduce the role of advocacy positions, which were perceived by many to generate wasted effort during meetings.

Another common recommendation from the team was to employ a neutral facilitator to keep meetings organized and to ensure that everyone has an opportunity to be heard. The facilitator should also help maintain focus by reminding the team of overall objectives and decisions already reached.

DISCUSSION

In addition to the conclusions drawn by CMT members above, the authors offer additional insight that might be useful to other cooperative modeling efforts. Key lessons learned included the importance of transparency, the need for consistent communication, acknowledgment of resource requirements, and lessons about using a model in planning.

Transparency

One unique attribute of the CMT was the group's fluidity. Unlike many other cooperative modeling efforts in which a small group is convened and remains static, the CMT was open to anyone in the region throughout the entire model development process. As already noted, raw numbers of participants decreased, but the individuals participating also changed throughout the process. While this contributed to the transparency of the project, it also created a management concern. How could all interested parties be kept apprised of progress and decisions being made? Some level of dissatisfaction with the process is likely attributable to its completely open nature.

One way the CMT addressed this open nature was with mass emailings to a list of stakeholders who were either active in the CMT or who simply expressed a wish to be kept informed. In this project a paid facilitator was responsible for keeping notes on the events, discussions, questions asked, and decisions made in each meeting and then distributing those notes via email. For the first several months of CMT meetings, notes were also posted to a website. Even if ignored, the regular outreach associated with the transmission of these notes help create an atmosphere of openness and transparency.

While providing an open venue was a consistent objective, one conclusion drawn from the interviews is that no one on the team consulted the solid body of literature on public participation and cooperative decision making involving technical and nontechnical individuals. The initial facilitator for the CMT had significant experience in consensus building and group facilitation, while a later facilitator had less experience. These facilitation skills, however, do not necessarily capture basic public participation principles. This became a liability in the MRG project, reflected especially in comments about special interests driving the process and concern that the process for making decisions about what data to use and which sectors to include had become opaque. Basic public participation principles would have indicated that transparency at all times in all ways was absolutely essential in this project and would have cautioned the modelers against having any meetings that were not fully open to the CMT. Any group contemplating cooperative modeling should consult the diverse literature to avoid common pitfalls related to communication and public processes.

Consistent Communication

Any cooperative effort must be based on open, consistent communication. This is especially true when diverse stakeholders consider potentially divisive issues. Feedback from CMT members revealed how difficult it can be to bridge the gap between those with a modeling perspective and those with no modeling experience. Concerns expressed about MRG model content and/or output generally reflect the limitations present in any model, specifically that a model cannot include everything. The large number of comments about content and output perhaps reflects insufficient communication about what models do and specifically about what this model was intended to do and what its limitations were. These responses also likely reflect a lack of consensus on what the key issues were and that some CMT members remained focused on a particular interest rather than some broader guiding vision. This contributed to ongoing debates about data sources, sector structure, and language used in the model interface.

The fact that respondents did not immediately know the project objectives is additional evidence that insufficient energy was dedicated to identifying and reinforcing the overall project goals, including highlighting limitations. The fact that some CMT members did not know that one of the modelers was a hydrologist reflects a lack of familiarity within the team, which ideally would be established at the outset of the endeavor and reviewed frequently for the benefit of both continuing and new participants. The comments related to transparency and concern with special interests driving the process perhaps reflect the need for a bridge to help technical personnel to appreciate the dynamics inherent in a public process, especially with a highly volatile topic.

The CMT was created late in the regional planning process, and hence, as one of the interviewees noted, the model was being used as a planning tool while it was still under construction. This obviously creates a difficulty, but it also reflects the reality in many resource-planning projects in which tools are identified as a need arises. The need for a model was not perceived at the outset of the planning process and was only deemed important as the contentiousness became acute. Because this is not an uncommon situation, it is especially important that both modelers and other members of a collaborative team appreciate the roles and values of models in any kind of planning effort. The point must be made, repeatedly if necessary, that one of the greatest values in a cooperative modeling project is not only the model completed as an end result but the ongoing modeling process itself. A modeling process leads to much greater understanding of the systems involved and better targeted data collection efforts. CMT respondents appreciated this as they noted the model's importance in the planning process, even though the model's output was not the key driver to the plan's recommendations.

The polarized comments about the model's interface underscore the difficulty of communicating quantitative model results to a wide variety of stakeholders. This is an area ripe for additional research.

Even with some fairly large missteps, this effort did improve communication among stakeholders. Over time, the model became the centerpiece of a discussion that included experts and advocates from around the state and from various social and institutional positions. The model integrated data, provided system understanding, and helped generate ideas. Despite CMT member comments highlighting that many people remained entrenched in their preconceived "positions," there was also ample evidence from the interviews that the model did help provide a basis from which to begin a dialogue. The interviews also showed that the model development process helped demonstrate to CMT members how interdependent the various subsystems (agriculture, urban, riparian, economic) in the MRG are and how important it will be for diverse stakeholders to work together in developing solutions.

Resource Requirements

Several interviewees noted that the CMT was a time intensive endeavor. The team met twice a month for a year, and each meeting was approximately two and a half hours long. In the second year, meetings were reduced to once a month and then to an "as needed" basis in the final year. Participants often did additional data gathering or component reviews in preparation for meetings. Van den Belt (2004) estimates that mediated modeling groups should plan for 40 to 60 contact hours spread over a period of months or years, although she acknowledges that significant variability exists in this estimate. While the CMT did not keep detailed records of time spent, a conservative estimate is 90 volunteer hours per person for those who remained involved throughout the entire project. Interviewees noted that this level of commitment may have exceeded reasonable expectations to ensure dedicated participation.

There was not a mandate from any policy making entity to develop this model, and therefore, in addition to concerns about biasing the project, staff from key agencies or organizations (e.g., city water utilities) may have faced time constraints, limiting their ability to participate. Having policy makers at the table would have been best for both the process and the final product. To ensure their participation, however, the project must be something that staff can do "on the clock" rather than as volunteers. Wondolleck and Yaffee (2000) emphasize that this requires support from throughout the hierarchy of an organization, and without a directive from above, water issues are often too politically charged to gain this support.

Cooperative modeling projects are also expensive. They require modeling expertise as well as a professional facilitator, and these require funding. Through a unique program, the CMT was funded at about US$100,000 per year for three years. This covered two modelers part-time, a facilitator, software and equipment, and institutional overhead. Like the project, the funding was collaborative, which largely precluded any concerns about a sponsor biasing the effort.

While resource constraints are not unique to cooperative modeling projects, the need to have highly technical expertise and specialized equipment may be unique. The MRG project had the benefit of skilled volunteers with extensive knowledge about the region and the ability to use their personal computers to review model versions as they were completed. Any group considering cooperative modeling must have funding guaranteed for the planned duration of the project, and ideally the funding should not be single source to avoid questions of bias.

Model Use in Planning

In the spring of 2003, a working model was delivered to the Water Assembly. The model was used to help guide and inform Water Assembly decisions about how best to balance the regional water budget. This involved developing "scenarios," or draft water management plans. Water Assembly volunteers developed scenarios that integrated various combinations and intensities of 44 management alternatives that the public had identified in early phases of the planning process. Ultimately, a series of five "scenarios" intended to represent perspectives from each of the five constituency groups (agriculture, environment, urban, specialists, managers) were developed. These scenarios were then vetted with the public to gather their preferences and perspectives. During late 2003 the Water Assembly worked closely with the MRCOG and used the MRG model to combine the individual scenarios along with public feedback into a "preferred scenario," which then became the basis for the regional water management plan (Middle Rio Grande Water Assembly, 2004). Once the public had commented, the plan was finalized and submitted. The Interstate Stream Commission formally accepted the plan in August 2004. Table 2 and Figure 2 show the settings and model output graphs for the default (*status quo*) scenario and for the preferred scenario that was incorporated into the regional plan. This figure shows that under the preferred scenario, by 2050 the region can comply with the Rio Grande Compact and simultaneously reduce the ground water depletion rate. Table 2 reveals, however, that to do this will require significant changes from the status quo. By comparing various scenarios, the model allowed people to see the level of adjustment required to balance water supply with water demand.

While the model was a key tool in facilitating the planning process, actual numbers from model output are not the basis for the plan's recommendations. One reason for this is the continued lack of consensus among the CMT, the Water Assembly, the MRCOG, and policy-making institutions as to the neutrality of the model, the validity of its assumptions, and the accuracy of various data sources. The lack of a mandate and policy maker participation in model development meant that these organizations were not vested in the model or its results, and hence there was always a question of how the model would be received outside the CMT. Because several water-relevant models are available in the region, there was a consistent tension about how the MRG model would compare with other models. A few interviewees raised idea of "dueling models" as an impediment to allowing the MRG model to help generate consensus among the public and policy makers. Still, the interviews made clear that, at least among CMT members, the model did ease the planning process as it let people see tradeoffs, and the model emphasized that balancing water supply with demand was not going to be easy for any constituency in the region. These ideas are included in the regional plan.

CONCLUSIONS

The objectives were well met in terms of identifying strengths and weaknesses in using cooperative modeling to build bridges that help nontechnical people understand system dynamics, determining the model's role in the planning process, and assessing how cooperative modeling efforts might be improved. All interviewees provided tremendous insight into the model's actual role in the planning process, and as Table 1 shows, the team members believed that it was appropriate to use the model in planning and that the planning process would have been more difficult without the model. The interviews provided strong evidence that even though the actual output from the model was not crucial to the final plan, the model was instrumental to the process for getting to a final plan.

Although some important criticisms were raised in the course of the modeling process and in the interviews for this paper, CMT members were generally quite happy with the modeling experience, the model, and the role it played in the planning process. During the interviews several team members asked about future plans for the model and expressed hope that it would continue to evolve and be a tool in future planning and implementation tasks. The high level of approval among CMT members and the modelers themselves may be a bit self-congratulatory. However, survey research among individuals not involved in the model development also shows high approval for the model, suggesting that the CMT team is justified in believing that the model is an effective tool (Cockerill *et al.*, 2004).

Information gleaned from this experience provides lessons to others who are considering a cooperative modeling effort. This largely positive experience in the Middle Rio Grande can contribute to positive

TABLE 2. Sample Settings From the Model's Default (status quo) Scenario Compared to the Settings in the Preferred Scenario Used in the Regional Plan.

Sample Model Sectors	Sample Management Actions	Default Scenario Settings	Preferred Scenario Settings
Residential	Convert existing homes to low flow appliances	0%	80%
	Low flow appliances installed in all new homes	no	yes
	Convert existing homes to xeriscaping	0%	30%
	Xeriscaping for all new homes	no	yes
	Reduce size of irrigated yards in new homes	0%	40%
	Reduce consumption by xeriscaping	50%	50%
	Convert existing homes to water harvesting	0%	25%
	Roof top harvesting in all new homes	no	yes
	Convert existing homes to on-site gray water use	0%	5%
	On-site gray water use for all new homes	no	yes
Nonresidential	Convert existing properties to low flow appliances	0%	80%
	Low flow appliances in new construction	no	yes
	Convert existing properties to xeriscaping	0%	30%
	Xeriscaping for all new construction	no	Yes
	Reduce landscaping for new construction	0%	5%
	Reduce future per capita growth rate for parks and golf courses	0%	80%
Bosque	Remove nonnative phreatophytes from all public bosque lands	no	yes
Agriculture	Line public conveyances, from a total of 1230 kilometers	0 km	1,230 km
	Laser level farmland, from a total of 20,235 ha	0 ha	10,117 ha
	Install drip irrigation	0 ha	1,011 ha
	Change crop type distribution	no	no
	Reduce agricultural croplands	no	no
Reservoir	Increase storage capacity in Abiquiu Reservoir	no	yes
	Maximize upstream storage/minimize Elephant Butte Reservoir storage	no	yes
	Minimum Elephant Butte Reservoir storage volume	400 Mm^3	493 Mm^3
	Build a new northern reservoir	no	no
	Implement artificial recharge	no	yes
Desalination	Desired quantity of desalinated water	0 Mm^3	27 Mm^3
	Water source	NA	Tularosa
	Year desalinated water becomes available	NA	2010

Notes: Table does not include all options available in the model. Mm^3 is million cubit meters.

efforts elsewhere as more groups employ cooperative modeling in water management and other resource planning.

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LITERATURE CITED

The Albuquerque Tribune, 2004. In Brief: As Goes the Water So Goes the Tourism (June 16).

Bjorklund, L.J. and B.W. Maxwell, 1961. Availability of Ground Water in the Albuquerque Area, Bernalillo and Sandoval Counties. New Mexico State Engineer Technical Report 21, New Mexico State Engineer, Santa Fe, New Mexico.

BBER (Bureau of Business and Economic Research), 2002. New Mexico Population Growth Projections by County. New Mexico Business Current Economic Report 23(7):8.

Cockerill, K., V. Tidwell, and H. Passell, 2004. Assessing Public Perceptions of Computer-Based Models. Environmental Management 34(5):609-619.

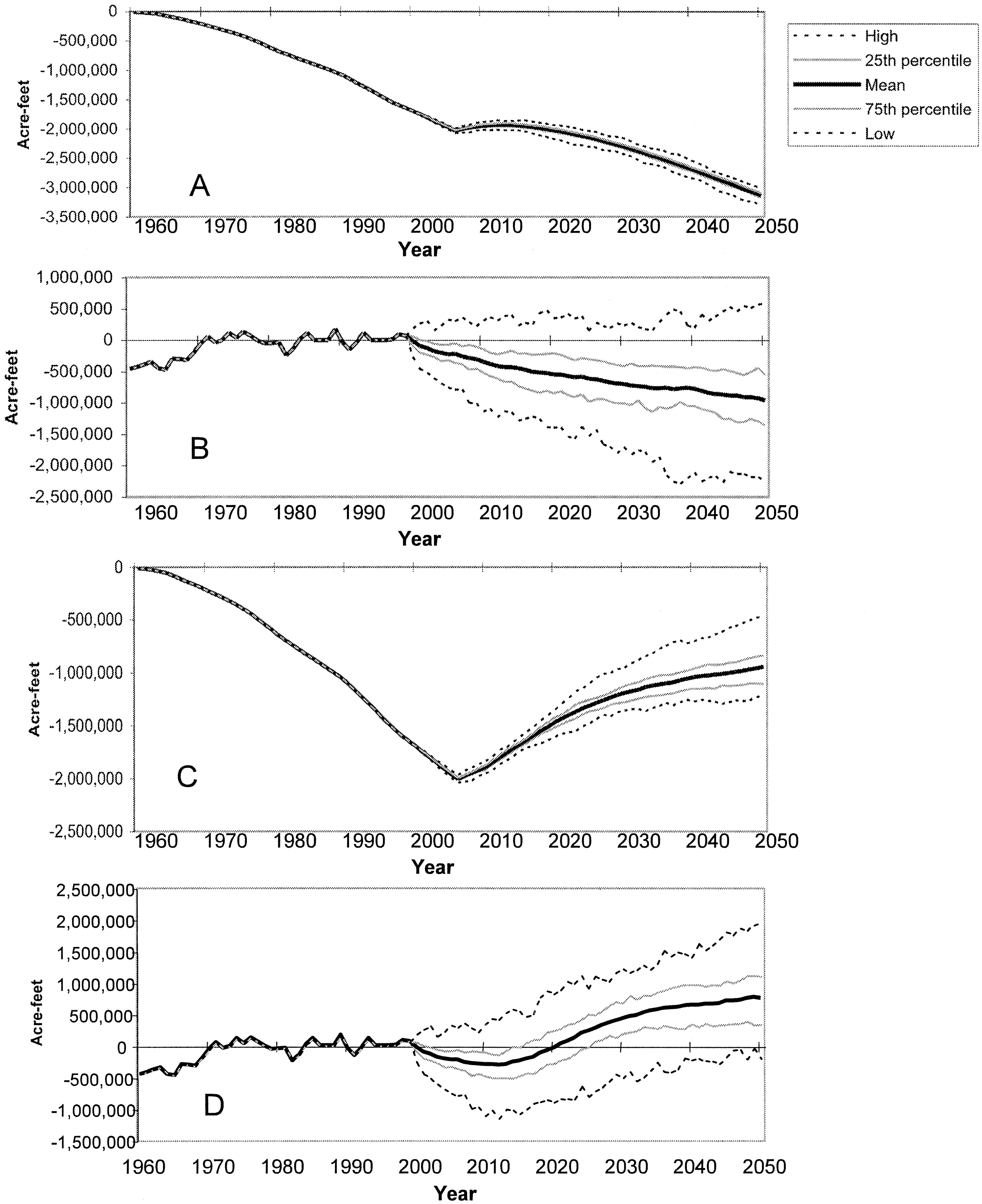

Figure 2. Model Results Showing: (A) Ground Water Depletion, (B) Rio Grande Compact Balance Using the Default (status quo) Settings, (C) Ground Water Depletion, and (D) Rio Grande Compact Balance Using the Preferred Scenario Settings. Results reflect 100 model runs. The dotted lines show the single best case and single worst case model run results; the gray lines enclose the middle 50 percent of the model run results; the black line represents the mean of the results from the 100 model runs.

Connick, S. and J.E. Innes. 2003. Outcomes of Collaborative Water Policy Making: Applying Complexity Thinking to Evaluation. Journal of Environmental Planning and Management 46(2):177-197.

Costanza, R. and M. Ruth, 1998. Using Dynamic Modeling to Scope Environmental Problems and Build Consensus. Environmental Management 22:183-195.

Crawford, C.S., L.M. Ellis, and M.C. Molles, Jr., 1996. The Middle Rio Grande Bosque – An Endangered Ecosystem. New Mexico Journal of Science 36:276-299.

Grissino-Mayer, H., 1996. A 2129-Year Reconstruction of Precipitation for Northwestern New Mexico, USA. *In:* Tree Rings, Environment and Humanity, J.S. Dean, D.M. Meko, and T.W. Swetnam (Editors). Radiocarbon, Tucson, Arizona, pp 191-204.

Kery, S.C., J.W. Utton, P.C. Chestnut, and S.E. Umshler, 2003. Legal Issues Specific to the Middle Rio Grande Water Planning Region. *Available at* http://www.waterassembly.org/pdfs2/Legal Issues.pdf. *Accessed in* February 2006.

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 in* February 2006.

Palmer, R.N., A.M. Keyes, and S. Fisher, 1993. Empowering Stakeholders Through Simulation in Water Resources Planning. *In:* Water Management in the 90's: A Time for Innovation, K. Hon (Editor). Proceedings of the 20th Anniversary Conference, American Society for Civil Engineering, New York, New York, pp 451-454.

Passell, H.D., C.N. Dahm, and E.J. Bedrick. 2004. Hydrological and Geochemical Patterns and Trends in the Upper Rio Grande, 1975-1999. Journal of the American Water Resources Association (JAWRA) 40(1):111-127.

Rouwette, E.A.J.A, J.A.M. Vennix, and T. van Mullekom, 2002. Group Model Building Effectiveness: A Review of Assessment Studies. System Dynamics Review 18(1):5-45.

Selin, S.W., M.A. Schuett, and D. Carr. 2000. Modeling Stakeholder Perceptions of Collaborative Initiative Effectiveness. Society and Natural Resources 13:735-745.

Sterman, J.D., 2000. Business Dynamics, Systems Thinking and Modeling for a Complex World. McGraw-Hill, Boston, Massachusetts, 982 pp.

Thorn, C.R. D.P. McAda, and J.M Kernodle, 1993. Geohydrologic Framework and Hydrologic Conditions in the Albuquerque Basin, Central New Mexico. U.S. Geological Survey Water Resources Investigations Report 93-4149, Albuquerque, New Mexico.

Tidwell, V.C., H.D. Passell, S.H. Conrad, and R.P. Thomas, 2004. System Dynamics Modeling for Community-Based Water Planning: Application to the Middle Rio Grande. Journal of Aquatic Sciences 66:357-372.

Tisdell, J.G., 2003. Equity and Social Justice in Water Doctrines. Social Justice Research 16(4):401-416.

USFWS (U.S. Fish and Wildlife Service), 2002. Designation of Critical Habitat for the Rio Grande Silvery Minnow. Draft Environmental Impact Statement, U.S. Fish and Wildlife Service, Albuquerque, New Mexico.

van den Belt, M., 2004. Mediated Modeling: A System Dynamics Approach to Environmental Consensus Building. Island Press, Washington, D.C., 296 pp.

Vennix, J., 1996. Group Model Building: Facilitating Team Learning Using System Dynamics. ISBN 047195355, Wiley, New York, New York, 312 pp.

Ward, F.A., 2002. Economic Impacts of Drought on Uses on the Rio Grande. *In:* Proceedings of There's No Doubt, We're in a Drought! 47th Annual New Mexico Water Conference. New Mexico Water Resources Research Institute Report No. 326, Las Cruces, New Mexico, pp 39-44.

Wondolleck, J.M. and S.L. Yaffee, 2000. Making Collaboration Work: Lessons From Innovation in Natural Resource Management. ISBN 1-55963-462-6, Island Press, Washington, D.C., 277 pp.