

Water: Science, Policy, and Management, ed. by R. Lawford, D. Fort, H. Hartmann, and S. Eden. 2003. American Geophysical Union Water Resources Monograph 16. Washington, DC: American Geophysical Union. pp. 143-159.

Moving Borders from the Periphery to the Center: River Basins, Political Boundaries, and Water Management Policy

Robert G. Varady and Barbara J. Morehouse¹

WHY TRANSBOUNDARY BASINS ARE SIGNIFICANT

Boundaries are a fact of life. We owe much of our understanding of the world, and of biophysical as well as societal interactions, to the order imposed by borders and boundaries. Yet, at the same time, we recognize "borderlands" as important areas that transcend political boundaries. These zones of interaction provide a place for utilizing things held in common (such as shared water resources) as well as reinforcing differences (for example, differing regulatory structures). Borders sometimes serve as legal or political barriers to scientific data gathering and collaboration. Of equal or even greater importance, borders often impede the rational application of scientific knowledge to the problems it is meant to solve. As Aaron Wolf and others have noted, the problems of managing water and other resources are exacerbated when those resources cross political boundaries and jurisdictions [Wolf, *et al.*, 1999; Udall and Varady, 1994]. While this reasoning has been persuasive, the persistence of political and administrative practices that treat border areas as peripheries has prevented transboundary management issues from receiving the attention they deserve—an observation that is especially meaningful in the case of river basins. The distinctiveness of the transboundary condition should be of particular interest to scientists because of the contrast between the disparities engendered by political borders and the continuity found in natural processes.

By and large, managers, decisionmakers, and the public-at-large accept that transboundary basins are distinct from watersheds that do not cross borders, and

¹Respectively, deputy director and research professor at the Udall Center for Studies in Public Policy; and program manager of the Climate Assessment for the Southwest (CLIMAS) project at the Institute for the Study of Planet Earth, and adjunct assistant professor of Geography—all at The University of Arizona.

Lawford Book

Water Resource Monograph

© 2003 by the American Geophysical Union

DOI ID NUMBER

2 River Basins, Political Boundaries, and Water Management

allow that the transboundary cases may require special policies and procedures. But because borders are so easily imagined as being “somewhere else” and “somewhere distant,” transboundary basins tend to be treated as exceptions to the norm. Table 1 demonstrates conclusively that such a perception is far from correct. This listing of the world’s 35 largest river basins shows that all but six (i.e., 83 percent) extend through more than one nation. On average, each of those 35 major basins flows through 4.3 countries.² The figures are even more convincing when basins cross significantly disparate domestic jurisdictions; in that case, 100 percent can be considered to be transboundary. In other words, far from being rare and interestingly peculiar cases, river basins that require management approaches tailored to their multinational or multijurisdictional status represent the overwhelming norm.

BORDERS, BOUNDARIES, AND RESOURCE-MANAGEMENT POLICY

Physiographic boundaries exist, such as rivers, but more typically political and jurisdictional boundaries ignore biophysical patterns and functions. Boundaries define many kinds of geographies in the world, including, for example, countries, provinces, states, administrative districts, indigenous territories, military cantonments, counties, census tracts, irrigation districts, voting precincts, protected areas, marketing or trade zones, and school districts.

Within boundaries, agencies and jurisdictional authorities at various levels pursue their own, often conflicting, missions. Their activities often affect each other. Nowhere is this truer than in natural resource management. Here, geopolitical boundaries slice across geographical areas where natural and human processes and interactions converge to produce very particular landscapes, as well as resource use opportunities and pressures. Differences in laws, rules, practices, and values on either side of the boundary often increase the pressures on both the natural and human systems.

Disparity and Complexity

A different kind of boundary-drawing occurs in science: here, boundaries serve to define that which is within the scope of data collection, modeling, and analysis from that which is not. Boundaries allow the scientist to specify initial conditions, conduct a controlled analysis of identified variables, stimulate perturbations to those variables and/or their interactions, and measure the results [Morehouse, 2000]. Such data collection and analysis may benefit from the rationality imposed by boundaries. However, ordering social and natural processes into tidy, bounded units is likely to generate as many problems as it solves, for border areas where things tend to blur can seldom be eliminated.

²Roger Pulwarty (2001) offers a similar analysis of transboundary river basins to stress their prevalence and importance.

These often hazily defined areas are the interface where differentiated systems, processes, cultures, or social structures come together, where ordered assumptions are most apt to break down. The problem may be examined from several perspectives.

Table 1. Major River Basins and Number of Countries

RIVER	CONTINENT	SIZE (10 ³ km ²)	NO. CTRIES	INCL. DEVEL. CTRY. ^a	INCL. ARID TERRIT. ^b
Amazon	S. Amer.	5,866	8	✓	X
Congo	Africa	3,699	11	✓	X
Mississippi	N. Amer.	3,226	2	X	✓
Nile	Africa	3,038	12	✓	✓
La Plata/ Parana	S. Amer.	2,967	5	✓	✓
Ob	Asia	2,735	3	✓	✓
Yenisey	Asia	2,498	2	✓	✓
Lena ^c	Asia	2,430	1	---	---
Niger	Africa	2,118	11	✓	✓
Yangtze ^c	Asia	1,950	1	---	---
Amur	Asia	1,884	4	✓	✓
Mackenzie ^c	N. Amer.	1,800	1	---	---
Ganges	Asia	1,665	6	✓	✓
Volga	Europe/Asia	1,554	3	✓	✓
Zambezi	Africa	1,388	9	✓	✓
Hsi	Asia	1,350	2	✓	X
Nelson	N. Amer.	1,109	2	X	X
Indus	Asia	1,086	4	✓	✓
Murray ^c	Australia	1,070	1	---	---
St. Lawrence	N. Amer.	1,055	2	X	X
Orinoco	S. Amer.	959	2	✓	✓
Tarim	Asia	950	7	✓	✓
Orange	Africa	948	4	✓	✓
Tocantins ^c	S. Amer.	900	1	---	---
Yukon	N. Amer.	830	2	X	X
Juba- Shibeli	Africa	805	3	✓	✓
Tigris- Euphrates	Asia	794	6	✓	✓
Mekong	Asia	780	6	✓	X
Danube	Europe	780	17	X	X
Huang He ^c	Asia	745	1	---	---
Okavango	Africa	709	4	✓	✓
Columbia	N. Amer.	668	2	X	✓
Colorado	N. Amer.	651	2	✓	✓
Dnieper	Europe	496	3	X	X
Senegal	Africa	437	4	✓	✓
SUMMARY			Avg: 4.3	Tot.: 22	Tot.: 20

Sources: Wolf, et al. (1999); World Bank (2002); UNESCO (1977)

Notes:

^a Transboundary basin includes at least one developing country. ✓ = Yes

^b Transboundary basin includes arid or semiarid territory. X = No

^c Not a transboundary basin.

4 River Basins, Political Boundaries, and Water Management

First, “borders separate problems and solutions.” Because borders are typically distant from the centers where policies are conceived and applied, potential solutions are likewise formulated in locations far removed from where the problems are felt. Second, “borders create perverse economic opportunities.” Globalization erodes incentives for conservation, sustainable growth, and equitable taxation. This process is most pronounced at the geographical extremities of political jurisdictions, where authority is weakest and cooperative management most difficult to achieve. Third, “borders aggravate perceived inequalities.” In most countries, law, administration, and infrastructure financing are the province of national governments; resulting in a disregard for the specifics of local conditions. This disregard, in turn, has the effect of perpetuating inequitable practices that manifest in border regions. Finally, “borders obstruct grassroots problem-solving.” In general, bottom-up, community-based, stakeholder-driven efforts to manage water and other resources tend to be inhibited by more powerful, centralized decisionmaking forces—a common inhibition in border regions. In those areas, which are distant from the loci of national influence, citizens may feel more disenfranchised than in centrally located communities.³

A symposium on transboundary challenges associated with climate and water management in the Americas, held in the summer of 2000, highlighted an array of boundary issues that affect the management of shared water resources.⁴ The issues identified ranged from high variability in the quality, quantity, and accessibility of scientific data to the nature of laws and other institutional arrangements that inhibit development and implementation of policies that allow for rational, cooperative management of shared resources.

The symposium also highlighted the need to harmonize data across scientific boundaries, such as the boundaries of grid cells used in climate models. In these types of cases, what may appear to be an externality to a particular cell might in fact have relevant effects when complex inter-cell dynamics are taken into account. For example, in the case of the US Southwest, due to complex terrain and related high variability across the area, the boundaries of a grid cell may fail to recognize important snowpack or other hydroclimatological influences originating in a nearby grid cell on conditions within the cell in question. While the concept may be abstract, the implications of such boundary-related scientific assumptions are critical when applying such principles to problems affecting human and natural systems. Nowhere is this more clearly seen than in the development of finer-scale models that can be coupled to coarser, larger-scale models. Such modeling requires addressing uncertainties and instabilities occurring at these kinds of “edges” in order to produce valid, usable information to apply to specific locales in the finer-scale model.

³These characteristics, based on an example in the U.S.-Mexico border, are described in a 1994 essay in *Environment* (Ingram, Milich, and Varady, 1994).

⁴Symposium on “Climate, Water and Transboundary Challenges in the Americas,” University of California-Santa Barbara, Santa Barbara, California, July 16-19, 2000.

Differing National Priorities

Transboundary water-resources management brings into sharp relief differences in the goals and strategies of the parties involved. At the national level, priorities on one side of a border may favor improving urban water delivery, while on the other they may promote environmental protection. If the upstream state pursues protection, the downstream state could benefit by gaining cleaner water or greater instream flows. However, if protection is the downstream state's priority while its upstream neighbor suffers from inadequate supply and treatment infrastructure, the downstream state is unlikely to achieve its priority. This common type of disparity impedes cooperative transboundary management.

In the San Pedro River basin that straddles the U.S.-Mexico border, grassroots organizations have arisen to address just this type of problem. The river, a tributary of the Colorado River, originates in Mexico, outside the copper mining town of Cananea, Sonora. It contributes to the community's urban and mining water needs and sustains agricultural activities downstream, before crossing into Arizona. North of the border, while the river continues to support agriculture and urban development, a stretch, the San Pedro Riparian National Conservation Area, is protected for its nationally and internationally recognized value as bird habitat for both resident and migratory species, and for its recreational opportunities and its importance as one of the few functional riparian areas remaining in Arizona. Local residents strongly support the environmental values of the area and continue to work for its preservation. On each side of the border, a diverse collection of stakeholders vies for influence over allocation, habitat protection, and water-quality concerns. Since the late 1990s these often-competing interests have organized cooperative watershed associations: the U.S.-based Upper San Pedro Partnership and the Mexico-based Asociación Regional Ambiental de Sonora y Arizona (ARASA). Separately and jointly, these organizations are attempting to overcome divergent national priorities and some of the disadvantages of being marginalized along the border [Varady, Moote, and Merideth 2000; Varady and Browning, in press].

Regardless of how robust civil-society institutions may be, severe drought or flooding usually exposes underlying institutional barriers to effective cooperation. Strong increases in natural resource demands on either side of a border—from population growth, industrial/commercial growth, or some combination of these factors—often confront contradictions embedded in notions of sovereignty, local control, and other such institutional arrangements. Differences in levels of infrastructure development also serve as barriers. Across their border, for example, residents in the United States and Mexico have access to substantially different levels of water-supply and treatment infrastructure [Ingram, et al., 1995]. Pronounced industrialization and urbanization in Mexico strain the capacity of local systems to keep up with growing demand as ever more residents pour into the cities. In many of the poorest *colonias* (unplanned settlements), water is

6 River Basins, Political Boundaries, and Water Management

delivered by truck, not through pipes. The cost of water is very high, and its quality is generally poor, especially among the poor. By contrast, on the U.S. side of the border water-supply infrastructure has accommodated population growth—with the notable exception of some very poor colonias in southern Texas and New Mexico [Lemos, *et al.*, 2002]. As a result, water remains relatively inexpensive and of higher quality.

In the U.S.-Mexico region, there has been some progress in addressing such imbalances. As one example, paired crossborder communities such as El Paso-Juárez, Ambos Nogales, Yuma-San Luis Río Colorado, and San Ysidro-Tijuana have developed dialogues aimed at solving shared water-resource management problems. Yet much remains to be done there and elsewhere in the world. Models such as the above one, which rely on public participation in decisionmaking, show signs of effectiveness. But they may be difficult to adapt to *developing-country* transboundary river basins (three-quarters of the largest such basins, according to Table 1), where political traditions are generally inhospitable to public involvement in policymaking. For obvious reasons of resource paucity and data scarcity and inconsistency, developing countries are particularly vulnerable to water-management problems [Vörösmarty, *et al.*, 2001]. Extreme climatic conditions—drought, heat, and flood—strain already-inadequate systems. The impacts of such stresses generally spill across borders, affecting neighboring systems and services [Morehouse, *et al.*, 2000].

In areas where water scarcity is a consistent or recurrent issue (Table 1 below shows that two-thirds of transboundary basins include some arid or semiarid territories), allocation decisions are influenced most heavily by policies articulating a hierarchy of use values. Meeting basic human survival needs tends to be paramount, and where legal provisions so state, agricultural water use may be deferred in favor of addressing human and municipal needs. Yet rules like these typically have validity only within individual countries, states, or other jurisdictional units—not across political boundaries. Obviously, climate and its impacts do not stop at jurisdictional lines [Morehouse, 2000]. How to negotiate science and policy interactions across borders, particularly international ones, remains a significant challenge to both scientists and policymakers. This question will be addressed following a brief discussion of key institutional forms, below.

Diverse Transboundary Institutions

The institutional mechanisms associated with decisionmaking and implementation can differ substantially. Nearly always, where local control over water supplies meets a nationalized system at an international boundary, cooperation is difficult [Kliot, *et al.*, 2001]. Local interests are likely to resist national-level assertions of authority, but managers of those interests lack power to negotiate internationally—a manifestation of sovereignty that nation-states strongly protect.

Typically, negotiations take the form of international treaties among two or more

sovereign nations. In the realm of transboundary water management, examples include the Mexico-United States Treaty of 1944 (for the Colorado and Rio Grande/Río Bravo Rivers), Danube Declaration, Indus Water Treaty, and Plata Basin Treaty. In some instances deriving their authority from such treaties, but more frequently arising from separate multilateral agreements or conventions, nations that possess territories within large river basins form multinational commissions. Prominent examples are the Mekong River Commission, Niger Basin Authority, Organization for the Development of the Senegal River, and Rhine Commission. Sometimes, these institutions are created through exogenous actions, as with the Action Plan for the Environmentally Sound Management of the Common Zambezi River System, an instrument facilitated by the United Nations Environment Programme. In some instances, permanent institutions such as the [U.S.-Mexico] International Boundary and Water Commission, have established protocols allowing the participating nations to agree to specific, ad-hoc actions—for example, through officially approved amendments to existing treaties.

Nearly all of the world's river-basin management instruments are rooted in an earlier age, when they were molded principally by geostrategic considerations. Not until the last two to three decades have such other concerns as pollution, human health, habitat protection, recreation needs, ecological costs of engineering structures, land-tenure rights, and relationship between water and climatic processes become accepted elements of river-basin management. Not surprisingly, the organizations created to manage transboundary rivers reflected the times of their origins. As instruments of diplomacy, they were part of nations' foreign-policy infrastructure and exhibited the features and tendencies of those establishments: they were typically top-down, secretive and tightly possessive of information, highly dependent on engineering/earth-moving solutions to water problems, and inclined to regulatory approaches. Until the 1970s, and since then only in selected places, nongovernmental stakeholders and the public-at-large were virtually excluded from helping to determine policies that affected livelihoods, local environmental conditions, and public health in the regions within the province of these transnational commissions. And when the "needs, constraints, and practices" of local users are ignored, watershed management often fails [Johnson, *et al.*, 2001b].

Only since the 1970s, and only in selected countries, have transboundary organizations shown signs of becoming more democratic, incorporating such features as openness, transparency, and public participation into their procedures. Such changes have been most evident along the U.S.-Mexico border and in western Europe [Milich and Varady, 1998, 1999]. Elsewhere, especially in some former communist nations of eastern Europe, nongovernmental organizations in are showing interest in adopting and adapting similar processes.⁵ But even in areas where processes have been reformed and integrated approaches adopted, cooperation among nations remains mainly crisis-driven, thus inhibiting steady, long-term collaboration [Van der Zaag and Savenije, 2000].

8 River Basins, Political Boundaries, and Water Management

SCIENCE AND TECHNOLOGY, AND DECISIONMAKING

A recent paper on transboundary river-management institutions identified their greatest vulnerability: they operate at the intersection of two largely incompatible world views, hydrology and politics [Kliot, *et al.*, 2001]. A large body of literature on the integration of science and technology into decision-making has attempted to understand this incompatibility [e.g., Baldwin, 2000; Gibbons, 2000; Gibbons, *et al.*, 1994; Jasanoff and Wynne, 1998; Latour and Wolgar, 1979; Weiss, 1978]. But application of models and concepts in empirical studies, particularly to transboundary settings, is not yet fully developed. This deficiency is very apparent in the use of scientific and technological tools for transboundary river-basin management. Not infrequently, disparities in data collection, analysis, archiving, and dissemination retard the use of information for transboundary regions.

As importantly, the degree and quality of collaboration between scientists, policymakers, and stakeholders varies from country to country. Whereas western-style democracies tend to emphasize openness and transparency, many societies restrict access and participation. Even in otherwise open societies, certain limitations may be imposed. For example, in Croatia and Bulgaria the authorities often restrict dissemination of climate information they believe could be misused (e.g., for setting forest fires). Elsewhere, water-supply information can be classified as sensitive, particularly where rights to shared water resources remain unresolved. Or even more commonly, technological developments such as state-of-the-art dams and delivery systems are typically considered internal matters, even when they adversely affect downstream users. Almost always, insufficient institutionalization of international water law obstructs resolution of such conflicts.

These kinds of challenges are exacerbated when nations assert their sovereignty to justify control of the amount, nature, and destination of information domestically and across borders. They are further worsened by national policies that affect where and how scientific results are kept, and by laws that curtail international collaboration and communication among scientists, decisionmakers, and other interested parties.

Several international examples illustrate the difficulties of integrated, international management of shared watershed. In the case of the Tigris-Euphrates, the countries sharing this basin are at peace with each other, but competing interests, mutual suspicions, and exercise of raw power assure that politics trumps science and technology.⁶ At the extreme, elsewhere in the Middle East, current conflict between Israel and Palestine poses an even more immediate and seemingly intractable challenge for cross-border cooperation on water issues. During

⁵One such effort, facilitated by Z. C. Kovács and P. Balogh, is taking place in Hungary, in the Tisza basin. International Water Conference, "Globalization and Water Management: The Changing Value of Water" (7 Aug. 2001, Dundee, Scotland).

calmer times, the 1995 Israeli-Palestinian Interim Agreement on the West Bank and Gaza Strip articulated Israel's recognition of Palestinian water rights in the West Bank and Gaza Strip. Both parties also recognized the need to develop additional water, assure sustainability, and adjust utilization to changing hydrological and climatic conditions [National Research Council, 1999]. The agreement, one of many such technical accords between the two entities, showed that scientists and technocrats can play useful roles in overcoming political differences. But when two nations are in a state of war, it is impossible to envision productive crossborder collaboration.

Transboundary scientific research can be problematic even between countries that are at peace and have similar levels of development and scientific expertise. Sometimes, arrangements to share data and scientific knowledge rely more on established scientific forums (publications, conferences, exchanges), supplemented by informal or personal networks than on institutional arrangements. Even where formal institutions exist, such as the International Joint Commission established by the United States and Canada to harmonize water management along the U.S.-Canadian border, collaboration on transboundary issues may be restricted to those narrowly defined by the agency as being within its mission.

Even more complex are the scientific and technological issues associated with river basins lying in more than two countries. The Plata River (Río de la Plata), which drains lands in five South American countries, has been the subject of international management efforts since the late 1960s [Tucci and Clark, 1999]. In 1969 the five nations signed the Plata Basin Treaty, which envisioned integrated development and identified joint objectives, but failed to include specific actions or mechanisms to implement the goals. In the early 1980s, within this framework, the member countries created the Hydrologic Warning Operations Center for the Plata Basin. While far from solving the basin's many problems, this warning system institutionalized the application of scientific and technological expertise to managing risk. To the extent that the member countries have the capacity and will to provide the data needed to develop forecasts for the basin, the Center offers a focal point for anticipating and planning for emergencies. However, with its narrow mission, it is not empowered to carry out much-needed transboundary collaboration on land and resource use in the Basin.

STRESSES, SURPRISES, SENSITIVITY, AND ADAPTATION

Issues associated with transboundary water resources frequently remain inchoate, until stresses become too great to ignore [Van der Zaag and Savenije, 2000]. Such stresses may include increases in demand where supplies are already

⁶ Turkey controls the headwaters, but the basin includes five other nations, of which Iraq and Syria depend most heavily on the supply.

10 River Basins, Political Boundaries, and Water Management

limited, degradation of water quality to levels below that required for intended use, political tensions manifested in conflicts over sharing water resources (whether or not the basic contest is over water, *per se*), technological changes that modify the nature and quantity of flows across a border, or climatic changes that alter water availability and flow regimes. Surprises are stresses that arise unexpectedly, such as flash floods. While plans may be devised to address surprises, the possibility always exists that an event will exceed an anticipated level or that other unanticipated factors may confound planned action. Linking predictions with policymaking and decisions is, in the best of circumstances, fraught with obstacles [Pielke, Jr. and Byerly, Jr., 2000]. In contexts involving political and jurisdictional boundaries, the barriers may multiply exponentially.

Crossborder collaborations that assess the sensitivity of human and natural systems to stresses and surprises, including climate variability and change [Morehouse *et al.*, 2002], are crucial to development of contingency plans. Such analyses help establish current baseline conditions, which then permit evaluation of potential impacts under different sets of conditions [Morehouse *et al.*, 2000]. Vulnerability assessments that seek to identify who is vulnerable to external stresses, how, and under what conditions they are vulnerable, are also valuable management tools for contexts of uncertainty and multiple stresses. The impacts of climate variability and change on transboundary water resources, for example, are likely to be unevenly experienced both within and across a border [Liverman, *et al.*, 1997]. As Liverman (2001) has emphasized, the most vulnerable are often those having the least flexibility and fewest resources with which to respond. Knowing where resilience and flexibility are least, and thus where adaptation capacity is most limited, allows for holistic appraisal of what sorts of planning are needed and where resources are likely to be most needed.

In border contexts, sensitivity analyses and vulnerability assessments carried out strictly within political and jurisdictional boundaries may result in crucial sensitivities and vulnerabilities being overlooked. Policies and actions that are based on narrow definitions of the bounds of analysis may exacerbate cross-border tensions. Examples of this sort of outcome may be found in conflict arising from downstream flooding of the Ganges-Brahmaputra river system in India and Bangladesh, generated by heavy upstream snowpack accumulation in Nepal and Tibet; and in tensions associated with potential implications of decreased snowpack in the mountains of British Columbia, foreseen in climate-change models, for summer water availability in the U.S. Northwest [Miles, *et al.*, 2000].

CONCLUSIONS

Key Issues Complicating Transboundary River Basin Management

There is no question that managing water resources in crossborder contexts is extraordinarily complex. Much of the complexity added by the transnational dimension is attributable to human agency. Questions relating to sovereignty and

jurisdictional autonomy, economic forces, and the applications of technological advances are the chief complicating factors.

Sovereignty and jurisdictional autonomy. The decisionmaking process typically is multidimensional, nuanced, and difficult to fathom. Further, it varies enormously from one nation to another, even when those nations are neighbors. Institutional and organizational frameworks that apply at international, national, regional, and local scales require differing levels of autonomy and authority to make decisions. Thus, local communities sharing a boundary and common problems may face insuperable barriers to cooperative management of water resources because of national policies that view any such cross-border interaction as the purview of the state.

A useful illustration of this tension between domestic priorities and a desire to transcend international borders is the potential impact on river-basin management of climate variability and change. Issuance of official hydrologic and climate forecasts is typically restricted to national-level entities, and the forecasts themselves are solely for areas within a nation's territories. To obtain a border-area forecast, users must reconcile or harmonize forecasts issued by each country, or turn to less official ones (though not necessarily less accurate or skillful) like those issued by research centers such as Columbia University's International Research Institute. In some cases, stakeholder-relevant forecasts may not be available at all, or even when they are, the latitude to take action based on those forecasts may be limited in different ways—by international tensions, for instance; such conflicts may prevent action in border zones.

Economic drivers. The formulation and enforcement of water policy is strongly influenced by economic factors. One of the most common such factors is the dominance of one or more sectors in a border area (e.g., agriculture, mining, or industrial activity). For example, upstream diversion of water for agricultural irrigation may significantly diminish water availability in the neighboring downstream country or jurisdictional unit. In such cases, tensions may quickly mount on both sides of the border. As contests over the waters of the Rio Grande/Rio Bravo and Colorado River have demonstrated, prolonged and sometimes acrimonious negotiation is required to resolve the issues.

Interbasin water transfers are another controversial, economically-driven form of river management. Such projects can raise potent issues for the affected region—even when they are within a single nation, and much more so when they are transnational. They may degrade ecosystems in one or both watersheds, or diminish the vitality of entire communities (as when diversion of water and elimination of agriculture dependent on that water causes a domino-like fall of commercial and retail activities that generate local revenues and jobs).

A third economically-propelled phenomenon is the rapid increase in urbanization in international borders areas. Massive urban growth may result from

12 River Basins, Political Boundaries, and Water Management

many trends. For example, intensive, spontaneous migration may swell populations over short time periods. Likewise, borderland urban growth may be an outcome of intentional policy, such as stimulating economic development through establishment of *maquiladoras* (foreign-owned manufacturing plants south of the U.S.-Mexican border) operations in border communities. In any event, the resulting urban agglomerations constitute an on-the-ground *fait-accompli* that challenges the ability of each neighboring country to supply sufficient resources to all sectors. In such situations, the government may provide potable water to meet residential needs while at the same time delivering water to competing users such as commercial and industrial concerns.

Applications of technological advances. Basic research and technological innovation, which can be the leavening for improved management [Vörösmarty, et al., 2001], are complicated by transboundary dimensions. Attempts to apply the fruits of science to basin management often encounter serious obstacles, ranging from data-access limitations to governmental policies that serve to inhibit interactions among researchers, managers, and stakeholders from different countries or even from different jurisdictions.

The San Juan River Basin Project, covering parts of Costa Rica and Nicaragua, typifies the challenges to internationally conducted river-basin research [Rucks, 1999]. The region is characterized by high poverty rates and rising population; it also features important geological reserves and conservation areas. The San Juan is considered essential to serving future development in the semiarid Pacific Slope areas of the two countries. Efforts to improve water quality and reduce erosion and sedimentation have had high priority with both governments, as has the development of a basin-wide information system containing data on regional and local hydrology and climate. Similarly, the two countries have agreed to develop an effective bilateral, basin-wide planning process, strengthen public and private institutions and organizations, and develop environmental education programs. The project represents an ambitious undertaking that requires substantial investment of financial and human resources, as well as of goodwill. But underlying problems have slowed collaborative attempts at integrated management. These have included inadequate planning and administration capacity, weak institutional and monetary support, and insufficient stakeholder participation in decisionmaking.

Like the Río de la Plata and San Juan projects, the North American Monsoon Experiment (NAME) is an attempt at transboundary, water-related science. NAME would sponsor the installation of observation systems in the monsoon region of Mexico and possibly the southwestern United States. The program aims to develop spatially and temporally rich datasets to improve scientific understanding of the dynamics driving the monsoon and its spatial and temporal variability. NAME is designed to satisfy several needs of

stakeholders in each country: good summer half-year precipitation forecast that are issued during the previous winter or spring; better data for input to regional and global-scale climate models; and improved understanding of interactions between the monsoon and other climate processes over seasonal, annual, decadal, and centennial timescales. The ideal outcome of NAME would be better transboundary hydrologic and climate forecasts; the extent to which such forecasts will include both countries on maps and other graphics remains to be seen and will surely be subject to the forces slowing binational environmental cooperation more generally. Still, NAME is likely to benefit from the high degree of existing transboundary interaction and interlinkage within the shared borderlands and between the United States and Mexico. Forecasts spanning the Canada-U.S. border may be strongly justified for similar reasons.

Looking Ahead

Certain trends in science, combined with the dynamics of globalization and innovations in communications, provoke speculation about what the future of transboundary water management will look like. In the realm of water management, the past decade has seen a growing emphasis on funding society-relevant and policy-relevant science, supporting regionally focused and catchment-based integrated-assessment efforts, and producing “usable” science. Key examples of this approach are such relatively new programs as the HELP (Hydrology for Life, the Environment and Policy; described elsewhere in this volume) Initiative, the Dialogue on Water and Climate, and UNESCO’s World Water Assessment Programme for Development, Capacity-building and the Environment [HELP 2001; Kabat, *et al.*, 2002; UNESCO 2001].

These progressive trends in the epistemology of water management, if sustained, hold promise for reducing sensitivities and vulnerabilities to multiple stressors and promoting adaptive capacity among decisionmakers and ordinary citizens. Yet realizing the potential benefits of these and similar initiatives requires explicit commitment to expend time and resources to grapple with complicated border and boundary issues of all kinds. And, as the International Panel on Climate Change has discovered, while science is essential, it is insufficient to address society-environment problems. There is no alternative to wading into the messy world of social process—including the effects of drawing, justifying, and enforcing boundaries.

Meanwhile, globalization processes—including the restructuring and relocation of manufacturing operations, growth of border cities and associated water demand, and reallocations of capita—intensify the need to translate scientific advances into improved transboundary water-resources management. Added to all this is the rapid diffusion of communications technologies that permit instant

14 River Basins, Political Boundaries, and Water Management

and global dissemination of information of all kinds—scientific, political, economic, and environmental. As governments are discovering, attempts to exert sovereign rights over information dissolve in the borderless flows emanating from Internet, satellite, and other communications sources. Further, in an era of global trading of financial instruments and commodities of all kinds, many have argued that because under-valuation of water is the largest contributor to shortages, international trading in water and water futures is highly likely to occur [Johnson, *et al.*, 2001a]. Serious questions have been raised about what such commoditization of water will mean for equitable access around the world.

These and related changes necessitate the construction and acceptance of water-resource institutions that can respond to all the forces at play. Finally, most significantly, in view of the prevalence and “centrality” of transboundary river-basins, it is clear that these institutions will have to “be” transboundary in both design and outlook.

Acknowledgments

The authors are grateful for assistance from Robert Merideth, Leah Stauber and Allison Davis at the Udall Center. Some of the ideas are extensions of previous work, cowritten with Helen Ingram, Lenard Milich, Vera Pavlakovich-Kochi, and Doris Wastl-Walter. Additionally, W. James Shuttleworth, Michael Bonell, and James Wallace, formulators of the HELP initiative; and Aaron Wolf and Roger Pulwarty have, perhaps unknowingly, contributed influential insights. Finally, we acknowledge the Ford Foundation, the Morris K. Udall Foundation, the National Oceanic and Atmospheric Administration, and the Science and Technology Center for the Sustainability of Semi-arid Hydrology and Riparian Areas (SAHRA) for their past and present support for investigations on river-basin management.

REFERENCES AND SELECTED BIBLIOGRAPHY¹

- Baldwin, S. 2000. Interactive social science in practice: new approaches to the production of knowledge and their implications. *Science and Public Policy* 27, 3:183-194.
- Blatter, J., and H. Ingram (eds.). 2001. *Reflections on Water: New Approaches to Transboundary Conflicts and Cooperation*. Cambridge: MIT Press. 356 pp.
- Gibbons, M. 2000. Mode 2 society and the emergence of context-sensitive science. *Science and Public Policy* 27, 3:159-163.
- Gibbons, M., C. Limoges, H. Nowotny, S. Scharzman, P. Scott, and M. Trow. 1994. *The New Production of Knowledge*. London: Sage Publications. 179 pp.
- HELP (Hydrology for the Environment, Life and Policy) Task Force. 2001. *The Design and Implementation of the HELP Initiative*. Paris: UNESCO International Hydrological Programme (IHP)-V Technical Documents in Hydrology No. 44. 67 pp.
- Ingram, H., N. K. Laney, and D. M. Gillilan. 1995. *Divided Waters: Bridging the U.S.-Mexico Border*. Tucson: University of Arizona Press. 262 pp.
- Ingram, H., L. Milich, and R. G. Varady. 1994. Managing transboundary resources:

¹ All but four of the titles (90%) are cited in the text. The remaining are useful, closely related works.

- lessons from Ambos Nogales. *Environment* 36, 4:6-9, 28-38.
- Jasanoff, S. and B. Wynne. 1998. Science and decisionmaking. In S. Rayner and E. L. Malone (eds.), *Human Choice and Climate Change: The Societal Framework, Vol. 1*, pp. 1-88.
- Johnson, N., C. Revenga, and J. Echeverria. 2001a. Managing water for people and nature. *Science* 292:1071-1072.
- Johnson, N., H. Munk Ravnborg, O. Westermann, and K. Probst. 2001b. User participation in watershed management and research. *Water Policy* 3:507-520.
- Kabat, P., et al. (c. 40 contributing authors). 2002. *Dialogue on Water and Climate: First "White" (Position) Paper*. Dialogue on Water and Climate: Delft and Wageningen. 113 pp.
- Kliot, N., D. Shmueli, and U. Shamir. 2001. Institutions for management of transboundary water resources: their nature, characteristics and shortcomings. *Water Policy* 3:229-255.
- Latour, B., and S. Wolgar. 1979. *Laboratory Life*. Beverly Hills: Sage. 272 pp.
- Lemos, M. C., D. Austin, R. Merideth, and R. G. Varady. 2002. Public-Private Partnerships as Catalysts for Community-based Water Infrastructure Development: The Border WaterWorks Program in Texas and New Mexico Colonias. *Environment and Planning C: Government and Policy* 20:281-295.
- Liverman, D. M. 2001. Vulnerability to drought and climate change in Mexico. In (eds.) J. X. Kasperson and R. E. Kasperson, *Global Environmental Risk*, New York: Earthscan, United Nations University Press, pp. 343-352.
- Liverman, D. M., C. Conde, and V. Magaña. 1997. *Climate Variability and Transboundary Freshwater Resources in North America: U.S.-Mexico Border Case Study*. Montreal: Commission for Environmental Cooperation. 37 pp.
- Miles, E. L., A. K. Snover, A. Hamlet, B. Callahan, and D. Fluharty. 2000. Pacific Northwest Regional Assessment: The impacts of climate variability and climate change on the water resources of the Columbia River Basin. *Journal of the American Water Resources Association* 36:399-420.
- Milich, L. and R. G. Varady. 1999. Openness, sustainability, and public participation: new designs for transboundary river-basin institutions. *Journal of Environment and Development* 8, 3:258-306.
- Milich, L., and R. G. Varady. 1998. Managing transboundary resources: lessons from river-basin accords. *Environment* 40, 8:10-15, 35-41.
- Morehouse, B. J. In Press. Theoretical approaches to border spaces and identities. In Pavlakovich-Kochi, V., B. J. Morehouse, and D. Wastl-Walter (eds.), *Challenged Borderlands: Transcending Political and Cultural Boundaries*. Ashgate Press, 2003.
- Morehouse, B. J. Boundaries in Climate Science-Water Resource Discourse. 2000. Paper presented at the Symposium on Climate, Water, and Transboundary Challenges in the Americas, University of California – Santa Barbara, Santa Barbara, CA, 16-19 July.
- Morehouse, B. J. 1995. A functional approach to boundaries in the context of environmental issues. *Journal of Borderlands Studies* 10, 2:53-73.
- Morehouse, B. J., R. H. Carter, and P. Tschakert. 2002. Sensitivity of urban water resources in Phoenix, Tucson, and Sierra Vista, Arizona, to severe drought. *Climate Research* 21: 283-297.

16 River Basins, Political Boundaries, and Water Management

- Morehouse, B. J., R. H. Carter, and T. W. Sprouse. 2000. The implications of sustained drought for transboundary water management in Nogales, Arizona, and Nogales, Sonora. *Natural Resources Journal* 40: 783-817.
- National Research Council. 1999. *Water for the Future: The West Bank and Gaza Strip, Israel, and Jordan*. Report prepared by the U.S. National Academy of Sciences, Royal Scientific Society of Jordan, Israel Academy of Sciences and Humanities, Palestine Academy for Science and Technology. Washington, DC: National Academy Press. 244 pp.
- Pielke, Jr., R. A., and R. Byerly, Jr. 2000. *Prediction: Science, Decision Making and the Future of Nature*. Washington, DC: Island Press. 400 pp.
- Pulwarty, R. S. 2001. Transboundary river flow changes. In *Handbook of Climate, Weather, and Water*. Ed. by T. Potter. McGraw-Hill. Pp.1-20.
- Rucks, J. 1999. Manejo integrado de recursos hidricos en cuencas transfronterizas: el caso de la cuenca del Río San Juan Costa Rica-Nicaragua. *Proceedings of the Third Inter-American Dialogue on Water Management: "Facing the Water Crisis in the 21st Century."* Organization of American States. Panama City, Panama. http://www.iwrn.net/D3_Proceedings.pdf. Accessed 10 May 2002.
- Symposium on "Climate, Water and Transboundary Challenges in the Americas," University of California-Santa Barbara, Santa Barbara, California, July 16-19, 2000.
- Tucci, C. E. M., and R. T. Clarke. 1999. Environmental issues in the Plata Basin. *Proceedings of the Third Inter-American Dialogue on Water Management: "Facing the Water Crisis in the 21st Century."* Organization of American States. Panama City, Panama. http://www.iwrn.net/D3_Proceedings.pdf. Accessed 10 May 2002.
- Udall, Stewart N., and R. G. Varady. 1994. Environmental conflict and the world's new international borders. *Transboundary Resources Report* 7, 3:5-6.
- UNESCO. 2001. *Fitting the Pieces Together: The World Water Assessment Programme (WWAP) for Development, Capacity-building and the Environment*. Paris: UNESCO. 15 pp.
- UNESCO. 1977. *World Distribution of Arid Regions*. Map Scale: 1/25,000,000. Paris: UNESCO.
- Van der Zaag, P., and H. H. G. Savenije. 2000. Towards improved management of shared river basins: lessons from the Maseru conference. *Water Policy* 2:47-63.
- Varady, R. G., and A. Browning-Aiken. In Press. The birth of a Mexican watershed council in the San Pedro basin in Sonora. In *Planeación y Cooperación Transfronteriza en la Frontera México-Estados Unidos (Transboundary Planning and Cooperation in the U.S.-Mexico Border Region)*, ed. by C. Fuentes and S. Peña.
- Varady, R. G., M. A. Moote, and R. Merideth. 2000. Water allocation options for the Upper San Pedro Basin: assessing the social and institutional landscape. *Natural Resources Journal* 40, 2:223-235.
- Vörösmarty, C., P. Green, J. Salisbury, and R. Lammers. 2001. Global water resources: vulnerability from climate change and population growth. *Eos* 82:54.
- Weiss, C. 1978. Improving the linkage between social research and public policy. In L. E. Lynn (ed.), *Knowledge and Policy: The Uncertain Connection*. Washington, DC: National Academy of Sciences, pp. 23-81.
- Wolf, A. T. 1998. Conflict and cooperation along international waterways. *Water Policy* 1:251-265.

Varady and Morehouse 17

- Wolf, A. T., J. A. Natharius, J. J. Danielson, B. S. Ward, and J. K. Pender. 1999.
International river basins of the world. *International Journal of Water Resources
Development* 15, 4: 387-427.
- World Bank. 2002. *World Development Report 2003: Sustainable Development in a
Dynamic World—Transforming Institutions, Growth, and Quality of Life*.
Washington, DC: The World Bank. 231 pp.