ECOLOGY AND CONSERVATION OF THE SAN PEDRO RIVER

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TWENTY-ONE

Integrating Science and Policy for Water Management

The politicization of science is undoubtedly a slippery slope.
But so is the scientization of politics. The boundary organization
does not slide down either slope because it is tethered to both,
suspended by the coproduction of mutual interests.
(Guston 2001)

Introduction

Freshwater and the ecosystems from which it originates are indispensable to human health and survival. Yet, population growth, climatic variability, and land uses such as mining and agricultural practices along the U.S.-Mexico border challenge our ability to adequately manage this indispensable resource. As the Southwest grapples with ways to increase water supplies and ensure water quality for its burgeoning population, various institutional and political drivers of change, including government agencies at all levels and elected officials trying to serve their constituents' interests, directly affect water management policies in the region.

This chapter describes the collaborative efforts of scientists, agency representatives, non-governmental organizations, elected officials, and other stakeholders (table 21.1) to address water policy and management issues in the Sierra Vista subwatershed of the upper San Pedro River basin. The recent efforts of the Upper San Pedro Partnership (the Partnership) to manage groundwater resources through an adaptive management approach are

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TABLE 21.1. **The twenty-one member agencies and organizations of the Upper San Pedro Partnership, as of 2007.**

Arizona Association of Conservation Districts
Arizona Department of Environmental Quality
Arizona Department of Water Resources
Arizona State Land Department
Audubon Arizona
Bella Vista Ranches
Cities of Sierra Vista, Tombstone, and Bisbee
Cochise County
Fort Huachuca (Department of Defense)
Hereford Natural Resource Conservation District
The Nature Conservancy
Town of Huachuca City
U.S. Agricultural Research Service
U.S. Bureau of Land Management
U.S. Bureau of Reclamation
U.S. Fish and Wildlife Service
U.S. Forest Service
U.S. Geological Survey
U.S. National Park Service

described. Adaptive management has been described as implementing projects or policies as experiments (Holling 1978, Walters 1986). This approach does not postpone action until "enough" is known, but instead acknowledges that time and resources are too short to defer *some* action, particularly actions to address urgent problems (Lee 1999).

The work of the Partnership has evolved the furthest of any watershed group in the San Pedro basin to date. This progress is at least partially attributable to the federal mandates and regulatory levers at play within this portion of the basin. However, there is a need for similar water management efforts in other portions of the basin, and the need for a more integrated basin-wide approach is apparent. The binational context of the upper San Pedro basin complicates integrated watershed management (Liverman et al. 1999), and the potential risks and uncertainty associated with ineffective basin-wide groundwater management remain high for all stakeholders. The Benson subwatershed is looking to Sierra Vista upstream for evidence of good management, and Sierra Vista is looking to the Sonoran portion of the basin for indications of progress in establishing watershed governance. Unfortunately, water within different portions of the basin have no effective venue for communication or coordination with one another. However, the Mexican Binational San Pedro Commission recently invited the Partnership to embark on a series of meetings for planning and information exchange.

Each of the three subwatersheds within the upper basin has responded in various ways to meet their respective groundwater-management challenges. Some efforts have made much more progress than others in terms of the implementation of technical studies and/or water management projects or policies. The ability to initiate studies or implement projects is largely dependent upon the resources available, which, in many cases, reflects the leverage provided from legal mandates and political context. Efforts in the Sierra Vista subwatershed have secured the most resources to date, where federal mandates associated with both Fort Huachuca and the San Pedro Riparian National Conservation Area (SPRNCA) strongly affect policy and decision making. However, even without this leverage, the motivation and initiative demonstrated by local residents in a given area can play a pivotal role in launching watershed initiatives, as has occurred in the Benson subwatershed.

In Mexico, the responsibility for water management has been decentralizing since the 1990s. The onus has shifted from the Mexican National Water Commission (CNA) to local water users such as state and municipal offices and agricultural water-use associations in irrigation districts (Browning-Aiken et al. 2004). The National Water Law in Mexico (Ley de Aguas Nacionales 1997) calls for the development of localized watershed councils and irrigation districts to serve water users, establish water infrastructure, and preserve water resources in the borderlands. However, in reality, Mexican municipalities along the U.S.-Mexico border remain very dependent upon the federal government or upon a mixture of national and international sources for investment in water infrastructure projects (Romero-Lankao 2002). Local initiatives along the northern Mexican border are linked to national policy demands. In addition, the CNA, despite its policy of decentralized water management, has been slow to support the development of a Mexican water council in the San Pedro, a necessary step in establishing good governance in the Mexican portion of the basin. Also complicating matters is the fact that Mexican environmental policy frequently runs counter to Mexican economic policy, especially in terms of mineral resources and maquiladoras along the northern border (Browning-Aiken et al. 2006). Considerable challenges to good governance remain with water policy implementation in Mexico, which hamper policy makers' abilities to address issues of equitable access to clean water, sustainable development of water resources, and ecosystem protection in the context of climate variability.

On the U.S. side of the border, the Sierra Vista subwatershed has been subject to considerable pressure from sociopolitical drivers with regard to water management over the past decade in the form of federal and/or international mandates, such as the Commission for Environmental Cooperation in 1999 and the Defense Authorization Act in 2004. Two significant national assets in that area, the SPRNCA and Fort Huachuca, home of the U.S. Army Intelligence Center, have resulted in a myriad of strong drivers and in the establishment of a highly developed, collaborative water management effort in this subwatershed.

In contrast, the Benson subwatershed, located downstream, lacks this level of federal participation. However, accelerated rates of residential development and large-scale master-planned communities are proposed for the area, likely a result of its proximity to Tucson. A newly established watershed coalition, the Community Watershed Alliance of the Middle San Pedro Valley, led by landowners, residents, and other organizations and government entities, was formed in 2005 to "promote collaboration and cooperation to advance research, education, and policies for the sustainable health of their watershed." They are assisting the U.S. Geological Survey and other agencies and organizations by helping to coordinate research and monitoring studies with private landowners in the area, and initiating watershed improvement projects, among other endeavors.

To a limited degree, monitoring and research data have been shared between individual scientists and agencies conducting studies throughout the upper San Pedro basin, yet regional water management planning or coordinated project implementation among the three subwatersheds has not begun. In addition, it remains unclear what entity might provide this type of integration in the future.

Drivers of Change in the Upper San Pedro: Federal and International Mandates and State Programs

The upper San Pedro River was designated as the first Riparian National Conservation Area in the United States in 1988, when the San Pedro Riparian National Conservation Area (SPRNCA) was established by the U.S. Congress as part of Public Law 100-696. The SPRNCA's enabling legislation established the existence of federally reserved water rights to maintain the riparian ecosystem (B. Childress, personal communication). Approximately a decade after the SPRNCA's designation by Congress, a team of experts was commissioned by the trinational (Canada, United States, Mexico) Secretariat of the Commission for Environmental Cooperation (CEC 1999a) to produce an interdisciplinary study of the upper San Pedro basin, intended to "serve as an example of how to protect a transboundary watershed" (Udall Center 1998, Varady et al. 2000). This study elevated the San Pedro basin issues to national attention (Christiansen 1999, Kingsolver 2000).

Following the CEC report, during the 1999 binational Divided Waters, Common Ground conference on the upper San Pedro River basin (Brady et al. 2000), then–Secretary of the Interior Bruce Babbitt provided further incentive for local decision makers to work together for effective watershed management. The secretary noted that if effective local management could not be brought to bear on the San Pedro's water issues, then external forces, such as the federal courts, would impose restrictions or management plans. Collectively, these federal drivers began to highlight the growing need for more collaborative approaches toward water management.

In 1999, Governor Jane Hull established the Rural Watershed Initiative to address rural watershed-management issues throughout Arizona. Administered by the Arizona Department of Water Resources, this program was intended to stimulate rural watersheds to develop their own water management plans with input from local citizens and stakeholders. Funding for water resource studies was provided to those rural areas that created watershed groups. The Partnership was one of seven initial watershed groups that formed in response to this initiative. To formalize and document the Partnership's commitment to work together, a total of 21 private, public, and non-governmental organizations eventually signed a Memorandum of Understanding (MOU) that defined the purpose of the group: "to coordinate and cooperate in the identification, prioritization, and implementation of comprehensive policies and projects to assist in meeting water needs in the Sierra Vista Subwatershed of the Upper San Pedro River Basin" (http://www.usppartnership.com). Nothing within the MOU limits the respective legal authorities or decision-making ability of any of the participants or requires expenditures of funds; membership in the group is strictly voluntary. This group serves as a "boundary organization," as described by Guston (2001), in that it blurs the boundaries between science and politics, directly linking scientists with decision makers and, in the process, not only serves the mutual interests of both but also leads to more productive decision making.

In 2002, the U.S. Fish and Wildlife Service issued Fort Huachuca a Biological Opinion on its compliance with Section 7 of the Endangered Species Act. The Biological Opinion addressed several endangered or threatened species potentially affected by Fort Huachuca's activities, including the southwestern willow flycatcher (*Empidonax traillii extimus*) and the Huachuca water umbel (*Lilaeopsis schaffneriana* var. *recurva*), both riparian species. Within this document the Sierra Vista subwatershed groundwater deficit was quantified as 5,144 acre-feet per year. Fort Huachuca committed to implement conservation measures resulting in water savings of 3,077 acre-feet per year toward this deficit. In addition, the Fort requested that the communities and agencies within the Partnership commit to reduce by 3,306 acre-feet per year

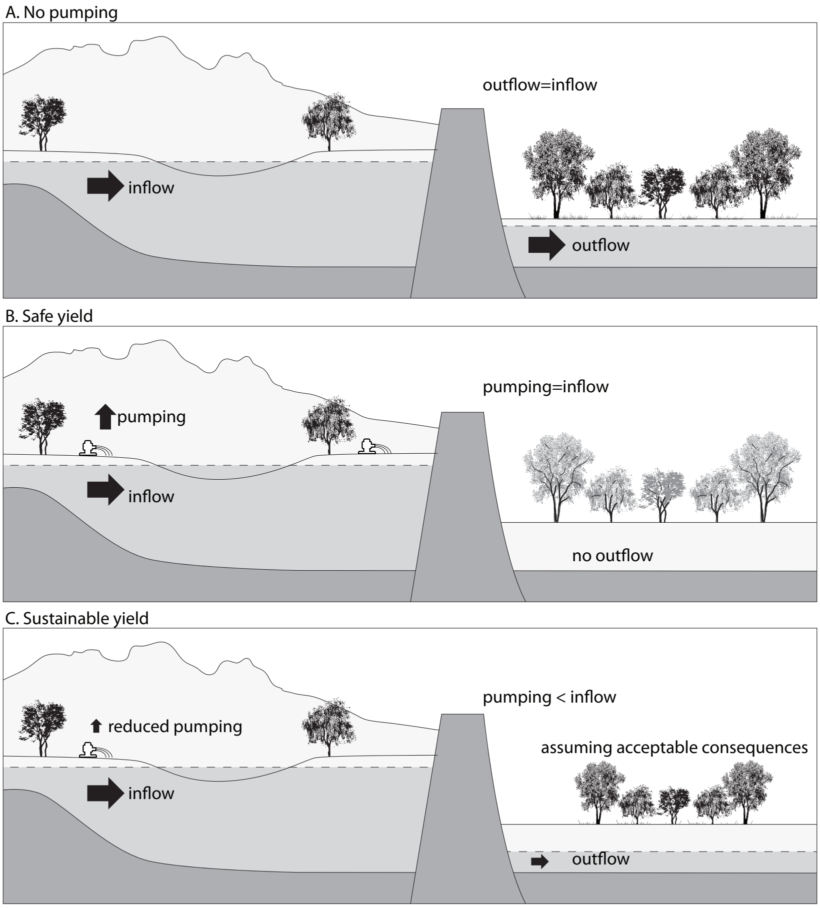

Fig. 21.1. Reservoir analogy to the response of a groundwater system to pumping comparing no pumping with safe yield and sustainable yield (USDI 2005).

the estimated groundwater pumping demands projected by 2011. Clearly, at this point, the role of the Partnership as a coordinating water management body had been recognized, even though the group had no formal regulatory authority.

One of the most recent legislative drivers within the Sierra Vista subwatershed is Section 321 of the National Defense Authorization Act of 2004, Public Law 108-136 (see chap. 22). The incentive, or "carrot," of this bill in terms of local interests is the potential for federal funding for conservation projects, scientific research, and monitoring needs. The cost, or "stick," is the requirement to report "measurable annual goals for the reduction of the overdrafts of the groundwater of the regional aquifer, identified specific water use management and conservation measures to facilitate the achievement of such goals, and identified impediments in current federal, state, and local laws that hinder efforts on the part of the Partnership to mitigate water usage in order to restore and maintain the sustainable yield of the regional aquifer by and after September 30, 2011" (Upper San Pedro Partnership 2004—Appendix 3). The legislation shifted the focus of

TABLE 22.2. Initial criteria established by the Upper San Pedro Partnership for sustainable yield of groundwater.

Social and economic	Environmental
· Sufficient water quantity for human needs · Fort Huachuca remains operational unless for reasons unrelated to water · Cost of living, specifically affordable housing and the cost of doing business, remains within the means of a diverse population · Maintain local participation in water management · Sustain water quality	· Groundwater levels in alluvial aquifer within the SPRNCA maintained · Stream baseflow and flood flows maintained · Accrete aquifer storage · Riparian habitat and ecologic diversity maintained · Water quality sustained in SPRNCA · Overall riparian condition maintained · Springs in the SPRNCA continue to flow

groundwater-management efforts from balancing a water budget, or safe yield, toward the concept of sustainable yield, a more comprehensive concept involving broader social, economic, and environmental factors. Under safe yield, wherein total groundwater withdrawals are equal to total recharge, no groundwater is allocated toward riparian or instream uses (fig. 26.1). The Partnership subsequently began to define criteria for meeting sustainable yield (table 2) through a consensus process (USDI 2005).

Constantly Rising Stakes: Increasing Demand and Prolonged Drought Conditions

Population growth and prolonged drought have also been key incentives for action. Increasing human demands on groundwater resources are widespread, as populations continue to grow on both sides of the international border. Much of the population growth within Cochise County on the U.S. side has occurred in unincorporated areas. The county as a whole experienced a growth rate of 10.6 percent from 2000 to mid-year 2004.

The recent multi-year drought, which began in many areas in 1999, pales in comparison to earlier periods of aridity in the western United States over the past 1,200 years (E. Cook et al. 2004), but nonetheless it is an important factor affecting water demand and supply in the region. Risks associated with drought are a product of both the severity of the event and the vulnerability of society (and the environment) to the event. At a minimum, recent climatic trends have increased the awareness by local decision makers regarding the amount of variability in precipitation patterns, and the uncertainty and vulnerability associated with managing for "average annual" rates of precipitation and groundwater recharge. Water and climate surveys assessed the quality and usability of climate and hydrologic information available to water managers and communities in the Mexican portion of the San Pedro River basin. The surveys indicated that the central concern for urban residents is the lack of reliable potable water due to frequent service breakdown—with climate change and variability, specifically drought and high temperatures, as contributing factors (Browning-Aiken et al. 2007).

Scientific Studies in the Sierra Vista Subwatershed

To meet the water management challenges presented by the federal mandates (i.e., federally reserved water rights, Biological Opinion for Fort Huachuca, Section 321 legislation), Partnership member agencies needed to establish sound research and monitoring programs that could be used to inform science-based decisions. The upper San Pedro basin has long served as an outdoor laboratory for scientific investigations aimed at increasing understanding of physical watershed processes. The U.S. Department of Agriculture's (USDA) Walnut Gulch Experimental Watershed has been researching hydrologic processes and soil erosion for more than 40 years, and other research efforts date back to the nineteenth century.

Since 1988, research investigations in the upper San Pedro basin have progressed so as to allow scientific information to be a much more integral part of water management decisions. Interagency and interdisciplinary efforts, such as the Semi-arid Land-Surface-Atmosphere (SALSA) Program and the University of Arizona's Center for the Sustainability of Semi-arid Hydrology and Riparian Areas (SAHRA), a National Science Foundation Science and Technology Center, have allowed investigators to address larger spatial scales and more complex ecosystem processes. SALSA identified the consequences of natural and human-induced change on basin-wide water balance and on ecological complexity of semi-arid basins at event, seasonal, interannual, and decadal timescales. SAHRA identified stakeholder-relevant questions on which to focus its scientific research, all of which bear on management of water resources in semi-arid regions.

The Partnership has funded or facilitated technical studies that have served three primary purposes: (1) to identify and acquire key data sets that can increase understanding of hydrologic systems and/or processes that have water management implications, (2) to develop predictive modeling tools and forecast specific outcomes in response to land/water management actions, and (3) to investigate and develop new water conservation, recharge, or augmentation strategies. One of the leading studies facilitated by the Partnership was the "Hydrologic requirements of and consumptive groundwater use by riparian vegetation along the San Pedro River, Arizona" (see chap. 20). This interagency research effort by the U.S. Geological Survey, the USDA–Agricultural Research Service, and Arizona State University served both to estimate evapotranspiration losses from the riparian corridor and define the hydrologic context needed to sustain that ecosystem over the long term. Other studies have been undertaken to better understand stormwater and groundwater recharge processes, develop a regional groundwater model, and develop a decision support system. Additionally, costs and benefits for dozens of potential water conservation and reclamation projects were analyzed, and several augmentation alternatives were assessed.

Collaborative Learning Processes: Bringing Scientists and Policy Makers to the Table

In addition to generating information, these technical investigations also served as a venue for initiating collaborative learning processes within and between groups of scientists and decision makers. This motivated them to jointly frame their information needs and initiate group processes toward building consensus on key issues. However, decision makers had to be patient enough to endure long technical discussions, and scientists had to engage in understanding fully the social, economic, and political sideboards and constraints. Discussion of the uncertainties involved and the potential risks associated with those uncertainties early on, even before actual results were produced, helped to manage expectations as to what science could actually deliver. In the long run, the process will hold participants more accountable to one another, increase confidence in results regardless of outcome, and help all participants attain a deeper understanding of complex information on which to base decisions.

Decision makers and scientists typically operate under different time frames and constraints, and often with misconceptions about one another. The world of decision makers revolves around societal values, beliefs, and perceptions; political considerations; definite deadlines; and limited budgets. The culture of scientists involves establishing facts, taking measurements, and making incremental progress over time (V. Baker 1998, Moran and Heilman 2000). Although scientists are often influenced, even unwittingly, by their own values and beliefs, their ability to work effectively with decision makers is greatly improved if they remain objective and unbiased by these factors as they design, implement, and ultimately communicate the results of scientific investigations. To work together effectively, scientists and decision makers must accommodate each other's needs.

Evaluating Success

In 2003, Partnership members and frequent attendees to Partnership meetings were surveyed to evaluate the midcourse effectiveness of the collaborative process (Browning-Aiken et al. in review). The survey's intent was to identify strengths and weaknesses in the group's collaborative process, and to pinpoint strategies in organizational structure and problem-solving processes from which other Arizona watershed organizations could benefit. Participants were asked about (1) the nature of basin water issues, (2) management goals and priorities, (3) organizational structure, (4) stakeholder identification and positions, (5) the method of selecting and interpreting scientific and technical information, (6) the nature of stakeholder collaboration within the watershed, (7) the processes of planning and decision making, (8) the method of leader or facilitator selection, including the qualities of effective leadership, and (9) the method of establishing authority within the regional community.

One clear finding was that success in accomplishing the group's mission was correlated with the extent to which scientific "research findings [have] been interpreted or used by the Partnership to make management decisions." Ninety percent of the Partnership members and participants considered scientific studies as one of the most important projects undertaken by the watershed initiative. This finding pointed to the key role of research and monitoring—from the viewpoint of participants in watershed group meetings—in achieving the group's mission of sustainably managing water. Another finding was that almost half (47 percent) rated both the group's accomplishment of its mission and its capacity to identify water problems as relatively high, while the Partnership's success in addressing basin water problems was rated either as very high (37 percent) or average (37 percent).

Adoption of an Adaptive Management Framework

Collaborative water-conservation planning efforts by the Partnership have continued to evolve since the establishment of the group in 1998. During their first two years, Partnership members focused on defining common ground: shared groundwater-management goals and objectives, and associated information needs. The original intent of these planning efforts was to develop one comprehensive, long-term conservation plan for the Sierra Vista subwatershed by 2005. By 2002, their initial goal of developing one definitive plan evolved into a more complex, yet flexible, ongoing adaptive management planning process. They began to recognize that certain key management concepts that became apparent during ongoing investigations could be applied to decision making before the studies were finalized, and they wanted to be able to assess the benefits of projects that were already underway so that they could adjust their objectives and strategies as appropriate. Finally, they continued to discover additional gaps in their knowledge as their understanding of key issues increased. Thus, they established an iterative planning process and produced their first annual plan in 2003.

To construct the plan, the Partnership inventoried and categorized all member agency water management projects, policies, and programs currently underway. From this baseline inventory, the Partnership prioritized additional collaborative efforts for the coming year and published this information in their "Working Water Conservation Plan" completed in 2003. This plan was subsequently updated and revised based on new information and developments, and an annual adaptive management cycle became established. The shift to an adaptive management approach, while representing perhaps the best chance for incorporating good science into decision making over the long term, also represented a huge increase in the commitment of the stakeholders. No single document now marks the end of their planning efforts, defines total funding needs for science, or even assures absolute certainty or success as a result of these efforts. The definition of success itself became even more of a moving target as a more comprehensive understanding of this complex hydro-ecological system was developed. The overall goal of the Partnership's adaptive management planning process is "to ensure an adequate long-term water supply is available to meet the reasonable needs of both the area's residents and property owners (current and future), and the San Pedro Riparian National Conservation Area" (http://www.usppartnership.com). This goal is interpreted in terms of the aforementioned legislative and regulatory drivers affecting the area.

STRENGTHS AND CHALLENGES OF THE ADAPTIVE, COLLABORATIVE MANAGEMENT FRAMEWORK

This adaptive management framework, like all others, involves active and focused learning on the part of both scientists and decision makers and an acknowledgement that their current understanding of the issues is not perfect. The process also has the potential to openly communicate the Partnership's increasingly detailed understanding of complex systems to external audiences, including the general public (Holling 1978, Walters 1986, 1997).

One great challenge in collaborative groundwater management relates to timing issues associated with planning, research, and the implementation of projects and policies. Research and conservation planning typically do not commence until there is a perceived problem that merits attention. Unfortunately, the acquisition of data of sufficient quality and credibility to enable decision making requires a substantial investment of time and resources. Therefore, decision making will be limited, at least at the onset of planning efforts, by the amount of information that is readily available and considered acceptable to all interests concerned. Additional data collection will likely be required, particularly to support decisions that involve high financial, political, or environmental risks, and/or high levels of uncertainty. Thus, certain decisions could be delayed due to lack of information.

One strength of an adaptive management approach is that it allows actions that have low risk or uncertainty to be taken early on. Partnership member agencies realized that the implementation of certain water management strategies requires substantial information through monitoring, research, and modeling efforts as well as political assessments, while other projects represented relatively low-risk strategies whose implementation could be more immediate. In 2003, the Partnership identified more than 100 projects for immediate implementation, ranging from the repair of leaky infrastructure, car-wash water recycling, voluntary retirement of agricultural pumping through conservation easements, recharge of treated effluent, and reintroduction of beavers. In their 2004 Water Management and Conservation Plan, the Partnership prioritized additional projects for implementation, including the development of model codes and ordinances, the establishment of water-conservation surcharges for excessive use, exploration of a transfer-of-development-rights (TDR) program, and other measures. Other projects with greater uncertainty, higher political risks, and/or significant costs were targeted for additional feasibility studies and/or evaluation through use of a decision-support system (see Case Study Example #2).

Common Ground through Informed Decisions: Case Study Examples

EXAMPLE #1

One major point of controversy along the upper San Pedro River in the past revolved around the need for all water users in the basin who are part of the water problem to also be part of the solution. To reach equity among water users, many stakeholders believed that the riparian forest, which transpires considerable amounts of groundwater, needed to reduce its total consumptive water use. However, the concept of cutting down cottonwoods to keep the river flowing was not considered an acceptable management alternative by the U.S. Bureau of Land Management (BLM). Environmental and conservation interests also strongly opposed this concept, since one of the primary drivers for groundwater management in the basin revolves around providing adequate water to sustain the SPRNCA's riparian forest.

The interagency study on groundwater use described previously (Leenhouts et al. 2006) resulted in information that created new management options and choices. Isotopic analysis of the water transpired by mesquite, including those plants that had established on floodplain grassland habitats, revealed that these shrubs were utilizing significant volumes of groundwater, in addition to opportunistically using precipitation. Removal of these recently established scrublands, in locations that historically had been sacaton grasslands, would significantly reduce per area water consumption rates, while also improving habitat conditions for some species and decreasing habitat for others (see chaps. 7 and 8). Vegetation mapping efforts revealed that the mesquite stands within the SPRNCA were far more

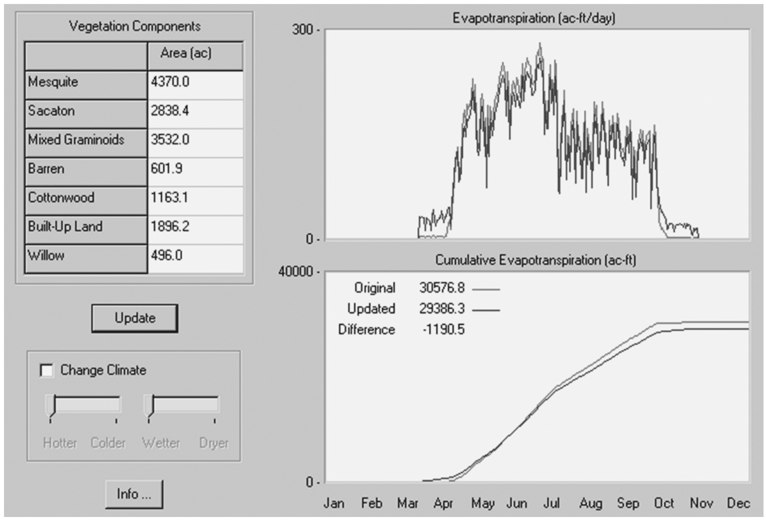

Fig. 21.2. "Screen capture" of a software program showing the change in SPRNCA evapotranspiration as a function of change in various vegetation types defined by the user to simulate potential land management actions (e.g., prescribed burn of mesquite and revegetation with desert grasses).

abundant than cottonwood forests, and that the total consumptive use of groundwater by mesquite was approximately triple that of cottonwood and willow forests (mesquite used between 6448–8135 acre-feet of groundwater per year, while cottonwood/willow forests used a total of approximately 2569 acre-feet per year) (see chap. 3). Moreover, BLM had already developed the capacity to implement a prescribed-fire program.

Another closely associated product of this same study is the Riparian Vegetation Evapotranspiration (ET) Tool (R. Scott, Watts et al. 2003). Although the ET Tool was developed based on extensive field work, large empirical data sets, and complex calculations and analyses, the result is a user-friendly GIS-based interface which can be employed by resource managers with basic training and support. This tool encapsulates many complex biophysical processes in a form that allows decision makers to easily evaluate what is important *to them*—various potential management scenarios and their resulting impacts on habitat conditions and riparian water use (fig. 21.2).

This new knowledge and tool enabled BLM management to prioritize burn plans with the incentive to maximize water savings, while still meeting the agency's ecological goals for the SPRNCA. It also enabled the BLM to contribute their part toward "equitable" groundwater management in the region. The effective use of such tools over the long term requires an ongoing commitment from scientists and programmers for training, support, and future modification as conditions and management issues change.

EXAMPLE #2

A decision support system (DSS), developed by SAHRA and linked to a regional groundwater model, is being used by the Partnership to evaluate different combinations of management options (scenarios), such as the possible relocation of municipal wells, construction of additional recharge facilities, and various water-augmentation strategies. Such a tool allows for the consideration of spatial and temporal groundwater-management concerns, as opposed to a simple annual "bottom line" water-budget approach. The former approach is essential for maintenance of the hydrologic context needed to sustain all 43 miles of the SPRNCA. Questions that can be asked of the DSS include: How will a proposed project, or group of projects collectively, influence groundwater levels at a specific point along the river? Or, where could municipal wells for a particular community be located to minimize the impact on the river?

Most importantly, development of the conceptual model upon which the DSS is based provided those Partnership members engaged in its development with a useful road map for understanding the complex and dynamic interaction of water management variables and functions (H. Richter 2006). A total of 74 individual water management options were initially identified for consideration within the DSS, and each was described in terms of estimated annual yield in acre-feet, cost per acre-foot, and other factors. As of 2006, the San Pedro DSS is now available online for decision-making purposes by Partnership members, but outreach applications have yet to be developed (Serrat-Capdevila and Browning-Aiken in review).

Meeting the Information Needs of Decision Makers

Very few elected officials and policy makers read scientific journals after spending a long day at city hall. Can we blame them? How often do scientists attend city council meetings in the evenings to improve their local political savvy? Given these realities, how then could we best ensure that local decision makers would have access to the best technical information currently available and that scientists would be aware of the complex political and social factors that might influence many aspects of their studies?

Most scientists typically design their studies in response to themes suggested by their sources of research funding. Once tools and knowledge are developed, results are published in peer-reviewed professional journals. The pace at which this information diffuses into the decision-making arena can be painfully slow, or non-existent. Efforts at technology transfer, in which research products or findings are transferred from their originators to users (E. Rogers 1995, Lai and Guynes 1997), represent a more proactive approach for scientists to get their knowledge and tools to decision makers. In this process, scientists identify a potential information user, or vice versa; thus, a scientist–decision maker relationship is established. In this type of knowledge transfer, the scientist develops his or her research protocol after direct communication with potential users or decision makers. In essence, the research and resulting information or products are conceived and designed by both the scientist and the decision maker.

Within the Upper San Pedro Partnership, scientists and decision makers have embraced this type of knowledge transfer. This represents a step beyond the traditional type of knowledge transfer resulting from strictly scientist-conceived research. This approach does not imply that scientists should eschew peer-reviewed journal publications. The journal publication process helps maintain currency of knowledge and is pivotal to the reward system of many research organizations and universities. The complexity of applied research issues typically allows ample opportunity for publishable research. However, those scientists who address applied management issues need to work more efficiently by continuing to publish while also making a commitment to work closely with policy and decision makers.

ESSENTIAL BUILDING BLOCKS OF THE SCIENTIST/DECISION MAKER INTERFACE

Making a long-term commitment to a partnership can be difficult for scientists if their research is largely supported by grants awarded on a typical three-year-or-less funding cycle. Many investigators have conducted research in the San Pedro basin under these circumstances. However, they are not the same scientists that decision and policy makers look toward as a reliable source of information over the long term. Decision makers recognize that these researchers will be providing only temporary assistance with their information needs, and therefore they do not invest the time to build strong working relationships. Several funding agencies have recognized this weakness and are now beginning to fund centers with substantially longer time horizons, such as SAHRA and the Climate Assessment for the Southwest project (CLIMAS; established with seed money from the National Oceanic and Atmospheric Administration).

A commitment by relatively senior scientists is necessary to effectively integrate science with policy. Elected officials and decision makers, who manage large staffs and significant budgets, expect to deal with scientific counterparts who can also make substantial programmatic commitments to their shared endeavors. While it is important that graduate students, postdoctoral researchers, and new researchers contribute to investigations, they are often not in a position to initiate or revise investigations in a relatively rapid manner. Several federal research agencies, and their senior scientists, have had a long history of conducting investigations in the upper San Pedro basin, and this has helped to develop mutual trust and respect between the agencies and local entities.

Senior technical-staff members are often expected to serve as facilitators in collaborative planning processes, in addition to their job responsibilities as scientists. While many technical specialists such as engineers or scientists can provide valuable experience and authority in this role (Wakeman 1997), the need for professional facilitation cannot be underestimated in complex collaborative decision-making processes if participants lack the time, neutrality, training, and/or experience to effectively facilitate a consensus-based process (Leach and Pelkey 2001, Browning-Aiken et al. 2004).

Effective communication is essential to building trust and to building successful watershed partnerships (Leach and Pelkey 2001). Successful communication requires openness, understanding, and listening. Openness and understanding imply patience to allow for the unimpeded sharing of everyone's ideas, information, and data. Scientists and decision makers both have an innate tendency to come to the table with their version of the answer already in mind. However, frequently the best answers in collaborative problem solving are generated from combining the input from multiple participants, or from an entirely new concept that emerges through well-facilitated group discussions (Imperial and Hennessey 2000, National Policy Consensus Center 2002, Pahl-Wostl 2002, Imperial and Kauneckis 2003).

Learning the nuances of the different vernacular spoken by scientists, decision makers, and laypersons takes commitment and patience, and may be no less difficult than committing to learning a foreign language. Scientists must make a conscious commitment not to communicate as if they were attending a scientific meeting. There is no quicker way to lose the attention of policy and decision makers than to speak in technical jargon and acronyms. This requires adopting a common language among partners that is comfortable for all. All partners also can benefit from developing an eye for glazed-over expressions and body language that suggest frustration or confusion.

Listening implies true two-way communication between scientists and partnership members. Sufficient discussion must take place during the design of research programs to ensure that researchers are properly focused on the real-life needs of the decision makers. On the other hand, the policy and decision makers must understand the limits and uncertainties associated with the scientific methods and research results. Because research is typically an iterative process, the principles of adaptive management and ongoing two-way communication between scientists and decision makers are essential.

Location is also an important factor in maintaining productive working relationships between partners. In most cases, it is essential to meet on the home turf of local managers and decision makers, within the basin or watershed of interest. These locations are typically not adjacent to research institutions, universities, or federal agency offices. Therefore, scientists must make an additional commitment to travel frequently and participate in partnership meetings in person, on-site.

Scientists should deliver results to decision makers that contain only the essential information needed to move forward. Many scientists want to study numerous facets of a problem in intricate detail and share all of that detail with others since it is fascinating to them. This tendency must be tempered by the time and resource constraints under which decision makers operate (V. Baker 1998). Data should be interpreted in straightforward terms that are relevant to the decisions at hand. If trust and transparency are developed early in investigative efforts, decision makers will be more confident that a strong foundation of data analyses underpins the bottom line results, allowing the conclusions to withstand close scrutiny by other interests.

The Importance of Community Engagement

Certain water management conservation strategies are more complex, costly, or politically difficult to implement than others. While some strategies, such as water conservation efforts in the home and the recharge of treated effluent, may be widely acceptable to most people, other strategies, such as the transfer of development rights, may require a much deeper level of understanding to attain support from residents. The process of engaging the general public in decision making can be just as important, if not more important, than the engagement of community leaders and decision makers. Elected officials in particular need to know that their constituency will support their decisions.

Recent efforts in California provide an example of the importance of community engagement to the successful implementation of water management efforts. In 1999, a $55-million water reclamation project that Los Angeles officials claimed would drought proof the city was derailed by public outrage over the prospect of drinking recycled toilet water. In contrast, Orange County took a similar plan to the community. The county held neighbor pizza parties, water treatment plant tours, and scores of public meetings where they explained how water treatment processes would work. As a result, Orange County broke ground on a $487 million "toilet to tap" project that opened in 2007 and serves 140,000 families. The difference between these two efforts primarily revolves around differences in community engagement. Support solely by the scientific and political leadership is simply not enough.

In the case of the San Pedro, complex and controversial strategies such as water importation, the transfer of development rights, and surcharges for excessive water use all have the capacity to divide the community, as did "toilet to tap." These particular issues must be carefully managed by direct engagement of the community early on in planning processes. Toward that end, the Partnership conducted a series of community connector meetings during 2004 to begin this type of strategy-specific dialog and to provide citizens with an opportunity to thoughtfully consider issues, help shape their own destiny, and provide meaningful input. A professional firm was hired to assist the Partnership with the process of facilitating public involvement and to ensure effective and equitable participation throughout the Sierra Vista subwatershed. The Partnership held workshops in public meeting rooms, as well as in the living rooms of interested volunteers within Sierra Vista and nearby communities. Residents clearly expressed a need for fairness between conflicting interests, and a need for clear and consistent information, as opposed to conflicting messages. There was a wide divergence between rural and urban perspectives, and between the need for mandatory versus voluntary measures. A distrust of public institutions about doing what they say they will do, especially in terms of the use of funds, was also evident.

Summary and Lessons Learned

The combination of a complex regulatory framework, coupled with a myriad of interacting environmental, social, and political factors, presents tremendous challenges related to groundwater management within the Sierra Vista subwatershed for local decision makers, elected officials, and the general public. The need to apply strong science and the best analytical tools is apparent. But, in addition, the role that collaborative learning processes play in effectively transforming this science into informed decisions will continue to be one of the most essential factors that determines the future of this river, and the fate of the waters that sustain it.

To transfer some of the lessons learned, we conclude with this checklist of questions that can serve as a guidepost for other watershed planning groups. To determine if science and policy are effectively being integrated into water-management planning efforts for any watershed, participants must pose the following questions:

- Is the geographic scale of collaborative planning/learning efforts appropriate? Does the planning area represent a relatively homogeneous area within the watershed, without too many vast differences in political, social, or economic sideboards, or regulatory constraints, to overly confound efforts?
- If multiple water-management and planning efforts are underway within different parts of the same watershed, are they well coordinated with one another?
- If a watershed crosses international boundaries, what opportunities are available for binational dialogue that bridges language barriers, and institutional and policy differences, to address basic management concerns between decision makers, water managers, and scientists?
- Are professional facilitators integrated into planning and decision-

making processes to ensure balanced participation and consensus building?

- Are the federal, state, and local drivers for policy change, and their associated implications, clear to scientists, decision makers, and the public?
- Has an adaptive management framework been adopted by water managers that allows for the immediate implementation of low-risk strategies while additional information is being collected for higher-risk projects, or for those with more uncertainty in outcome?
- Are the research, management tools, and monitoring results developed by scientists actually being used to make decisions by policy makers on an ongoing basis?
- Do face-to-face communications between scientists and decision makers occur regularly?
- Do these communications include openness, understanding, and good listening skills between participants, at on-site locations?
- Do political leaders at the federal and state levels acknowledge and support the efforts of locally based, collaborative decision-making processes? Are they advocates for transferring pertinent aspects of these efforts to other watersheds facing similar challenges?
- Are policy and decision makers eager to continue seeking out funding and resources for scientific support and monitoring efforts as needs continue to change over time?
- Are senior-level scientists easily accessible to local decision makers?
- Is the general public, in addition to elected officials and scientists, actively engaged in planning efforts for future conservation projects and policies, especially issues with a high potential for controversy?

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