Water Demand Management in Arid Regions

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Abstract

Arid and semi-arid regions exist in many parts of the world. They are particularly likely to experience water shortages if water infrastructure and management are poor. There are two strategies to cope with water scarcity: import water (which may be costly and unsustainable) or do more with less. This paper focuses on the second approach. The question asked is this: How can water management reduce water stress and allow for sustainable development in the watershed? The author argues that applying the principles and tools of integrated watershed management will help to achieve this goal. Integrated watershed management operates at the basin level, deals with both surface and ground water, and links natural to social systems. Examples from the water scarce watersheds on the U.S.-Mexican border and Southern Australia are used to illustrate steps towards implementing integrated watershed management.

Definitions and geographical distribution

Water availability differs from region to region. So do the resulting problems and risks. Many water rich regions suffer from poor water quality and flooding. Water poor regions encounter additional problems, such as permanent or periodic water shortages, environmental degradation, water conflicts, social hardship and economic loss. At the outset it is important to recognize that water scarcity is a regional problem and must be addressed in the context of unique regional conditions, both natural and social.

The volume of water available in a region is a function of climate and climate variation. How much water is withdrawn and consumed is determined by population density and level of development. Combining these factors provides a metric to distinguish between water rich and water poor regions. Rosegrant (1997) distinguishes between two levels of insufficient water supply. *Water stress* is present when annual per capita water availability is limited to 1,000 to 1,600 m^3. *Water scarcity* reigns when people have less than 1,000 m^3 to meet their needs. Currently, 28 countries, with a total population of 338 million, are water stressed. Of these, twenty suffer from water scarcity. Rosegrant predicts that water shortages will increase dramatically in the future, expanding the number of water stressed countries to about 50 by 2025.

Shiklomanov (2000) distinguishes between six categories of regional water availability, ranging from catastrophically low (less than 1,000 m^3 per person/year) to very high (more than 20,000 m^3 per person/year). He finds that 35 percent of the world population lives under conditions of low, or catastrophically low, fresh water availability. By 2025, conditions will be worse, as 30-35 percent of the world population is expected to live in areas with catastrophically low water availability.

Strzepek et al. (2000) use the demand/supply ratio as a proxy for water-related stress on nature and people. If the ratio is <0.1, the region experiences no stress. Low stress, stress, and high stress regions have demand/supply ratios of 0.1-02, 02-04, and >04, respectively. Strzepek, using the results of the World Water Vision 2000 assessment, calculates the regional demand/supply ratio by dividing the world into 18 large regions. He finds that the regions with the largest populations exposed to water stress are South Asia (including parts of India, Pakistan, and Bangladesh), China, the Middle East, North Africa, and the Iberian peninsula. Water stress will significantly increase by 2025. Considering a region's potential for growing food, the author reports that the number of people at risk of hunger is high in South Asia and China. These regions will have to deal with scarcity of both water and food.

According to Strzepek, the total number of people living in water-stressed regions was 1.9 billion in 1995 and is estimated to be 3.4 billion in 2025. This projection assumes a business-as-usual development path. Under a more normative view of a sustainable world that embraces less resource intensive values and adopts lifestyle changes, 2.8 billion will live under water stress in 2025.

The authors cited above, while using different methodologies for their estimates, agree that about 1/3 of the world's population will suffer from water scarcity—today and twenty years from now. Their estimates give an indication of the size and regional distribution of water stress and water scarcity. Yet, the real extent of water shortages may be even larger. All global water assessments completed to date use a limited number of world regions (under twenty) to calculate supply and demand. Some of these huge regions include both water rich and water poor areas. The reported averages, in North and South America alone, miss water scarcity in Northeast Brazil, Chile, northern Mexico and the southwestern United States. It is likely that additional regional scarcity would be reported for other continents if a smaller scale were used.

The per capita water needs defined above combine human domestic needs with water needed for producing food. The amount of water needed for growing food varies greatly, depending on the kind of diet (vegetarian or meat) people consume and the extent to which they rely on food grown close to home. It is useful, therefore, to consider the regional availability of meeting human domestic water needs alone. Various organizations (World Bank, World Health Organization and U.S. Agency for International Development) have set a standard between 20 and 40 liters per capita per day to meet the needs for drinking water and sanitation. Gleick (2000, p. 11) uses a slightly broader standard which adds water needed for bathing and food preparation (not production). Taking these categories together—drinking water, sanitation, personal hygiene and food preparation—he arrives at a basic needs standard of 50 liters per person per day. He finds that 2.2 billion people live in 62 countries where 50 liters a day is not available. One third of the world population faces this predicament. Gleick adds an important point: In most cases the deficiency is not due to an absolute lack of water but to poor infrastructure and management that does not get water to the people that need it.

Integrated Watershed Management

Modern water management began early in the last century when dams and reservoirs were first built and technology was developed to reduce industrial and municipal pollution. This hydrological phase of management lasted during much of the century. The most important professionals at this time were water and chemical engineers who had the knowledge to design and manage reservoirs and water treatment plants. Their efforts made it possible to reconcile the often conflicting goals of navigation, flood control, safe water supply for irrigation and cities, and energy production. Hydrologists and geologists assisted by assessing the available water supply and selecting the best location for new reservoirs. Beginning in the 1950s, economists began to measure the costs and benefits of river improvements. More recently, population growth and urbanization next to major rivers led to increased stress on aquatic and riparian resources. To understand these new risks environmental scientists, biologists and land use planners were called upon to study water-related environmental and land use issues.

As the water management team grew, an important transformation began to take place. River management became basin management. The Ruhr-River Valley Authority in Germany and the Tennessee Valley Authority (TVA) in the United States pioneered this approach. The TVA, created during the great depression of the 1930s, used flood control, navigation and power generation as a means to advance social and economic development in the multi-state basin. TVA was also ahead of its time in developing strong grassroots support for its work throughout the Tennessee basin thus emphasizing the need to work with local stakeholders (World Bank 1998). Integrated watershed management (IWM) builds on this experience as well as more recent concepts about water and its importance for all forms of life, not just human activities. In its fully developed form IWM links issues that previously were addressed separately:

- Surface and ground water resources,
- Water and surrounding land, and
- Natural and social systems.

IWM includes the entire drainage area of the river and its tributaries. As a result, the basin or watershed becomes the unit of analysis and management. Conceptually, rivers and aquifers are placed in the context of the surrounding natural and social systems (Heathcote 1998, Newson 1997). An integral part of IWM are two new tools— integrated basin assessments and structured interaction between water managers, experts and stakeholders.

Integrated basin assessment: Problems encountered at the watershed level have many components, some natural, and some social. Problem clusters of this kind can only be untangled by the coordinated effort of multiple disciplines. A study by the National Academy of Sciences finds that science is good at understanding single issue problems, such as acid rain, soil erosion or fisheries depletion, but has failed to elucidate causes, pathways and interactions of complex problem clusters. The study states: "Developing an integrated and place-based understanding of such [complex] threats and options for dealing with them [presents] a central challenge" for science (National Research Council 1999, p. 8).

An integrated assessment is needed to guide the manager through the muddle presented by a complex problem. The Office of Global Change, U.S. Department of Energy, offers the following definition: "An integrated assessment analyzes a complex problem by identifying causes and evaluating impacts. Feedbacks within the system are described, if possible quantified." Oak Ridge National Laboratory adds the policy dimension: "Integrated assessment is a process that can be used to evaluate and clarify resource management policy options and outcomes for decision makers." This is a large order. It entails careful analysis of quantitative and qualitative data from multiple disciplines, construction of an integrated knowledge base, vision about feasible options for action, and imaginative outreach to communities and policymakers. Because the problem mix differs from place to place the assessment must be prepared at the smallest possible geographical scale, i.e. the watershed and its sub-basins. Finally, there must be continuity of the assessment effort, so that assessment institutions can learn over time.

Water scarcity in arid regions represents a perfect example of such a complex problem cluster. Natural stresses include drought, climate variation and change, ecosystem and land degradation, desertification, and salinity build up. These conditions interact with, and are partly caused by, socio-economic stresses resulting from population growth, irrigated agriculture, urbanization, lack of infrastructure, and poor water management. In many instances, there is ample information available on the various components making up the problem cluster. But the total picture remains obscure until the pieces of the puzzle are assembled. Multidisciplinary basin assessments integrate partial information into a holistic database, identify the severity of basin problems and define feasible solutions. The result provides guidance to decision makers.

Structured stakeholder participation: In the past, complex issues were studied and plans for improvements were prepared by groups of experts from government or academia. The people for whom these activities were intended were largely left out of the process. This is no longer acceptable. Nor is it enough to ask for public comment once reports or proposals have been completed. Instead, communication between managers, experts and citizens must accompany the entire project development process. This is an unfamiliar role for scientists. In many parts of the world nongovernmental organizations or other non profit organizations have taken on the role of project conveners. They can organize local knowledge and provide non-threatening leadership. There are many examples of successful expert-stakeholder interactions. Yet most have not gone beyond a particular project where the assessment team conducts a study and is then disbanded. Implementation of IWM entails the additional step of organizing assessment capacity and stakeholder participation as a continuing process within the basin agency.

The two methodologies—assessment and participation—are complementary and re-enforce each other. A participatory integrated basin assessment includes these steps: (1) preparation of a multi-disciplinary assessment of current basin-wide conditions and stresses; (2) consultation with stakeholders about future needs and development options; (3) selection and formulation of scenarios assessing alternative development options, such as likely, high-risk and desirable development; and (4) integration of stress and scenario analysis into policy and management recommendations.

Several international initiatives have advanced the theory and practice of IWM, among them the Dublin Principles (Solanes et al. 1999), Agenda 21 (United Nations 1993), the Helsinki Agreement (1992), and the water policy directive of the European Union (2000). All member countries of the European Union have committed to implementation of IWM over the course of the next decade. The state of California will do the same (California Environmental Protection Agency 2003).

The U.S./Mexico Border

The U.S./Mexico border crosses the entire North American continent, from the Gulf of Mexico to California. There are two large river systems. The Colorado River drains the area west of the Rocky Mountains, and the Rio Grande (called the Río Bravo in Mexico) drains the land east of the Rocky Mountains. Both rivers are shared by international agreements between Mexico and the United States, signed as far back as in 1906 and 1944. While the Colorado marks the international border for less than 50 km, the Rio Grande does so for 1600 km, from El Paso to the Gulf of Mexico. The author's field work, which is reported in this section, takes place in the Rio Grande basin.

The Rio Grande originates in the Rocky Mountains of Colorado (see Figure 1). It is the fifth largest river in North America and the longest river in the world to mark the border between countries at significantly different levels of development. During its entire 3000 km run to the Gulf of Mexico the river crosses arid or semi-arid lands.

From a hydrological point of view, the Rio Grande consists of two distinct segments. The Northern segment (Upper Rio Grande) extends from the headwaters to south of El Paso—a distance of about 1,400 km. The Upper Rio Grande receives its water from snowmelt in the Rocky Mountains. During much of the year, due to scarcity of supply and high consumptive use, the river runs dry South of El Paso. The Southern segment (Lower Rio Grande) depends for its water on tributaries, primarily the Mexican Río Conchos and, to a lesser extent, the American Pecos River (Schmandt 2002).

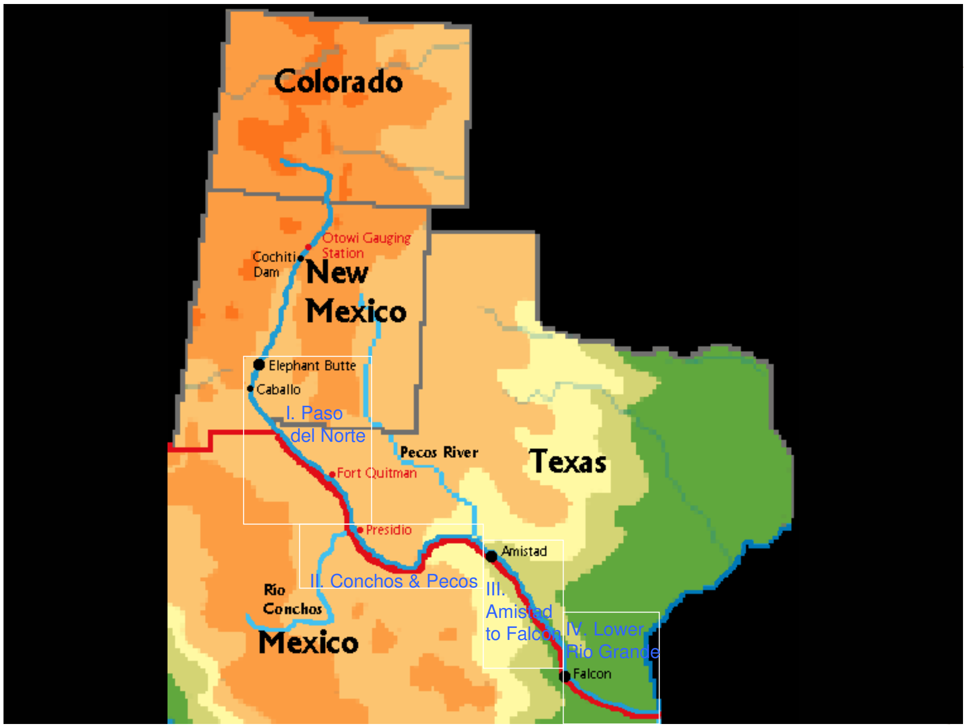

Figure 1. Rio Grande/Río Bravo Basin

Both segments of the river experience water supply problems. According to the International Panel on Climate Change, Rocky Mountains snow pack volume is likely to diminish because of global climate change. For the first time in almost 30 years, the Upper Rio Grande is experiencing a major drought, which is now in its second year. The cause may be the recurrence of a historical drought cycle or an early sign of climate change. In the Lower Rio Grande, contributions from the Río Conchos have fallen behind historical averages for the last ten years. The reasons are complex and not fully understood. They include drought, deforestation, development in the Conchos basin, and internal conflicts between the Mexican federal and state governments. This has caused a serious and continuing water dispute between Mexico and the United States. Nothing of the kind occurred in previous decades. Ground water exists in all parts of the basin, but quality is poor in many places. El Paso and Juárez, the largest twin cities on the border, used to get good quality ground water from the Hueco Bolson. However, both cities over pumped this aquifer, which is likely to run out of good quality water within twenty years. El Paso is responding by building a large desalinization plant, which will come on line in 2006. Because of the cost involved, the Mexican city across the river, Cd. Juárez, is unlikely to follow suite.

The basin drains a huge area from the eastern slopes of the Rocky Mountains to the Gulf of Mexico. The international part of the river basin accounts for ¼ of the total, with 137,412 km² located in the United States and 87,193 km² in Mexico. The climate is arid, and evaporation high. Runoff from rainfall is minimal. Annual rainfall does not exceed 20 cm in part of the basin, while the headwaters and areas close to the Gulf of Mexico may receive 75 cm. Few people lived in the basin until two things happened: air conditioning made the desert climate attractive, and special tax and import provisions attracted industry and workers to the international border. Since the 1950s, the population has doubled every twenty years. By now, the river supports 5 million people, and 10 million will live there by 2020.

Parts of the basin, both in the Upper and Lower Rio Grande, have good soil and a long tradition of making a living from irrigated agriculture. Early in the last century, the U.S. government built the largest dam then in existence in Southern New Mexico. Ever since, Elephant Butte Reservoir has supplied water to farmers in New Mexico, West Texas and across the border in Cd. Juárez, The Rio Grande Project, developed by the U.S. Bureau of Reclamation, is a small version of the large irrigation projects the Bureau later built in California. Downstream in the Lower Rio Grande, Mexico and the United States built two large reservoirs, eliminating floods and supporting irrigated agriculture on both sides of the border.

Options for securing future water supply include conservation, desalinization of brackish ground water, conservation and transfer of agricultural water to urban use. All of them require time, money and changed mindsets. Two examples illustrate the point. Irrigated agriculture uses more then 80 percent of river water. As the urban population grows, farmers may see higher economic benefits from leasing or selling their water rights to the cities than continuing their traditional activities. Restoring in-stream flow will have ecological benefits. Whether they outweigh economic benefits is hotly debated within the region.

To unravel the problem cluster linking water to development in this arid, rapidly growing region our team conducted an integrated assessment of the Lower Rio Grande basin, downstream from Falcón Reservoir (Aguilar-Barajas et al. 2001). The question to be answered was straightforward: Will there be enough water, of acceptable quality, to support the sustainable development of the region to the year 2030? The binational assessment included specialists from hydrology, water quality, ecology, demographics, economic development and water management. In addition, a full time project manager and a project leader with experience in integrative analysis coordinated and integrated the work. This provided the capacity to examine the main drivers of change and stress: population growth, changes in land use, water scarcity, deteriorating water quality, and ecological degradation. The assessment proceeded in three stages: initial scoping of issues and concerns, detailed analysis of major issues and development scenarios, integration and policy recommendations. Throughout the process, water managers and users were consulted. With few exceptions, existing information and population projections were used, even though some data sets from Mexico and the United States were not immediately compatible. The main task was not to generate new data but to interpret and link existing information that had been produced by different disciplines and territorial jurisdictions.

There were several important findings: 1. Irrigated agriculture uses 88 percent of available river water. Improvements in water distribution and use, water metering as well as changes in crop patterns, can maintain current crop yields while reducing water use by 40 percent. 2. Urban and industrial activities use 12 percent of river water. To meet demand of the growing population by 2030 the share for municipal and industrial use must rise to 20 percent. 3. The necessary transfer of agricultural to municipal water can be accomplished by regulatory changes, which will constrain the existing rights of water users. A better solution will be the development of a water market that is at present underdeveloped in the region. 4. The region has already suffered significant damage to aquatic and terrestrial resources. While full restoration is unlikely, governments can still act to prevent further deterioration. 5. Desalinization of brackish groundwater or seawater is not yet cost effective but will be in the near future.

The assessment, completed in 2000, included a number of scenarios to evaluate the severity of possible future events. Two of these contingencies have since materialized—multi-year drought and a dramatic reduction in water delivery from a Rio Grande tributary located in Mexico. The assessment showed that a combination of these two factors would lead to severe water shortages and economic losses. Indeed, farmers on both sides of the border suffered large losses in recent years. As a result, disagreement of this water issue has strained diplomatic relations between Mexico and the United States beyond anything experienced since the water treaties were signed in 1906 and 1944. This illustrates a critical deficiency in water management in the basin. To this day, the engineering model of water management dominates, complicated by the fact that the management regime involves two countries and several states in Mexico and the United States who jealously protect their roles in water management. The U.S.-Mexico water treaty of 1944 mandates the appointment of professional engineers as leaders of the International Border and Water Commission (hereafter: Commission). The treaty also restricts Commission authority to the management of river water. Groundwater is largely unregulated or managed under different rules from one political jurisdiction to the next.

At present, water management institutions in the basin do not have the authority or resources to conduct, or contract for, scientific studies that could guide management. To facilitate the transition to integrated basin management, using sustainability science as a tool, a private group of Mexican and U.S. experts has formulated a two-pronged proposal.

At the basin level, the Commission should be assisted by a binational Basin Council made up of stakeholders, managers, experts and government representatives. The Commission will create a joint assessment office for the conduct of scientific studies and policy analyses. The Council, with support from the science office, will have three tasks: (1) Prepare and update a basin water and development plan; (2) recommend improvements to the water infrastructure; and (3) convene temporary task forces to study urgent issues, such as drought management or groundwater management.

At the sub-basin level—smaller areas that share similar economic and hydrological conditions—water task forces will be created. Membership would include city water utilities, irrigation districts, industrial users and community leaders. Each task force will be responsible for preparing a regional water plan, formulating proposals for action, and addressing specific issues as they may arise. Each regional committee will work with local universities to receive scientific support of its work. Regional committees will work closely with the Basin Council in sharing of information, developing the water plan for the whole basin, and discussing action proposals. A prototype regional water task force has been at work for the last five years in the Las Cruces-El Paso-Ciudad Juárez sub-basin of the Rio Grande (Paso del Norte Water Task Force 2004).

The Murray-Darling Basin

While managers in the Rio Grande have made progress toward better understanding their complex web of water-related problems, they have not yet built the institutions capable of using IWM for dealing with water scarcity. From the author's research to date he concludes that the Murray-Darling Basin Commission in Australia is the world's model for taking this additional step ((Blackmore 1995, Ellway 2002, Gippel 2002, Global Water Partnership 2003, Goss 2002, Murray-Darling Basin Agreement 1992). The Murray is one of Australia's most important waterways, stretching 2,560 km, providing water for half of Australia's commercial agriculture and drinking water for two million people. About 80 percent of the basin lies in arid or semi-arid regions. The basin is shared by five states and covers 14 percent of Australia's land mass.

In 1985, the Murray-Darling Ministerial Council was created with members coming from the federal government, five partner states and the Australia Capital Territory. As its first project the Council conducted a Basin Environmental Resources Study. The study documented widespread degradation of natural resources in the basin. An executive agency, the Murray-Darling Basin Commission (MDBC), was established in 1988. The Commission has the following mission: "Through the Government-community partnership, to foster joint action to achieve the sustainable use of water, land and other environmental resources of the Basin for the national benefit of present and future generations, and to maintain responsible, efficient and cost-effective delivery services of water of agreed quality from the River Murray." A third institution—the Murray-Darling Community Advisory Committee—provides community input. Members of the Committee are appointed by the Ministerial Council.

The problems faced by the Commission are typical of arid regions with growing irrigated agriculture and populations: fierce competition for water, resistance to further land clearing, conflict over who should pay for remediation of the degraded environment, and lack of institutions and consensus for common action. Taking IWM as a guiding strategy the Commission has completed a natural resources management strategy, a basin sustainability plan, and specific project plans, as well as an overall strategic plan. The MDC has used this database to conclude agreements between the States to share water through a water trading scheme. Other measures taken by the Commission have improved salinity management, increased efficiency of water use and imposed temporary water extraction caps. MDBC has a staff of about sixty people and an annual budget of approximately $US35 million. Financial support of the secretariat is provided by the federal government, and all partners contribute to the financing of various management programs.

Conclusion

Water agencies in arid and semi-arid regions can do more with less water by building capacity to perform the tasks of integrated basin management. Integrated assessments will identify the linkages between water and development in the basin and lay the groundwork for stakeholders, experts and officials to jointly develop feasible options for the sustainable management of water and land. Once this is done decisions will be based on a clear picture of how water supply and demand are going to develop over time. Decision makers can use this information to determine a realistic and equitable balance between different uses of scarce water.

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