

## Upper San Pedro Basin: Fostering Collaborative Binational Watershed Management

ANNE BROWNING-AIKEN\*, HOLLY RICHTER\*\*,  
DAVID GOODRICH†, BOB STRAIN\*\* & ROBERT VARADY\*

\*Udall Center for Studies in Public Policy, University of Arizona, Tucson, AZ, USA

\*\*Upper San Pedro Partnership, 1011 N, Coronado Drive, Sierra Vista, AZ, USA

†USDA Agricultural Research Service, Southwest Watershed Research Center, Tucson, AZ, USA

**ABSTRACT** Successful binational planning and management of water resources is a complex process dependent on informed decision-making across diverse economic, social and political sectors. Additional technical and scientific information is often required as a part of this process. A critical factor in this process is how effectively social and physical scientists can help build collaboration and trust among stakeholders, water and land managers, and policy-makers. Within the international San Pedro River Basin, disparities between Mexico and the USA regarding economic development and political orientation, combined with a highly variable and complex physical setting, suggest that the successful engagement of scientists with communities and stakeholders will be essential for addressing challenges in water management. Based upon concepts associated with collective action theory, adaptive management and conflict resolution, the present paper proposes a process for fostering collaborative binational water management in basins such as the San Pedro that span international borders.

For the most part, success or failure does not arise from issues confronted in watershed planning, or in the pattern of interests per se, but rather in the processes of decision-making and in the way issues and concerns have been framed in particular settings or situations.

(McGinnis *et al.*, 1999, p. 9)

### Introduction

Increasingly, decision-makers and natural resource managers require much more sophisticated levels of information (e.g. physical, ecological, economic, etc.) to make complex decisions. At the same time, there has also been a global trend toward more participatory management of natural resources that reflects both ethical-democratic and pragmatic motivations for the involvement of public and stakeholders in both policy design and implementation (Webler & Renn, 1995). In addition, within binational watersheds, additional expert knowledge of respective cultures and legal and governing institutions is required.

*Correspondence Address:* Anne Browning-Aiken, Udall Center for Studies in Public Policy, 803 East First Street, Tucson, AZ 85719, USA. Email: [browning@email.arizona.edu](mailto:browning@email.arizona.edu)

While consultants may help to provide support for this process, few firms or individuals can provide comprehensive interdisciplinary assistance to decision-makers over the long term. Therefore, a great need exists for participation by social and physical scientists from other sectors including federal and state agencies, academic institutions, and non-governmental organizations, particularly for scientists who can commit to a long-term process occurring over several years or to decades and beyond. The potential for successful binational planning and management of water resources depends strongly on how effectively scientists, stakeholders, water managers and planners, and policy-makers can develop and build trust. The US–Mexico Upper San Pedro basin experiences indicate that the potential for successful planning and management efforts greatly increases when scientists work closely side by side with water managers, policy-makers and other water stakeholders in a watershed partnership context.

In this venue, the research scientist can move beyond the more typical model of simple technology transfer (adapting prior research) toward designing specific research and monitoring projects in concert with decision-makers to ensure that their unique information needs are met.

Within such a long-term partnership, mutual education of scientists by decision-makers and vice versa can take place incrementally as new information becomes available or as new circumstances arise. In a watershed context, scientists can respond to water managers' and stakeholders' needs for the research necessary to understand better the impacts of climate variability, land-use changes and hydrologic processes. In turn, decision-makers better understand the sources of uncertainty related to decisions, what variables are most difficult to estimate (e.g. groundwater recharge rates) and, alternatively, which management strategies are likely to be 'no regrets' projects or policies where immediate action can occur with minimal risk.

In addition, with disparities between Mexico and the USA in economic development, infrastructure capacity and political orientation, the greater engagement of social scientists and/or facilitators at the regional level with communities and stakeholders in priority-setting for water resources issues, the greater the chances for success in addressing water conflicts. Access to data and effective decision-making tools have been regularly named as critical to building institutional capacity of watershed planning, but management decisions must also reflect the attitudes, meanings and values attached to water and land use (Wolf, 2002). As research collaborators with stakeholders and policy-makers, scientists have the responsibility to provide the best available scientific information to answer questions about the hydrologic, social, economic and policy conditions within the basin.

It is argued here that the potential for success in this process of binational resource planning and management increases with an informal, regional, 'bottom-up' approach rather than with the more formal, 'top-down' diplomatic or regulatory approach based on treaties. The importance of a bottom-up, people-centred approach that emphasizes social processes, builds relationships, and strives for consensus through shared value formation and the co-evolution of perceptions and preferences is being recognized across the globe for integrated water resource management. The international San Pedro basin provides an excellent case study on the processes that foster this approach. The San Pedro has already become a demonstration basin for North American Hydrology for the Environment, Life and Policy (HELP) (<http://www.unesco.org/water/ihp/>

help) and Dialogue on Water and Climate projects with the idea that water managers, policy-makers, and social and physical science researchers, especially those confronted with transboundary water management, can learn from each others' experiences.

This paper will explore key principles along with a generalized process for collaborative watershed management based on the principles of collective action theory, dispute resolution and adaptive management. There are seven steps that can be identified within this process, and while the process should be iterative in nature, the seven steps can be summarized as follows:

- assessing the physical, economic and institutional landscape;
- identifying the critical issues and key stakeholders;
- appraising the policy terrain and institutional constraints;
- developing desired outcomes and associated strategies (Phase I);
- implementing integrated water basin management projects and policies (Phase II);
- monitoring and evaluation; and
- adaptive management: implementation of additional strategies, projects or policies based on increased knowledge of landscape, policy, issues, stakeholders and strategies.

### **Collaborative Watershed Management: Theoretical Challenges**

Disputes about collective management of natural resources continue even after the earlier debate about the 'tragedy of the commons' (Hardin, 1968). Privatization of water resource management is advocated by current neoliberal politicians in Latin America as the solution to inefficient and costly centralized government control of resources and the infrastructure associated with them. However, neither the state nor the market "has been uniformly successful in enabling individuals to sustain long-term, productive use of natural resource systems" (Ostrum, 1990, p. 1). Moreover, there exists a large number of water resource management systems, run neither by the state nor private industry, that groups of individuals have successfully developed under a wide variety of ecological environments to manage water in an equitable and efficient manner (Berkes, 1986; Sheridan, 1988; Lansing, 1991; Chamala & Keith, 1995; Reij *et al.*, 1996). Using Ostrum's concept of institutional developments for natural resources as games, the process of institutional development becomes extremely important: the particular options available, the sequencing of those options, the information provided, and the relative rewards and punishments assigned to different sequences of moves can all change the pattern of outcomes achieved. Further, the particular structure of the physical environment involved will also have a major impact on the structure of the game and its results (Ostrum, 1990, p. 23).

The process of collaborative planning and management merits careful attention, and one form of coordinated management does not appropriately fit all situations. Theories of self-organized collective action typically focus on game theories, yet these tend to be abstract and leave out a large range of possible human behaviours. Nonetheless, if one looks at institution building as a process of self-organization and self-governance centred on natural resource use, one can begin to see a pattern in the development of common integrated watershed management. Ostrum's (1990, p. 51) definition of institutions is followed:

sets of working rules that are used to determine who is eligible to make decisions in some arena, what actions are allowed or constrained, what aggregation rules will be used, what procedures must be followed, what information must or must not be provided, and what payoffs will be assigned to individuals dependent upon their actions.

Well-defined decision rules are necessary so that stakeholders view the process as being fair and transparent and so that each stakeholder's rights and responsibilities are clear under any agreement (Leach & Pelkey, 2001).

Gleick (2002, p. 3) further identifies an important evolution in this process of institution-building: the shift from the 'hard path' with its emphasis on supplying water in a technological or engineering sense to the 'soft path' with a greater emphasis on the

nonstructural elements of a comprehensive approach to sustainable water management, including equitable access to water, proper application and use of economics, incentives for efficient use, social objectives for water quality and delivery reliability, public participation in decision-making, and more.

However, for us what is missing in this case is the important role of social and physical scientists as researchers, facilitators and mediators. When the developmental stages for integrated watershed management are discussed, we are discussing scientists working cooperatively alongside water managers, policy-makers and other water stakeholders to 'assess, identify, appraise, develop, implement, monitor, compare, and adapt' to the challenges of binational basin management. Thus, attention is turned to scientists' collaboration with stakeholders, managers and decision-makers at each stage of development of an integrated watershed planning and management institution.

### **Process of Developing an Integrated Watershed Planning and Management Institution**

#### *Starting the Process with a Defining Event*

The threat of excessive groundwater pumping within the Upper San Pedro riparian system prompted the first application of international environmental law within the USA via the environmental side accord of the North American Free Trade Agreement (NAFTA) (CEC, 1999a). In its report, *Ribbon of Life* (1999b), CEC's technical-expert team recommended the creation of a Coordinated Resource Management Program to develop a basin water-management plan. The Udall Center for Studies in Public Policy at the University of Arizona, Tucson, approximately 50 miles outside the basin, facilitated the collaboration and coordination among these water interests and the general public in the Upper San Pedro Basin (USPB). This process heightened the awareness of the issue locally and led to subsequent efforts to address the issue from a more bottom-up, regionalized approach.

#### *Assessing Physical, Economic and Institutional Landscape*

As a result of the CEC panel's investigation, scientists in both Sonora and Arizona began conducting further research into the USPB's characteristics. The basin's boundaries lie within the semiarid border region of south-eastern Ari-

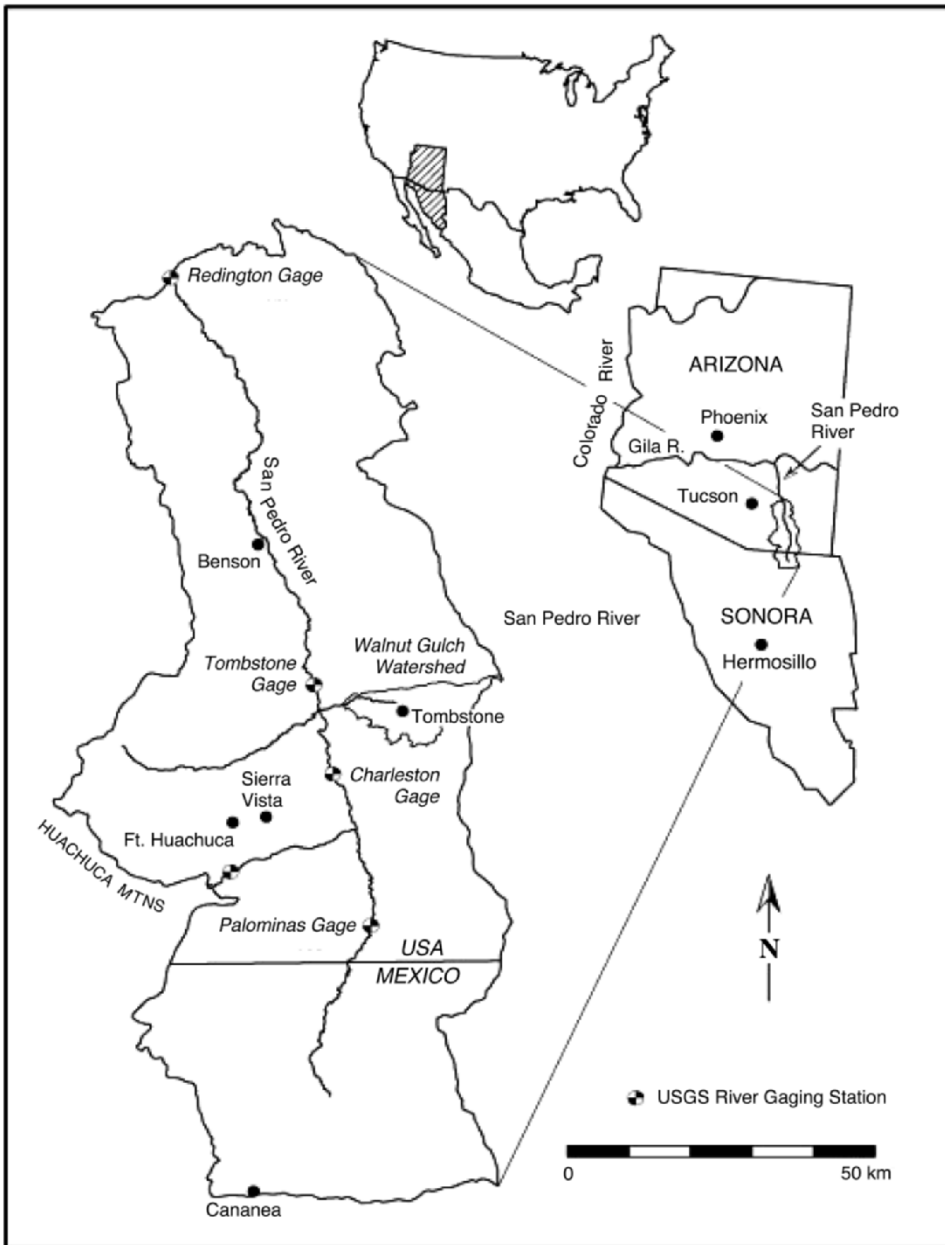


Figure 1. Upper San Pedro basin.

zona and north-eastern Sonora (Figure 1) in the 'basin and range' physiographic province. The USPB, a broad, high-desert valley bordered by mountain ranges, is bisected by a narrow riparian corridor sustained by groundwater discharge. It is an international basin whose headwaters originate in Mexico. Vastly different historical and contemporary land use practices have occurred on either side of the international border, including fire suppression policies, livestock-grazing management practices, and urban and rural development patterns.

Annual precipitation in the USPB ranges from around 300 mm in the lower and northern portions of the basin to over 750 mm in the Huachuca and Catalina Mountains. Approximately 65% of this typically occurs during the July–September monsoon season from high-intensity air-mass convective thunderstorms. Roughly 30% comes from less intense winter frontal systems. Potential evapotranspiration is estimated at more than eight times annual rainfall at lower elevations in the basin (Renard *et al.*, 1993). Interannual climate variability is also high with a demonstrated linkage to the El Niño–Southern Oscillation (Woolhiser *et al.*, 1993). Landcover in the basin changed dramatically between 1973 and 1986, with mesquite woodlands increasing from 2.75 to 14.05%, largely replacing desert grasslands (Arias, 2001; Kepner *et al.*, 2002). These changes are largely attributable to climatic fluctuations, livestock grazing and, more recently, rapid urbanization affecting fire regimes and other factors.

Approximately 114 000 people live and work in seven incorporated towns and several unincorporated communities in the two countries within the USPB. Principal economic drivers in the valley include the US Army's Fort Huachuca on the Arizona side of the border and the copper mines near Cananea on the Sonora side (CEC, 1999a). Population in the Mexican portion of the Upper San Pedro River basin is mainly concentrated in Cananea and Naco, Sonora. Most of Cananea's 36 000 residents (INEGI, 2004) depend economically on the copper-mining operation that has been there for over 100 years. This mine represents the largest single source of human water consumption in the watershed. However, groundwater availability is essential to sustain the ranching and agricultural industry. Approximately nine *ejidos*, or communal agricultural settlements, are dispersed across the Mexican portion of the region. Closer to the border, the municipality of Naco has approximately 5300 residents, which can swell to 7000 including transient workers waiting to cross into the USA. In the US part of the basin, population is concentrated near the city of Sierra Vista, with 40 000 residents drawn largely from the military base and retirees (Varady *et al.*, 2000). The San Pedro basin sits at the ecotone between the Sierra Madre Mountains to the south, the Rocky Mountains to the north, the Sonoran Desert to the west and the Chihuahuan Desert to the east. As the last perennial stream in the region, the San Pedro River serves as an international flyway for over 400 species of birds. One of the most ecologically diverse areas in the western hemisphere, the basin contains as many as 20 different biotic communities, supports a number of endangered plant and animal species, and "possesses one of the richest assemblages of land mammal species in the world" (CEC, 1999a).

### *Identifying the Critical Issues and Key Stakeholders*

Although the US Congress established the San Pedro Riparian National Conservation Area (SPRNCA) in the Arizona portion of the basin in 1988, its survival was not automatically assured. The US Bureau of Land Management has been administering the SPRNCA with the goal of protecting the 60-km riparian corridor north of the US–Mexico border. In the face of continued population growth, great concern remained about the long-term viability of the San Pedro riparian system. Groundwater is essential for sustaining baseflows within the river during dry seasons.

Most of the water demand in the basin has been for mining, municipal, domestic and agricultural use. Recent research suggests that riparian vegetation

also requires a large portion of the water budget. The basin is currently considered to be in a water deficit, with annual water withdrawals exceeding recharge by approximately 6–12 million m<sup>3</sup>. Water use is increasing and is expected to continue to do so. A predicted decline in northern Mexico's water availability not only threatens the viability of the San Pedro River, but also exacerbates the increasing competition for water resources between productive sectors such as agriculture and industry and domestic consumption (Magaña & Conde, 2001).

In addition to the potential for water scarcity associated with over extraction and climate variability, groundwater and surface water contamination also impact potable water supplies near the source of the San Pedro River, as the river flows from Cananea through *ejidal* land and into Arizona near Sierra Vista. Inadequate (Naco) or non-existent (Cananea) wastewater treatment plants contribute to uncontrolled discharge of residual waters into the river. Unlined landfills introduce a variety of known and unknown substances that infiltrate into the aquifer. Moreover, the mine produces industrial waste that infiltrates groundwater supplies via unlined and occasionally overflowing tailing dams (Jamail & Scott, 1979; Zavala, 1987; Moreno & Luis, 1991). Water-quality monitoring indicates evidence of sewage and mining discharges, including arsenic, near the headwaters of the San Pedro and in wells close to Cananea (Da Viana, 1998; Kamp, 1999). Stakeholders in the Arizona portion of Upper San Pedro created the Upper San Pedro Partnership (hereafter 'Partnership') formed under an interagency Memorandum of Understanding in 1998 to facilitate and implement sound water management and conservation strategies in the Sierra Vista subwatershed of the basin.

A survey on water issues in this region, *Views from the Upper San Pedro River Basin: Local Perceptions of Water Issues*, was published in Spanish and English in mid-2001 and was used within community forums on basin water issues. According to the survey, Mexican residents "are faced with major water-supply and water-quality problems, and their top priority for both water management and water policy is an assured supply of potable water". Both US and Mexican water scientists and managers noted a lack of basic water supply and water-use data on which to base management and policy decisions (Moote & Gutiérrez, 2001).

The Partnership effectively leveraged private, local, state and federal funding to implement projects in support of its goal. It developed the political support necessary for effective water policy formation and project implementation and supported member agencies in their efforts to conserve water resource. The Partnership also developed and implemented a public education and participation plan that encourages citizens and businesses to conserve and use water wisely. At the same time, it began turning attention to a sister city to the south, Cananea, to promote collaboration with their Mexican counterparts regarding water resources.

The Partnership's organizational structure, membership composition and method of operation demonstrate an effective approach in breaking the old 'paradigm lock' of scientists completing their research without stakeholder involvement associated with the 'hard path' to water-management institution building. Partnership scientists remain focused on research and monitoring issues critical to the information needs of decision-makers, to the extent that they and scientists jointly designed research projects from initiation. In turn, decision-

makers are now in a position to assist effectively with securing the financial and political resources required to support pivotal projects. The Partnership is currently operating under a US\$33.9 million 5-year financial plan. The potential for breaking the paradigm lock and planning successful binational management efforts increases with informal communication and cooperation among local borderlands agencies and non-governmental organizations (NGOs).

As a complement to the work of the Partnership, the Udall Center supported the growth of a new Sonoran grass-roots effort called the Sonora–Arizona Regional Environmental Association (ARASA) through a series of workshops with other Sonoran environmental NGOs. The group wanted to work with basin residents from both sides of the border on environmental issues, specifically water pollution, conservation of the river and the collection of basin research. To support further the potential collaboration between the Partnership and ARASA, the Udall Center sponsored ARASA and USPB participants at meetings of the Border Environment (Encuentro Fronterizo), which strengthened their capacity to improve environmental quality.

#### *Appraising the Policy Landscape and the Institutional Constraints*

Differences in water policy between the USA and Mexico challenge binational collaboration on resource management, especially since Mexico has been adopting a neoliberal perspective that advocates privatized management and trade markets as the path to economic solvency. This policy, along with the Mexican National Water Commission's (CNA) limited ability to enforce water and environmental policies, contradicts the conservationist impulse to some extent. Since the 1990s, the government, specifically the CNA, has been decentralizing the responsibility for water management to local users such as state and municipal offices and agricultural water-user associations in irrigation districts. The 1992 Mexican Ley de Aguas Nacionales (National Water Law) further called for the development of watershed councils and irrigation districts to serve the many users of hydraulic resources, to establish water infrastructure and to preserve water resources in the borderlands (La Ley de Aguas Nacionales, 1997). In reality, Mexican municipalities along the US–Mexico border remain very dependent upon the federal government or upon a mixture of national and international credits (World Bank, Inter-American Development Bank, or Banobras, the Mexican bank for infrastructure projects) for investment in water infrastructure (Romero Lankao, 2001). Private participation in the financing, construction and administration of water services has been encouraged in Mexico, but Mexican communities themselves do not have fiscal authority to impose new taxes or to issue bonds for financing repairs or new infrastructure (Peña, 2002). Revenues from water bills are not enough for the water sector to become self-sufficient, let alone to encourage efficient patterns of use, and SEMARNAT (Mexico's environmental ministry) receives very limited resources that must be allocated among too many programmes for it to manage environmental policy effectively (Romero Lankao, 2001, pp. 2–6). This problem was further confirmed by a recent survey of 560 urban domestic water users and water managers in the basin (Browning-Aiken *et al.*, 2004).

By contrast, US towns and states have played a much stronger role in managing water and planning growth in general. The Environmental Protection Agency has a statutory responsibility to regulate water quality in accordance



with established national standards. As such, it has partially served as a model for SEMARNAT. But unlike in Mexico, where authority remains highly centralized, the 10th Amendment to the US Constitution empowers states and local governments to make decisions about user fees and taxes. Accordingly, communities may apply to the Environmental Protection Agency for grant assistance in carrying out research projects and environmental programmes.

In the Arizona portion of the basin, municipal, state and federal agencies are represented in the Partnership. This provides the Partnership with considerable expertise and funding leverage. Water policy is regulated locally by the state departments of Environmental Quality (ADEQ) and Water Resources (ADWR). The Department of Water Resources promotes the establishment of the Arizona Rural Watershed Initiative, which enables local communities to form watershed groups to address local issues. The Partnership is one of the most successful watershed groups evolving from this initiative.

Finally, one other national regulatory consideration plays an important role in decisions about water use on the US side of the border: the Endangered Species Act of 1973. In this regard, two endangered species occur along the Upper San Pedro: the Southwestern willow flycatcher (*Empidonax traillii extimus*) and the Huachuca water umbel (*Lilaeopsis schaffneriana recurva*), as well as two species of fish, have been the basis of previous lawsuits aimed at the Department of Defense and Fort Huachuca.

In addition to these regulatory constraints, local communities and states in the USA and Mexico cannot legally enter into formal binational agreements regarding surface water. Border water planning by the two federal governments was defined in a treaty of 1944 placing the transnational water authority in the hands of a binational commission: the International Boundary and Water Commission (IBWC) in the USA and the Comisión de Límites y Aguas (CILA) in Mexico. While most planning in the past specialized in purely technological solutions to transboundary water and sanitation problems, the IBWC more recently has begun to incorporate sustainable development and public participation as part of its mission (Peña, 2002). At the same time, transboundary water basins remain largely unregulated.

More recently, as a result of the NAFTA trade accords, the Commission for Environmental Cooperation (CEC), with the USA, Mexico and Canada as partners, has the responsibility to 'consider and develop recommendations regarding ... transboundary and border environmental issues' (North American Free Trade Agreement, 1993). In the case of the San Pedro basin, the CEC, with its authority to investigate and report on border environmental conditions, commissioned and completed an Advisory Panel Report on the Upper San Pedro River Initiative. This report solicited and included public participation that recommended 'a broad and robust dialogue to explore opportunities for conservation, preservation, and economic betterment' (CEC, 1999a, p. 3). Pursuant to the spirit of this mandate, basin stakeholders established the Upper San Pedro Partnership and ARASA.

The third arm of this institutional triangle includes a pair of sibling organizations, the Border Environment Cooperation (BECC) and the North American Development Bank (NADB). These institutions were designed to improve environmental infrastructure along the border. Together they have certified and helped to fund a number of joint water and wastewater projects in the border region costing a total of more than US\$600 million. BECC's technical assistance

programme has allocated an additional US\$16.3 million to develop proposals (Border Environment Cooperation Commission & NadBank, 2004). Cananea has applied for a water-treatment system, but the project has stalled for lack of financial support from the state of Sonora (Fernando Macias, 2003, private conversation).

In general, it can be argued that these offshoots of NAFTA demonstrate the transformation of the roles of community planners, resource managers and elected officials along the US–Mexico border. Negotiating binational resource management has shifted from a diplomatic to a transborder and translocal process (Milch & Varady, 1999; Vasquez-Castillo, 2001). Perhaps the best means to bring CILA and CNA into the formation of watershed or municipal water councils is to ‘build on successful local initiatives that advance regional cooperation on water resources’ (Brown & Mumme, 2000, p. 912).

### *Developing Strategies and Desired Outcomes (Phase I)*

To encourage the development of a collaborative binational water resource management plan, in 2001 the Udall Center began facilitating binational Dialogues on Water and Climate (DWC) that focused on climate changes and their impacts on basin water between the Upper San Pedro Partnership and the newly formed Mexican ARASA. Three events supported by a UN organization (World Meteorological Organization and Food and Agriculture Organization), between the Partnership and ARASA were held under this programme in 2001–03. These efforts continue under a grant from the National Oceanic and Atmospheric Administration (NOAA) to promote the use of climate-information products by water managers and other stakeholders in this basin. The San Pedro DWC developed a collaborative binational watershed alliance for San Pedro with administrative, project implementation, educational outreach and technical committees.

This binational watershed alliance consists primarily of Partnership members and participants in the newly forming Mexican municipal water council, made up of representatives from the town, COAPAES, the Mexican National Water Commission and ARASA. However, the alliance also includes participants from ranches, NGOs, Sonora and Arizona universities, and representatives from Sierra Vista, Bisbee, Huachuca City, and Naco, Arizona, and from Cananea and Naco, Sonora. The Alliance is in the process of developing a Strategic Action Plan for collaborative transboundary water management.

### *Implementation of Watershed Projects and Policies (Phase II)*

As mentioned above, the Partnership has effectively leveraged considerable resources toward their water conservation goals within the US portion of the basin. Their Water Conservation Plan for 2003 catalogued over 100 projects currently underway or planned for the near future by its member agencies. This included projects as diverse as wastewater effluent recharge facilities, installation of water efficient fixtures, retirement of irrigated agriculture via conservation easements, limitations of the amount of turf at golf courses in the county to no more than 5 acres per hole, and installation of waterless urinals at all new commercial facilities.

On the Mexican side, The Nature Conservancy has partnered with IMADES

(Instituto del Medio Ambiente y Desarrollo Sustentable del Estado de Sonora), the State of Sonora natural resource management agency, to work collaboratively with private landowners and *ejidos* to implement localized range improvement projects. However, significant challenges still lie ahead for the implementation of more complex binational water conservation projects. Some of these will entail large investments in infrastructure, such as construction of wastewater treatment and/or effluent recharge plants. It is these larger projects that require a firm basis of support from a diverse assemble of interests in both countries. That consensus-building process is now in progress, but it will require adequate time to build the required trust and understanding among members of the Alliance, and subsequently to secure the necessary resources needed for implementation.

### *Monitoring and Evaluation*

To measure the success of the basin management plan, the binational Watershed Alliance will need to establish clear long-term goals, shorter-term objectives and key milestones, along with an effective monitoring programme that can be used to assess progress and inform adaptive management processes for the future. Much work remains in this regard. Within the US portion of the basin, over 200 hydrologic monitoring locations were previously established by the United States Geological Survey to calibrate their groundwater model, a fraction of which will continue to be used to determine long-term trends in an ongoing basis. Significant hydrologic and vegetation monitoring of the riparian system in the USA is also being carried out. However, this intensive monitoring network is contrasted by only limited quantitative groundwater data on the Mexico side, much of which has been collected by the Cananea mine as part of its regulatory reporting requirements. Access to this information has only recently been made available through the facilitated discussions among Alliance members, including mine hydrologists. While this is marked progress toward improved communications, an upcoming challenge for the Alliance will be the collaborative design of a cross-boundary hydrologic monitoring plan, with open access to all of the data generated. In addition, physical scientists on both sides of the border must be willing to work closely with stakeholders, such as mine officials, to define these specific monitoring objectives and reach consensus as to appropriate methodology.

Likewise, social scientists and professional facilitators will need to support the administrative and procedural aspects of ongoing meetings and discussions throughout the adaptive management process through their essential contribution of conflict resolution skills.

### **Adaptive Management**

Adaptive management is an iterative process that assesses monitoring results and new knowledge about policies, landscape and stakeholders in order to adapt project strategies for more effective outcomes. This process involves both stakeholders and scientists as they learn from each other.

### **Suggestions for Successful Collaboration**

While certain aspects of the decision-making process will vary from basin to

basin, some building blocks for collaborative watershed management are likely to remain consistent regardless of location. Creation of a common vision for the future is one of the most important aspects of engaging participants and launching the momentum that is required for sustained efforts to build consensus. Many times, directly addressing current resource management problems can invite conflict due to a tendency to defend previous actions or the status quo when beginning negotiations. However, partnerships built upon a vision of an uncertain but exciting future allow one to examine the most pressing problems more constructively and to build a vision of working toward the future while avoiding the distracting conflicts of the present.

A review of watershed partnerships from around the world emphasizes the importance of effective leaders, facilitators and coordinators in collaborative processes. Many partnerships, especially those initiated by governmental agencies, ask senior technical staff to play these roles in addition to their regular job responsibilities as scientists. Although such staff can contribute valuable expertise and authority (Wakeman, 1997), they lack the time, neutrality, training and experience to coordinate and facilitate effectively a consensus-based process over the long run (Leach & Pelkey, 2001). Therefore, the ongoing need for professional facilitation skills cannot be underestimated for watershed decision-making processes.

While there is certainly no one recipe for successful collaboration, there are certain questions that should be asked about the collaborative process and the participants, including scientists, managers, policy-makers and general stakeholders. Drawing from the results of a collaborative workshop, these questions can be listed under the categories of participation, representation, group dynamics, decision-making, adaptive management and sustainability (Moote *et al.*, 2000):

- Participation:
  - what incentives exist for people to participate?
  - who chooses not to participate and how can they be brought to the table?
  - how can collaborative groups avoid burnout?
  - how can/should collaborative groups recruit and train new participants?
- Representation:
  - who is represented and how are they selected? Who decides which interests and/or individuals have a legitimate place at the table?
  - what happens to those whose interests or positions are not included in the process?
  - how can diverse groups be trained constructively to engage one another and try to recognize the legitimacy of others' interests?
- Group dynamics:
  - how do collaborative groups compromise or find balance among competing interests?
  - how much of collaboration is an exercise in negotiating pre-existing positions, and how much learning, recognition of diverse viewpoints and change occurs?
  - what processes or structures serve all stakeholders' interests?
  - how do stakeholders assess risk and power? What are the reasons for their change or lack of change in assessment?

- Power dynamics:
  - what is the distribution of power and resources among the group?
  - how are hidden power and advantages dealt with or abused in the collaboration process?
  - how can local, national and binational interests be equitably addressed?
- Decision-making:
  - how do groups come to an agreement?
  - how do groups monitor their agreements?
- Adaptive management: does the collaborating group measure its ongoing progress and use adaptive management to change, improve or cease failing actions over time?
- Sustainability:
  - given the voluntary nature of most collaborations and the large amounts of time and energy involved, how does one keep them functioning over the long haul?
  - what makes a collaboration hit a ceiling that prevents progress beyond that level?

## Conclusion

While one can describe the process for developing collaborative watershed management and provide pointers for increasing the successful partnership between scientists, managers, policy-makers and general stakeholders, creating the conditions under which they can address serious issues of sustainable resource use and equitable distribution will always be a learning process for those involved. Essential to this process are (1) accurate representation of stakeholders' interests, (2) open, frequent and clear communication, (3) an understanding of the social, economic and policy contexts, (4) a clear articulation of expectations and strategies to carry them out, (5) the development of long-term relationships, (6) strong science and (7) the establishment of mechanisms for monitoring and feedback. Financial and institutional supports are important for sustaining local, national and binational interests. As this case study of the USPB (as well as the other examples of US–Mexico binational collaboration) demonstrates, the process of adaptive management is ongoing and essential in a region where increasingly complex issues require interdisciplinary research and strong integration of science with a diverse array of decision-makers and stakeholders.

## References

- Arias, H. M. (2003) Land cover changes and climate fluctuations in the Upper San Pedro River Basin in Sonora, Mexico, in: H. F. Diaz and B. J. Morehouse (Eds) *Climate and Water: Transboundary Challenges in the Americas*, pp. 393–402 (London: Kluwer).
- Berkes, F. (1986) Marine inshore fishery management in Turkey, in: *Proceedings of the Conference on Common Property Resource Management*, pp. 63–83 (Washington, DC: National Academy Press for the National Research Council).
- Border Environment Cooperation Commission & Nadbank (2004) Joint Status Report, available at: <http://www.cocof.org>.
- Brown, C. & Mumme, S. (2000) Applied and theoretical aspects of binational watershed councils (Consejos de Cuencas) in the US–Mexico borderlands, *Natural Resources Journal*, 40, pp. 895–929.

- Browning-Aiken, A., Morehouse, B., Davis, A., Wilder, M., Varady, R., Merideth, R., Goodrich, D., Carter, R., Moreno, D., Dellinger, E., Delgado, F., Rodriguez, A., Villaseñor, F. & Cons, M. (2004) Climate, water management, and policy in the San Pedro basin: results of a survey of Mexican stakeholders near the U.S.–Mexico border, *Climate Change* (submitted).
- Chamala, S. & Keith, K. J. (1995) *Participative Approaches for Landcare: Perspectives, Policies, Programs* (Brisbane: Australian Academic Press).
- Commission for Environmental Cooperation (1999a) *Sustaining and Enhancing Migratory Bird Habitation on the Upper San Pedro River* (Montreal: CEC).
- Commission for Environmental Cooperation (1999b) *Ribbon of Life: An Agenda for Preserving Transboundary Migratory Bird Habitat* (Montreal: CEC).
- Da Viana, V. (1998) *Hallan arsénico*, *El Imparcial*, 19 August, p. 1.
- Gleick, P. H. (2002) *The World's Water, 2002–2003: The Biennial Report on Freshwater Resources* (Washington, DC: Island).
- Hardin, G. (1968) The tragedy of the commons, *Science*, 162, pp. 1243–1248.
- INEGI (2004) Población total, edad mediana e índice de masculinidad por municipio según sexo, available at: <http://www.inegi.gov.mx>.
- Jamail, M. H. & Scott, J. U. (1979) *Pollution of the San Pedro River. International Water Use Relations Along the Sonoran Desert Borderlands*. Paper No. 14 (Tucson: Arid Lands Resource Information).
- Kamp, D. (1999) *Northeast Sonora Water Project: Summary of the First Phase* (Bisbee: Border Ecology Project).
- Kepner, W. G., Edmonds, C. M. & Watts, C. (2002) *Remote Sensing and Geographic Information Systems for Decision Analysis in Public Resource Administration: A Case Study of 25 Years of Landscape Change in a Southwestern Watershed* (Las Vegas: US Environmental Protection Agency).
- Lansing, J. S. (1991) *Priest and Programmers: Technologies of Power in the Engineering Landscape of Bali* (Princeton: Princeton University Press).
- Leach, W. D. & Pelkey, N. W. (2001) Making watershed partnerships work: a review of the empirical literature, *Journal of Water Resources Planning and Management*, November/December, pp. 378–385.
- Magaña, V. O. & Conde, C. (2001) Climate variability, climate change, and its impacts on the freshwater resources in the border region: a case study for Sonora, Mexico, in: H.F. Diaz & B.J. Morehouse (Eds), *Climate and Water: Transboundary Challenges in the Americas*, pp. 373–392 (London: Kluwer).
- McGinnis, M. V., Woolley, J. & Gamman, J. (1999) Binational conflict resolution: rebuilding community in watershed planning and organizing, *Environmental Management*, 24, pp. 1–12.
- Milch, L. & Varady, R. G. (1999) Openness, sustainability, and public participation: new designs for transboundary river basin initiatives, *Journal of Environment and Development*, 8, pp. 258–306.
- Moote, A., & Gutiérrez, M. (2001) *Views from the Upper San Pedro Basin: Local Perceptions of Water Issues* (Tucson: Udall Center).
- Moote, A., Conley, A., Firehock, K. & Dukes, F. (2000) *Assessing Research Needs: Summary of a Workshop on Community-Based Collaboratives*. No. 00-5 (Tucson: Udall Center) (available at: <http://www.cbrc.org>).
- Moreno, V. & Luis, J. (1991) El Futuro de la Problemática Ambiental en Cananea y Nacozari. Paper presented at the XVI Simposio de Historia y Antropología de Sonora. Instituto de Investigaciones Históricas, Universidad de Sonora, Hermosillo, Sonora, 23 February.
- North American Free Trade Agreement (NAFTA) (Washington, DC: US Government Printing Office).
- Ostrum, E. (1990) *Governing the Commons: The Evolution of Institutions of Collective Action* (Cambridge: Cambridge University Press).
- Partnership Working Water Conservation Plan 2003, Sierra Vista, Arizona.
- Peña, S. (2002) Land use planning on the U.S.–Mexico border: a comparison of the legal framework, *Journal of Borderland Studies*, 17(1), pp. 1–20.
- Reij, C., Scoones, I. & Toulmin, C. (1996) *Sustaining the Soil: Indigenous Soil and Water Conservation in Africa* (London: Earthscan).
- Renard, K. G., Lane, L. J., Simanton, J. R., Emmerich, W. E., Stone, J. J., Weltz, M. A., Goodrich, D. C. & Yakowitz, D. S. (1993) Agricultural impacts in an arid environment: Walnut Gulch studies, *Hydrological Science and Technology*, 9(1–4), pp. 145–190.
- Romero Lankao, P. (2001) *Effectiveness of New Water Policy Schemes for Managing Climate Change Water Scarcity Quality* (Tucson: Udall Center for Studies in Public Policy).
- Sheridan, T. E. (1988) *Where the Dove Calls: The Political Ecology of a Peasant Corporate Community in Northwestern Mexico* (Tucson: University of Arizona Press).

- Upper San Pedro Partnership (2000) *Semi-Annual Report* (Sierra Vista: USPP).
- Varady, R. G., Moote, M. A. & Merideth, R. (2000) Water management options for the Upper San Pedro River basin: assessing the social and institutional landscape, *Natural Resources Journal*, 40, pp. 223–235.
- Vasquez-Castillo, M. T. (2001) Mexico–US bilateral planning: institutions, planners, and communities, *European Planning Studies*, 9, pp. 649–662.
- Views from the Upper San Pedro River Basin: Local Perceptions of Water Issues* (2001).
- Wakeman, T. H., III (1997) Engineering leadership in public policy resolution, *Journal of Management in Engineering*, 13, pp. 57–60.
- Webler, T. & Renn, O. (1995) A brief primer on participation: philosophy and practice, in: O. Renn, T. Webler & P. Weideman (Eds) *Fairness and Competence in Citizen Participation: Evaluating Models for Environmental Discourse*, pp. 1–33 (Dordrecht: Kluwer).
- Wolf, A. T. (2002) Pre-conference statement for the session on 'Transboundary Water Conflicts and Cooperation'. Paper for the Conference 'Allocating and Managing Water for a Sustainable Future: Lessons from Around the World', 11–14 June, Natural Resources Law Center, University of Colorado School of Law, Boulder, CO, USA.
- Woolhiser, D. A., Keefer, T. O. & Redmond, K. T (1993) Southern oscillation effects on daily precipitation in the southwestern United States, *Water Resources Research*, 29, pp. 1287–1295.
- Zavala, E. V. (1987) Minera de Cananea, SEDUE y el Medio Ambiente, *Comunicobre*, February (62), p. 5.

