The U.S.-Mexican Border Environment

Binational Water Management Planning

SCERP Monograph Series, no. 8

A series edited by Paul Ganster

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The Southwest Center for Environmental Research and Policy (SCERP) is a consortium of U.S. and Mexican universities dedicated to addressing environmental issues in the U.S.-Mexican border region through applied research, outreach, and regional capacity building.

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Binational Water Management Planning

Edited by Suzanne Michel

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No. 7 Trade, Energy, and the Environment: Challenges and Opportunities for the Border Region, Now and in 2020

About this volume:
All times are local
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Contents

Foreword
Preface and Acknowledgements
Abbreviations

Executive Summary. Opportunities, Costs, Benefits, and Unintended Consequences: Secure and Sustainable Water by 2020
Resumen Ejecutivo. Oportunidades, Costos, Beneficios y Consecuencias No Intencionales: Agua Segura y Sostenible para el Año 2020
D. Rick Van Schoik 1

I. Managing Border Water to the Year 2020: The Challenge of Sustainable Development
El Manejo del Agua en el Área Fronteriza Hasta el Año 2020: El Reto del Desarrollo Sustentable
Stephen P. Mumme and Ismael Aguilar Barajas 51

II. Interdependent Border Water Supply Issues: The Imperial and Mexicali Valleys
Aspectos de la Interdependencia en el Abasto de Agua en la Frontera: Los Valles de Imperial y Mexicali
Jesús Román Calleros and Jorge Ramírez Hernández 95

III. Meeting the Water Needs of the Border Region: A Growing Challenge for the United States and Mexico
Enfrentando las Necesidades de Agua de la Región Fronteriza: Un Reto Creciente para los Estados Unidos y México
William A. Nitze 145

IV. The Challenge of Balancing Water Supply and Demand in Paso del Norte
El Reto de Equilibrar el Abastecimiento y la Demanda de Agua en el Paso del Norte
Charles Turner, Edwin Hamlyn, and Oscar Ibáñez Hernández 185

V. Water Without Borders: A Look at Water Sharing in the San Diego-Tijuana Region
Agua Sin Fronteras: Una Mirada a la Repartición del Agua en la Región San Diego-Tijuana
Barbara R. Bradley and Emilio de la Fuente 247

VI. Comparative Analysis of Transborder Water Management Strategies: Case Studies on the U.S.-Mexican Border
Análisis Comparativo de Estrategias de la Gestión de Aguas Fronterizas: Estudio de Casos en la Frontera México-Estados Unidos
Christopher Brown, José Luis Castro Ruiz, Nancy Lowery, and Richard Wright 279

VII. Evolving Political Institutions: A New Water Policy and its Impact on the Border Region
Desarrollando Instituciones Políticas: Una Nueva Política del Agua y su Impacto en la Región Fronteriza
Daniel McCool 363

Border Institute IV Participants
Index

Foreword

I was most honored to have been asked to participate in the opening session of Border Institute IV, and was deeply appreciative to my friends at the Southwest Center for Environmental Research and Policy for the kind invitation. When I attended Border Institute II in 2000, I was able to sense the enormous importance of this type of gathering. I remember being especially impressed by the presentations made by several participants on the issues relating to water and its many uses, among others.

My concerns about the border economy and other aspects of development in this region of North America shared by Mexico and the United States goes back more than 20 years. Then I was involved in the early stages of studies that led to the creation of COLEF, the Colegio de la Frontera Norte, as a multidisciplinary center in the social sciences for research and post-graduate teaching. I must confess that I was a little surprised at the recommendation made by the original working group to establish the center in Tijuana, but I soon realized the significance of the proximity of that city to San Diego and other parts of the state of California, and to the many research and university institutions in that area. I am pleased that COLEF has been able to expand its activities along the Mexican side of the border and across to research centers and universities in the other border states of the United States.

At one of the meetings I attended in Colorado, yet another state also related to the border region through its waterways, I argued that at least in environmental matters and by implication in matters concerning water, the notion of the border should not be limited to the 100 kilometers on each side that appears on maps drafted as a result of the La Paz Agreement in the early 1980s. It should go beyond to areas on both sides that relate directly to conditions along the border areas, outside of those artificial limits. I noted that both Monterrey and Corpus Christi are beyond the 100 kilometer "limit."

My own interest in the broader border has led me to focus on a much bigger, encompassing view of the future: the need to promote—in all its different aspects through more intensive cooperation and coordination among institutions, government agencies, and

civil society organizations—a process of sustainable development. By sustainable development I mean not only environmental improvement, but an expanded definition implicit in the original concept put forth in the Brundtland Report—the gradual creation of better conditions of social equity for ever-larger portions of the population and labor force, institutional development to help induce such improvements and conditions, and greater participation of civil society in the whole process under increasingly democratic trends. I am aware that in spite of the lofty declarations on the subject at the United Nations Conference on Environment and Development held at Rio de Janeiro in 1992, and the deluge of statements and further declarations made throughout the world since those days, very little has been achieved, even in narrowly defined environmental conditions. Reports by United Nations agencies and many national and regional reports, as well as the watchdog activities of non-governmental agencies, academic centers, and the media, are constant reminders of the lack of commitment to environmental improvements, let alone to the beginnings of a process of sustainable development. Energy savings, and in particular the limitation of carbon emissions that contribute to global warming, have not gone far enough. Nevertheless, if the future of the human species—and not only the endangered animal and plant species—is to mean anything, all efforts must move decisively and simultaneously in the direction of sustainable development.

The Mexican border region is still lacking in the kind of commitment I have in mind, involving all of the components of the local societies, be they governmental, household, or business activities. Water is evidently a resource that has become less abundant and more expensive to make available to different types of consumers, and I hope Border Institute IV will enhance the understanding and importance of a proper social and environmental valuation of water in all its qualities and forms of sourcing and delivery. I also hope it is not to be taken as an isolated issue but one closely related to other resources and environmental problems. Moreover, it is my expectation that these issues may become more closely interrelated across the many points of contact on the U.S.-Mexican border.

I believe there is a need for a long-term study of the gradual implementation of sustainable development policies on both sides of the border, taking into account, of course, all the current issues already identified, including water, energy, and waste disposal. I don't share the view, held by some scholars in both Mexico and the

United States, that we have a "seamless border," but I think that the basic issues have to be approached through closer cooperation on both sides and a long-term evaluation of benefits for the great border region as a whole.

I am particularly glad to note from a first look at some of the papers presented to this Border Institute IV, that in matters of water policy, a number of important ideas are being put forth, for instance a move from water management as such to river ecosystems management involving a participatory process. Past practices will have to be replaced by innovative management arrangements in which changes will be required on both sides of the border. This should become one of the leading components of a growing and irreversible sustainable development process. As one of the authors says clearly: "Water management in many ways exemplifies the challenge of sustainable development." Thus, water may lead the way, but I believe it is not enough to lead with one resource issue if other resources and sectors fail to follow.

Victor L. Urquidi, former president El Colegio de México
Rio Rico, Arizona, May 6, 2002

Me honra mucho el que se me haya propuesto participar en la sesión de bienvenida de este IV Instituto Fronterizo, y agradezco profundamente a mis amigos del Centro de Investigación y Política Ambiental del Suroeste la amable invitación que me extendieron. Cuando asistí hace dos años al II Instituto Fronterizo en 2000, me percaté de la enorme importancia de este género de reuniones. Recuerdo que me llamaron mucho la atención, entre otras, las ponencias de varios participantes acerca del agua y sus múltiples usos.

Llevo ya más de veinte años interesado en la economía de la región de la frontera y en otros aspectos del desarrollo de estos territorios compartidos por México y Estados Unidos, desde la época en que me tocó participar en estudios preliminares que condujeron a la creación del COLEF, El Colegio de la Frontera Norte, como centro multidisciplinario de las ciencias sociales en materia de investigación y docencia de posgrado. Cuando el grupo de trabajo original propuso que dicho instituto se estableciera en Tijuana, quedé un poco perplejo, pero no tardé en darme cuenta de la significación que

tenía la proximidad a San Diego y a otras partes del estado de California, así como a las muchas instituciones universitarias y de investigación en esa zona. Es satisfactorio comprobar cómo el COLEF ha extendido sus actividades a lo largo de la parte mexicana de la frontera y en contacto además con centros y universidades en los demás estados limítrofes de la Unión Americana.

En una de las reuniones a las que asistí en otro estado de la Unión Americana, Colorado, sostuve que al menos en materia ambiental, y por ende en asuntos referentes al agua, la zona de la frontera no debiera limitarse a los 100 kilómetros de cada lado que aparece en los mapas como resultado del Acuerdo de La Paz de los años ochenta, sino que sería necesario ir más allá de esos límites artificiales en asuntos que se refirieran directamente a las condiciones imperantes en la zona de la frontera. Advertí que Monterrey y Corpus Christi eran ciudades situadas fuera del límite de los 100 kilómetros.

Mi propio interés en los temas de una zona más amplia de frontera me llevaron a considerar una visión más extendida del futuro: la necesidad de promover, en todos sus variados aspectos—por medio de una cooperación y coordinación intensos entre instituciones, dependencias oficiales y organizaciones de la sociedad civil—un proceso de desarrollo sustentable. Por desarrollo sustentable entiendo no sólo el mejoramiento ambiental sino, adoptando una definición ampliada que está implícita en el concepto original propuesto en el Informe Brundtland, la creación gradual de mejores condiciones de equidad social para proporciones cada vez más amplias de la población y de la fuerza de trabajo, con el desarrollo institucional necesario para inducir tales mejoras y tales condiciones, y la participación creciente de la sociedad civil en el proceso general con base en tendencias cada vez más democráticas. Sé bien que no obstante las elevadas declaraciones sobre la materia en la Conferencia de las Naciones Unidas sobre Medio Ambiente y Desarrollo efectuada en Río de Janeiro en 1992, y los torrentes de declaraciones y tomas de posiciones anunciados en todo el mundo desde esa época, es bien poco lo que se ha logrado, aun en las situaciones ambientales concretas que suelen definirse. Los informes de los organismos de las Naciones Unidas y muchos otros de carácter regional y nacional, así como las actividades de vigilancia de las organizaciones no gubernamentales, los centros académicos y los medios de comunicación, nos recuerdan a cada instante que ha habido poco compromiso por mejorar las condiciones ambientales, y mucho menos por emprender un proceso de desarrollo sustentable. A pesar de ello, si nos ha de

importar el futuro de la especie humana—y no sólo el de especies de la fauna y la flora—será necesario dirigir todos los esfuerzos posibles de ma- nera decisiva y simultánea hacia el objetivo del desarrollo sustentable.

La zona mexicana de la frontera no ha adquirido aún el compromiso requerido al que me refiero, que abarque todos los elementos componentes de las sociedades locales, sean autoridades gubernamentales, los hogares o los sectores empresariales. El agua es a todas luces un recurso cada vez más escaso y más costoso si se ha de satisfacer la demanda que puedan ejercer los distintos tipos de consumidores, y espero que este IV Instituto Fronterizo sirva para lograr mayor comprensión y dar mayor importancia a la valoración social y ambiental adecuada del agua en todas sus calidades y formas de obtención y de entrega al consumidor. Espero además que el agua no se considere de manera aislada sino como asunto que deba relacionarse con otros recursos y problemas del ambiente. Más aún, esperaría yo que estos temas se interrelacionen cada vez más a través de los puntos de contacto en la frontera entre los Estados Unidos y México.

Considero que hace falta emprender un estudio a largo plazo de la aplicación gradual de políticas de desarrollo sustentable en ambos lados de la frontera, teniendo en cuenta, por supuesto, todos los temas ya identificados, entre ellos los del agua, la energía y la disposición de desechos. No comparto la idea que algunos académicos sostienen tanto en los Estados Unidos como en México, de que ya te- nemos una frontera sin líneas divisorias; creo sin embargo que los problemas fundamentales deberán abordarse mediante mayor cooperación entre ambas partes y con una evaluación de los beneficios a largo plazo para la gran región de la frontera en su total dimensión.

Me complace en especial advertir al examinar algunos de los trabajos presentados en esta Conferencia que, en materia del agua, se entregan algunas ideas importantes. Por ejemplo, la de que hay que pasar de la administración del agua como tal a la administración de ecosistemas hídricos en que se tenga en cuenta un proceso de participación ciudadana. Las viejas prácticas habrán de reemplazarse por sistemas de administración innovadores, que requieran cambios en uno y otro lado de la frontera. Ello deberá convertirse en uno de los componentes principales de un proceso creciente e irreversible de desarrollo sustentable. Como lo afirma con claridad uno de los autores: “La administración del agua ejemplifica de muchas maneras

el desafío que plantea el desarrollo sustentable." Así, el agua podrá mostrar el camino a seguir, pero a mi juicio no basta abrir brecha con un sólo recurso si los demás recursos y sectores no emprenden el mismo camino.

Victor L. Urquidi, ex presidente de El Colegio de México
6 de Mayo

Preface and Acknowledgements

This volume is the record and substance of Border Institute IV, "Binational Water Management Planning," held in Rio Rico, Arizona, May 6-8, 2002. Since the first Border Institute in 1998, this annual event has established itself as a key venue for consideration of important border environmental issues. The two days of the workshop provide time for directed and wide-ranging discussion among a diverse group of researchers, practitioners, and border stakeholders. Not only are current issues dissected, but also considerable reflection occurs regarding future scenarios in the border region. This, in turn, enriches discussions about near-term policy options.

The border institutes are based on a series of commissioned papers produced by leading scholars and practitioners. These papers, which are sent out to participants prior to of the meetings, provide the informational base upon which the discussions are constructed. These essays form the core of this present volume. Additionally, an executive summary is included that captures key points of the panels and break-out sessions at Border Institute.

Many individuals contributed to the success of Border Institute IV and this volume. Rick Van Schoik, Managing Director of the Southwest Center for Environmental Research and Policy (SCERP), organized the meetings and identified the authors of the papers. He also drafted the first version of the executive summary. The expertise and diligence of the authors who prepared papers for the Border Institute is also acknowledged. The panelists and other participants, especially commissioners Arturo Herrera Solís of the Comisión Internacional de Límites y Aguas and Carlos Ramírez of the International Boundary and Water Commission, were important in setting the tone for the discussions. The facilitators and rapporteurs for the break-out sessions deserve special recognition for their labors, especially Jessica Swartz Amezcua, Christopher Brown, Kimberly Collins, Bob Currey, Denise Moreno Ducheny, Craig Forster, Erik Lee, Nancy Lowery, Suzanne Michel, David Rohy, Paul Rasmussen, Elsa Saxod, Alan Sweedler, and Erin Ward.

Many individuals participated in the production of this book. Amy Conner, SCERP's managing editor of publications, copy-edited and coordinated the production of this volume. Graphic artist Jenny

Carlsson reproduced many of the figures used in the volume. Guillermo Torres Moye, of the Universidad Autónoma de Baja California, provided the Spanish-language translations of the Executive Summary and chapter abstracts. The Center for Strategic and International Studies kindly granted permission for the use of Bill Nitze's key article.

The many SCERP partners who assisted in co-sponsoring Border Institute IV are also acknowledged. The U.S. Environmental Protection Agency (EPA) Office of International Affairs, the Border Trade Alliance, and the U.S.-Mexico Chamber of Commerce all provided valuable assistance. Finally, SCERP wishes to recognize the efforts of its EPA Program Officer, Paul Rasmussen. Paul has done yeoman duty in coordinating EPA participation in the annual border institutes and has provided important suggestions for substantive improvements in the program contents. His enthusiasm has set the positive and collaborative tone that characterizes this annual endeavor.

Paul Ganster
SCERP Monograph Series Editor

Abbreviations

AAC	All-American Canal
af	acre-feet
BECC	Border Environment Cooperation Commission
CEA	Comisión Estatal del Agua
CEC	Commission for Environmental Cooperation
CESPM	Comisión Estatal de Servicios Públicos de Mexicali
CESPT	Comisión Estatal de Servicios Públicos de Tijuana
CNA	Comisión Nacional del Agua
CoAPAES	Comisión de Agua Potable y Alcantarillado del Estado de Sonora
COBRO	Committee on Binational Regional Opportunities
COLEF	El Colegio de la Frontera Norte
cfs	cubic feet per second
EPA	U.S. Environmental Protection Agency
GNEB	Good Neighbor Environmental Board
gpc/d	gallons per capita per day
IBWC-CILA	International Boundary and Water Commission-Comisión Internacional de Límites y Aguas
IID	Imperial Irrigation District
INEGI	Instituto Nacional de Estadística, Geografía e Informática
ITESM	Instituto Tecnológico y de Estudios Superiores de Monterrey
IWTP	International Wastewater Treatment Plant
JMAS	Junta Municipal de Aguas y Saneamiento
km	kilometers
LGEEPA	Ley General del Equilibrio Ecológico y la Protección al Ambiente
MAF	million acre-feet
MGD	million gallons per day
Mm^3	million cubic meters
MWD	Metropolitan Water District of Southern

	California
NADBank	North American Development Bank
NAFTA	North American Free Trade Agreement
NEPA	National Environmental Policy Act
NGO	non-governmental organization
ppm	parts per million
SANDAG	San Diego Association of Governments
SEMARNAT	Secretaría de Medio Ambiente y Recursos Naturales
TDS	total dissolved solids
TEIA	Transboundary Environmental Impact Assessment
TRW	Tijuana River Watershed
USBR	U.S. Bureau of Reclamation
USDA	U.S. Department of Agriculture
USDI	U.S. Department of the Interior

Executive Summary

Opportunities, Costs, Benefits, and Unintended Consequences: Secure and Sustainable Water by 2020

D. Rick Van Schoik

Introduction

Water has emerged as a first-tier issue between the United States and Mexico, a situation that has potentially serious implications for the whole of the bilateral relationship. Border Institute IV, held in Rio Rico, Arizona, from May 6–8, 2002, successfully initiated another level of binational dialogue on border water issues, a necessary first step toward long-term planning and regional sharing of water and water-related resources.

Water management in many ways exemplifies the challenge of sustainable development. As population explodes in the border region, the demand for clean water increases. This increased demand intensifies competition among water users, including the economy, communities, and the environment itself. The challenge is to balance the needs of natural resources—which represent the future—with current demands from the two nations' economies and citizens.

Because border rivers and aquifers are inherently binational and because the institutional capacity to address groundwater issues is lacking, the Institute participants generally agreed that the federal governments of the United States and Mexico should take more proactive roles in addressing border water issues. Even top-level decision makers recognize the need for long-term planning. As the *New York Times* reported on May 24, 2002: "President [Vicente] Fox says Mexico has spent decades squandering what it has 'without planning, without sense.'" Similarly, water use and distribution are less-than-optimally distributed in the United States because water policy is based more upon precedent than principle.

Some efforts by the federal governments to implement river basin planning have been successful at integrating various components of

overall environmental quality. The U.S.-Canadian International Joint Commission (IJC), for example, monitors and regulates water drawn from the Great Lakes. However, long-term planning to meet demand in the United States is confounded by states' rights over groundwater and some surface water, while in Mexico, water is wholly a federal matter. These institutional and jurisdictional "mismatches" clearly necessitate a carefully constructed, high-level resolution by the two nations.

Objectives and Focus of the Border Institute Series

The Southwest Center for Environmental Research and Policy (SCERP) created the Border Institute series in 1998 because it recognized the need for a binational forum that would facilitate environmental policy discussions within the complex framework of Border XXI. SCERP foresaw the potential value of translating the results of scientific investigation into solid environmental policy. Hence, the purpose of the Border Institute series is to convene academics, policymakers, industry leaders, and other border stakeholders in a collegial yet highly work-intensive atmosphere to formulate policy recommendations and devise potential solutions to pressing environmental border problems. Participants are encouraged to focus on the region as a whole and on "the current year plus twenty" horizon, a conceptual two-decade window and landscape scale that foster the development of long-term policy recommendations.

Each Border Institute addresses the policy implications of selected border environmental issues. It must be emphasized, however, that the Institutes are not a series of isolated conferences. Rather, the thematic focus of the Institutes seeks to address border environmental policy problems in a programmatic way. Border Institutes I, II, and III investigated, respectively:

- Demographics and economic development asymmetry across the border
- Environmental infrastructure, natural capitalism, and environmental accounting
- Energy and its interdependencies in the border region

Recommendations from the Border Institutes, in the form of

executive summaries and this volume in the SCERP Monograph Series, are widely disseminated to decision-makers and other border stakeholders. Presentations from Border Institute IV are available online at www.scerp.org.

Overview of Water Issues

There is no more important issue than water. Few substances are as vital to the border's future as water and no subject has dominated the past decades' headlines as the scarcity of water and its human dimensions. Furthermore, water capital on the border to the year 2020 is shaped by two fundamental factors: first, the variable supply of naturally occurring water, and second, the steadily rising water demand. The sources of conflict stem from competition among user groups, as summarized in Figure 1.

Figure 1. Competition among Water User Groups

Upstream Users	–	Downstream Users
Surface Sources	–	Ground Sources
Urban Inhabitants	–	Rural Inhabitants
Economic	–	Environment and Ecology
Agriculture	–	Cities and Industry
Drought Years	–	Normal Years

Source: Author

Other users—including tribal nations, ecological resources, and rural communities—now compete for water of which they were once the sole user. Water is becoming such a major international issue that many foresee serious conflicts emerging from worsening tensions and disputes over this resource.

Water along the International Boundary

Although water in the arid U.S.-Mexican border region has a long history of negotiation and engineering, it remains a highly contentious issue. Water is locked up by treaties, pipes, and channels. The 1944 Treaty for Utilization of Waters of the Colorado and Tijuana Rivers and the Rio Grande still serves as the principal point of reference for the two nations on questions of boundary waters, although many consider it to be too limited in today's context of demographic growth and drastically shrinking supply.

The current binational appropriation structure is a hopeless anachronism. While all recognize the difficulty of changing the treaty, most also realize that it has greater flexibility than many realize and can be used to deal with current and emerging problems.

For water planning purposes, the border region can be divided into three subregions (Figure 2): the western region, which is dominated by the Colorado River watershed (the Californias, western Arizona, and western Sonora); the central region, dominated by no large or single river system (Sonora, Arizona, New Mexico, and western Texas); and the Rio Grande/Río Bravo drainage (eastern New Mexico, Texas, and the four eastern Mexican
border states).

It is important to remember that many tribal nations are also in the border region and that they face important water issues. For example, the very existence of the Cocopah or "People of the River," who once had flourishing communities along the lower Colorado River and delta, is now threatened because of decreasing river flows.

Interdependencies and Discontinuities

Water is connected to nearly all measures of quality of life (human health, environmental processes, ecological integrity, and economic vitality), yet is subject to control by disparate agencies and competing interests. Water quality cannot be divorced even slightly from water quantity, nor can groundwater issues be separated from surface water concerns. Flows of water underneath the border, for example, not only replenish aquifers but can also transport contaminants. Additionally, water is intimately linked with energy, air quality, and economic development issues.

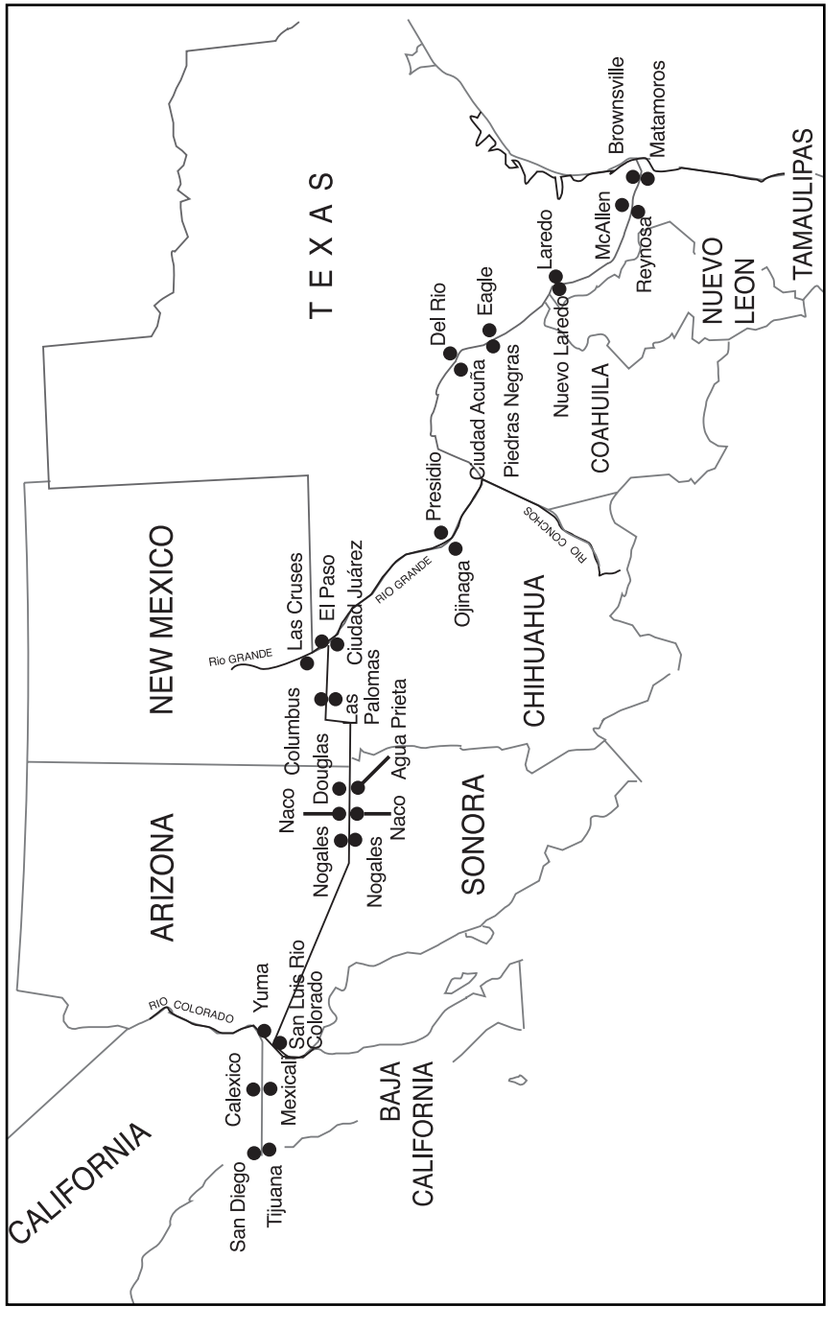


Figure 2. U.S.-Mexican Border

Source: Author

Table 1. Principal Events in the Evolution of Water Management between the United States and Mexico

Year	Event	Objectives
1848	Treaty of Guadalupe Hidalgo	Definition of the international boundary
1889	Convention that created the International Boundary and Water Commission (IBWC)	Observance of the rules of the Boundary Treaties and the Convention in relation to the changes of course in the international rivers
1944	Treaty for Utilization of waters of the Colorado and Tijuana Rivers and of the Rio Grande	Allocated waters of the international rivers between the two countries and extended the functions of the IBWC
1983	Agreement for the Protection and Improvement of the Environment in the Border Area (La Paz Agreement)	Provided formal guidelines for the binational participation of various government levels in the design and implementation of transboundary environmental solutions by specific work groups
1992	Release of the Integrated Environmental Plan for the U.S.-Mexican Border Area (IBEP)	Strengthened enforcement of environmental laws, increased cooperative planning, completed the expansion of wastewater treatment facilities
1993	Creation of the Border Environment Cooperation Commission (BECC) and the North American Development Bank (NADBank)	Assists communities on both sides of the border in coordinating and carrying out environmental infrastructure projects
1996	Release of Border XXI program	Promotes sustainable development in the border region

Source: Christopher Brown, Stephen Mumme, and Mark Spalding

There is a kaleidoscope of jurisdictions on the border. These include hydrological, jurisdictional, and competing sector discontinuities as well as mismatches between the two governments, among the levels of governments, and even within governments. For example, the water supply, water treatment, wastewater treatment, and public health agencies are often separate organizations with different organizational cultures operating in different locations. Institute participants concluded that strategic planning is necessary to get disconnected agencies to connect and march together.

Figure 3. Lower Colorado River System Average Water Budget 1977-1999

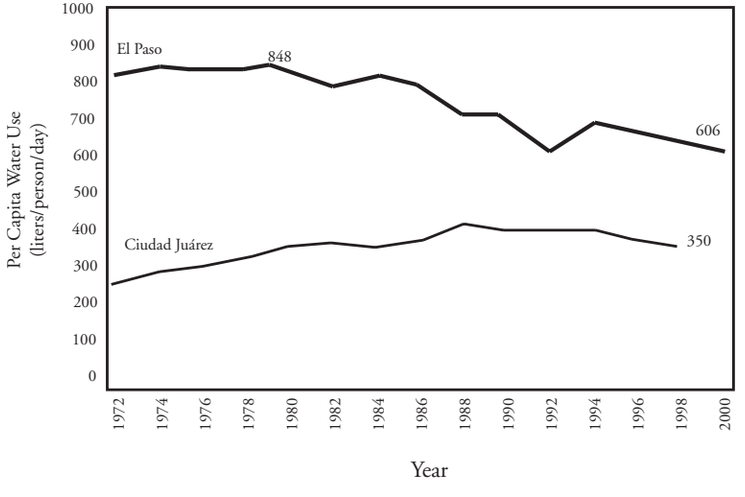
Sources: Jessica Swartz Amezcua and Harry Johnson

There are also unnecessary and potentially damaging links in the 1944 treaty addressing border water issues. The Colorado River and Rio Grande, for example, are linked by mention in the same treaty, yet each possesses different issues and has diverse mechanisms to resolve problems. Furthermore, groundwater is not included in the bilateral treaties between Mexico and the United States.

Past, Present, and Future Trends

While the region has been water-scarce for decades, extreme shortages and higher costs are looming. Historic and current usage patterns reflect the asymmetry in water availability and price. Agricultural use is relatively constant, using between 60% and more than 80% of surface waters while municipal withdrawals range from 10% to 30%, depending on location. However, increased demand for water is being driven by urban growth. Per capita use is higher in the U.S. border cities than Mexican border cities (Figure 4; Figure 5). Likewise, information quality, institutional capacity, and budget size is better on the U.S. side.

Figure 4. Per Capita Water Use Trends in El Paso and Ciudad Juárez



Source: Edwin Hamlyn

Although Ciudad Juárez relies almost solely on groundwater, the allocation of 74 million cubic meters per year (Mm^3/year) of surface waters from the Rio Grande is especially critical. Water demands in Ciudad Juárez are increasing and its source of groundwater, the Hueco Bolsón aquifer, is over-extracted and declining in quality. The impact of increasing water shortages on many dimensions of quality of life will be felt on both sides of the border.

Of course, all water availability is threatened by global climate change. Already, the warmer temperatures have caused greater evapotranspiration and there is some indication that less precipitation occurs regionally in the border zone.

Current Solutions

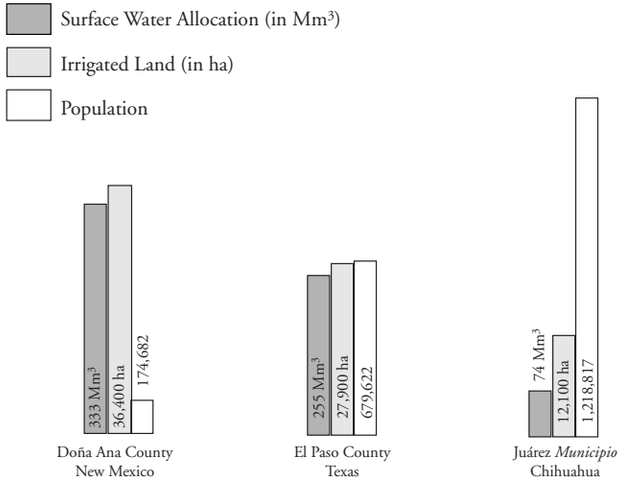
Many engineering and technology solutions to water crises exist. Satellite or decentralized facilities, for example, save money by more effectively addressing local needs, replacing extensive lengths of pipes with less expensive systems, and reducing flow rate fluctuation. Another scenario involves reuse of water within a single community. This option entails re-treating water within a twin-city pair, rather than transferring water over long distances, which often involves high energy and infrastructure costs.

Additionally, current water loss could be reduced on the order of 50% if efficient irrigation practices were applied. Low efficiency in agricultural water management results primarily from the use of gravity irrigation systems, where evaporation and infiltration losses occur through open and unlined channels. The main challenge for the region is to increase irrigation efficiency. The solution is in the introduction of high technology irrigation infrastructure and practices coupled to rational management of water resources under sustainability criteria.

Yet another point of view recognizes that demand for water is absolute and growing, water availability is flexible but shrinking, water prices are variable but related to supply, and water use must be prioritized according to grades, ultimately providing potentially more and sometimes cheaper water to various users. Currently, partial, traditional, and additional treatment of wastewater makes it available for use for groundwater recharge, industry, agriculture, landscaping, and parks. Soon, wastewater will probably be used for cooling new power plants. Any number of grades of water can safe-

ly and economically be used for additional purposes. For example, brackish groundwater may soon be used directly to irrigate some salt-tolerant crops; it may also be treated less expensively than ocean water for general irrigation purposes.

Figure 5. Surface Water Allocation



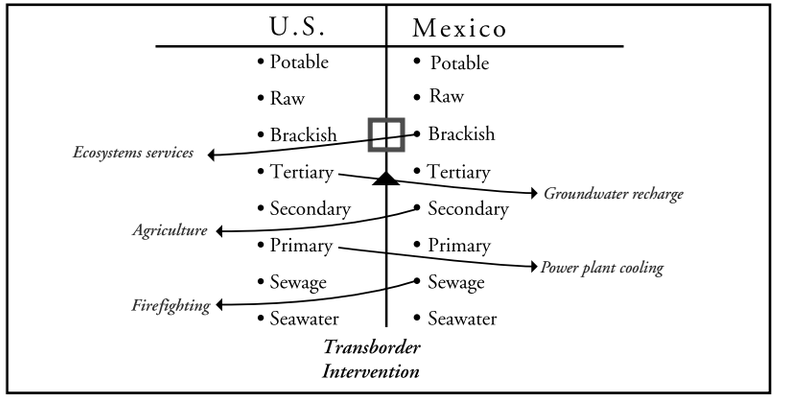
Source: Edwin Hamlyn

It is clear that the opportunity to match and trade across the border exists. The challenge is to motivate current users to make the different grades available for trade. For example, a Mexican farmer should be compensated for saving water (or perhaps temporarily fallowing) and "delivering" the saved water to a broker. The broker, in turn, could sell the water to a farmer in Texas, or to a government agency that wants to restore a habitat (Figure 6). In the year 2000, for example, agencies paid $61 million for just over 397Mm³ of water for habitat restoration. Clearly the possibilities of moving water across the border are many and wasted, reclaimed water can be engineered to serve either side without topographical hindrances and associated costs.

Ideally, wastewater treatment for agriculture should be primary—or no more than secondary—treated wastewater, as this maximizes the fertilizer content while minimizing the concentration of salts.

However, the water should be applied through a drip irrigation system for maximum safety. Although the farmer should bear some of the costs because drip irrigation alone will increase yields, this is a cost that should not be borne by the farmer alone. The current situation should actually be reversed. Instead of the farmer first receiving and using the water, which then gets treated and passed on to the city, clean water from rivers or aquifers should be run through the city, partially treated, and then applied to farmland. Currently, shared aquifer storage and reuse of recycled water represent largely untapped, yet valuable, options. Through injection of aquifers—which are accessible from both sides of the border—recycled water could overcome some of the transport barriers caused by urban development.

Figure 6. Examples of Potential Binational Water Exchanges



Source: SCERP

Since three existing wastewater treatment plants and four future plants in the San Diego-Tijuana region are potential sources of recycled water, several alternatives may emerge for large-scale aquifer storage and reuse. One possibility is to combine plants for conjunctive use resulting in transboundary sharing and multiple benefits. Conjunctive use is the coordinated management of surface, reclaimed, and groundwater supplies. In addition to trades of agricultural drainage and fresh, brackish, ground, and reclaimed water, other potential options for water sharing include binational facilities such as aqueducts, treatment plants, storage facilities, recharge

and extraction systems, desalination plants, and recycling/reclamation plants.

Furthermore, Geographic Information Systems (GIS) can act as a decision-support system by showing spatial water data and temporal projections. Currently, one GIS map is being developed for the Paso del Norte; a preliminary map already exists for the many water flows across the California-Baja California border.

Institutional and Funding Framework

For long-term solutions to border water problems, the current institutional framework and financial mechanisms are inadequate. To illustrate this, participants cited not a water scarcity but an "institutional scarcity." While all agree that revisiting the binational treaties is either unlikely or counterproductive, the existing agency model can be extrapolated to include these tasks.

Although existing institutions can be catalysts for change, they are not yet allowed to be. The International Boundary and Water Commission (IBWC) can incrementally expand its activities to become a process convener and the North American Development Bank (NADBank) has the financial instruments in its low-interest fund to build the necessary conservation projects. Many Border Institutes agreed that this is a good opportunity for NADBank to be relevant. However, the problem is that so few organizations, such as irrigation districts or watershed councils, can handle the scope of the challenge of water management planning, much of which entails promoting conservation. Eleven conservation projects have been proposed but they need sponsors. The NADBank can only do half.

There was a clear consensus among many of the participants that, while states and local entities have important roles to play, much more federal attention is needed to help resolve pressing transboundary water issues. A comprehensive approach to addressing border water issues appears necessary to meet current and future challenges.

The following points made by Institute participants suggest a clear role for the federal governments in binational water management planning:

1. Compacts and treaties allocate the existing interstate surface waters. The IBWC and its Mexican counterpart, Comisión Internacional de Límites y Aguas (CILA) distributes international

surface waters in accord with the treaties. As surface waters are committed, used, degraded, and evaporated, prospective users increasingly look to groundwater as new and permanent sources of less-brackish water. Furthermore, water is drawn from subsurface sources at increasing rates without understanding the consequences or even developing binational or watershed agreements for sustainable use. There is no movement toward limitations on wells, a necessity if dry or salinated wells are to be averted.

2. The 1944 Water Treaty did not discuss groundwater, and there has been little progress since. IBWC, however, is proposing a comprehensive program to assess transboundary aquifers. The Border XXI Program had a framework for assessing contamination of groundwater resources, and hopefully the successor bilateral program, Border 2012, will continue in the same vein. Since many groundwater basins are rapidly being depleted or contaminated, the two nations cannot afford to wait for detailed studies.

3. It is particularly difficult to negotiate groundwater use because groundwater is a property right and an issue dealt with by U.S. states. But it is a federal matter in Mexico. To further complicate matters, there is a disincentive to establish serious dialogue between U.S. and Mexican states, or between the U.S. and Mexican federal governments, since many U.S. and Mexican states compete for water resources.

4. IBWC-CILA has recently shown its adaptability to new challenges and is encouraged to continue to evolve in the near future. Minute 306 on binational technical committees and ecosystems in the lower Rio Colorado is seen by many as a sign of this new direction.

5. IBWC-CILA has recently demonstrated its interest and capacity for dealing with groundwater issues by approaching each of the U.S. states to encourage them to begin their conversations with the Mexican federal government about groundwater agreements. The Mexican Commissioner of CILA, Arturo Herrera Solís, and the U.S. Commissioner of the IBWC, Carlos Ramírez, agree that the respective sections of IBWC-CILA can "extrapolate" from existing models to include assessment, testing, use, and recharge of groundwater as part of their regular activities.

6. Commissioner Herrera recommends that the Mexican federal government:

- Reduce state-to-state competition by allocating groundwaters
- Provide grants to fix water infrastructure leaks and inefficiencies
- Facilitate fee structures as revenue streams to finance bonds

7. Additionally, and significantly, the United States Geological Survey has promoted groundwater issues by proposing the development of a groundwater inventory in conjunction with IBWC-CILA. However, other federal agencies should step up to their roles as binational water management facilitators and leaders.

Interestingly, the federal governments had agreed to do exactly what they have been called to do. At the summit of the new U.S. and Mexican presidents in March 2001, they proposed a binational summit on border water issues. This has not yet materialized.

While many traditional water subsidies are perverse and counterproductive, conservation depends upon a series of positive and negative incentives. An abundance of overly subsidized, overly water-intense irrigation projects are wasting water. Water is grossly underpriced. In many cases the price merely constitutes the cost needed to move the water to the user. The Comisión Nacional del Agua estimates 60% of agricultural water is wasted and between 35% and 53% of municipal water in Mexico is lost through leakage.

Water pricing should be revised to encourage conservation. New development can pay the higher true cost of water while allowing current users to pay only incrementally more immediately, easing the transition to full pricing. "Water is too cheap to conserve," was a refrain heard frequently at Border Institute IV.

Risks of the Status Quo

Significant risk exists if the current situation continues. Indeed, the cost of implementing remedies is significantly less than addressing the long-term consequences of business as usual. Due to the acceleration of water degradation and scarcity, the U.S.-Mexican border region suffers tangible economic costs. It is estimated that:

- More than $1 billion are accrued in health costs
- Nearly $1 billion are lost due to water pollution
- Approximately $1 billion are lost due to decreased recreational and leisure use of water
- Billions of dollars of biodiversity are lost due to habitat destruction

There are 450 plant and animal species native to the region and 700 migratory species are found in the border area. Thirty-one percent of all species in the United States listed by the Department of Interior as threatened or endangered are found in the borderlands. On the Mexican side of the border, 85 species of plants and animals are in danger of extinction. The border region's many parks and wildlife refuges need protection from water transfers that would further jeopardize ecosystem health.

All of the aforementioned add up to serious problems for the region's "bottom line." If left unaddressed, these multiple environmental stresses will ultimately have dire consequences for the region's economic health.

The risks are not just to Mexico, which is running out of water faster than across the border. Water issues in Mexico will "boomerang" back to the United States if they are not addressed, resolved, and indeed, shared. Few want to guess at the full extent of transboundary effects if water becomes too expensive or limited for one sector or country to provide an adequate supply for its buyers and users. If the negotiations for the Transboundary Environmental Impact Assessment (TEIA) were not stalled in Mexico City and Washington, D.C., now would be the best time to expand the scope of TEIA to address such questions as water supply and to mitigate and minimize impacts.

Scenarios for Resolution

Solutions mean addressing the asymmetries and differences across the border. The cultural and socioeconomic impacts of water availability and price must be studied and appreciated for both the U.S. and Mexican sides of the border.

Assuming active roles by the federal governments, solution scenarios are possible. An examination of binational case studies reveals both obstructions to successful water management planning as well as guiding principles. Numerous factors that impede cooperation include inflexible water allocation systems, different legal systems, different economic pressures and financial capabilities, centralized versus decentralized institutional structures, history of water dis-

putes, cultural differences that influence water use, different perspectives, and lack of comprehensive information regarding the water resources of the region. Principles of binational cooperation should rule water issues. One goal should be to build upon the success of local watershed councils and encouraging their capacity through small grants should be goals. Water sharing agreements can be supported by providing a broker and a database of potential buyers and sellers.

The principles leading to binational coordination and cooperation on water use are:

- Exchange of information, technology, and equipment
- Joint use of transfer and storage projects
- Local water exchanges and trades
- Emergency transfers across the border
- Binational approaches to watershed management
- Cooperative transborder groundwater recharge
- Protection of transboundary riparian habitat
- Understanding the differences (economic, perspectives, capacity, etc.) on both sides of the border
- Binational restoration of natural hydrology and flows
- Joint U.S. and Mexican flood control

Success stories discussed at Border Institute IV include the folowing features:

- Local coordinating mechanisms, such as the Border Liaison Mechanism, that enable local and state officials in the border region to talk directly about binational issues
- Joint university initiatives such as SCERP water quality, watershed, and water atlas projects
- The Committee on Binational Regional Opportunities (COBRO), a public advisory committee of the San Diego Association of Governments (SANDAG) that addresses cross-border planning in areas such as environmental management and water supply
- Binational environmental infrastructure such as the international wastewater treatment and reclamation plants at some twin cities
- Recognition that surface and groundwaters are connected
- The creation of transborder *consejos de cuencas*, or watershed councils
- Increased conjunctive use/perpetual reuse

- Alternative negotiation, such as the New Mexico-Texas Water Commission—formed as a result of a litigation settlement between El Paso and several New Mexico entities—to avoid long, expensive, and polarizing lawsuits
- Expansion of bi-state task forces to binational task forces such as the Paso del Norte Water Task Force, which unites water managers, water users, experts, and citizens to work cooperatively to promote a tri-state binational perspective on water issues that impacts the future prosperity and long-term sustainability of the region
- Evolving role of non-governmental organizations (NGOs) such as the Río Bravo/Rio Grande Coalition, whose purpose is to support and strengthen grassroots groups of citizens working to sustain the river basin
- Implementation of Promagua, a program in Mexico designed to attract private investment to water projects via federal subsidies
- Open and transparent processes such as the Citizen Forums program, which was recently implemented by IBWC
- Recognition of states' rights issues by beginning subregional, state-to-state negotiations

Recommendations

Binational Water Management Planning

For far too long there have been calls on both sides of the border for water management planning that is binational, with transparent and transdisciplinary public participation. This also includes the call for comprehensive planning that addresses all the competing sectors in Figure 1, and that is wasteland-based in scale and scope. However, this has not been the reality.

Many NGOs, including academia as independent and science-based facilitators, have tried to catalyze water discussions or agreements among users. The process itself is straightforward. The steps necessary to implement the plan—authorizing the process, convening stakeholders, approving the findings, and funding the bulk of the recommendations—are confounded by jurisdictional mismatches. This underscores the urgent need for the federal governments to play an active, facilitative, and supportive role. Ideally the two nations should grant joint planning authority to an existing

commission. Repeatedly, at Rio Rico and elsewhere, the IJC is cited as a potential model to emulate for reaching consensus about groundwater, water quality, ecosystem services, and other contentious issues. Already the Border Environment Cooperation Commission (BECC)/Comisión de Cooperación Ecológica Fronteriza (COCEF), whose mandate expansion includes water conservation, is investigating such a mechanism at the local level. Ultimately a binational water bank could be created that:

- Provides storage capacity during wet years
- Allots those reserves during dry years
- Adjudicates among potential buyers
- Allocates portions for natural systems and services
- Facilitates the mix and match trade schemes as illustrated in Figure 6

In the area of water quality, approaches such as lagoons, wetlands, and other SCERP-developed techniques hold promise in the border region as alternative wastewater treatment technologies. These alternatives, which require relatively inexpensive land and labor costs, should be recognized as viable options, and planned, funded, and promoted for small-scale applications and for rural and remote settings.

Sourcing, Transfers, and Storage

Because transferring water over long distances from traditional users often has unintended consequences, local water should be used first. The proposal to fallow fields in the Imperial Valley in order to send water to San Diego threatens the viability of the inland Salton Sea, which depends on agricultural drainage flows from Imperial Valley agriculture. Since many cities are depleting their water sources, water transfers are seen as options. However, water transfers should only be authorized for "saved" water and only if all parties, including natural systems, are not harmed.

Groundwater recharge standards are needed to take advantage of reclaimed water. For example, groundwater planning must begin with the understanding that an incurred debt to aquifers must be paid before renewed pumping may begin.

Throughout the U.S.-Mexican border region, water agencies are focusing upon conjunctive use of groundwater as a cost-effective source of water, even in times of drought. Numerous municipalities

are extending their local water supplies by improving brackish groundwater quality, and by blending surface and groundwater supplies. Water agencies are examining the possibility of desalinating groundwater resources with elevated salt levels due to the increasing costs and uncertainties associated with water transfers (particularly from the Colorado River). Since groundwater does not evaporate, groundwater storage is emerging as a vital water banking option to store water during wet years to use during times of drought.

Recommendations for binational water sourcing include:

- Reducing physical losses to the system by seepage, evaporation, and transpiration
- Avoiding contamination of sources that renders them unusable
- Planting less water-intensive and more salt-tolerant crops
- Improving storage, particularly subsurface storage
- Re-plumbing infrastructure to benefit the environmental and ecological systems
- Managing the intensities and durations of droughts

Drought Management

All Border Institute participants agreed that droughts are an opportunity and a call for action for both short-term solutions and long-term strategies. Solutions are available within the context of current and anticipated climate and weather patterns. Water management also requires drought management, which includes setting up municipal reserves in anticipation of severe and extended dry spells. Additionally, mandatory conservation measures should be established during droughts and post-drought assessments should be conducted.

Conservation

Conservation must be a priority for all border planning organizations. The priority has to be water conservation, but that is not currently a mission of existing border institutions. Water savings clearly start with agriculture. On average, agriculture uses 78% of all the water in the region, but all sectors can save. The Mexican government is drafting legislation to productively reorganize irrigation districts and units based on the criteria of efficient water usage and productive competition.

Irrigation districts can make tremendous savings, but these will have their costs. In the border region, most water conservation projects must focus on irrigation systems, which must be funded partial-

ly by grants. It is estimated that the cost of irrigation system improvements for Texas is $400 million and $100 million for the Lower Rio Grande Valley.

Equity Issues

The existing framework is inadequate to define or assure equitable distribution of water. Existing water resources are inequitably distributed across the border and among sectors. Because many groups lack sufficient access to information and institutions, institutions should incorporate various mechanisms to insure their flexibility and accessibility. Solutions to equity issues that should be taken into account to promote sustainable use of resources should include flexible and inclusive binational planning mechanisms; regulated market mechanisms, including creative and flexible water pricing schemes; the reallocation of subsidies; water education; and a leveling of the playing field through capacity building. The recognition that "equitable use" needs rigorous attention to integrate science, environmental justice, and social welfare considerations is a significant research challenge for SCERP and others.

Ecosystems

Transferring water away from natural communities and processes today reduces water quality and quantity for human uses tomorrow. Ecological use of water is recognized by the 1983 La Paz Agreement and later by IBWC-CILA minutes, especially Minute 306 addressing the Lower Colorado River Delta. Advantages offered by natural systems and ecosystem services include flood control, navigation, pollution abatement, climate buffering, and fisheries and other natural habitats for economically important species. The numerous benefits associated with allocating water to the environment include:

- Increased wildlife habitat and biodiversity
- Increased groundwater recharge
- Increased surface and groundwater storage
- Increased economic development potential for communities
- Increased water quality
- Decreased storm water peak discharge rate
- Decreased stream channel erosion
- Decreased frequency of local flooding
- Decreased pollution through cleaning action of riparian vegetation

Perhaps the environment can be better understood as an "in-between" user to store, filter, and move water. The public perception of wastewater needs to shift from that of "waste" to "recyclable."

Database/Knowledge Sharing, Monitoring, and Indicators

The issues need to be quantfied understand and resolve them. Indeed, there is as much disinformation as misinformation about water. Few consistent long-term data sets, along with a need for comparable methods of data analysis, have resulted in data stress. The harmonization of protocols would improve the process of collecting, analyzing, and distributing water data.

Water use indicators are needed to determine how to direct funding for this work, as well as to encourage appropriate sourcing, conservation, sequential reuse, and sharing. Academia is especially good at determining and maintaining data quality; gaining access to governmental or proprietary data; and aggregating up or disaggregating down in scales, both temporal and spatial. Better presentation of existing data is necessary to support border water policy decisions. Although existing data need to be improved and more data collected, Institute participants agreed that decisions should not be delayed due to lack of complete, perfect, or symmetric databases.

Water Education

Water, which traditional cultures have considered sacred since time immemorial, has become transformed into a mere utility. As such, drought education is crucial to sensitize and prepare people to deal with the realities of water scarcity. As competition for water continues to increase (and the cost of exploiting new water resources is often prohibitively expensive) it is imperative to institute water education programs to promote a more realistic and appreciative water-conscious "culture." These programs should involve schools, communities, and the media. Additionally, conservation measures must be shared among all people, including the wealthy, and that water for all sectors—especially for the most vulnerable, including the poor, tribal nations, and the environment—is distributed sensibly and equitably. In essence, the sanctity of water needs to be rediscovered.

Conclusion

Water issues along the border are infinitely complex and include incessantly rising demands; a finite, depleting, and degrading supply; competing sectors; and, in some cases, cumbersome and antiquated regulating institutions on both sides of the border. Because of the interconnectivities and interdependencies of water and other concerns, a solution for one issue often becomes a problem for another. As a result, the U.S.-Mexican border faces unprecedented sustainability challenges. It is time for policymakers on both sides of the border to accept proactively the reality that water scarcity is the norm rather than an anomaly. These challenges underscore the importance of tackling solutions collectively, which is the primary purpose of the Border Institute—to bring together academics, policymakers, industry leaders, and other border stakeholders from both sides of the border to address key issues. Solutions were formulated during Border Institute IV and many of the possible outcomes were elucidated and dissected to avoid unintended consequences.

Because of the sheer complexity of these problems, however, solutions will have to emanate from compromise. At best, solutions should work for all sectors; at worst, they should not harm any. Interdisciplinary and sustainability science—SCERP's aim and mantra—should be at the forefront to ensure long-term solutions.

Whether or not these proposed solutions—however imperfect—after implemented, the United States and Mexico will face consequences. If actions are not taken, many (if not all) sectors will be affected; institutions and individuals will have to change their habits and large sums of money will have to be invested. In short, everyone and all institutions will have to conserve. The 1998 reportings of the first Border Institute were clear: The border population will likely increase by 6.3 million people by 2030. Unless most of the recommendations from Border Institute IV are followed, the burgeoning population will lead to increased demand for water—water that is already inadequate in terms of quantity and quality. The current situation is simply unsustainable. All sectors face untold and irreversible ramifications if border water scarcity is not addressed now. Put simply, the U.S. and Mexican federal governments must take proactive roles and competing sectors must work together to avert environmental, economic, and social disaster.

Resumen Ejecutivo

Oportunidades, Costos, Beneficios y Consecuencias No Intencionales: Agua Segura y Sostenible para el Año 2020

D. Rick Van Schoik

Introducción

El agua ha surgido como uno de los problemas de primer orden entre los Estados Unidos y México, constituyendo una situación que potencialmente puede tener implicaciones serias para la relación bilateral. El IV Instituto Fronterizo, que se llevó a cabo en Río Rico, Arizona, del 6 al 8 de mayo de 2002, exitosamente inició otro nivel del diálogo binacional sobre la problemática del agua fronteriza, lo cual constituye un primer paso necesario hacia la planeación a plazo largo y la compartición regional del agua y los recursos relacionados con el agua.

La gestión del agua ejemplifica en muchas maneras el desafío que presenta el desarrollo sustentable. Conforme crece la población en la región fronteriza, la demanda de grandes cantidades de agua limpia aumenta. Esta mayor demanda intensifica la competencia entre los usuarios del agua, incluyendo la economía, las comunidades y el medio ambiente mismo. El desafío estriba en equilibrar las necesidades de los recursos naturales—que representan el futuro—con las demandas actuales que presentan las economías y los ciudadanos de las dos naciones. El desafío que representa llevar a cabo una planeación mientras se está frente a recursos menguantes es que cambian los tiempos, las poblaciones, las economías y la riqueza, únicamente permanece igual el flujo de agua.

Debido a que los ríos y acuíferos fronterizos son inherentemente binacionales y dado que es insuficiente la capacidad institucional para resolver la problemática relacionada con las aguas freáticas, los participantes en el Instituto acordaron en general que los gobiernos federales de México y los Estados Unidos deben tener un desempeño más proactivo hacia la solución de la problemática del agua fronteriza. Aun quienes tienen el poder de tomar decisiones al más alto

nivel reconocen que existe la necesidad de una planeación a plazo largo. Como reportó el *New York Times* el 24 de mayo de 2002: "El Presidente Fox dijo que México durante décadas ha malgastado lo que tiene 'sin ninguna planeación, sin sentido." De modo parecido, el uso del agua y su distribución se lleva a cabo de una manera que dista mucho de ser la óptima en los Estados Unidos debido a que la política relativa al agua se basa más en precedentes que en principios.

Algunos esfuerzos realizados por los gobiernos federales para implantar una planeación relativa a las cuencas hidrológicas han tenido éxito en cuanto a integrar el desarrollo económico, la calidad ambiental y el bienestar social. La Comisión Conjunta Internacional Estados Unidos-Canadá (IJC, por sus siglas en inglés–International Joint Commission), por ejemplo, monitorea y regula el agua que proviene de los Grandes Lagos. Sin embargo, la planeación a plazo largo para cumplir con la demanda en los Estados Unidos se ve complicada por los derechos de los estados sobre los mantos freáticos y algunos cuerpos de agua superficiales, mientras que en México el agua es completamente un asunto federal. Estos "desfasamientos" institucionales y jurisdiccionales claramente requieren de una solución a alto nivel cuidadosamente elaborada por las dos naciones.

Objetivos y Enfoque de la Serie del Instituto Fronterizo

El Centro de Investigación y Política Ambiental de Suroeste (CIPAS) creó la serie del Instituto Fronterizo en 1998 porque reconoció que existía la necesidad de tener un foro binacional que facilitara las discusiones sobre la política ambiental dentro del marco complejo de Frontera XXI. CIPAS previó el valor potencial de traducir los resultados de la investigación científica a una política ambiental firme. Por lo tanto, el propósito de la serie del Instituto Fronterizo es agrupar a los académicos, a quienes formulan las políticas, a los líderes de la industria y a otros interesados/afectados en la frontera en una atmósfera académica, pero al mismo tiempo conducente al trabajo muy intenso con la finalidad de formular recomendaciones sobre políticas y diseñar soluciones potenciales para los problemas fronterizos más apremiantes. A los participantes se les exhorta a que se enfoquen en la región como un todo y en el horizonte temporal del "año actual más veinte," una ventana conceptual de dos décadas y una escala del entorno que promoverán el

desarrollo de recomendaciones sobre política a largo plazo.

Cada Instituto Fronterizo se aboca a las implicaciones que ciertos problemas ambientales fronterizos selectos tienen sobre las políticas. Sin embargo, debe enfatizarse que los Institutos no son una serie de conferencias aisladas. Más bien, el enfoque temático de los Institutos es buscar, de una manera programática, la solución de problemas en cuanto a la política ambiental fronteriza. Los Institutos Fronterizos del I al III investigaron:

- La asimetría que existe a lo largo de toda la frontera en cuanto a cuestiones demográficas y de desarrollo económico
- La infraestructura ambiental, el capitalismo natural y la contabilidad ambiental
- La energía y sus interdependencias en la región fronteriza, respectivamente

Las recomendaciones del Instituto Fronterizo, a manera de resúmenes ejecutivos y un tomo en la Serie de Monografías del CIPAS, se diseminan ampliamente entre quienes formulan las decisiones y otros interesados/afectados en la región fronteriza. Las presentaciones del IV Instituto Fronterizo se encuentran disponibles en internet en www.scerp.org.

Panorámica de la Problemática del Agua

Ningún tema es más importante que el agua. Pocas sustancias son tan indispensables para el futuro de la frontera como el agua y ningún tema ha dominado los encabezados en las últimas décadas como la escasez de agua y sus dimensiones humanas. Más aun, el capital hidrológico en la frontera en el año 2020 lo conforman dos factores fundamentales: primero, las existencias variables del agua que ocurren de manera natural y, en segundo lugar, la demanda de agua que constantemente va en aumento. Las fuentes del conflicto derivan de la competencia que se da entre grupos de usuarios, como se resume en Figura 1.

Los usuarios no tradicionales—incluyendo las naciones tribales, los recursos ecológicos y las comunidades rurales—ahora compiten por el agua de la cual alguna vez fueron el único usuario. El agua se está convirtiendo en un problema internacional tan grande que se prevee que muchos conflictos graves surgirán al empeorar las tensiones y los conflictos relacionados con este recurso.

Figura 1. Competencia entre Grupos de Usuarios

Los usuarios corriente arriba	– Los usuarios corriente abajo
Las fuentes superficiales	– Las fuentes freáticas
Los habitantes urbanos	– Los habitantes rurales
El motor económico	– El medio ambiente y la ecología
El riego	– Las ciudades y la industria
Los años de sequía	– Los años normales

Fuente: CIPAS

El Agua a Lo Largo de la Frontera Internacional

Aunque el agua en la árida frontera entre México y los Estados Unidos tiene un largo historial de negociaciones y de ingeniería, continúa siendo un tema altamente contencioso. El agua se encuentra encerrada en tratados, tuberías y canales. El Tratado de 1944 para la Utilización de las Aguas del Río Colorado, el Río Tijuana y el Río Grande/Río Bravo aún sirve como el principal punto de referencia para las dos naciones en lo que se refiere a dudas sobre las aguas fronterizas, aunque muchos lo consideran demasiado limitado en el contexto actual de crecimiento demográfico y reducción drástica de las existencias.

La estructura binacional actual para la asignación [de cuotas de agua] es un anacronismo irremediable. Aunque todo el mundo reconoce cuán difícil sería cambiar el Tratado, la mayoría de las personas comprenden que éste tiene mayor flexibilidad de lo que muchos suponen y puede usarse para lidiar con los problemas actuales y los que surjan.

Para el propósito de la planeación sobre el agua, la región fronteriza puede dividirse en tres subregiones: la región occidental, dominada por la cuenca hidrológica del Río Colorado (las Californias, la parte occidental de Arizona y la parte occidental de Sonora); la región central, que no se encuentra dominada por ningún sistema grande ni por un solo río (Sonora, Arizona, Nuevo México y la parte occidental de Texas); y los desagües del Río Grande/Río Bravo (la parte oriental del estado de Nuevo México, el estado de Texas y los cuatro estados orientales de México).

Tabla 1. Eventos Principales en la Evolución de la Gestión del Agua por parte de México y los Estados Unidos

A o	Evento	Objetivo
1848	Tratado de Guadalupe Hidalgo	Definir la l nea internacional
1889	Convenci n que cre la Comisi n Internacional de L mites y Aguas (CILA)	Observar las reglas de los Tratados Fronterizos y la Convenci n en relaci n a los cambios de curso en r os internacionales.
1944	Tratado para la Utilizaci n de las Aguas de los R os Colorado y Tijuana y del R o Bravo	Asignar las aguas de los r os internacionales entre los dos pa ses y ampliaci n de las funciones de la Comisi n.
1983	Acuerdo para la Protecci n y Mejora del Medio Ambiente en la Regi n Fronteriza (Acuerdo de La Paz)	Proporcionar pautas formales para la participaci n binacional de los diferentes niveles de gobierno en el dise o y la implementaci n de soluciones ambientales transfronterizas por grupos de trabajo espec ficos.
1992	Lanzamiento del Plan Ambiental Integrado para la Regi n Fronteriza M xico-Estados Unidos (IBEP, siglas en ingl s)	Fortalecer la ejecuci n de las leyes ambientales, increment la planeaci n en colaboraci n, complet la ampliaci n de las instalaciones para el tratamiento de aguas residuales.
1992	Creaci n de la Junta Ambiental del Buen Vecino (GNEB, siglas en ingl s)	Asesorar al Presidente y al Congreso [de los Estados Unidos] sobre temas relacionados al medio ambiente y la infraestructura.
1993	Creaci n de la Comisi n de Cooperaci n Ecol gica Fronteriza (BECC/COCEF) y el Banco de Desarrollo de Am rica del Norte (BANDAN)	Asistir a las comunidades en ambos lados de la frontera para coordinar y llevar a cabo proyectos de infraestructura ambiental.
1996	Lanzamiento del programa Frontera XXI	Promover el desarrollo sustentable en la frontera.

Fuentes: Christopher P. Brown; Stephen Mumme; Mark Spalding

Es importante recordar que muchas naciones tribales también se encuentran en la región fronteriza y que éstas se enfrentan a importantes problemas relacionados con el agua. Por ejemplo, la existencia misma de los Cucupá o "Gente del Río" quienes en un tiempo tenían comunidades florecientes a lo largo de la parte baja y el delta del Río Colorado, se encuentra amenazada debido a la disminución del caudal del río.

Interdependencias y Discontinuidades

El agua está conectada a casi todas las medidas de la calidad de vida (salud humana, procesos ambientales, integridad ecológica y vitalidad económica) y sin embargo se encuentra sujeta a controles por dependencias desiguales e intereses en competencia. La calidad del agua no puede separarse en lo más mínimo de la cantidad de agua, ni los temas relativos a los mantos freáticos pueden estar separados de las inquietudes relativas a las aguas superficiales. Las corrientes de agua por debajo de la frontera, por ejemplo, no sólo reabastecen los acuíferos sino que también pueden transportar contaminantes. Adicionalmente, el agua se encuentra íntimamente vinculada con la energía, la calidad del aire y temas relativos al desarrollo económico.

Exisle un caleidoscopio de jurisdicciones en la frontera que a menudo se encuentran en conflicto las unas con las otras, en lugar de algún tipo de cooperación para abocarse a la solución de la compleja problemática del agua. Entre ellas se encuentran discontinuidades hidrológicas, jurisdiccionales y de sectores en competencia, así como también los desfasamientos que se dan entre los dos gobiernos, los diferentes niveles de gobierno y aun dentro de los gobiernos mismos. Por ejemplo, las dependencias a cargo del abasto de agua, del tratamiento del agua, del tratamiento de aguas residuales y de la salud pública son a menudo organizaciones separadas con diferentes culturas organizacionales que se encuentran operando en distintos lugares. Los participantes del Instituto concluyeron que se necesita la planeación estratégica para lograr que las dependencias desconectadas se conecten y caminen juntas.

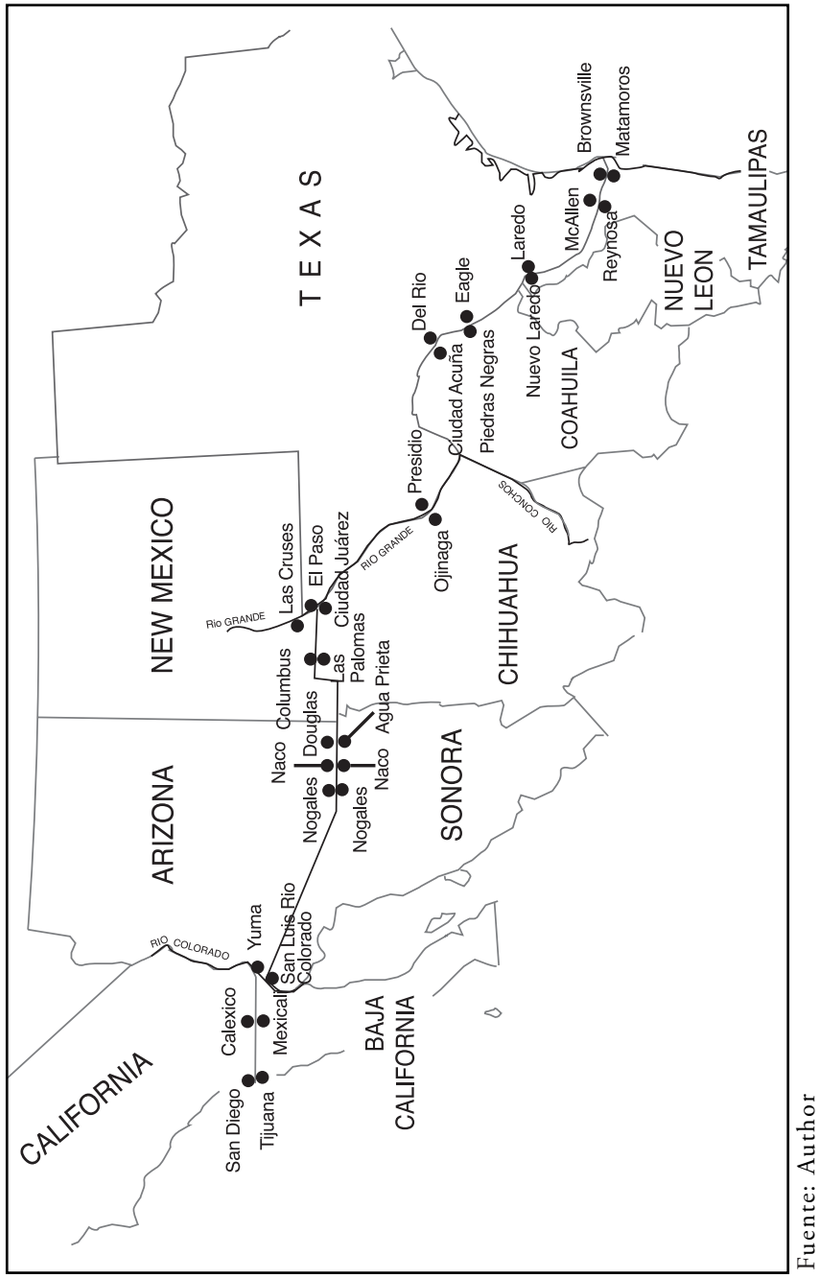


Figura 2. Las Subregiones de la Frontera México-Estados Unidos

Fuente: Author

También existen vínculos innecesarios y potencialmente dañinos en el tratado que trata sobre la problemática del agua en la frontera. Los Ríos Colorado y Bravo, por ejemplo, se encuentran vinculados ya que se les menciona a ambos en el mismo tratado; sin embargo, cada uno presenta problemas sumamente diferentes y tiene mecanismos diversos para la solución de problemas. Más aún, el tema de los mantos freáticos no se encuentra incluido en los tratados bilaterales entre México y los Estados Unidos.

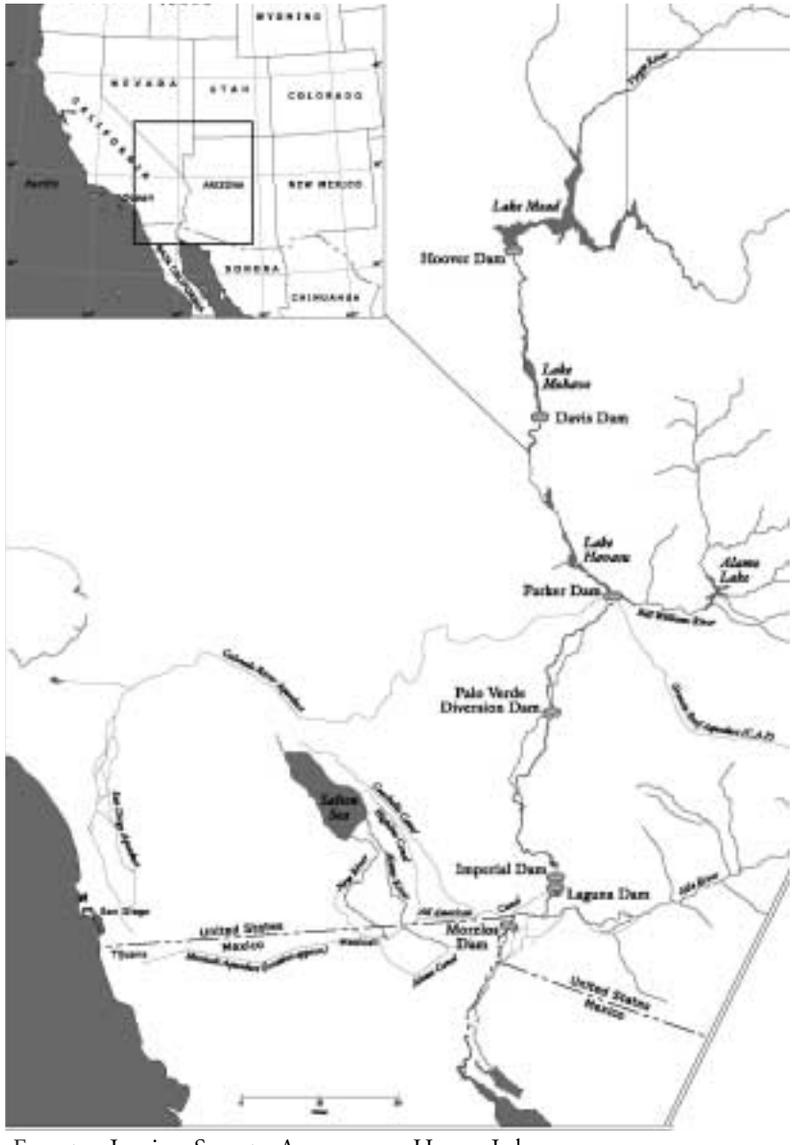
Tendencias Pasadas, Presentes y Futuras

Aunque la región desde hace décadas ha sufrido de escasez de agua, una escasez extrema y costos altos se encuentran en el horizonte, acercándose probablemente a un lado de la frontera más rápidamente que al otro. Los patrones de uso históricos y actuales reflejan la asimetría tanto en la disponibilidad del agua como en su precio. El uso agrícola se encuentra relativamente fijo (utilizando de un 60 a más de un 80 por ciento de las aguas superficiales mientras que el consumo municipal varía de un 10 a un 30 por ciento, dependiendo de la ubicación) y que el incremento en la demanda de agua está siendo impulsado por el crecimiento urbano. El uso per cápita es mayor en las ciudades fronterizas estadounidenses que en las ciudades fronterizas mexicanas. De igual manera, la calidad de la información, la capacidad institucional y el presupuesto son mejores del lado estadounidense.

Aunque Ciudad Juárez depende casi exclusivamente del agua en el subsuelo, la asignación de 74 millones m^3/año de aguas superficiales del Río Colorado es especialmente crítica. La demanda de agua en Ciudad Juárez está aumentando y su fuente de agua subterránea, el acuífero Hueco Bolsón, se está sobreexplotando y está declinando en calidad. El impacto de una escasez de agua cada vez más severa—sobre muchas dimensiones de la calidad de vida—se sentirá en ambos lados de la frontera.

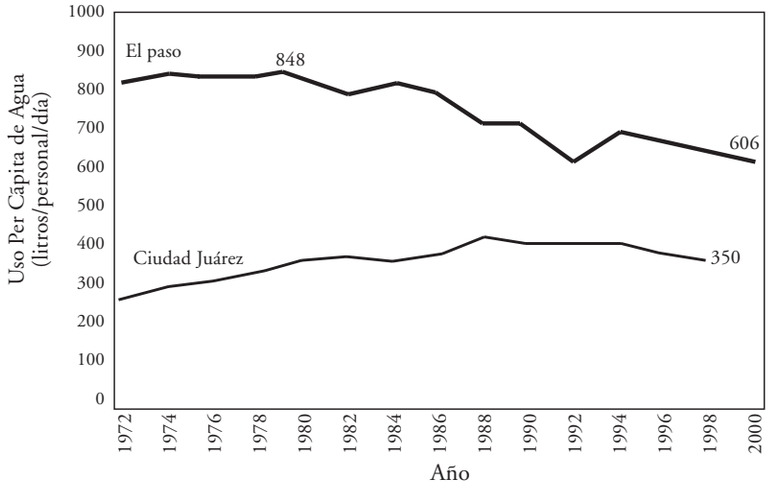
Desde luego que toda la disponibilidad de agua se encuentra amenazada por los cambios globales en el clima. Las temperaturas más cálidas ya han ocasionado mayor evapotranspiración y existen ciertas indicaciones de que a nivel regional hay menos precipitación.

Figura 3. El Sistema de la Parte Baja del Río Colorado Presupuesto Promedio de Agua 1977-1999



Fuente: Jessica Swartz Amezcua y Harry Johnson

Figura 4. Uso Per Cápita de Agua en El Paso y Ciudad Juárez



Fuente: Edwin Hamlyn

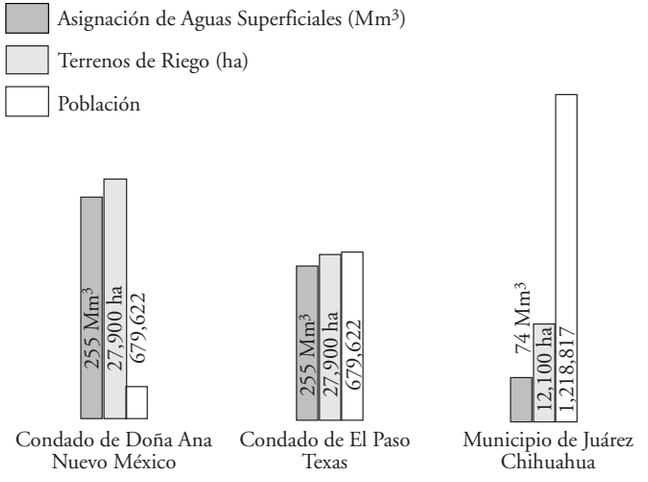
Soluciones Actuales

La ingeniería y la tecnología ofrecen muchas soluciones para la crisis del agua. Las instalaciones satélite o descentralizadas, por ejemplo, ahorran dinero ya que pueden resolver de manera más eficiente las necesidades locales al reemplazar tramos extensos de tuberías con sistemas menos costosos y con una reducción en la fluctuación de la velocidad del caudal. Otro escenario implica el reutilizar el agua dentro de una misma comunidad. Esta solución implica volver a tratar el agua dentro de un par de ciudades gemelas, en lugar de transportar el agua sobre largas distancias que a menudo implica costos elevados de energía y de infraestructura.

Adicionalmente, las pérdidas actuales de agua podrían disminuir en un 50 por ciento si se aplicaran prácticas de riego eficientes. La baja eficiencia en la gestión del agua para usos agrícolas deriva principalmente del uso de sistemas de riego por gravedad, donde se presentan pérdidas por la evaporación y la infiltración a lo largo de

canales abiertos y sin revestimiento. El reto principal para la región estriba en incrementar la eficiencia en el riego. La solución se encuentra en la introducción de una infraestructura y de prácticas de riego de alta tecnología aunadas a un manejo racional de los recursos del agua bajo criterios de sostenibilidad.

Figura 5. Asignación de Aguas Superficiales

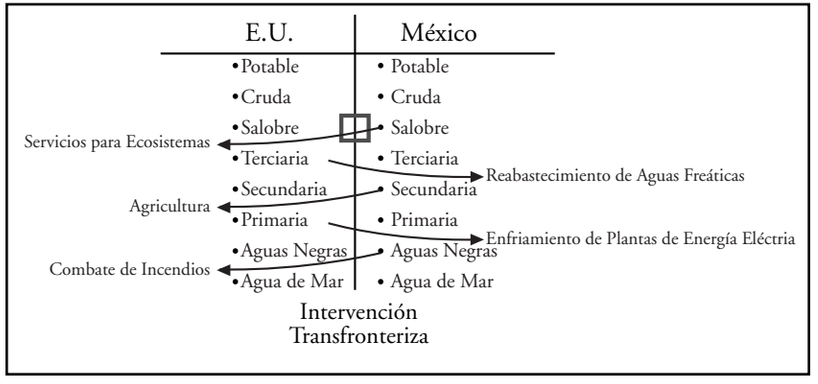


Fuente: Edwin Hamlyn

Aun otro punto de vista reconoce que la demanda de agua es absoluta y crece a diario, que la disponibilidad del agua es flexible pero que cada vez hay menos, que los precios del agua son variables pero que están ligados a la cantidad existente y que se debe realizar una priorización del agua de conformidad con ciertos grados (véase el esquema en Figura 6), logrando así finalmente poder proporcionar más agua y a un costo más barato a varios usuarios. Actualmente, el tratamiento parcial, tradicional y adicional de las aguas residuales hacen que esté disponible para reabastecer los mantos fréaticos, para la industria, la agricultura, la jardinería y los parques. En poco tiempo, el agua residual probablemente se usará para enfriar las nuevas plantas de energía eléctrica. Diferentes grados de agua pueden ser usados de manera segura y económica para propósitos adicionales. Por ejemplo, el agua salobre del subsuelo pronto podrá usarse de manera directa para regar algunos cultivos tolerantes a la sal;

también se le puede tratar a menor costo que el agua del océano para usarse en el riego en general.

Figura 6. Potenciales Intercambios Binacionales de Agua



Fuente: CIPAS

Queda claro que existen oportunidades para que a lo largo de la frontera se pueda encontrar quienes tengan agua de cierto grado y que la quieran intercambiar. El desafío se encuentra en poder motivar a los usuarios actuales a que hagan lo necesario para que los diferentes grados de agua estén disponibles para hacer intercambios. Por ejemplo, a un agricultor mexicano se le debe compensar por ahorrar agua (o quizás por dejar de cultivar temporalmente) y "entregar" el agua que haya ahorrado a un corredor. El corredor, a su vez, podría venderle el agua a un agricultor tejano o a una dependencia de pesquerías y vida silvestre que desee restaurar un hábitat. En el año 2000, por ejemplo, ciertas dependencias pagaron 61 millones de dólares por un poco más de 397 millones m^3 de agua que se uso en la restauración de hábitats. Es evidente que son muchas las posibilidades para transportar el agua al otro lado de la frontera y usando la ingeniería podemos recuperar el agua residual para que sirva a cualquier de los dos lados sin los obstáculos topográficos y los costos asociados.

Idealmente, el agua residual debiera tener tratamiento primario o no más de tratamiento secundario, ya que esto optimiza el contenido fertilizante al mismo tiempo que minimiza la concentración de sales. Sin embargo, el agua deberá aplicarse a través de un sistema de riego por goteo para máxima seguridad. Aunque el agricultor deberá

absorber parte de los costos debido a que la irrigación por goteo por sí sola aumentará el rendimiento, éste es un gasto que no debe sufragar el agricultor solo. La situación actual de hecho debe ser revertida. En lugar de que el agricultor reciba y utilice el agua primero, y que después se le dé tratamiento y luego se le envíe a la ciudad, el agua limpia de los ríos o acuíferos debería primero pasar por la ciudad, ser parcialmente tratada y después utilizarse en la agricultura. Actualmente, el compartir el almacenamiento de los acuíferos y reutilizar agua reciclada representan opciones muy valiosas que en su mayoría no se aprovechan. Por medio de la inyección de acuíferos—que son accesibles desde ambos lados de la frontera—el agua reciclada podría sobreponerse a algunas de las barreras del transporte que ocasiona el desarrollo urbano.

Ya que tres plantas existentes y cuatro plantas futuras en la región de Tijuana-San Diego son fuentes potenciales de agua reciclada, varias alternativas pueden surgir para el almacenaje y reutilización de acuíferos a gran escala. Una posibilidad es el combinar plantas para un uso conjunto que resulte en la compartición transfronteriza y beneficios múltiples. El uso conjunto es la gestión coordinada de las existencias de agua superficial, recuperada y subterránea. Aunado a los intercambios de agua de escurrimiento agrícola, agua fresca, salbre, subterránea y recuperada, otras posibles opciones para la compartición del agua incluyen instalaciones binacionales como acueductos, plantas de tratamiento, instalaciones para el almacenaje, sistemas de reabastecimiento y extracción, plantas desalinizadoras y plantas de reciclamiento y recuperación.

Además, el SIG puede funcionar como un sistema de apoyo a la toma de decisiones al mostrar datos espaciales sobre el agua y proyecciones temporales. Actualmente se está desarrollando un mapa SIG para el Paso del Norte; ya existe un mapa preliminar para los numerosos caudales de agua que cruzan la frontera entre California y Baja California.

Marco Institucional y de Financiamiento

Para las soluciones a plazo largo, el marco institucional y los mecanismos de financiamiento actuales son inadecuados. Para aclarar esto, los participantes citaron no una escasez de agua sino una "escasez institucional." Aunque todos estuvieron de acuerdo en cuanto a que, o era poco probable o podría resultar contraproducente el que se modificaran los tratados binacionales, el modelo exis-

tente de la dependencia podría extrapolarse para incluir estas tareas.

Aunque las instituciones existentes pueden ser catalizadoras del cambio, aún no se les permite serlo. La CILA puede de manera incremental ampliar sus actividades para convertirse en un ente que agrupe el proceso y el BANDAN tiene los instrumentos financieros en su fondo a bajos intereses para construir los proyectos de conservación necesarios. Muchos están de acuerdo y comparten el parecer de que ésta es una buena oportunidad para que el BANDAN tenga trascendencia. El problema, sin embargo, es que son tan pocas las instituciones, tales como distritos de riego o consejos de cuencas hidrológicas, que pueden manejar toda la gama de retos que presenta la planeación para la gestión del agua, gran parte de lo cual involucra el promover la conservación. Se han propuesto once proyectos para la conservación, pero necesitan quien los patrocine. El banco únicamente puede hacer la mitad.

Hubo un consenso general entre muchos de los participantes de que, aunque los estados y las entidades locales tienen papeles importantes que deben desempeñar, se requiere de mucha más atención federal para ayudar a resolver los apremiantes problemas transfronterizos relacionados con el tema del agua. Un enfoque más intergral para tratar la problemática del agua en la frontera es necesario para enfrentar a los desafíos actuales y futuros.

Existe un papel claro que el gobierno federal debe desempeñar en la planeación para la gestión del agua binacional por las siguientes razones:

1. Los acuerdos y tratados asignan las aguas superficiales interestatales existentes mientras que la Comisión Internacional de Límites y Aguas/International Boundary and Water Commission (CILA-IBWC) realiza la asignación de las aguas superficiales internacionales. Conforme se comprometen, utilizan, degradan y evaporan las aguas superficiales, los usuarios probables cada vez más buscan en las aguas subterráneas fuentes nuevas y permanentes de agua menos salobre. Aunado a esto, el agua se extrae de las fuentes subterráneas en cantidades cada vez más grandes, sin saber qué cantidad, sin entender las consecuencias y sin que siquiera se hayan desarrollado acuerdos binacionales o de cuencas hidrológicas en cuanto a su uso. Adicionalmente, no hay ninguna actividad tendiente a limitaciones en cuanto a pozos, lo cual es indispensable si hemos de evitar pozos secos o salados.

2. El Tratado de 1944 no trata el tema del agua en el subsuelo, y desde entonces ha habido poco progreso. La sección estadounidense del IBWC, sin embargo, propone un programa integral para evaluar los acuíferos transfronterizos. Adicionalmente, el Programa Frontera XXI tiene un marco que permite evaluar la contaminación de los recursos en el subsuelo. Ya que muchas cuencas subterráneas se están agotando o contaminando rápidamente, las dos naciones no pueden permitirse el lujo de esperar hasta tener estudios más detallados.

3. Es especialmente difícil negociar el uso del agua subterránea, ya que ésta comprende un derecho de propiedad y es un asunto que queda bajo la jurisdicción de los estados, mientras que en México es un asunto de competencia federal. Para complicar aún más las cosas, existe un desincentivo para que se establezcan diálogos serios entre los estados estadounidenses y los estados mexicanos, o entre los gobiernos federales de México y de los Estados Unidos, ya que muchos estados estadounidenses y mexicanos compiten entre sí por el recurso del agua.

4. La CILA-IBWC recientemente ha dado muestras de su capacidad para adaptarse a nuevos desafíos y se le insta para que continúe evolucionando en el futuro próximo. El Acta 306 que trata sobre los comités técnicos binacionales y los ecosistemas en la parte baja del Río Colorado es considerada por muchos como indicativa de esta nueva dirección.

5. La CILA-IBWC recientemente ha demostrado su interés y capacidad para manejar la problemática relativa a las aguas subterráneas al abordar a cada uno de los estados estadounidenses y exhortarlos a que inicien conversaciones con el gobierno federal mexicano tocante a convenios sobre las aguas en el subsuelo. El Comisionado mexicano de la CILA, Arturo Herrera Solís, y el Comisionado estadounidense del IBWC, Carlos Ramírez, están de acuerdo en que las respectivas secciones de la CILA-IBWC pueden “extrapolar” a partir de modelos existentes para incluir evaluaciones, análisis y reabastecimiento de los mantos freáticos como parte de sus actividades normales.

6. El Comisionado Herrera recomienda que el gobierno mexicano:
   - Reduzca la competencia estado por estado realizando la asignación de las aguas subterráneas

- Proporcione subsidios para arreglar las fugas y las ineficiencias en la infraestructura del agua
- Facilite el que se estructuren cuotas como fuentes de ingresos que permitan el financiamiento de bonos

7. Adicionalmente, y de modo significativo, el Servicio Geológico de los Estados Unidos (USGS, porsus siglas en inglés) ha promovido la temática de los mantos freáticos al proponer que se desarrolle un inventario de aguas subterráneas en conjunto con la CILA-IBWC. No obstante, otras dependencias federales, específicamente el Departamento del Interior (DOI) de los Estados Unidos, deben asumir su función como facilitadores y líderes en la gestión binacional del agua.

Resulta interesante que los gobiernos federales habían aceptado llevar a cabo exactamente lo que se les está exhortado a que realicen. En la reunión cumbre entre los dos nuevos presidentes en el mes de marzo de 2001, ambos propusieron una reunión cumbre binacional sobre la problemática del agua en la frontera. Esto aún no se ha hecho una realidad.

Mientras que muchos subsidios tradicionales conectados con el agua son inadecuados y contraproducentes, la conservación depende de una serie de incentivos positivos y negativos. Una sobre abundancia de proyectos de riego, excesivamente subsidiados, que requieren un excesivo uso intensivo de agua, están desperdiciando el agua. El precio del agua está muy por debajo de su valor real. En muchos casos el precio únicamente cubre el costo de transportar el agua al usuario. La Comisión Nacional del Agua calcula que el 60 por ciento del agua para uso agrícola se desperdicia y entre el 35 y el 53 por ciento del agua para uso municipal en México se pierde.

El precio del agua debe utilizarse para alentar a la conservación. Nuevos desarrollos pueden pagar el verdadero costo más caro del agua, al mismo tiempo que se permite que los usuarios actuales paguen únicamente un aumento incremental de manera inmediata, facilitando así la transición a que se pague el precio completo. “Actualmente el agua es demasiado barata como para que se conserve,” fue una frase que se escuchó frecuentemente durante el IV Instituto Fronterizo.

Los Riesgos del Statu Quo

Existe un riesgo importante, de continuar así la situación. En efecto, el costo que tiene la implementación de correcciones es considerablemente menos que enfrentarse a las consecuencias a plazo largo que tendría el continuar con las cosas como siempre. Debido a la aceleración de la degradación y la escasez de agua, la región fronteriza México-Estados Unidos sufre costos económicos tangibles. Se calcula que:

- Se acumulan más de mil millones de dólares en costos relacionados a la salud
- Casi mil millones de dólares se pierden debido a la contaminación del agua
- Casi mil millones de dólares se pierden debido a la disminución de actividades recreativas y de descanso relacionadas con el agua
- Quizás muchos miles de millones de dólares en biodiversidad se pierden debido a la destrucción de hábitat

Existen 450 especies endémicas de a la región y 700 especies migratorias, por ejemplo, que se encuentran en la región fronteriza. El 31 por ciento de todas las especies en los Estados Unidos que, el DOI ha identificado como amenazadas o en peligro se encuentran en el área de la frontera. Del lado mexicano, 85 especies de plantas y animales se encuentran en peligro de extinción. Adicionalmente, los muchos parques y refugios de vida silvestre que se encuentran en la frontera necesitan que se les proteja de la transferencia de agua. Todo lo anterior da como resultado problemas muy serios para la subsistencia de la región, ya que de no hacer nada al respecto este estrés ambiental múltiple a final de cuentas tendrá consecuencias nefastas para la salud económica de la región.

Los riesgos no existen únicamente para México que se está quedando sin agua más rápidamente que el otro lado. La problemática del agua en México revertirá a los Estados Unidos si no se trata, resuelve y, en efecto, comparte. Pocos desean especular en cuanto a cuál sería la extensión completa de los efectos transfronterizos si el agua se torna demasiado cara o limitada para que un sector o país pueda proporcionar un abasto suficiente para sus compradores. Si las negociaciones en torno a la Evaluación del Impacto Ambiental Transfronterizo (TEIA, por sus siglas en inglés–Transboundary Environmental Impact Assessment) para la

región fronteriza México-Estados Unidos, no se encontrasen atoradas en la Ciudad de México y en Washington, D.C., sería oportuno ampliar el alcance de TEIA para tratar inquietudes tales como el abasto de agua y para mitigar y minimizar los impactos. El TEIA es un convenio entre Canadá, México y los Estados Unidos para la evaluación del impacto ambiental transfronterizo que incluirá disposiciones relativas a la evaluación de impactos ambientales transfronterizos.

Escenarios que Permitirían Llegar a un Acuerdo

Por soluciones se entiende tomar en cuenta las asimetrías y diferencias que existen al otro lado de la frontera. Los impactos culturales y socioeconómicos relativos al precio y disponibilidad del agua deben estudiarse y entenderse plenamente tanto en el lado mexicano de la frontera como el estadounidense.

En el supuesto de que los gobiernos federales adopten desempeños activos, "escenarios de solución" son posibles. Un examen de los estudios de caso binacionales revela tanto obstáculos como planes exitosos para la gestión del agua, así como también principios básicos. Numerosos factores que impiden la colaboración incluyen: sistemas de asignación de agua inflexibles, sistemas jurídicos distintos, diferentes presiones económicas y capacidades financieras, estructuras institucionales centralizadas versus descentralizadas, una historia de disputas sobre el agua, diferencias culturales que influyen sobre el uso del agua, diferentes perspectivas y una falta de información integral sobre los recursos de agua en la región. Los principios de la cooperación binacional deben gobernar la temática del agua y debemos construir sobre los cimientos del éxito que han tenido los consejos locales de cuencas hidrológicas y motivar su capacidad a través de subsidios pequeños. Se pueden apoyar los convenios para compartir el agua proporcionándoles un corredor y una base de datos de posibles compradores y vendedores.

Los principios que conllevan a la coordinación y cooperación binacional sobre el uso del agua son:

- El intercambio de información, tecnología y equipo
- El uso conjunto de proyectos para la conducción y almacenamiento

- Intercambios y canjes de agua
- Transferencias de emergencia al otro lado de la frontera
- La gestión del agua basada en un enfoque de cuenca hidrológica binacional
- La cooperación en el reabastecimiento transfronterizo de los mantos freáticos
- La protección del hábitat ribereño transfronterizo
- La comprensión de las diferencias (económicas, perspectivas, capacidad) a ambos lados de la frontera
- La restauración binacional de la hidrología y los caudales naturales
- El control de inundaciones de manera conjunta por parte de México y los Estados Unidos

Los relatos de éxitos durante el Instituto Fronterizo contienen las siguientes características:

- Mecanismos de coordinación local, tales como el Mecanismo de Enlace Fronterizo, que facilita el que los funcionarios públicos locales y estatales en la región fronteriza puedan discutir directamente problemas binacionales
- Iniciativas universitarias conjuntas tales como los proyectos CIPAS relativos a la calidad del agua, la cuenca hidrológica y el atlas del agua
- La creación del Comité Binacional sobre Oportunidades Regionales (COBRO, por sus siglas en inglés), un comité público de asesoramiento que se aboca a la planeación transfronteriza en áreas tales como la gestión ambiental y el suministro de agua, dentro de la Asociación de Gobiernos de San Diego (SANDAG, por sus siglas en inglés–San Diego Association of Governments)
- Infraestructura ambiental binacional, como por ejemplo las plantas internacionales de tratamiento y recuperación de aguas residuales con que cuentan ciertas ciudades gemelas
- El reconocimiento de que las aguas en el subsuelo y las superficiales se encuentran conectadas
- La creación de Consejos de Cuencas o *Watershed Councils* transfronterizos
- Un incremento en la planeación dirigida al uso en conjunto
- Negociación alternativa como, por ejemplo, la Comisión del Agua Texas-Nuevo México (que se formó como resultado de un convenio de finiquito entre la Ciudad de El Paso y varias

entidades del estado de Nuevo México) que ha logrado evitar demandas judiciales prolongadas, costosas y polarizantes
- Ampliación de los equipos de trabajo biestatales a equipos de trabajo binacionales tales como el Grupo de Trabajo del Agua de Paso del Norte que reune a administradores del agua, usuarios del agua, perítos y ciudadanos para que trabajen de manera cooperativa a fin de promover una perspectiva binacional, triestatal sobre la problemática del agua que impacta la prosperidad futura y la sostenibilidad a plazo largo de la región
- La evolución del papel que desempeñan las ONGs tales como la Coalición del Río Bravo/Río Grande cuyo propósito es apoyar y fortalecer a los grupos de base ciudadana que trabajan para la sustención de la Cuenca del Río Grande/Río Bravo
- La implementación de Promagua, un programa en México que está diseñado para promover la inversión privada en proyectos del agua a través de subsidios federales
- Procesos abiertos y transparentes, como por ejemplo los Foros Ciudadanos que recientemente fueron implementados por la IBWC-CILA
- El reconocimiento de la problemática relativa a los derechos de los estados al iniciar negociaciones subregionales directamente entre estados

Recomendaciones

Planeación para la Gestión del Agua

Durante demasiado tiempo, en ambos lados de la frontera ha existido el llamado a una planeación binacional, transparente y transdisciplinaria con participación del público. Esto incluye el llamado a una planeación integral que comprenda a todos los sectores en competencia (que se indican en la matriz de la Figura 1), y una planeación que, con respecto a la escala y alcance, tenga como base las cuencas hidrológicas. Esto, sin embargo, no ha sido la realidad.

Muchas organizaciones no gubernamentales, incluyendo el sector académico como facilitadores independientes y basados en la ciencia, han tratado de catalizar las discusiones o los convenios sobre el agua entre los usuarios. El proceso en sí es bastante directo. Los pasos necesarios para implementar el plan—la autorización del proceso, el reunir a los respectivos interesados/afectados, aprobar los resultados y el financiamiento del grueso de las recomendaciones—se complica por las disparidades jurisdiccionales. Esto subraya la urgente e inmensa necesidad que existe de que los gobiernos federales desempeñen un papel activo que facilite y apoye. Idealmente las dos naciones deberían otorgar la facultad de realizar una planeación conjunta a un comité ya existente. Repetidas veces, en Rio Rico y otros lugares, al Comité Internacional Conjunto se le ha mencionado como un posible modelo a emular, a fin de llegar a un consenso sobre los mantos freáticos, la calidad del agua y los servicios para los ecosistemas—entre otros temas contenciosos. Ya de por sí la COCEF/BECC (cuyo mandato de expansión incluye la conservación del agua) está investigando un mecanismo tal a nivel local. Finalmente, podría crearse un banco binacional del agua que:
- Proporcione capacidad de almacenamiento durante los años de exceso
- Asigne dichas reservas durante años cortos
- Realice la adjudicación entre posibles compradores
- Asigne proporciones para sistemas naturales y servicios
- Facilite los esquemas de intercambio por medio de equiparación y mezcla que se detallan en Figura 6.

En el área de la calidad del agua, las lagunas, los humedales y otras técnicas desarrolladas por CIPAS, ofrecen cierta promesa en la región fronteriza como tecnologías alternativas para el tratamiento de aguas residuales. Estas alternativas, que requieren terreno y mano de obra a un precio relativamente barato, deben reconocerse como opciones viables, planeadas, subsidiadas y promovidas para ser aplicadas a una escala pequeña así como también para entornos rurales y remotos.

Trasferencia y Almacenaje

Debido a que la trasferencia del agua por largas distancias desde los usuarios tradicionales a menudo tiene consecuencias no deseadas, debe usarse primero el agua local. La propuesta de barbechar los campos en el Valle Imperial para poder enviar agua a San Diego, amenaza la salud y la existencia misma del mar interior debido a que

el Mar Salton depende de los escurrimientos agrícolas que provienen de la agricultura del Valle Imperial. Sin embargo, como muchas ciudades están agotando sus fuentes de agua, las transferencias de agua se consideran opciones viables. Empero, las transferencias de agua únicamente deben autorizarse para el agua "ahorrada" y únicamente si ninguna de las partes, incluyendo los sistemas naturales, resulta afectada adversamente.

Adicionalmente, se requiere de estándares para el reabastecimiento de los mantos freáticos para poder aprovechar el agua recuperada. Por ejemplo, la planeación relativa al agua del subsuelo debe comenzar bajo el entendido de que antes de que pueda reiniciarse el bombeo, primero deberá reintegrarse el agua que se le adeuda a un acuífero.

A través de toda la región fronteriza México-E.U., las dependencias encargadas del agua están concentrándose en el uso en conjunto del agua del subsuelo como una fuente de agua a costo eficiente, aun en tiempos de sequía. Numerosos municipios están incrementando sus fuentes locales de agua al mejorar la calidad del agua subterránea y después mezclar agua superficial con agua del subsuelo. Las dependencias encargadas del agua están estudiando la posibilidad de desalinizar los recursos subterráneos que contienen elevados niveles de sal debido al incremento en los costos y a las incertidumbres inherentes en las transferencias de agua (especialmente provenientes del Río Colorado). Como el agua del subsuelo no se evapora, el almacenamiento del agua en el subsuelo está emergiendo como una opción vital de almacenamiento que permitirá almacenar agua durante años de lluvia y utilizarla en tiempos de sequía.

Las recomendaciones en torno a fuentes binacionales del agua incluyen:

- Reducir las pérdidas físicas que sufre el sistema debido a la trasminación, la evaporación y la transpiración
- Evitar la contaminación de las fuentes que las convierte en inutilizables
- Plantar menos cosechas que requieren un uso intensivo del agua y plantar más cosechas que son tolerantes a la sal
- Mejorar el almacenamiento, especialmente en el subsuelo
- Reconfigurar la infraestructura a fin de beneficiar los sistemas ambientales y ecológicos
- Administrar la intensidad y la duración de las sequías

Gestión de las Sequías

Todos los participantes en el Instituto Fronterizo estuvieron de acuerdo en cuanto a que las sequías representan una oportunidad y un llamado a la acción, tanto para las soluciones a plazo corto como las estrategias a plazo largo. Las soluciones se encuentran disponibles dentro del contexto de los patrones actuales y anticipados del tiempo y el clima. La gestión del agua también requiere la administración de las sequías. La administración de las sequías incluye el conformar reservas municipales en anticipación a y en reconocimiento de la severidad y la duración de las temporadas secas. Adicionalmente, deben establecerse medidas obligatorias de conservación durante las sequías y realizarse evaluaciones depués de las mismas.

Conservación

La conservación debe ser una prioridad para todas las organizaciones fronterizas involucradas en la planeación. La prioridad tiene que ser la conservación del agua pero actualmente esa no es una de las misiones de las instituciones fronterizas existentes. Los ahorros claramente comienzan en el sector agrícola. En promedio, la agricultura utiliza el 78 por ciento de toda el agua en la región, pero todos los sectores pueden ahorrar. El gobierno mexicano está preparando legislación que permita "reorganizar los distritos y unidades de riego de manera productiva con fundamento en los criterios de uso eficiente del agua y competencia productiva."

Los distritos de riego pueden lograr ahorros increíbles, pero estos tendrán sus costos. En la región fronteriza, la mayoría de los proyectos de conservación del agua deben enfocarse en los sistemas de riego y esa prioridad debe trasladarse de nuevo a los sistemas naturales, lo cual requiere cantidades importantes de dinero que deberán provenir parcialmente de subsidios. Se calcula que el costo de las mejoras al sistema de riego del estado de Texas es de 400 millones de dólares y 100 millones de dólares para la parte baja del Valle del Río Bravo.

La Problemática de la Equidad

El marco existente es inadecuado para poder definir o garantizar una distribución equitativa del agua. Los recursos existentes de agua se

encuentran distribuídos de manera no equitativa por toda la frontera y en diferentes sectores. Debido a que muchos grupos no tienen suficiente acceso a la información y a las instituciones, las instituciones deben incorporar diferentes mecanismos para garantizar su flexibilidad y su accesibilidad. Adicionalmente, una diversidad de valores culturales asociados con el agua y su uso, existen en la región fronteriza México-E.U. Las soluciones a esta problemática, que es necesario tomar en cuenta a fin de promover el uso sostenible del recurso, incluyen mecanismos de planeación binacional flexibles e inclusivos; mecanismos de mercado regulados, incluyendo estructuras de precios creativas y flexibles; la reasignación de subsidios; educación sobre el recurso del agua; y el nivelar el campo de juego a través del fortalecimiento institucional. El reconocimiento de que "uso equitativo" requiere de una atención rigurosa para integrar la ciencia, la justicia ambiental y la teoría del bienestar social, lo cual representa para CIPAS y otros organismos de investigación un desafío importante.

Ecosistemas

El transferir el agua, alejándola de sus comunidades y procesos naturales el día de hoy, reduce la calidad y cantidad de agua disponible para uso humano el día de mañana. El uso ecológico lo reconoce el Acuerdo de La Paz de 1983 y posteriormente las actas de la CILA-IBWC; es decir, la 306 referente a la parte baja del delta del Río Colorado. Las ventajas que ofrecen los sistemas naturales y los servicios de ecosistemas, incluyen el control de inundaciones, la navegación, las pesquerías y otros habitats naturales para especies de importancia económica, reducción de la contaminación y amortiguación climatológica. Los numerosos beneficios asociados con la asignación de agua para el medio ambiente incluyen:

- Un incremento en el hábitat y la biodiversidad de la vida silvestre
- Un incremento en el reabastecimiento de los mantos freáticos
- Un incremento en el almacenamiento de agua superficial y subterránea
- Un incremento en el potencial para el desarrollo económico de las comunidades
- Mejor calidad del agua
- Una disminución en la velocidad de la descarga pico de agua pluvial

- Una disminción en la erosión de los cauces de los arroyos
- Una disminución en la frecuencia de las inundaciones locales
- Una disminución en la contaminación a través de la acción limpiadora de la vegetación ribereña

Quizás el medio ambiente puede entenderse mejor como un usuario intermedio que almacena, filtra y transporta el agua. Adicionalmente, la percepción que tiene el público de aguas residuales necesita cambiar del concepto de "residual" a "reciclable."

Compartir Base de Datos/Conocimiento, Monitoreo e Indicadores

Los problemas deben ser cuantificados a fin de poder entenderlos y resolverlos. En efecto, tanto existe la falta de información como la información errada en cuanto al agua. El hecho de que no haya conjuntos de datos consistentes a plazo largo, aunado a la necesidad de que existan métodos comparables de análisis de datos, da como resultado un estrés de datos. La "armonización de protocolos verdaderamente ayudaría al proceso de la recolección, el análisis y la distribución de datos sobre el agua.

Los indicadores del uso del agua son necesarios para determinar cómo dirigir el financiamiento para este trabajo experimental, asi como también para motivar a que se tome el agua de las fuentes apropiadas, alentar la conservación de agua y motivar el reuso secuencial y la repartición. El sector académico es particularmente bueno para la obtención de datos de calidad, para el acceso a datos gubernamentales o datos exclusivos y para la agregación o desagregación en escalas temporales y espaciales. Una mejor presentación de los datos ya existentes es necesaria para poder apoyar las decisiones relativas al agua en la frontera. Aunque es necesario mejorar los datos ya existentes y recolectar más datos, los participantes en el Instituto estuvieron de acuerdo en cuanto a que las decisiones no deben demorarse debido a una falta de bases de datos completas, perfectas o simétricas.

Educación sobre el Agua

El agua, que desde tiempos inmemoriales ha sido considerada sagrada por las culturas tradicionales, se ha convertido en un simple ser-

vicio. Puesto que esta es la situación, es indispensable que a la gente se le eduque sobre las sequías con el propósito de sensibilizar y preparar a las comunidades para que puedan enfrentarse a la espantosa realidad de la escasez de agua. Conforme continúa aumentando la competencia por el agua, (y el costo de explotar nuevas fuentes de agua a menudo es prohibitivamente caro), resulta imperativo instituir programas educativos sobre el tema del agua para promover una "cultura" que sea más realista y que esté consciente de la importancia del agua y su valor. Estos programas deben involucrar a las escuelas, las comunidades y los medios de información. Adicionalmente, necesitamos asegurarnos de que las medidas de conservación se compartan entre todos, incluyendo a la gente acaudalada, y que el agua para todos los sectores—especialmente los más vulnerables, incluyendo a los pobres, las naciones tribales y el medio ambiente—se distribuya con sensatez y equidad. En esencia, lo que necesitamos es volver a descubrir el aspecto sagrado del agua.

Conclusión

La problemática del agua en la región fronteriza es infinitamente compleja e incluye una demanda incesante que aumenta cada día; un abasto finito que cada vez es menos y de menor calidad; sectores en competencia; y, en algunos casos, instituciones reguladoras rígidas y anticuadas en ambos lados de la frontera. Adicionalmente, debido a la interconectividad y la interdependencia que existen entre el agua y otros intereses, la solución de un asunto deriva en un problema para otro. Como resultado, la frontera México-E.U. se enfrenta a retos sin precedente para su sostenibilidad. Ya es hora de que quienes formulan las políticas en ambos lados de la frontera acepten de modo proactivo la realidad de que la escasez de agua es la norma y no una anomalía. Estos retos enfatizan la necesidad de que las soluciones se busquen de manera colectiva—lo cual es el propósito fundamental del Instituto Fronterizo—reunir al sector académico, a quienes formulan las políticas, a los líderes de la industria y a otros interesados/afectados de ambos lados de la frontera para abocarse a los problemas principales. Se formularon soluciones durante el IV Instituto Fronterizo y muchos de los posibles resultados se dilucidaron y se analizaron minuciosamente para evitar consecuencias no intencionales.

Debido a la absoluta complejidad de estos problemas, las soluciones tendrán que provenir de concesiones mutuas. En el mejor de los casos, las soluciones deberán funcionar en todos los sectores; en el peor de los casos, no deben perjudicar a ninguno de ellos. Una ciencia interdisciplinaria con un enfoque en la sostenibilidad—la meta y el mantra de CIPAS—debe estar en primer plano para garantizar soluciones a plazo largo.

Independientemente de que implementemos estas soluciones propuestas—no importa cuán imperfectas sean—México y los Estados Unidos habrán de enfrentarse a consecuencias. Si sí actuamos, algunos (si no es que todos los) sectores se verán afectados; las instituciones y los individuos tendrán que cambiar sus hábitos y grandes cantidades de dinero tendrán que invertirse. En resumidas cuentas, todos y todas las instituciones tendrán que conservar. Empero, si no actuamos, nuestra situación—ya de por sí en modalidad de crisis—degenerará aún más. Los informes de 1998 del primer Instituto Fronterizo fueron muy claros. De continuar la tendencia actual, la población fronteriza probablemente se incrementará en unos 6.3 millones de personas en el año 2030. A menos que se sigan la mayoría de las recomendaciones del IV Instituto Fronterizo, la población creciente necesariamente resultará en una mayor demanda de agua—agua que ya de por sí es inadecuada en cuanto a cantidad y calidad. La situación actual es simple y sencillamente insostenible. Todos los sectores se enfrentan a ramificaciones inimaginables e irreversibles si la escasez del agua en la frontera no se resuelve ahora. Muy llanamente, los gobiernos federales de México y de los Estados Unidos deben adoptar desempeños proactivos y los sectores en competencia deben trabajar juntos para evitar un desastre ambiental, económico y social.

I

Managing Border Water to the Year 2020: The Challenge of Sustainable Development

Stephen P. Mumme and Ismael Aguilar Barajas

Abstract

The demand for water today outpaces the available water supply in many regions on both sides of the U.S.-Mexican border. Nearly 60 years of institutional development has created a complex matrix of jurisdictions and practices that, allowing even for the most recent reforms, remains deficient for advancing sustainable development. Policy is still fundamentally national, driven by sovereign concerns, and coordinated binationally at the federal level. However, the benefits of water are binational and have synergistic effects. As a result, binational cooperation is fundamental for the sustainable development of water as a resource. The framework for allocating and planning is insufficient for dealing with the sustainable development of water resources in the next 20 years. Almost all renewable water resources in northern Mexico are already being used at maximum capacity. Water use in Mexico will double within the next 20 years. During the same period in El Paso, the municipal-industrial use of water is projected to increase 30%, which is indicative of the rapid increase in consumption on the U.S. side of the border. Water transfers from agriculture are unavoidable.

Although the 1944 U.S.-Mexico Water Treaty allots water quantities for each country, it is inadequate in dealing with long-term drought, the management of groundwater, ecological needs, and water quality. New binational institutions struggle in dealing with the complexities of multiple jurisdictions and the competing goals of binational, national, tribal, state, and municipal agencies charged with water management. The binational water planning system provides limited capacity for fashioning cooperative, long-term binational policy responses to systemic, border-wide water challenges. Sovereignty is both an opportunity and an obstacle in attaining sustainable development. Innovative solutions to address drought, groundwater, and ecology require strong support by federal governments.

The foundations of the 1944 Water Treaty need to be strengthened in order to manage drought, groundwater, and ecological uses of water. Priorities need to be established through Border XXI and subsequent border programs. The capacities of the Border Environment Cooperation Commission (BECC) and North American Development Bank (NADBank) need to be reinforced while still maintaining their transparency and ability to respond to problems. These programs need more funding and an even greater focus on sustainable development. At the binational level, coordination of strategic planning needs to improve.

Sustainable development should be more than just a vision—it should work. The sustainable use of water resources in the border region is only possible through binational cooperation. Although it would be difficult to develop an all-encompassing border water plan, the use of watershed management principles in decision-making would enable the two countries to make progress toward this goal. Market-based solutions should contribute to watershed management.

El Manejo del Agua en el Área Fronteriza Hasta el Año 2020: El Reto del Desarrollo Sustentable

Stephen P. Mumme y Ismael Aguilar Barajas

Resumen

La demanda para el agua ahora supera al surtido de la misma en muchas regiones en ambos lados de la frontera. El agua se debe de manejar de una manera sustentable si la frontera será prospera en las próximas dos décadas. El manejo del agua en la zona fronteriza es administrado por grupos complejos de instituciones nacionales y binacionales que tienen objetivos de soberanía. Pero los beneficios del agua son binacionales y tienen efectos sinergéticos. Por lo tanto, la cooperación binacional es fundamental para el desarrollo sustentable del agua como recurso. El marco de la asignación y planeación no es suficiente para el reto del desarrollo sustentable del agua como recurso en los próximos 20 años. Casi todos los recursos renovables del agua en el norte de México ya están siendo usados a su máxima capacidad. El uso del agua en México se duplicará en 20 años. El uso municipal-industrial en El Paso se incrementará el 30 por ciento durante la misma etapa, lo cual es evidencia de un rápido incremento en el consumo en la región fronteriza del lado norteamericano. Las transferencias de agua de la agricultura no se pueden evitar.

Aunque el venerable tratado de 1944 sobre el agua preserva las cantidades de agua para cada país, no es suficiente para tratar una sequía de largo plazo, el manejo del agua subterránea, las necesidades ecológicas, y la calidad del agua. Nuevas instituciones binacionales tienen problemas por la complejidad de la múltiples jurisdicciones y por las metas diferentes de las agencias binacionales, nacionales, tribales, estatales y municipales sobre el manejo del agua. El sistema binacional de la planeación sobre el agua nos deja

con una capacidad limitada para construir respuestas binacionales, cooperativas, y de largo plazo a los retos sobre el agua en la frontera. La soberanía es una oportunidad y también un obstáculo para lograr el desarrollo sustentable. Soluciones innovadores sobre la sequía, el agua subterránea, y la ecología requieren un fuerte apoyo de parte de los gobiernos federales.

Hay que reforzar las bases del Tratado para manejar la sequía, el agua subterránea, y los usos ecológicos del agua. Hay que establecer las prioridades dentro del programa Frontera XXI; reforzar la capacidad del Comisión de Cooperación Ecológica Fronteriza (COCEF) y Banco de Desarrollo de América del Norte (BANDAN) mientras se preserva su capacidad para responder a los problemas y preservar su transparencia; también hay que enfocarse en el desarrollo sustentable, y reforzar el apoyo financiero para estos programas. Hay que mejorar la coordinación de la planeación estratégica que ya existen a nivel binacional.

El desarrollo sustentable debe de ser más que una visión, debe de funcionar. El uso sustentable de los recursos hidráulicos fronterizos solamente es posible por medio de la cooperación binacional. Aunque sería difícil lograr un plan fronterizo global para el desarrollo del agua, el uso de los principios del manejo de las cuencas en la toma de decisiones hará posible que los dos países avancen hacía esa meta. Soluciones basadas en el mercado deben de contribuir al manejo de las cuencas.

Introduction

Few resources are as vital to the U.S.-Mexican border's future as water. Along the border from Texas and Tamaulipas to California and Baja, no subject has dominated the past decade's headlines like water, or more accurately, the scarcity of water and its human dimensions.

The border is an arid region. Its wettest zone, the Lower Rio Grande Valley, rarely sees more than 21 inches of annual rainfall; its driest years average less than five inches. The border region also saw some of the fastest human settlement growth in North America in the 1990s. Placing these facts side-by-side, it seems counterintuitive

to argue that the rapid development of the border area is fueled by an abundant water supply. Yet that is the prevailing perception. And from the manicured turf of hundreds of golf greens to the galvanized roofs of thousands of maquiladoras, it is certainly a problem that must be dealt with today.

On both sides of the border communities are running out of water; this would be the case even if these areas had not been experiencing persistent, sustained drought for the last several years (Gleick 2002). The border's explosion in human settlements, climate and social attractions, historic role as a breadbasket for North America, and comparative advantage as a crossroads for trade and investment combine to place unprecedented stress on its limited water supplies. Moreover, as consumptive demands have cumulated, norms and values related to water and its multiple uses have also changed. More is expected today of the water supply than at any time in history. Water is valued not simply as the draught of life for the material essentials it ensures or the recreational values that enhance life's quality, but as sustenance for a seamless ecosystem, a web of life that links the border to the Yukon and Northwest Territories to the north, to Chiapas in the south, and beyond.

Today it is recognized as never before the myriad ways water affects lives and the world around them—the many ways water sustains. That is why, now, 11 years since the United Nations Conference on Environment and Development in Rio de Janeiro, conservationists are compelled to frame the border's multiplying challenges in managing its limited water supply as a problem of sustainable development. As for the first part of this concept—sustainability—there should be no doubt that in an arid region water is the most essential resource and managing it to ensure its adequacy in the present and its availability in the future is the responsible thing to do. Water is certainly a sustaining resource. And sustaining and perfecting its use is the essential task of development; indeed, this may well be an acceptable definition of development.

In the border zone, when the multiple uses of water are taken into account, it is increasingly difficult to deny that these are binational in scope and synergistic in effect. Both geography and economy make this true. The water resources of the border region are geographically organized in vast watersheds of rivers—including the

Tijuana, the Colorado, the Santa Cruz, the San Pedro, the Mimbres, the Conchos, the Pecos, the San Juan, and the Rio Grande—virtually all of which are international in scope. The human societies located astride these folds and conduits are increasingly part of an equally vast stream of trade and commerce and the resources they use are North American and global in origin and distribution. As Mexico and the United States accelerate the pace of economic integration, the border region has been thrust to center stage and made more interdependent than ever. The growth and development of the national economies in the border region has become ever more tightly linked. In this context, management decisions for water resources are no longer truly sovereign, for while they may yet be sovereign in execution they are most certainly not sovereign in their effects. The unintended or neglected effects of failing to account for the externalities of local management decisions impedes development and restricts the capacity to make better use of the limited resources available.

From this perspective, which is both a sustainability perspective and a binational perspective, the fundamental challenge in achieving sustainable water use in the border area is one of avoiding the human tendency to exhaust the common resource through isolated, abstracted decisions. Institutional practices that produce such results must be modified, conservation must become a priority, and better use must be made of resources across a wide panorama of human and ecological needs. These aims must be achieved through greater binational cooperation at the economic, political, and institutional levels.

At the binational level, it has often been said that the system in place for managing international rivers and water resources symbolizes a mutual capacity for resolving otherwise contentious issues peaceably; in many ways, this has been the case (Friedkin 1967). However, a cautionary note must be sounded. While the architecture of binational allocation and planning has served both countries for more than 50 years, it is no longer sufficient to ensure sustainable development in this new century, nor does it adequately incorporate non-traditional stakeholders in border water decision-making. The 2002 U.S.-Mexican water deficit dispute affords a stark lesson in this regard.

To better understand the basis for these preoccupations and the challenges of strengthening cooperative approaches to the sustainable use of water resources on the border, it is useful to trace briefly the current situation in water availability and use, and sketch the role and reach of binational institutions now in place along the border. The intention here is not to replicate the more detailed work subsequent chapters will offer, but rather to identify some of the important challenges of sustainability that lie ahead and highlight certain institutional options that the United States and Mexico, separately or in concert, should consider in striving to satisfy these needs and demands.

Border Water Availability and Use Trends to the Year 2020

Water capital on the border to the year 2020 is shaped by two fundamental factors: the variable supply of naturally occurring water and the steadily rising water demand driven by human settlements and economic growth in the border area. On the supply side, if naturally occurring rainfall is the measure, it has been known for quite a while that earlier precipitation estimates for the region's major catchment basins were overgenerous. The extraction of naturally occurring groundwater is no panacea, as most known groundwater basins are currently at risk of overdraft. Thus, net supply is lower than anticipated at the middle of the 20th century, creating a supply problem even if long-term climate trends were not expected to reduce precipitation in the next quarter century. Various supply enhancement options exist, ranging from water conservation and groundwater infusion to cloud seeding, desalinization, and water importation (Wood 2002), but until recently these options have proven inordinately costly in regulatory or monetary terms. This may be changing, but the simple truth is that the end of the reclamation era of big dams and storage projects, now more than a quarter century past (Western Policy Review Advisory Commission 1999), spelled the end of easy solutions to augmenting border water supplies.

On the demand side, the growth of border cities, the satisfaction of indigenous water rights claims, and the emergence of non-tradi-

tional demands is competing with irrigated agriculture for border water as never before. In northern Mexico, nearly all water that can be extracted from renewable resources is now being extracted (INEGI 1999). While 87% of all water consumed in northern Mexico is used by agriculture, an increasing volume, 13%, is consumed by municipal-industrial uses (Instituto Nacional de Estadística, Geografía e Informática [INEGI] 1999). The industrialization of Mexican border cities means steadily rising per capita demand as the population multiplies at remarkable rates (Westerhoff 2000). Multiplying annual liters consumed per capita in 1995 by the medium population projections for 1995 and 2020 used by Peach and Williams shows Mexican border water consumption should double. Expectations are that it will rise from 1.07 billion annual liters consumed per capita in 1995 to 2.35 billion annual liters consumed per capita by 2020—an increase of nearly 120% even if current rates of consumption hold constant, which is unlikely (Peach 2000; Westerhoff 2000). In Ciudad Juárez, for example, the Paso del Norte Task Force projects municipal and industrial demand will rise from 151,000 acre-feet (af) annually in 2000 to 301,000af annually in 2020 (Paso del Norte Water Task Force 2001). Satisfying this burgeoning demand is a major challenge for water authorities. While in the past increasing the efficiency of urban water use could increase supply, Mexican border cities are now operating at relatively high levels of water-use efficiency, foreclosing this water conservation mechanism in the near future (INEGI 1999). There is now little margin for avoiding direct transfers from agricultural to municipal uses as urban demand grows.

These dynamics raise important questions about the proper valuation of water among uses and users. Mexico, for example, is just now confronting critical questions about measuring the real cost of water provision, social and economic tradeoffs associated with particular subsidies, and the provision of data central to tackling these issues. Without a clear valuation of the costs and benefits of alternative policies, designing an economically sound and financially sustainable water system is simply not possible. However, Mexico's Water Consulting Council is taking on these questions in order to properly advise the Comisión Nacional del Agua (CNA).

The picture is similar on the U.S. side. Population-wise, U.S.

border states are among the fastest growing in the country, with Arizona and New Mexico registering double-digit growth between 1995 and 2000 (Western Policy Review Advisory Commission 1999). Five of the 10 fastest growing U.S. cities are border cities (Western Policy Review Advisory Commission 1999). The U.S. Geological Survey reports that in U.S. western states between 1960 and 1990, irrigated agriculture consumed 86% of the total water supply, with domestic and industrial uses accounting for just 10% (Western Policy Review Advisory Commission 1999). Per capita municipal water use is not growing as quickly as in Mexico, but it is 41% greater than per capita water consumption in Mexican border cities (Westerhoff 2000). In the case of El Paso, the Paso del Norte Task Force foresees a 30% increase in municipal and industrial water use by 2020 (Paso del Norte Water Task Force 2001). These trends, when seen in the light of rapid urban population growth, exert significant pressure on existing supplies, particularly on irrigated agriculture. Statistics show a net decline in irrigated agriculture in all border states except California between 1982 and 1997, which supports existing evidence that transferring water from agriculture to urban uses is unavoidable and already occurring (Lorey 1993).

These multiple and burgeoning demands on border-area water resources have practically eliminated any institutional slack in border water management. In response, communities border-wide are redoubling their efforts to secure adequate water supplies. In the Imperial Valley, conservation measures in place for a decade are the basis for securing water uses while satisfying the competing claims of Southern California's water-thirsty coastal cities. An Interior Department-brokered arrangement between lower Colorado River users mandates greater efficiencies in U.S. downstream water use, practically eliminating surplus flows for 15 years. In El Paso, where fresh groundwater is rapidly depleting, city officials are shifting to greater dependence on limited Rio Grande surface stocks while investigating a range of complex augmentation and conservation measures including desalinizing groundwater, remote imports, and a groundwater management agreement with Mexico.

Such demands are testing the institutional framework for binational water management as never before, at once amplifying the imperative of binational cooperation while highlighting the com-

plexities of doing so. Differences in national governance and policy structures coupled with the rigidities and frailties of binational water management institutions complicate the process of building sustainable water management practices at the border. It is worth a moment to review this architecture and the difficulties it presents before moving to an issue-specific review of the border water management challenges for the next 20 years.

Binational Governance and Water Resources on the Border

The institutional fabric of binational water management is a rich tapestry of domestic statutes and international agreements reflecting the different and shared histories of each country. In both countries, these institutions evolved over time, producing a mix of jurisdictions, agencies, commitments, and practices designed to capture and deliver water for national development and to protect and preserve public health. Subsequently, other institutions emerged with mandates for environmental protection. In many ways these institutions have served us well. They are not, however, a coherent, harmonized, or well-integrated policy that can be readily mobilized in the enterprise of sustainable development.

The evidence is found at every tier of the system. At the domestic level, for instance, the institutions could not be more different. Mexican water management is centralized, federal, and predicated on administrative and proprietary principles that concede a greater interest to the state in managing water resources. Recent trends toward privatization and decentralization have modified—not replaced—these tendencies. The U.S. tradition—which gives federal jurisdiction to matters of navigation, commerce, defense, and regional development—places fundamental control over water in the hands of the separate states and, by extension, private holders of water rights. This federal arrangement, in addition to supporting a decentralized water policy system, has also encouraged a multi-sectoral and administratively segmented approach to water management at the national and state levels.

Binational water management institutions reflect these differences. The most important framework document for border water

management is the 1944 U.S.-Mexico Water Treaty. This document is largely an allocation document aimed at securing and defending national water endowments. Without going into its details, it is fair to say its provisions adequately reflect the state of water management along the border at the time it was written, as evidenced by the fact that it is not a comprehensive document but one that segments water resources by basins (the Colorado, the Rio Grande, and the Tijuana). As such, it reflects the priorities and the influence of the various political localities along the border with a stake in the development of each river's water resources. That certain water resources were neglected by its terms may be attributed in part to the desire of subsidiary bodies (in this case, U.S. basin states) to hedge their bets and make the most of uncertainty and complexity in the hope of gaining control over additional water resources.

The 1944 treaty is also archaic. Its Article 3 priorities failed to anticipate important contemporary water concerns, reflecting a preoccupation with old-style development, industry, and agriculture—not sustainable development. Its drought provisions arguably failed to anticipate or arrange for an adequate response to long-term drought and climate change.

The treaty also established a management system that directly reflects the power of decentralized interests as well as the institutional infighting among big U.S. water agencies. In 1945, the International Boundary and Water Commission (IBWC) and its Mexican counterpart, Comisión Internacional de Límites y Aguas (CILA), or, "that Texas state agency" as one New York congressmen used to call it, was located on the border, not the beltway, reflecting the power of U.S. regional interests. IBWC was endowed with infrastructure development functions that in Mexico remained in the hands of lead domestic water agencies, not with CILA. This situation is reflected in the official responses to drought in the past decade where most conservation options fall outside CILA's jurisdiction and, technically at least, beyond the scope of the 1944 treaty. The U.S. border states made certain they had a body they could control, not one located in the U.S. Department of the Interior that would be beholden to the entire western region or, as the U.S. Army Corps of Engineers does, cater to the U.S. eastern seaboard and the Mississippi basin.

At the level of endowment defense, the 1944 treaty has performed the role both countries more or less expected it to perform. The treaty framework, however, was less adaptable to emerging and contemporary concerns for sustainable development. Its very intractability as a mechanism for dealing with transboundary water pollution led to the La Paz Agreement. The La Paz framework, which commits the two countries to a process of cooperation in dealing with border environment concerns, including those related to water, directly takes into account the fragmentation of water policy at the federal and subnational levels, aiming less at substantive results than simply establishing venues in which different agencies from each country can exchange information and intercede with national and international counterparts in a cooperative manner that at least appears to be responsive to public stakeholders. The Border XXI Program was crafted atop this framework to provide an overarching strategic vision and binational commitment to the broader values of sustainable development. It is worth noting that the term "sustainable development" does not appear in the 1983 La Paz Agreement, but is a major theme and general objective in the Border XXI Program, the 1993 BECC-NADBank agreement, and the 1993 North American Agreement on Environmental Cooperation.

Much the same may be said of BECC and NADBank, agencies that are driven by the North American Free Trade Agreement (NAFTA). The 1944 treaty, while providing a mechanism for developing solutions to binational sanitation and sewage problems, proved much too narrow for addressing a wide range of border water infrastructure needs. The 1993 BECC-NADBank agreement is innovative in stipulating that "sustainable development" must be a criterion for authorization of BECC-NADBank projects and in that particular sense it links these projects to a larger vision of sustainability for the border. However, the development of BECC's projects is far from programmatic. Like earlier institutions, BECC's binational mandate for border infrastructure provision is designed to fit atop the particular needs and policy mechanics of border localities fitted into the welter of national and subnational jurisdictions in play in any particular part of the border region. While its mandate reaches to functional areas in water management beyond the scope of earlier agreements, its operational structure is predicated on national

administrative differences, jurisdictional complexities, and the decentralized patterns of governance found in the border zone.

In sum, nearly 60 years of institutional development has created a complex matrix of jurisdictions and practices that, allowing even for the most recent reforms, remains deficient for advancing sustainable development. Policy is still fundamentally national, driven by sovereign concerns, and coordinated binationally at the federal level. Water priorities are set in an ad hoc manner and water disputes resolved in similar fashion. Jurisdictions at all levels overlap and compete. Both formal practice and economic trends favor consumption over savings and investment in the mix of development factors. Water policy instruments are not comprehensive and often conflict with economic, fiscal, agricultural, and urban development policies, which adds to public confusion over what national, sectoral, and regional priorities really are, as is evident in the heated binational debate over the Rio Grande water deficit.

These attributes of the binational water management system have created a limited capacity for fashioning cooperative, long-term, binational policy responses to systemic, border-wide water challenges. A host of problems—including adjustments in the balance of consumptive uses, managing climate-induced water scarcity, and sustaining regional ecosystems—can only be dealt with in the most ad hoc fashion by government and the market, given present political and policy limitations. Mexico's most recent national environmental plan, for example, admits that despite the institutional improvements in national environmental management, the country has pursued an unsustainable route toward development (Programa de Medio Ambiente 2001).

It is unrealistic to suppose these structural realities will not continue to define the context for binational water management well into this century, and resist best efforts to advance the agenda of sustainable development of border water resources. Given the circumstances, promoting sustainable development seems destined to be more of a bottom-up and incremental process than a centrally driven, rational-comprehensive one. However, recent events have brought into focus the need to deal with several compelling challenges. Dealing with these challenges cannot, and should not, be done in a mutually exclusive way, since the solution to any one challenge is likely to be implicated in solutions to others.

Challenges in Achieving Sustainable Development in Border Water Management

Moving toward sustainability in binational water management along the border means dealing more effectively with a range of issues at the top of the binational agenda. These include finding ways to manage or cope with prolonged drought, allocating and managing groundwater in a more sustainable and cooperative way, accommodating non-traditional demands for water resources, and maintaining water quality. It also means strengthening the capacity for binational strategic planning in managing border water resources.

Persistent, Prolonged Drought

The specter of prolonged drought is now here. Unfortunately, the institutional capacity to deal with acute protracted drought is limited under the 1944 treaty and other existing institutional mechanisms. Clear relief along the Rio Grande—where shortages on tributary streams like the Río Conchos have already fired tensions in binational relations—has appeared.

The problem of Mexico's water deficit on the Rio Grande points to several enduring deficiencies in the framework for dealing with climate-induced water scarcity. The first arises from the treaty's framework for rationing water under circumstances of "extraordinary drought." The treaty, in the case of the Rio Grande, stipulates a rationing scheme for extraordinary drought based on five-year cycles. It allows debtors to repay creditors, if they also agree to the scheme, in the next cycle for arrears incurred in the first. The difficulty with this formula, as recently seen, arises when debtors lack the capacity to repay their arrears in the second cycle. Under these circumstances, debtors might well choose to approach creditors for a further rollover of their arrears, which Mexico has done recently. Creditors, of course, may justly demand repayment, which the United States has done, or may agree to rollover the debt to another cycle.

The merit of this scheme is its flexibility, providing at least a limited mechanism for adjustment and cooperation when hydrological and political circumstances allow. Its demerits arise from the fact that the cycles are essentially political and not based on hydraulic realities. Excepting the proviso that a new cycle must be declared if

U.S. conservation capacity in the two major downstream dams—Amistad and Falcon—is met (Water Treaty 1944), there is no reference or mechanism for adjusting national expectations to hydrological realities. The outcomes remain zero-sum within a specified temporal context, enhancing the prospects for conflict. Conflicts under this system may be expected in at least two circumstances that are not mutually exclusive: First, when the scope of drought affects the entire basin, establishing a generalized sense of scarcity that affects both debtor and creditor; and second, when the duration of a drought exceeds the 10-year timeline the treaty provides for normal repayment. (That the treaty formula is highly political is evident in the U.S.-Mexican dispute over the baseline for initiating the system of cycles in the early 1950s).

Those familiar with the Rio Grande drought situation will also rightly point to the dramatic increment in regional water demand, the need for better water conservation, and other social pressures that have steadily reduced those surpluses that in the past might have cushioned a debtor's ability to repay under the treaty's provisions. Solving this problem with demand-side solutions, even allowing for near-term implementation of efficient water management and new technology, may take years, the provisions for which are not in the treaty. (IBWC-CILA Minute 293 [1995] and Minute 307 [2001] commit the two countries to technical cooperation and data-sharing in seeking a solution to the Mexican water debt- and drought-based shortages on the Rio Grande.)

A second, long-recognized, problem is related to the treaty's failure to establish the meaning of "extraordinary drought," which is mentioned in the document with reference to both the Rio Grande and the Colorado. While the recent negotiations on Mexico's water debt—reflected in IBWC's Minutes 293 and 307—clearly respond to the treaty's terms in Article 4 paragraph B, which establish contingency in the event of "extraordinary drought," it is fascinating that neither agreement formally acknowledges that fact (IBWC-CILA 1995 and 2001). Part of the problem may be related to the fact that the protocols for responding to "extraordinary drought" differ from one basin to another. Thus, the provisions for coping with drought on the Rio Grande differ from those on the Colorado, a situation that derives from the different hydrological and political realities that influenced treaty framers in allocating waters in each of these

basins.

Yet, the failure to arrive at an accepted definition of the concept of "extraordinary drought" introduces considerable uncertainty into the reckoning of drought conditions and responses, further politicizing national and binational responses to drought situations (IBWC-CILA 1995 and 2001). The failure to make reference to extraordinary drought in Minutes 293 and 307 could be interpreted as allowing an extrapolation from the circumstances of the recent drought in the Conchos to construct a definition of the concept. Alternatively, it could be interpreted as allowing the implementation of provisions in Article 4, paragraph B, in the case of what might be called "normal" drought. At present, many Mexicans, including Mexico's Secretaría de Relaciones Exteriores (its Foreign Ministry), view the concept of "extraordinary drought" as adequate justification to avoid covering the current deficit.

As the two nations have grappled with the problem of the Mexican water debt, some progress has been made. Under Minutes 293 and 307, for instance, the United States and Mexico have agreed to share important technical data on water availability and management and to "work jointly to identify measures of cooperation on drought management and sustainable management" of the Rio Grande river basin (IBWC-CILA 1995 and 2001). Outside these agreements important progress has been made toward providing technical assistance on water conservation. But serious problems remain. Absent a definition of "extraordinary drought," each drought situation will be determined on a case-by-case basis, as Minutes 203 and 307 provide no specific guidance on handling future droughts. There has, as yet, been no effort to extrapolate the 1944 treaty to address the problem of drought in border-wide strategic planning terms.

It seems obvious a good deal more could and should be done. Working within the treaty's framework, the IBWC's capacity to serve as a clearinghouse and coordinator of binational drought management efforts might be strengthened. The Commission for Environmental Cooperation (CEC) already serves as coordinator of the Border XXI binational interagency water task force and could build upon this mechanism to develop a drought contingency planning group or related body to consider responses to drought emergencies. While much of the effort to deal with drought unavoidably falls on federal and subnational bodies in each country, the CEC could spearhead efforts to better articulate binational-, federal-, and state-level planning. The two countries should move expeditiously to clarify the meaning of the "extraordinary drought" clauses within the treaty and should link that definition to new protocols dealing with climate change.

Any broad-gauged and sustainable solution to binational drought management has to be based on better conservation of water resources in the border region. Many of these conservation options lie outside the narrow scope of the treaty, though they are complementary to it. Programs and agencies such as Border XXI, CEC, and BECC and NADBank have important roles to play in supporting and assisting border water managers as they pursue water conservation initiatives. Other recent federal and state programs, such as the border-wide binational GIS system and the Border Environmental Indicators database, will provide valuable assessment and prognostic tools that are essential to informing and coordinating regional drought response. Complicating this picture, however, is the fact that the headwaters of major river basins extend well outside the administrative zones for the Border XXI Program, and BECC and NADBank.

In sum, an agenda of sustainable development must begin to take the prospect of drought seriously. Climatic and socio-economic circumstances now appear to be converging in ways that suggest more frequent and more acute droughts are likely and may aggravate the social impact of drought. As decentralized as water management is along the border, there is little doubt the federal governments will need to take the lead in orchestrating systematic responses to binational cooperation in mitigating the effects of prolonged drought. With heightened attention to national security now strengthening federal prerogative, now is the time to grapple with this issue. It is not too broad a stretch to argue that the national security of both countries depends on more effective binational cooperation in this area.

This point cannot be over-stressed. Despite the border region's known vulnerability to periodic drought, no formal mechanism for drought management currently exists in the border area. While

Texas has recently passed legislation mandating development of a state-wide drought management plan, the process is in its initial stages. A comprehensive, border-wide evaluation of the sectoral and intersectoral impacts of drought, an essential precondition for responding to drought emergencies, has yet to be done. This is also the view of Mexico's latest urban development program, which highlights the urgent need for post-evaluation of drought mitigation measures. As well, Mexico's national water program expresses concern for the devastating impacts of prolonged droughts but specifies no policy responses.

Groundwater Management

The 1944 Water Treaty's failure to allocate or otherwise prescribe an approach to managing border groundwater is often considered one of the most important lacunaes in border water management. While groundwater has figured in the balance of border water use for more than a century—considering Native American and frontier dependence on springs and bogs—it is now a critical source of supply for urban and agricultural water interests all along the border zone. More border cities are blending groundwater with surface supplies to improve water quality. Some cities, El Paso and Ciudad Juárez, for instance, are critically reliant on groundwater to satisfy municipal water needs. Even high-tech solutions to inland water supply problems—desalinization being just one—may depend on the extraction of groundwater in various border localities. Groundwater storage is also emerging as a vital water banking option as conservation schemes in various localities look to infusion as a means of augmenting and safeguarding water supplies.

The sustainable management of border groundwater requires binational cooperation on both allocating and conserving groundwater stocks. Although no formal agreements have been reached in allocating border groundwater since the IBWC's Minute 242 set limits on pumping in the San Luis Río Colorado zone and recognized the need for a binational understanding on groundwater, some binational progress has been made in the past decade. The IBWC, in cooperation with federal, state, and municipal agencies on both sides of the border, is spearheading the technical assessment of groundwater basins, which is essential if the two countries are to

cooperate in managing shared groundwater basins. In fact, IBWC's Strategic Plan made groundwater investigations its first strategic objective under the Transboundary Cooperation category. Much remains to be done in understanding the quantity, quality, and hydrodynamics of most groundwater basins on the border. Border XXI provides a framework for identification and remediation of potential threats to groundwater quality. The evolution of state-level regulation, as seen in Arizona, is a positive development, as are basin-specific initiatives such as the Paso del Norte Watershed Council (U.S. Good Neighbor Environmental Board [GNEB] 2000).

Unfortunately, the demands on border groundwater resources are such that some of these basins may be badly depleted or contaminated by the time the two countries are prepared to reach an agreement. Complicating matters is the enduring ambiguity of whether the 1944 treaty actually extends to the settlement of groundwater questions as the IBWC's Minute 242 clearly implies, or whether an entirely new agreement or set of agreements would need to be reached on groundwater questions, as some experts would argue needs to be done. While these allocative issues are thorny, the two countries need not wait to make moves to protect groundwater stocks and storage basins from the threat of point-source and nonpoint pollution and to conserve the resource for urban and agricultural use.

Non-Traditional Uses and Claimants

The notion of non-traditional water uses may well be a misnomer. As transboundary water has been allocated, however, various uses fall into this category. Traditional water uses, if the 1944 Water Treaty's stipulated order of uses is the cardinal example, include domestic and municipal, agricultural, hydroelectrical, industrial, navigational, and certain limited recreational uses of water. Nontraditional uses, as defined in the treaty, are for all practical purposes a residual category of other beneficial uses apart from those named above.

Now there is little doubt that an ecological use of water is and should be a legitimate priority within the treaty context, and that such a non-traditional use is essential for the sustainable development of the border region. Allocating water to ecological functions

should be understood as an essential support for local and continent-wide ecosystems, habitats that sustain values essential to quality of life, and the maintenance of species on which the future depends. Unfortunately, the over-allocation of border water resources in the traditional spectrum of uses and the absence of binational agreements dedicating water to these aims has left little or no margin for setting aside water for conservation of natural values. Instead, operating within the context of the U.S. law protecting endangered species, high-risk litigation all too frequently becomes the only option to force traditional rights-holders to relinquish water for these functions.

To date, the volume of water that might be needed to protect and sustain existing ecosystems within the border region has not been quantified. If examples like the San Pedro or the Colorado Delta are any indication, however, the volume of water needed to sustain and partially restore native habitats is apt to be modest within the greater balance of uses. Unfortunately, up-basin trends on the border are moving in the opposite direction, implementing greater efficiencies and conservation of water for traditional purposes. Greater binational commitment is needed to prioritize and defend these ecological values and to mobilize public concern in their defense.

But there is some good news on both counts. Though a modest beginning, the IBWC's Minute 306, struck in December 2000, provides a framework for technical and scientific cooperation in studying the Colorado Delta's water needs in the express interests of preserving its ecology. Though it falls well short of amounting to an ecology clause to the 1944 treaty, it is a constructive beginning. A substantial binational coalition of regional and international nongovernmental organizations, which includes academic and scholarly research centers, has mobilized to explore the options for securing the delta's minimum water needs, drawing on market and non-market mechanisms. If they succeed, their example will prove useful in mobilizing political support for securing critical ecological needs elsewhere in the border region. Both in the delta case and elsewhere along the border, recent litigation aims to force U.S. federal, state, and local agencies to manage water to protect endangered species. This litigation is sure to shape the strategies and arguments deployed in the future in defense of border watershed ecology.

Just as there are growing demands for non-traditional uses of

border water resources, there are also non-traditional claimants. However, the notion of non-traditional claimants may be a misnomer since, along with environmentalists, these new claimants include the oldest stakeholders in the border community—indigenous people. Some 27 tribal governments are found in the U.S. border zone alone, and if river basins are considered, just one, the Colorado, has 34 tribal entities (EPA 2001; GNEB 2001). In the United States, the quantification of Native American tribes' water rights as an extension of federal reserved water rights is one of the most important redistributive initiatives presently underway, affecting the whole range of traditional uses and stakeholders (Western Policy Review Advisory Commission 1999). While the settlement of these disputes is far from finished, the uncertainty created contributes to the jealous guarding of individual and corporate water rights in the U.S. part of the transboundary river watersheds. Few observers dispute that settling these claims is critical to establishing a new equilibrium in the allocation of border water supplies, and this new equilibrium is vital to creating water use solutions that support the sustainable development of border water resources. In Mexico, long-neglected assertion of indigenous resource claims and the representation of indigenous stakeholders in binational policy is now beginning to make itself felt (EPA 2001).

Maintaining Water Quality

With trade integration, the quality of border region water resources is stressed as never before. The border's water quality problems are nearly as old as its human settlements. Water quality was also a driver of the 1983 La Paz Agreement. Since NAFTA, the range of actual and potential pollution and salinity problems from point and non-point sources has increased. The problem list is lengthy. Industrial and commercial facilities bleed contaminants from inadequate on-site collection and disposal facilities. The need for wastewater infrastructure remains acute. At the binational level, differences persist about what quality of water is operationally necessary to meet basic public health requirements. Existing standards of treatment may be inadequate at the level of pathogenic disease. The lack of adequate solid and hazardous waste disposal facilities poses a severe threat to groundwater and surface runoff. Practically none of the existing binational programs deal with diffuse, non-point, pol-

lution control. The list goes on (EPA 2001).

Without delving into the many details, which have been adequately profiled elsewhere, it is safe to say that there has been substantive and institutional progress on water quality. While NAFTA brought pressures that may outstrip its solutions, those solutions, in the form of new institutions and greater binational concert in response to these problems, are not immaterial. BECC and NADBank have mandates to develop water and wastewater infrastructure along the border, and that effort is directly linked to advancing sustainable development. With the support of the EPA and Secretaría de Medio Ambiente y Recursos Naturales (SEMARNAT), the two countries have invested more of their Border XXI Program funds in this area than any other (EPA 2001). More border residents have water services than in the past, thanks to the achievements of the Border XXI Water Resource group, which in the years between 1996 and 2000:

- Increased potable water service from 88% of the population served in 1995 to 93% served in 2000
- Increased wastewater collection service from 34% of the population served in 1995 to 95% served in 2000
- Disinfected 100% of border drinking water since 1996
- Increased total funding for border environmental infrastructure projects to $550.8 million, of which the United States contributed $425.5 million and Mexico contributed $125.3 million
- Began 36 BECC-certified projects (including three solid waste projects) for an estimated investment of $891 million; six projects have been completed, 16 more are under construction
- Granted a total of 22 U.S. tribal water infrastructure awards, totaling $11.8 million

Virtually all nine of Border XXI's working groups have responsibilities affecting water quality management. Critical indicators of water quality have been adopted, baselines set, and progress studied. Watershed management principles have been incorporated in technical studies and policy discussion. The search for solutions has led to more creative approaches to financing binational infrastructure involving the traditional turf of IBWC-CILA, including inter-

agency agreements that are changing the orientation and commitments of these established bodies. It has pushed agencies toward partnerships in technical assessment. BECC's and NADBank's mandates have been widened to accommodate a broader range of projects impacting water quality. The NAFTA-linked CEC has helped direct attention at water quality problems in the border region through its Article 13-15 procedures, which enable non-governmental and citizens' groups to highlight problems in national environmental enforcement. In 1998, the U.S. section of the Border Health Commission was created to better coordinate U.S. federal, state, and local agencies in dealing with Mexico on border area health issues, many of which are water-related (Border Health Commission 1998). And this does not include a wide range of local and municipal efforts to deal with water quality.

At the political and policy-development level, there is greater attention to public participation and institutional transparency than ever before, and an explicit binational commitment to strengthening local capacity for environmental management and incorporating citizens in project decision-making. Both Border XXI and BECC advance these principles and provide new venues for their expression.

These achievements, as good as they are, will not suffice if border water quality is to be improved and sustainable development advanced. Neglected problems such as non-point source management must be taken up. Within the context of Border XXI, the governments must set and deliver on critical priorities. More national and binational partnerships must be built between federal, state, and local agencies that coordinate water quality solutions. Comprehensive technical assessment of water basins must go forward, but it must not be an end in itself. More BECC-certified projects should be built within a broader framework of border-wide priorities for infrastructure development and adequate technical assistance for needy communities. Obviously much of this depends on the governments' willingness to back these programs with adequate funding, which, in turn, depends heavily on the effectiveness of border states' congressional delegations in articulating the importance of these programs in both the short and longer terms. And, as the two governments recognized in March 2001 when Presidents

Vicente Fox and George W. Bush met, it also depends on the willingness of U.S. authorities to extend to Mexico greater access to funds and credits as an investment in the binational future.

Strategic Planning for Sustainable Development of Water Resources

Any serious approach to sustainable development generally must incorporate longer-term planning and evaluative perspective. And that must be based on a pragmatic balancing of evaluation criteria and ecological and socio-economic concerns and objectives. It must be mutually arrived at through an open, transparent, and participative processes. In fact, the General Accounting Office (GAO) has recently called for more strategic planning in the management of environmental affairs along the U.S.-Mexican border. (GAO 2000; Spalding 2000). Achieving and implementing an integrative and long-term vision of common goals and objectives in support of sustainable water management practices is an immense challenge in the border region, especially considering the welter of jurisdictions and mix of national and subnational priorities and practices now in place. Some progress has been made, however. It is worth reviewing this progress before considering the challenges and possibilities of moving further in consolidating strategic planning of water resources in the border region.

Border water policy is still a considerable way from anything approaching integrated and comprehensive binational planning of even shared water resources (transboundary water basins), and it may never fully reach this goal, but a number of important reforms at the binational and national levels—including those achieved by the Border XXI Water Resources Group outlined previously—move modestly in this direction.

The most important is the Border XXI framework for environmental cooperation, which, operating within the authority of the 1983 La Paz Agreement, sets out an overarching set of goals and objectives encompassing sustainable development extending to water management. Border XXI, chaired by the national environmental ministries and operating through its Water Working Group and related work groups, provides a regular venue and consultative mechanism that brings together national agencies at multiple levels of government in a binational effort to identify actual and potential

water problems and coordinate national responses to the extent feasible. Because it operates within the La Paz process, it is possible to use this mechanism to reach binational protocols, outlined in the form of annexes to the 1983 agreement. However, this option remains under-used. The Border XXI process has recently been strengthened to better incorporate tribal, state, and local governments through the Ten Party Coordination Principles Agreement in 2000 (EPA 2001; GNEB 2000).

Like the La Paz Agreement on which it is based, Border XXI has been much criticized as an ad-hoc framework driven by administrative and sectoral differences amongst participating national agencies (EPA 2001). The process inevitably reflects the realities of political and policy decentralization in managing water resources. As a binational coordinating mechanism, it is liable to all deficiencies found in national systems of water administration, particularly the fiscal balkanization amongst agencies. As Border XXI is now up for review and renewal, it is possible the governments may address some of these deficiencies. Despite these administrative weaknesses, Border XXI has advanced the level of contact, discussion, evaluation, public participation, and accountability evident in considering binational water management concerns. It also has the advantage of providing a framework for cross-sectoral discussions within the broader umbrella of Border XXI's coordinating mechanism. The program has been a key mechanism for developing critical border-based environmental data, particularly water quality data, essential to long-term planning. Seen from the perspective of sustainable and binational development of border water resources it is a considerable improvement over the status quo.

BECC and NADBank also have mandates to promote sustainable development in the border region and attend to the water-related infrastructure needs of border communities. These mandates are largely implemented on a project-by-project basis. A recent agreement to expand their operational range has opened a window to more systematic, border-wide assessments of needs and priorities and broadened the range of water-related projects they may consider for certification and funding. Unfortunately, even with enhanced mandates, the agencies remain more reactive than proactive, depending heavily on locality, non-governmental, and private-sector

initiatives in setting their agenda.

At the national level, the IBWC has recently, and for the first time, developed a strategic plan that establishes a mission fixed on environmentally friendly boundary and water services driven by sustainable development principles. Its aims and objectives (Table 1), though limited to IBWC and not including CILA, are binational in spirit and scope. Its strategic goals in the categories of transboundary cooperation and water management are supportive of sustainable development and ecologically sensitive practices in spite of the fact that the mandate of its 1944 treaty, inclusive of formal minutes, does not yet extend this far. On the Mexican side, CILA has not yet formalized such a statement of mission, goals, and objectives, but may do so in the near term. While the status of such operational codes is unclear at the binational level and would need to be formalized to alleviate this ambiguity, there should be little doubt that these initiatives represent a constructive re-centering of IBWC's national section orientations within the treaty's limits. Though BECC—by dint of its investment-driving capacity, geographic scope, and direct links to Border XXI and IBWC—may offer the best venue for a cooperative binational effort to promote sustainable border water management, the IBWC, with its treaty mandate and river basin orientation, is a vital strategic partner.

Deserving mention at this level, too, is the U.S. Good Neighbor Environmental Board (GNEB), an independent federal advisory committee created in 1992 and charged with informing Congress and the U.S. president about environmental conditions and infrastructure needs of U.S. border communities. As an advisory body, GNEB lacks operating or implementing authority but its mandate allows a broad view of environmental needs in the border region with an eye toward sustainable development based on cross-jurisdictional and cross-sectoral expertise. Water management, particularly water quality problems, have been featured in each of its annual reports. Its fourth annual report (2000) urged the U.S. government to adopt a strategic water plan for the border region based on a watershed approach. GNEB attempts to reflect a multi-stakeholder perspective and, though it is not truly binational, it consults with a similar body for Mexico's northern border states, the Region 1 National Advisory Council for Sustainable Development. Though it

is not very visible in the policy community, GNEB has been successful in profiling more innovative approaches to water management and providing needed support for the action-oriented programs mentioned above.

In addition to these binational and national initiatives, a number of recent quasi-governmental and non-governmental initiatives aim to support or advance strategic planning and management at the river-basin level. Within the framework of the Border XXI Program, the Rio Grande Alliance, now unfortunately in administrative limbo, sought to engage mostly governmental stakeholders on both sides of the border in diagnostic and planning activities with respect to the Rio Grande/Río Bravo basin. In the same basin, the non-governmental Río Bravo Coalition initiative is coordinating stakeholder groups basin-wide in monitoring, advocacy, and policy development aimed at conservation and conflict-resolution in managing the river's water resources. Other river-basin planning initiatives exist on the San Pedro, Santa Cruz, and Tijuana rivers (Table 2).

Collectively, these various planning initiatives share a concern for sustainable development, an ecologically sensitive vision of the complexities of managing water resources, an explicit orientation toward binational cooperation, and an appreciation of the need for multi-stakeholder perspectives and venues in managing border water resources. At minimum, they reflect greater governmental and public awareness of the competing pressures on border water resources and the greater need for a conservation perspective over the long-term.

Effective strategic planning, however, requires effective governance which, in turn, implies responsible, accountable administration. However, overlaying the various jurisdictions, missions, strategic roles, and goals and objectives in border water management would present clear evidence of fundamental problems in pursuing sustainable water management. The most obvious problems are jurisdiction. The scope of authority varies considerably among these agencies, ranging from broad border-wide initiatives like Border XXI and those with narrower mandates, such as the IBWC, to irrigation districts and state and local agencies dealing with particular river basins and watersheds. Despite their commitments in principle to sustainable development at the organizational level, their operating modes vary considerably. BECC still operates largely on a case-

Table 1. Binational Strategic Planning Mechanisms Related to Sustainable Water Use on the U.S.-Mexican Border

	Border XXI Program	*BECC/NADBank*	*IBWC/CILA*
Goals and Strategies	To work toward sustainable development through the protection of human health and the environment and proper management of natural resources in the United States and Mexico through public involvement; decentralization of environmental management through state and local capacity building; and improved communication and cooperation among federal, state, and local governmental agencies.	To provide technical assistance to border communities and to certify environmental infrastructure projects in the border region for financing consideration by the NADBank and other sources.	To Provide environmentally sensitive, timely, and fiscally responsible boundary and water services, while applying sustainable development principles, along the U.S.-Mexico border region...to provide these services in an atmosphere of binational cooperation and in a manner that is responsive to the public Specific goals include transboundary cooperation, boundary preservation, water agency management, and agency resource optimization
Objectives	Variable by working group. Water working group objectives focus on improving water and wastewater infrastructure, pollution prevention, watershed planning and management, water quality monitoring, training and development, efficient water use, and public participation.	Ensuring community support for projects that meet the principles of sustainable development; strengthening the institutional capacity of public utilities; developing programs and projects that are adequately designed and financially feasible; identifying additional sources of capital and credit, and developing financial packages based on the capacity to meet financial obligations; promoting structural changes essential to long-term project success, including proposals for reforming the legal and institutional frameworks in which projects are developed.	Under the transboundary cooperation specific goal: • Partner with other entities with to carry out border ground water investigations in support of regional sustainable development efforts • Partner with other entities in developing water marketing and water transfer approaches to dealing with water quality and quality and quality questions • Coordinate exchange of expertise, technology, and other information • Cultivate regional and international stake holder support; partner with other entities in problem prevention and resolution • Partner with other agencies in international problem prevention and resolution Under the water resources management specific goal: • Apply and renovate flood control activities that incorporate stakeholder input • Renovate water data gathering, exchange, and accounting activities in support of stakeholders needs • Operate river system structures... in concert with other agencies in a manner that is responsive to stakeholders and the riparian ecology
Geographic Scope	100 kilometers on either side of the border, coast to coast.	100 kilometers either side of the border, recommended expansion to 300 kilometers south of the border.	Boundary line coast to coast; jurisdiction narrowly focused on transboundary aspects with the proviso that problems originating in treaty-denominated river basins may also fall within its authority.
Planning Interval	5 Years	Variable by Project	Variable by Project
Assessment Mechanisms	Water quality indicators; investment indicators; project-by-project assessment.	Projects approved meet or exceed rigorous sustainable development criteria; little post-project review by these binational bodies.	Variable by functions and projects.

Sources: EPA; McKinney; IBWC

by-case basis to develop urban border water infrastructure, and its managers are responsible to a representative and binational board of directors reflecting a diverse range of stakeholder views. IBWC, in turn, functions as a unified organizational hierarchy at the level of its national sections with an overriding goal of preserving national endowments—a goal to which other objectives are subordinate. Its treaty basis is the most rigid legal instrument for water management found at the binational level. Border XXI operates more at the level of a confederation of federal, tribal, and state agencies in which certain agencies, by dint of their administrative and budgetary position within their respective governments, carry more weight in driving policy action.

Planning horizons also vary, though most, including Border XXI, fall well short of the longer-term strategic aims necessary for truly sustainable development. Most investment decisions, whether taken in the context of Border XXI, BECC, NADBank, IBWC, or some combination thereof, are still reactive and politically driven rather than proactive or precautionary and based on a long-term calculus of sustainability. Other mechanisms—the river basin councils, for instance—operate less formally to educate and build consensus on problems and solutions.

Balkanization of authority and effort has temporarily derailed one of the most innovative planning initiatives to come along in some time, namely, the CEC initiative for a North American Transboundary Environmental Impact Assessment (TEIA) agreement. Such an agreement would certainly provide another piecemeal mechanism for mitigating against certain adverse ecological effects of water-related development. While supported in principle by the three federal governments, U.S. border states continue to resist any preemption of their local project licensing authority while Mexico, with its tradition of administrative centralism, insists on nothing less.

Given the political realities of federal government and regional planning on both sides of the border, there is a slim likelihood of achieving anything in the next decade or two that resembles comprehensive strategic planning of border water resources. This does not mean, however, that the border community cannot aim for and demand a greater level of functional articulation between the binational and nationally constituted units presently in place, nor that it should not demand longer-term planning horizons and policy commitments. The planning and quasi-planning initiatives that have been undertaken thus far are certainly contributing to the binational capacity to frame problems within the optic of sustainable development and explore solutions along these lines.

Table 2. A Partial List of Watershed Councils, Commissions, Forums, and Task Forces Along the Border Created Since 1990*

Watershed/River Basin	Governmental/Quasi-Governmental	Non-Governmental
Rio Grande/Río Bravo	Rio Grande Alliance	Rio Grande/Río Bravo Coalition
	Rio Grande Citizens Forum	Alliance for Rio Grande Heritage
	Paso del Norte Watershed Council	Rio Grande Restoration
	Paso del Norte Water Task Force	Rio Grande Institute
	Consejo de Cuenca, Río Bravo	
Rio Conchos	Fundacion para Conservacion del Rio Conchos	
San Pedro River	Upper San Pedro Initiative	Upper San Pedro Program
Santa Cruz River	Nogales Citizens Committee	
Colorado River	Consejo de Cuenca, Rio Colorado	
	Colorado Delta Binational Technical Task Force	
Salton Sea/New River	Salton Sea Authority	
Tijuana River	South Bay Citizens Forum	

*This list is not meant to be comprehensive, nor does it include university and research institutes, government agencies, particular environmental organizations, irrigation districts, and many other bodies and stakeholders interested in managing these watersheds.
Source: Authors

More can and should be done. Much of the progress realized over the past two decades has been achieved through framework agreements and memoranda of understanding at the interagency and binational levels, which allows for the better coordination and commitment of

government efforts in pursuit of environmental and water management objectives. These procedures should be reinforced and elaborated. The Border XXI agreement, for example, should move toward more public participation, institutional capacity building, specific interagency commitments in pursuit of water management objectives, and commitments that advance its strategies of decentralization (EPA 2001). Following the letter and spirit of the Border XXI Coordination Principles, tribes, states, and municipalities should be better incorporated into the working group processes. Participating governmental organizations should continue to develop and strengthen strategic partnerships with non-governmental and citizen bodies in promoting sustainable water management objectives. Even these changes will require greater presidential commitment on both sides of the border. IBWC-CILA should move toward formalizing their respective sectional commitments to sustainable development. A further mechanism should be created that would enable IBWC-CILA to engage the BECC, NADBank, and subgovernmental units in both nations in long-term planning for border environmental infrastructure. Finally, the two governments should renew their efforts to reach a viable TEIA agreement that can be used at the project level to explore options for mitigating the adverse environmental impacts of development related to the use of border water resources.

Innovative Management Concepts: Markets and Watersheds

The search for innovative strategies to advance sustainable water management in the border region has lately embraced both market and watershed tools. Markets and watersheds are not mutually exclusive ideas; both concepts challenge politically denominated boundaries. As policy prescriptions for sustainable development, however, they move in different directions, responding to different problems and offering different solutions.

Market Solutions

Market-based solutions are usually advanced for solving the problem of resource supply, or scarcity. As economists are fond of saying, market effectiveness is contingent on a clear assignment of property rights supporting the dynamics of negotiation and exchange among owners. In the absence of clearly assigned rights, property values remain poorly represented and uncertain, restricting the effective transfers of property necessary for the operation of an efficient market system. Markets are fundamentally decentralizing and, in the minds of many advocates, distorted by government intervention. Thus market-based solutions usually entail some prescription for a reduction of government ownership or regulation.

Because market principles and mechanisms are well-institutionalized for the assignment of water uses in both the United States and Mexico, there should be little doubt that markets will be part of any repertoire of mechanisms for promoting sustainable development of border water resources. They are vital on two levels: First, in facilitating transfers of water to higher-value uses along the border, and second, in enabling and directing investment in support of needed water-related infrastructure. Market solutions currently figure in policy responses to any number of specific water-based issues in the border area, be it a long-term solution to minimal water requirements of the Colorado River delta ecosystem or fiscal capacity-building for projects seeking BECC's certification.

Applied to the problem of advancing the sustainable development of water resources in the border, however, markets are deficient in several aspects. First, they do not function in a vacuum but directly express pre-existing inequities in the assignment of uses within and between states. In a border environment defined by underdevelopment and poverty, markets cannot be relied upon to remedy inequities by themselves, and perceptions of equity may affect the willingness of stakeholders to participate in the cooperative practices essential to sustainable development. Second, markets function in highly decentralized and particular ways that often favor short-term profit-taking over long-term investment and savings. Markets may clash with the long-term perspective that is central to sustainable development. Third, markets are theoretically boundless. Evidence of their global reach and force is voluminous at the border.

They cannot be expected in themselves to advance place-oriented goals and values. Fourth, as common-pool theorists generally caution, where shared, transboundary, resources are concerned, the uncertainty associated with dissimilar systems of use assignment, in the absence of international agreement, supports market-driven exploitation of the resource to the point of exhaustion. These problems and others point to the necessity of public intervention if markets are to be harnessed to reach the goal of sustainable border region water use.

With these cautions in mind, market solutions are favored by leading international agencies and many stakeholder bodies. The World Bank and the Organisation for Economic Co-operation and Development (OECD) both support water pricing as a key instrument for dealing with water scarcity and redistributing water to areas of greatest need (CEC 2001). Policies promoting the absorption of the real cost of water by end-users are apparent at the border level in the certification and financing of border water infrastructure by BECC and NADBank. The key to successful application of these market reforms in regions of relatively high economic disparity, like the U.S.-Mexican border, is taking into account local capacity and willingness to pay, guarding against the development of exploitative monopolies, and imposing sufficient regulation to guard against the externalization of important social costs, such as adverse environmental effects.

Watershed Management

Advocacy of a watershed approach is predicated on the assumption that sustainable development is more likely to be achieved when a full accounting of the complex ecological and socio-economic interrelationships is made within a particular hydrographic unit. The term "watershed" is generally preferred to the term "river basin" as its meaning is somewhat more elastic. A watershed may be co-extensive with a river basin, or part of it, and incorporate the natural landscape in its reach. Using watersheds as a geographic referent in water management is not new, they are often the focus of apportionment efforts. Indeed, one could argue that a de facto acknowledgment of watershed realities is seen in binational efforts to divide equitably the surface runoff of the principal transboundary river

basins in the border region (GNEB 2000). As a policy concept, however, the attractiveness of watershed-based management has been driven by environmental concerns. Pollution prevention, biodiversity protection, and conservation of renewable and non-renewable resources are problems that, as related to water, are best understood within the natural catchment framework of watersheds. At the social level, the sense of the natural integrity of watersheds and their complexity supports both a sense of place and a logic of looking beyond fixed jurisdictions and organizational sectors to cooperate in sustaining the fluid dynamics on which life depends.

The problems of employing a watershed approach are economic and political, but ultimately they are social. First, watersheds usually clash with markets. Whereas a watershed approach is inherently conservative, examining a water-based problem through the lens and limits of the catchment, markets treat water as a commodity that ought to flow freely toward higher values whether or not these are catchment-contained. Both the Rio Grande and the Colorado now flow outside their original catchment in response to agricultural and urban demands in the Rocky Mountain region. The old adage of "water flowing uphill to money" accurately captures this reality. Water policy in the United States and Mexico has long been based, to a large extent, on market practices, and this means implementing watershed management concepts frequently requires modifying market-based commitments. This, in turn, amplifies the state's role in water governance.

Second, watersheds cross established political and administrative jurisdictions. This obvious fact has proven the bane of watershed management efforts in North America and remains the most difficult challenge. At the international level, the problem is aggravated by greater variation in political and administrative approaches to water management. This produces something of a paradox, namely that in theory, watershed management requires more governance than market-based systems because it conflicts with established jurisdictions. In short, watershed management is governmentally demanding and politically messy.

Despite these difficulties, watershed management's attractiveness is driven by the need to integrate and harmonize management practices across jurisdictions and better represent a greater range of

stakeholders in management decisions. Watershed management principles have been embraced by federal authorities in both countries with varying degrees of success. A recent report by the Western Water Policy Review Advisory Commission has gone so far as to propose the creation of a new federal authority to oversee the development of watershed management initiatives in the western United States (Western Water Policy Review Advisory Commission 1998). On the U.S. side, the EPA and other federal agencies have endorsed watershed management. The development of river basin or watershed councils, or *consejos de cuencas*, under Mexico's 1990 National Water Law has gradually evolved and these councils are now in place on both the Rio Grande and Colorado rivers. Mexico's previously mentioned latest environmental plan also fully supports the watershed approach as a unit for managing the nation's natural resources within the framework of integrated basin management.

On the border, national initiatives in watershed management are beginning to create opportunities. Watershed management approaches are seen in innovative efforts to: coordinate intergovernmental planning within major river basins and tributary watersheds; forge new partnerships with governmental and non-governmental stakeholders; establish new advisory and attention groups, sometimes formalized as watershed councils; and initiate studies within an ambit of public participation and stakeholder involvement. (A partial list of such initiatives in the border area is in Table 1). With the support of foundations, universities, and non-governmental organizations, a number of important citizen-based watershed initiatives have taken root.

As so many of these watershed initiatives are new, it is simply not possible to assess their general effects on border water management. Their operational scope, mode of decision-making, and links to participating actors vary considerably by area and project throughout the border region. What is certain is that more information on water management is now produced, exchanged, and diffused binationally than at any previous time in the border's history. At the level of particular watersheds, these collaborative and transjurisdictional endeavors have certainly contributed to binational understanding and a greater level of cooperation than before.

Much more difficult, however, is reaching consensus on management practices at the watershed level, even in a strictly national context. Within the context of the Border XXI Program, the Water Working Group is struggling to agree on binational priorities for watershed management in the two major international river basins, and various particular technical studies are linked to this effort (EPA 2001). Yet it is not by accident or failure of good intentions that the United States and Mexico have yet to establish a truly binational watershed council for the Rio Grande/Río Bravo, or the Colorado River, even at the framework level. GNEB strikes a more optimistic note in this regard (GNEB 2001). Despite the many impediments, watershed management approaches appear to offer the greatest promise for supporting a sustainable approach to the use of border-area water resources while drawing a broader range of stakeholders into the process. With the federal governments moving in this direction and as local experience grows, it should be possible to strengthen institutional commitments to these new modes of evaluation and decision-making in managing border water resources commitments that increasingly bridge the border.

Conclusion and Recommendations

At the binational level, the prospect of comprehensive, programmatic planning for sustainable development seems remote. The rapidly building pressures on the border environment from development have outstripped the capacity of current institutions to meet the challenge of sustainable development in the near-term.

In the face of the many critical pressures outlined above, there should be little doubt that sustainable development of border-area water resources requires further institutional development at the binational and national levels. Institutional progress must advance on both the substantive and procedural levels. Substantively, the countries must quicken their efforts to deal with the pressing problems of drought, groundwater management, ecological uses, and water quality. Procedurally, the governments must make better use of existing institutional mechanisms, give greater priority to binational cooperation and planning, and encourage more partnerships, inter-sectoral alliances, and public collaboration in planning mechanisms.

Progress is possible in all these areas, although the march of events has already begun. Some progress must come by revising binational mandates. In the cases of drought, groundwater, and non-traditional water uses, for instance, the clarification of treaty language is imperative if common water resources are to be sustainably managed. The legal ambiguities and substantive lacunae that contribute to unilateral and short-term benefits and resource exhaustion must be critically re-examined for the possibility of solutions that are long-term, binational, and satisfy the inter-generational criteria of sustainability.

Progress may also be had by demanding more existing institutional infrastructure. As the recent debate over BECC-NADBank functions shows, a reinterpretation of the basic mission may enhance the institutional capabilities and build operational synergies with favorable impacts border-wide. It may even be necessary, as Presidents Fox and Bush recently proposed, to rewrite the 1993 agreement to further integrate and optimize these institutions' functions (Abel 2002). Better use could also be made of the IBWC in coordinating binational responses to drought and groundwater scarcity. Recent efforts by IBWC-CILA's national sections to formalize commitments to sustainable development are a favorable sign and part of the process of intellectual agency orientation re-framing that is essential to building new partnerships and working across national and binational sectoral lines to find new solutions to pressing problems.

Central in this institutional re-orientation is that border water management must become drought management. This is a critical lesson of the present Rio Grande water crisis and one that is exceedingly relevant for the entire border region. As Ismael Aguilar and colleagues recently observed, an adequate drought management regime requires a radical policy departure, one that moves beyond the reactive mode of crisis-response to embrace a permanent, long-term drought mitigation effort (Aguilar et al. 2001). Absent such a proactive program—one that unites the various agencies of the two governments in a coherent action plan—efforts to achieve regional water security will be severely limited (Aguilar et al. 2001; Utton 1999).

To date, much of the real advancement toward treating border

water sustainably has come not through fixed treaties and agreements but through framework agreements that aim at opening procedural windows for binational cooperation. The La Paz Agreement and its second-generation offspring, the Border XXI Program, have contributed to an unprecedented level of binational interaction and information exchange. This should continue, but it is not enough. Binational commitment to specific tasks through specific partnerships that contribute to the broader goals and objectives within the Border XXI Program is needed. And these commitments must be better funded. The federal governments should heed the call of Border XXI's critics to develop budgetary review that requires participating ministries and departments to give priority to inter-agency investments. It may not be necessary (as some have argued with reference to particular problems with the U.S. budgetary process) to narrow Border XXI's scope by eliminating its natural resources functions, as this risks losing the very inter-sectoral synergies that Border XXI has nourished since 1996. Achieving further policy integration and force will, however, require greater executive attention to the process in both countries.

The importance of executive intervention compels us to recognize that the persistence of sovereignty, while often a barrier to binational cooperation, also affords an opportunity, even as both countries rightly pursue greater decentralization and local involvement in binational decision-making. The very structure of sovereign systems enables central governments to advance concepts and solutions that subsidiary governments may well resist for entirely parochial reasons. Alternatively, local governments and citizens groups are often better poised to articulate the place-based and ecologically sensitive values that central governments overlook or fail to comprehend. There should be little doubt that innovative solutions to regional drought or transboundary environmental impact assessment require considerable federal resolve, while watershed management needs local initiative and collaborative effort from stakeholders at all levels.

In this respect, there is much to be gained by looking carefully at the cooperative dynamics associated with watershed-based planning efforts in the border area. While cooperative management of transboundary watercourses is still in its infancy, if that, the multiplica-

tion of governmental and non-governmental mechanisms oriented to watershed planning is heartening. Whether the mechanism is river basin councils or less formal multi-stakeholder exercises in watershed stewardship, such processes soften the hard edges of established jurisdictions and spur innovation on trans-institutional and binational cooperation. Collaborative management approaches have applications for the conjunctive management of surface and groundwater. As such, they hold promise for dealing with both treaty-defined and non-treaty water stocks addressing both qualitative and quantitative issues. Although the proprietary aspect of water use is apt to complicate the process of reaching formal agreements on binational watershed management, it may be possible, following the recent effort in binational air quality management, to build such practices into the La Paz Agreement as annexes. Where impediments arise from treaty-based commitments or lacunae, as with groundwater, the development of framework agreements linked to treaty obligations offers a channel for reaching an agreement on technical issues and may serve as a catalyst for building binational coalitions for cooperative solutions.

In sum, there is much the two countries can and should do to improve their institutional arrangements for sustainable water resources management as they anticipate developments to the year 2020. The complex array of local, state, regional, federal, and international institutions at play in border water management presents an enormous challenge. Certainly it is in the best interest of the two nations and the binational border region that water is managed effectively. Yet, time is pressing and may prove the master of events. The United States and Mexico are now committed to a long-term process of economic integration that will intensify development in the border area for the foreseeable future. Whether that development ensures collective health and sustains common resources is an open question. What is certain, and what was learned so graphically on September 11, 2001, is that if this is to be, then binational cooperation is not an option. It is essential to health, well-being, and even national security over the very long haul. To do that, stakeholders must consolidate gains, thicken involvements, and strengthen commitment to sustainable development in the border region.

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II

Interdependent Border Water Supply Issues: The Imperial and Mexicali Valleys

Jesús Román Calleros and Jorge Ramírez Hernández

Abstract

The meaning of the word "interdependence"—defined as the dependence that exists among elements of a population located in the same area—implies that in order for the elements of the population to exist optimally, there should exist a certain degree of understanding and cooperation among that population. Interdependence has been and will continue to be the essence of growth along the U.S.-Mexican border.

Throughout the border region between Mexico and the United States, interdependence has been present in many forms for more than 150 years. Some 13 million people share this enormous social and cultural richness, which makes them part of one of the most dynamic border regions in the world. Several factors have been at the crux of this interdependent behavior. Among them, and probably the most important, is the interdependence that exists on water issues. The Colorado River has been the main source of water for the Imperial and Mexicali Valleys. The impressive system regulating its flow provides more than 15 million acre-feet (MAF) of water per year, which serves more than 23 million people.

In 1944, the United States agreed via an international treaty to deliver 1.5MAF of water to Mexico each year. At that time the population of northern Baja California was about 43,000 and had a consumption rate of 3 million cubic meters (Mm^3) per year. Today the population of Mexicali alone is 928,572 and the town has a water consumption rate of $100Mm^3$ per year, not to mention the growing consumption of residents in Tijuana, Rosarito, and Tecate. Available data from 2000 indicates consumption of 386 liters per person per day in Mexicali.

This growing consumption is not exclusive to Baja California. In 1989, the Imperial Irrigation District (IID) signed an agreement to divert up to 106,000 acre-feet (af) per year of conserved agricultural water for urban uses. In 1998, IID signed another agreement to transfer 200,000af of conserved water to San Diego County. All this water is taken from agricultural users, and increasing competition for water between cities and agriculture is now readily apparent.

This increase in water consumption has benefited population growth and has allowed the incremental increase in consumption per inhabitant. The former is a product of the economic boom of the border region, while the latter is a product of the lack of consciousness regarding rational water use.

South of Morelos Dam, in Mexican territory, the Mexicali Valley has a huge hydraulic net of channels that gives life to the northern region of Baja California. Five levels of authorization are needed to deliver water to the 14,126 users there. Since 1992, the Ley Nacional del Agua (Mexico's Law of National Waters) and its regulations have established a new way of managing water and agricultural lands in Mexico. Under the law, Mexican irrigation districts of 5.8 million hectares in size were administered by their own users. In 1993, the Comisión Nacional del Agua (National Water Commission, in Spanish CNA) began the process of transferring the administration of irrigation districts in Baja California. The users formed 23 civil associations of agricultural producers called "modules." Since that time, water for agricultural purposes has been administered by these groups, similar to processes in the Imperial Valley.

On the U.S. side of the border, the Imperial Dam delivers water

to the All-American Canal (AAC) and the Gila Main Canal. From the Colorado River, the supply of water is transported to the valleys of Yuma, Gila, and Wellton-Mohawk in Arizona; Imperial and Coachella in California; San Luis Río Colorado in Sonora; and Mexicali in Baja California. All are located on an agricultural irrigation surface of more than a half-million hectares. The AAC is the main conduit for water to the region, which includes the agricultural valleys of Coachella and Imperial, California, where nine small cities, 142,000 people, and 250,000 hectares of agricultural lands are located.

Because the water volume assigned to Mexico was not enough to irrigate all the agricultural lands in Mexicali Valley, in 1955 the Mexican government established a program to drill wells. At the present time, 725 wells extract water from the aquifer below the valley. Imperial Valley does not use water from the aquifer, mainly because of its poor quality. In the past, this aquifer was recharged principally by infiltrations from the Colorado River, but currently it is recharged by infiltrations from the irrigation channels and the return of irrigation water. Infiltrations from the Colorado River play a much smaller role.

For Mexico, water from the aquifer is a reliable resource, which is why the Mexicali Valley aquifer represents an important source of available water in Baja California. For this reason, any actions that affect the volumes of recharge to the aquifer, such as the lining of the AAC and the decrease of the Colorado River watershed's natural runoff, directly impact the quality and quantity of available water.

There are also other bodies of water at risk. The Salton Sea today is the largest inland lake in California. Approximately 66% of the water that enters the Salton Sea every year comes from agricultural drainage, which has high saline concentrations. The salty water and high evaporation rates have elevated the saline concentration to 44,000 parts per million (ppm), with an incremental increase of 0.5 parts per thousand per year.

Organic loads in the water that enters the Salton Sea cause eutrophic conditions, which could be the main cause of fish mortality. Intense deterioration of environmental quality in the Salton Sea has caused events such as the deaths of hundreds of thousands of birds in the first four months of 1998. However, agricultural activities in the region, which contribute most of the water that enters the Salton

Sea via irrigation drainage, have an enormous economic impact in the region—annual revenue here is reported at $1.4 billion.

The U.S. Department of the Interior (USDI) conducted environmental feasibility and scientific studies in the preparation of a Draft Environmental Impact Statement/Environmental Impact Report (DEIS/EIR) on the Salton Sea in 2000. The DEIS/EIR identified the Salton Sea as an important part of a much bigger and more complex ecosystem that is intimately bound to the ecosystem of the Colorado River. It also includes the lower delta of the Colorado River and the Upper Gulf of California. Therefore, efforts to restore the Salton Sea should be connected to all the ecosystems in this group, and restoration of them all should be seen as one unit.

The deviation channel from Wellton-Mohawk to Santa Clara Sludge was part of the solution to the Colorado River salinity problem from 1961 to 1977. An annual average of 160Mm^3 of polluted water and 720,000 metric tons of salt discharged into the Santa Clara Sludge have been significant sources of contamination of land and water for more than 25 years.

In 1973, when International Boundary and Water Commission (IBWC) Minute 242 was signed, providing for the discharge of this polluted water, it represented a convenient exit for both the U.S. and Mexican governments. Their negotiations had been framed in a sense of good neighborliness within overall binational cooperation. Today, the perception of this agreement has changed. Both governments need to look for a new, creative, and good-neighborly agreement.

When the Hoover Dam opened in 1934, the natural flow of the Colorado River was changed, drastically impacting riparian ecosystems. Today, almost all countries in the world understand that sustainable development does not end at their borders and that the responsibility to conserve ecosystems is not just a national concern. The need to maintain a permanent flow in the Colorado River Delta is more urgent every day to guarantee the existence of the ecosystem and its hydrological relationship with wetlands in the natural river course, the Santa Clara Sludge, the upper Gulf of California, and the Salton Sea.

Paradoxically, the so-called "Law of the River" is not concerned with the river's health because the documents and agreements that

allow for the management of the Colorado River water do not account for any volume used by natural users. Furthermore, the states in the Colorado River's lower basin defined the conditions under which "surplus" water can be declared. This water eventually flows through the streambed of the Colorado River. There have been several transboundary effects, including reduced flood flow frequency, since these criteria have been identified. Most of them have occurred in the Colorado Delta, the aquifer of the Mexicali Valley, and the Gulf of California. Adopting a new approach for the allotment of these surplus waters would seem a reasonable solution, unless U.S. decision-makers forget the users in Mexican territory, the river itself, and the Colorado's lower basin.

Aspectos de la Interdependencia en el Abasto de Agua en la Frontera: Valles Imperial y Mexicali

Jesús Román Calleros y Jorge Ramírez Hernández

Resumen

El simple significado de la palabra interdependencia, definida como la dependencia que existe entre los elementos de una misma población, implica que, para alcanzar la interdependencia, debe existir un cierto grado de entendimiento y cooperación entre los miembros de esa población que la conforman. La esencia del crecimiento de la zona fronteriza México-E.U., ha ido más allá de este significado. Para esta región, la interdependencia ha estado presente en múltiples formas y sentidos, y de manera permanente en más de 150 años de convivencia binacional. Diez millones de personas, que comparten una gran riqueza social y cultural, que los ubica en el contexto internacional como una de las regiones fronterizas más dinámicas del mundo entero.

Varios factores han sido la esencia de este comportamiento. Entre

ellos, probablemente el de mayor importancia es la interdependencia en torno al agua. El Río Colorado ha constituido la principal fuente de abastecimiento de agua para el Valle Imperial y el Estado de Baja California. El impresionante sistema de regulación de su flujo hace posible controlar un volumen de 15 millones de pies acre anuales, para que pueda ser utilizado por 23 millones de personas.

En 1944, Estados Unidos pactó con México, entregar 1.5 millones de pies acre por año. En ese momento, la población de Mexicali que recibía agua del Río Colorado, únicamente era de 43 mil habitantes, con un consumo de 3 millones de m^3 anuales. Actualmente, la población en Mexicali es de 928,572 habitantes, con un consumo de agua de 100 Mm^3 al año. Sin embargo, ahora debemos considerar el consumo de las ciudades de Tijuana y Tecate, que con 121 Mm^3 por año, incrementan el caudal a 221 Mm^3. Datos disponibles indican que durante el año 2000, Mexicali reportó consumos de agua de 386 l/persona/día.

Este incremento en el consumo, no es exclusivo de Baja California. En 1989 el Distrito de Riego de Imperial (IID) firmó un acuerdo con el Distrito Metropolitano del Agua de Los Angeles (MWDLA por sus siglas en inglés), para comprar anualmente hasta 106,000 pies acres de agua agrícola para usos urbanos. En 1998 el IID firmó un acuerdo con Distrito Metropolitano del Agua de San Diego, en el que se transfieren 200,000 pies acres de agua anualmente a San Diego. Toda esta agua proviene de usuarios agrícolas, evidenciándose una fuerte competencia por el agua entre las ciudades y la agricultura.

Este aumento desmedido en el consumo ha sido potenciado tanto por el crecimiento de la población, como por el incremento en el consumo por habitante. El primero es producto del auge económico de la franja fronteriza. El segundo es producto de la falta de cultura y concientización sobre el uso racional del agua entre la población.

Presa Morelos, representa el elemento integrador del Valle de Mexicali. Es base de una enorme red de 2,500km de canales principales y laterales, que abastecen de agua a la agricultura y al 84 por ciento de la población de Baja California. Cinco niveles de autoridad se requieren para entregar el agua a 14,126 usuarios.

En 1992, la Comisión Nacional del Agua, en su reglamento estableció una nueva forma de administrar el agua y las tierras agrícolas en México. El objetivo a alcanzar era que los distritos de riego mexicanos, con 5.8 millones de hectáreas, fueran administrados por sus propios usuarios. Para 1993, la CNA inició en Baja California el proceso de transferencia de los distritos de Riego. Los usuarios formaron 23 asociaciones civiles de agricultores llamadas Módulos de Riego. Desde ese momento, el agua agrícola es administrada por sus usuarios, tal como en el Valle Imperial. El resultado de este cambio, aun es cuestionado por técnicos y académicos.

Los estanques sedimentadores de Presa Imperial, dan origen al Canal Todo Americano (AAC, por sus siglas en inglés), del cual se deriva agua al Canal Principal Gila y al propio cauce natural del Río Colorado. Desde este punto, se regula el abasto de agua a los valles de Yuma, Gila y Wellton Mohawk, en Arizona; Imperial y Coachella, California; San Luis, Sonora y Mexicali, Baja California. Todos ellos ubicados sobre una superficie de más de medio millón de hectáreas bajo riego agrícola; y además, abastece de agua a una población de 2.8 millones de habitantes. El AAC, es el principal conducto para distribuir el agua a toda la región, incluyendo los valles de Coachella e Imperial en California, esta última con nueve pequeñas ciudades con 142,000 habitantes y 500,000 acres de tierras agrícolas.

En 1955, el gobierno mexicano inició un programa para perforar pozos, pues el volumen asignado en el Tratado era insuficiente para regar la superficie agrícola. Actualmente, se cuenta con 725 pozos para extraer agua del acuífero. En Valle Imperial, el acuífero no es explotado, debido a la baja calidad del agua, pero sobretodo, porque no lo requieren. La recarga original del acuífero provenía fundamentalmente de las infiltraciones del Río Colorado. Actualmente, la recarga está directamente relacionada con infiltraciones de canales de riego, el retorno agrícola y las infiltraciones del Río Colorado y el AAC.

Para México, el acuífero representa la única fuente de agua segura, y tal vez más la parte más importante de disponibilidad de agua para Baja California. Por esta razón, cualquier acción que afecte su recarga, tal como el recubrimiento del AAC, y la disminución de los escurrimientos naturales del Río Colorado, impactan directamente sobre la calidad y cantidad del agua disponible.

Otros cuerpos de agua están en riesgo. La presencia del Salton Sea (mar Salton) es ancestral aunque su historia moderna inició a prin-

cipios del siglo XX. Actualmente, el mar Salton constituye el cuerpo de agua interior más grande de California y sin embargo, este lago está a punto de morir. Aproximadamente el 66% de agua que cada año entra al mar Salton, proviene del drenaje agrícola de Valle Imperial, con alta concentración de sales. La concentración salina del agua en el mar Salton alcanza valores de 44 mil partes por millón, con un incremento anual de 0.5 partes por mil, propiciado por: el aporte de sales, la naturaleza endorreica de la cuenca y los altos índices de evaporación.

La causa más importante de mortalidad en peces podría ser la elevada carga orgánica que entra al mar Salton (provocando condiciones de eutrofismo), más que el aumento de la salinidad. El intenso deterioro de la calidad ambiental del mar Salton provocó que en 1992 miles de aves murieran. No obstante que las actividades agrícolas de la región contribuyan con la mayor cantidad de agua al mar Salton, provocan una derrama económica de más de $1.4 billones de dólares anuales. Sin embargo, esta situación no se ve reflejada en el desarrollo de la región, en ninguna de sus ciudades. Tal parece que la agricultura no le debe nada al Valle Imperial.

El Departamento del Interior de los Estados Unidos dirigió un estudio de impacto ambiental en el mar Salton, durante el año 2000, conocido como el Informe Borrador de Impacto Ambiental ("Draft Environmental Impact Statement/Environmental Impact Report", o DEIS/EIR). El DEIS/EIR ya contempla al mar Salton como una parte importante de un más grande y complejo ecosistema del Río Colorado, que incluye al Delta, y el Alto Golfo de California. Esta recomendación del Gobierno, en sus esfuerzos de restauración del SS, debe considerar también al Delta, ya que ambas áreas están conectadas dentro de un mismo ecosistema, y por tanto, deben ser tratados como un único sistema.

El canal Wellton-Mohawk (WM) desde 1977 desvía agua salina hacia la Ciénega de Santa Clara, como parte de la solución al problema de salinidad del Río Colorado (1961–1977). El volumen promedio anual de esta agua contaminada, que ha descargado, durante más de 25 años, en la Ciénega de Santa Clara es de 60Mm^3 lo cual implica que cada año 720,000 toneladas métricas de sales llegan al estero, constituyendo una importante fuente de contaminación del acuífero de Mexicali, y del suelo del Delta.

En 1973, cuando se firmó la minuta 242 de CILA, en la que se aprobaba descargar esta agua contaminada, se consideró como la forma más conveniente de dar salida a esta agua. Su negociación estuvo enmarcada en un sentido de buena voluntad, dentro de la cooperación bilateral. Hoy en día, la percepción de este acuerdo, ha cambiado totalmente. Por ello, ambos gobiernos requieren buscar instrumentos mixtos que combinen la buena voluntad, ingenio y creatividad, para hacer frente a este problema en un marco de buena vecindad, similar al que imperaba en 1973.

En 1934, cuando el Río Colorado fue controlado por la presa Hoover, el régimen natural del río cambió, impactando ecosistemas riparios de manera drástica. Actualmente, en casi todos los países del mundo, entienden que el desarrollo sustentable va más allá de sus fronteras y que la responsabilidad de conservar y hacer conservar esos ecosistemas, no es únicamente una responsabilidad nacional, sino de todos los que lo comparten. La necesidad de mantener un caudal perene en el Delta del Río Colorado que garantice la subsistencia del ecosistema y su relación hidrológica con los humedales naturales, en la vega del río, el Golfo de Santa Clara, la Laguna Salada, el Salton Sea y la cabecera del golfo de California, que cada día, es más apremiante.

Paradógicamente la llamada "Ley del Río" no considera la salud del Río. El compendio de documentos y acuerdos que permiten el manejo del agua del Río Colorado no considera el volumen de agua necesario para los usuarios naturales. Más aún, el U.S. Bureau of Reclamation, está proponiendo establecer un criterio para determinar las condiciones en las cuales los estados de la cuenca baja podrían hacer uso de los posibles caudales excedentes del Río. Esta agua eventualmente fluye a través del cauce natural del río. Se han cuantificado los efectos transfronterizos causados por la reducción de la frecuencia de este escurrimiento al establecer este criterio. La mayoría de los cuales serán sobre el Delta del Colorado, el acuífero del Valle de Mexicali y el Golfo de California. Adoptar un nuevo criterio para distribuir estos volúmenes excedentes, parecería razonable, a no ser porque en la distribución se han olvidado de los usuarios en el territorio mexicano y del río en si mismo, que también forma parte de la cuenca baja del Río Colorado.

Interdependence: 150 Years of Binational Coexistence

The meaning of the word "interdependence"—defined as the dependence that exists among elements of a population located in the same area—implies that for the benefit of all elements, there should exist a certain degree of understanding and cooperation within the population that is interdependent. Such an understanding makes it possible to guarantee the survival of all those who inhabit that region.

For the border region between Mexico and the United States, interdependence has been present in many ways during 150 years of binational coexistence. Throughout the history of the two countries the development dynamics and growth of their economies have been different, but intertwined. Without having been established in any document the traditions, customs, languages, nationalities, and countless other elements are nonetheless shared. This symbiotic coexistence between these two countries, which are so different in their essence, have become very similar.

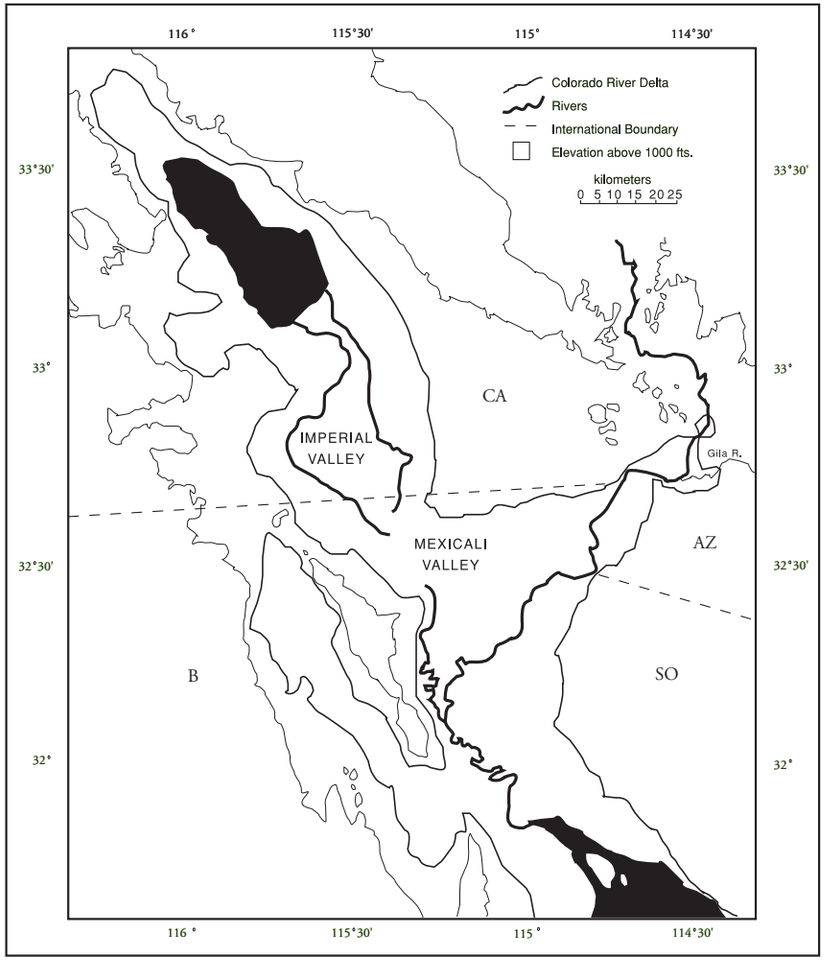
The U.S.-Mexican border, which extends 3,180 kilometers (km), is inhabited by 13 million people living in 35 Mexican municipalities and 25 U.S. counties. In this binational region, people share a great social and cultural richness that, in an international context, makes it one of the most dynamic border regions in the entire world. The rapid growth of border cities, starting in the 1950s, has caused enormous changes in these communities. People from every state in Mexico have migrated to this region in search of new opportunities.

Because of the region's semi-arid climate, interdependence of goods, services, and several other elements have not been as important as water. Water has made coexistence between the two countries more tense and their histories are plagued by needing to share it and, therefore, disputing rights to it.

For more than 100 years, the Colorado River has been the main water source for an important part of this binational region, which includes seven American states and two Mexican states. The economic development and social security of this region is based on water from the Colorado River (Román 1990). This water availability is possible not only due to the impressive system of regulation

and distribution of Colorado River water flow—including the construction of amazing engineering regulator and storage ponds and an enormous network of channels and aqueducts—but it is also due to a complex set of regulatory laws governing water rights and users (Román 1991a).

Figure 1. Study Area



Source: Modified from Cohen et al.

In 1849, the idea of taking advantage of the lands and the waters of the Colorado River Delta was proposed by a visionary man, Oliver M. Wozencraft. Today, the Imperial and Mexicali Valleys combined are one of the most important agricultural regions for the United States and Mexico and they will be the focus of this chapter.

Imperial Valley agricultural activities total more than $1.4 billion every year. A great part of the United States' wealth is generated in this region. However, when analyzing economic and social conditions of this region, that wealth is absent from many of the valley's communities.

In contrast, because of the Mexicali Valley's development and economic growth, this region is one of the most dynamic in the Mexican republic. At the present time, Baja California is the only Mexican state that has guaranteed access to water. The economic and social development realized during the last 60 years has been sustained mainly because of the availability of Colorado River water. Some 8.1% of the total volume available is transported to Baja California (Román 1990).

Problems caused by population growth in the borderlands include the emergence of new urban areas, insufficient urban water delivery infrastructure, and the lack of a legal framework that establishes priority uses for all consumption levels. The problem of water availability has increased significantly, not just in Mexico but in the United States as well. In the Southwestern region of the United States, the population is growing fast and commercial activity is developing quickly, but the benefits of services and the industrialization process cannot help water demand and consumption.

The urban region of the Colorado River Delta includes seven cities in the Imperial Valley and Mexicali, which are located 120 miles east of San Diego. The region has 1.2 million inhabitants, nearly 1 million acres of agricultural land, and receives a total water volume of 5.2 million acre-feet (MAF) per year.

Big cities outside the Imperial and Mexicali valleys criticize the enormous water volumes dedicated to agricultural uses there. Metropolitan water authorities from Los Angeles to San Diego are constantly working to find extra volumes of water for their giant populations. In Mexicali, a city with nearly 1 million inhabitants, the 2001 annual water consumption from the Colorado River as

reported by Comisión Estatal de Servicios Públicos de Mexicali (CESPM) exceeded 100Mm^3. That is 33 times more than allowed under the 1944 Water Treaty. But this is not the most serious problem, since today the diversion of Colorado River water for urban and industrial uses exceeds 221 million cubic feet per year—72.3 times more than the 1944 treaty allotted to Tijuana and Tecate.

This is one of the reasons border researchers are so concerned about demographic growth. Water demand in the Colorado River Basin increases every day, generating more and more wastewater, which is increasingly difficult to treat since the natural courses of the Colorado River and New River are so long. Evaporation, runoff from agriculture, and the build up of sediment are responsible for the Colorado River's high salinity, which is the major problem with the river today. The river's salt load increases progressively downstream and the greatest burden falls on the last downstream users—the Imperial and Mexicali Valleys.

Water planning errors on both sides of the border have resulted from city administrators' concerns only about how water is delivered to urban users. Planners forget about how their citizens are using water. There is no true culture of water conservation in the population and there will never be enough money to mitigate the deep thirst of a country that does not respect its most valuable resource.

The Imperial and Mexicali Valleys, located in the delta of the Colorado River, form part of this complex interdependency. This U.S.-Mexican border region is a good example of understanding and cooperation among a population that is interdependent on so many things, including water supplies. In the last 60 years, this border region has felt significant population growth and an intense pressure to transfer water from agricultural uses to urban centers. Issues that have played an important role in sharing water between both countries are analyzed here to highlight the need for interdependency to achieve economic and social development.

Colorado River Water: A Unique Resource for the Region

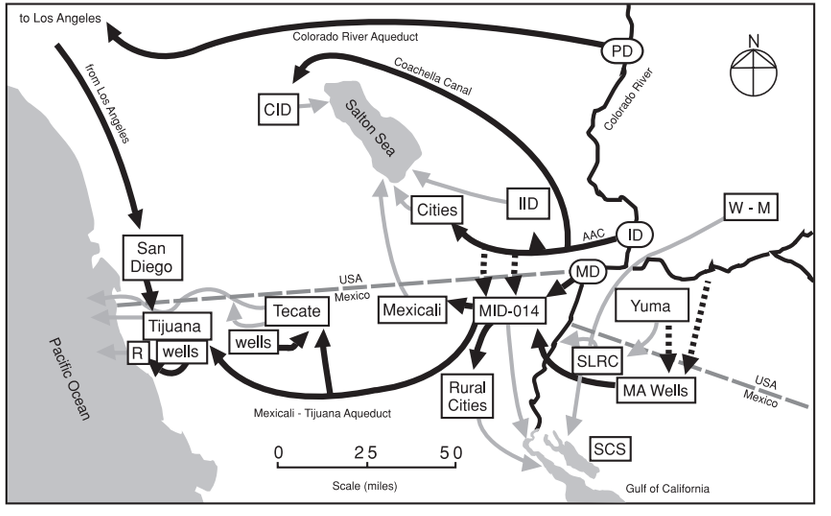
Although water is obtained from the Colorado River delta region, it is clear that the only source for a water supply is the actual Colorado River. From the total water distributed to the delta, more than 3.8Mm^3 per year are sent via the All-American Canal (AAC) to the Imperial and Coachella Valleys. For the main channel of Yuma, 2,000 cubic feet per second (cfs) are diverted to the valleys of Yuma, Gila, and Wellton-Mohawk, in Arizona. Via the natural course of the Colorado River, 1.3MAF flow to Mexico to irrigate the Mexicali Valley. At the delivery point, known as San Luis Río Colorado Valley, Mexico receives 200,000af (Comisión Nacional del Agua [National Water Commission, in Spanish, CNA] 2000),[1] of contaminated water (this volume was agreed to under the 1944 treaty) because it comes through the agricultural, urban, and industrial system drainage from Yuma, which is delivered through the south main drain of Yuma Valley (Román 2001b). To use this water on the Mexican side, it is necessary to combine it—in a place known as the "blender site"—with better quality water that comes from the Morelos Dam and the well system in the Mexicali Valley. Wastewater from the U.S. side has an annual average of 1,850 parts per million (ppm) of total dissolved solids, while water from Mexicali Valley has an annual average of 950ppm. The result of this mixed water is an average of 1,300ppm, 350ppm higher than the real Colorado River water has at this point.

Because the Colorado River water quota assigned to Mexico is insufficient to meet demand, producers in the Mexicali and San Luis Río Colorado need to obtain additional water by extracting it from wells that drill deep into the Mexicali Valley aquifer. Approximately 725 wells are located in the area. An average of 700Mm^3 are obtained in this way every year. The annual extraction of the battery of wells located in San Luis Río Colorado (International Boundary and Water Commission [IBWC] 1973) at the Mesa Arenosa, near the boundary with Yuma, is 197.4Mm^3. Aquifer recharge depends on returning water from the irrigation and infiltration processes back to the Colorado River. In this desert area, rain is practically nonexistent; annual precipitation averages 65 millimeters (mm), and

completely dry years have been known to occur (Dowd 1956). The ratio of precipitation to evaporation is 1 to 40.

As shown in Figure 2, Colorado River water supports several cities in southern California, Arizona, northern Baja California, and Sonora. Water flow from the Colorado River is denoted by black arrows and wastewater is denoted by gray arrows. This schematic representation of water flows represents, in a simple way, the true complexity of water delivery and waste disposal.

Figure 2. Interdependencies of Colorado River Water Flows



EXPLANATION:

PD:	Parker Dam	**SLRC:**	San Luis Rio Colorado
ID:	Imperial Dam	**MA Wells:**	Mesa Arenosa 67 wells
MD:	Morelos Dam	**SCS:**	Santa Clara Slough
IID:	Imperial Irrigation District	**W - M:**	Wellton and Mohawk Valleys
CID:	Coachella Irrigation District	**R:**	Rosarito City
MID-014:	Mexican Irrigation District *	**AAC:**	All American Canal

*Includes 725 wells Mexicali aquifer

Drinking Water
Waste Water
Groundwater Flows
Border Line

Source: Authors

In 1944, when the water treaty was signed, the Mexican population that received water from the Colorado River was about 43,000, and they consumed only 3Mm^3 per year. In 1970, the population that received Colorado River water grew to 310,940 and their annual consumption average increased to 12Mm^3. This consumption included Mexicali and a significant part of Tecate's and Tijuana's demand.

In that time, the biggest problem for the Mexican side of the border was the fundamental lack of water delivery infrastructure. For this reason, the U.S. government supplied water to the municipality of Tijuana through the Colorado River-Los Angeles aqueduct with the understanding that the Mexican Government would solve the Tijuana water supply problem in the short-term.[2]

In 1976, construction of the Colorado River-Tijuana Aqueduct began. In 1982, the first water delivery operation was carried out, with a flow of 2.1 cubic meters per second (m^3/s) instead of the 4m^3/s projected total. For 1990, water consumption in Mexicali was 83Mm^3 (CNA 2000) with an average daily consumption per inhabitant of 374 liters; that represented an additional volume of 102 liters per inhabitant when compared to the previous decade (Instituto Nacional de Estadística, Geografía e Informática [INEGI] 1991). For 2001, the Mexicali population, according to INEGI, was 928,572 inhabitants, and they had a water consumption rate of 100Mm^3. In numerical terms, this represents 71.7-times more water consumed than in 1944, and 17.9-times more than in 1970.

This increase in water consumption has been encouraged to sustain Mexican population growth, as has the increase in the water consumption per inhabitant. The first is a consequence of the economic peak of the border region, which has a demographic growth rate of 2.4%—much bigger than the national annual average of 1.96% (INEGI 2000). The second is a consequence of lack of culture and consciousness among the population regarding water conservation.

Competing water demands between cities and agricultural lands is a significant problem that has not been appropriately addressed by the institutions responsible for water administration, or by the three levels of Mexican government. The argument is that the water volume consumed by the cities is minimal compared to water consumption by agriculture. This assertion, until now at least, is true, as the urban-to-agriculture consumption ratio is 1 to 9. However, during the last five years, water consumption by urban and municipal and industrial users has been increasing, putting the future availability of water at serious risk (Román 2001b).

In Baja California, the urban water allotment from the Colorado River has increased 56 times since 1944. This volume is the equivalent of the water needed to irrigate 2,986 hectares of wheat, 4,157 hectares of green onions, or 1,507 hectares of cotton. This problem is not exclusive to Baja California. This resource is shared with the rest of the residents of the Colorado River basin and the same phenomenon is now becoming evident in most of the southwest United States (Román 1990).

The U.S. Supreme Court set the water allocation for the seven U.S. states that are members of the Colorado River basin in 1964 (Román 1990). However, residents of California's big cities protested against the volume of water assigned to agriculture. Now, the cities of San Diego, Las Vegas, Tucson, and Phoenix are also very interested in acquiring water rights from the Imperial Valley via water for sale from agricultural users. In 1989, the Metropolitan Water District of Southern California (MWD) and the Imperial Irrigation District (IID) signed a water conservation agreement enabling MWD to divert up to 106,000af per year of conserved agricultural water through MWD's Colorado River aqueduct (Pitt 2000). In 1998, a new agreement between IID and the San Diego County Water Authority would have allowed the transfer of as much as 200,000af of conserved water from agricultural users to the authority.

Proposals for water purchases are quite varied. Some of them include acquisition of agricultural lands with water rights, equipment for wastewater treatment, and water rights for lands no longer cultivated. Las Vegas, Los Angeles, and San Diego are carrying out impressive purchases of land and water rights for $12 per acre-foot for resale at $500 per acre-foot. In the 1990s, an investment group from Las Vegas purchased 40,000 acres of land in the Imperial Valley and then tried to sell or lease the water rights to San Diego, only to find out they could not do so legally without the approval of IID. Today, nearly 10 years later, a new possibility exists: San Diego

still needs water and a new aqueduct is required. An international aqueduct has been proposed as a private-sector concept.

Several years ago, the state of California began using water that had been allotted to, but unused by, Arizona and Nevada. However, these states now are demanding that they get that water back. The U.S. Bureau of Reclamation (USBR) required a strategic plan from California detailing how it would reduce its Colorado River water use by 2015. This plan is known as the CA Plan, or the California 4.4 Plan. In order to reduce its consumption and simultaneously establish the interim Surplus Criteria for the handling of surpluses of Colorado River water, California assured all users that within 15 years, the water would be regulated and that the states would receive their water quota from the Colorado River.[3]

Urban Water Consumption and Cost of Delivery

A priority of the Mexican government is providing drinkable water and sewer systems to urban centers. In 1999, the Mexican population was 97.3 million, and 87.4% of it had water services inside their houses. This population grew at an annual rate of 1.96%, which, although smaller than the growth rate during the 1990s (INEGI 2000),[4] has caused increases in demand that are difficult to satisfy due to the unequal distribution of the users' economic conditions. For this and other reasons, water acquires a growing economic value every day in areas of shortage and decreases in value in those areas where it is readily available (CNA 1999).

According to INEGI, in 1995 the daily average consumption per family was 1,706 liters. In 2000, water consumption decreased to 1,603 liters per family per day, which is slightly below quantities reported for Mexicali in 2000, when the reported consumption was 1,738 liters per day.[5] In Tijuana, consumption was 903 liters per family per day. In some areas of northern Mexico, solutions to water delivery have been limited. Financing and environmental costs of new projects have risen drastically, surpassing government investment possibilities. Table 1 presents information from CNA on water volume deliveries to CESPM[6] for urban and industrial uses from

1993 to 2000. In 1993, the allocated volume to Mexicali was 82Mm^3—but, the city used over 6Mm^3 more than they were allotted. Total consumption has gradually increased every year because of demographic growth.

Table 1. Baja California Peninsula Water Volume Deliveries to CESPM in Million Cubic Meters from 1993 to 2001

Year	Used	Allocated	Difference
1993	88.065	82	6.065
1994	90.285	82	8.285
1995	91.094	82	9.094
1996	93.111	82	11.111
1997	96.220	82	14.220
1998	94.355	82	12.355
1999	96.060	82	14.060
2000	99.000	82	17.000
2001	101.000	82	19.000
Total	849.190	738	111.190

Source: CESPM

In order to solve this problem of over-assigned water volume it is necessary to develop a plan that gives incentives for water conservation, taking into account water availability. In some cities, like Tijuana, increased rates for water delivery represent a viable alternative to the government conserving water. This collected money is the main source of revenues for service providers. An appropriate policy tariff, correctly applied, would allow the agencies to recover their investment costs. It would also enable them to invest more resources in infrastructure, improve and expand the services provided, and enable agencies to finance a wastewater treatment plant.

The development of new projects has been impacted by some marginal social sectors that do not have a real capacity to pay for water services. This impedes revenue increases and growth. In many cases the government has avoided granting subsidies—yet another factor that limits growth and provokes excessive water use.

In Mexico, two types of rates exist. Measured service offers a

price according to water volume consumed, which is quantified through a flow meter. Fixed quota rates require the same amount be paid year-round, independent of the water volume consumed. Rates are determined by a state-government conducted socio-economic and financial study of the geographic area. These tariffs reflect the marginal structure of extraction costs and distribution, as well as economic efficiency, financial sustainability, social justice, and good service.

In 2000, various water rates were analyzed in several Mexican states. The goal was to determine real behavior of water prices with an annualized inflation index from 1999 of 12.3%. This means the water service prices were maintained during 2000 with a price similar to 1999. The rates should increase in the same proportion to inflation registered during that year. CNA (2001) pointed out that from 1996 to 2000, Mexicali inhabitants every year paid an average of 8% of their wages for water service, versus 14.3% paid in the rest of the country.

In 2000, INEGI reported that 96% of the Mexicali population had water delivery service. This represents a total of 172,937 domiciliary water services (DWS), of which 160,746 were residential services, 11,672 were commercial services, and 519 were industrial. This DWS data does not correspond with the number of electricity inlets installed in Mexicali in the same year, which INEGI reported as 249,698. It is hard to justify the difference of 76,761 DWS, if it is assumed that a demand for water also exists in each home that requested electricity service. Data from CESPM indicates that in 2000 in each of the DWS in Mexicali, 578.2m^3 (1.58 cubic meters per day) were received. According to the density population index of 4.18 that INEGI reports for every home in Mexicali, this breaks down to 386 liters per person per day.[7]

Hydraulic Infrastructure in the Binational Region

Hydraulic Network Infrastructure in the Mexicali Valley

Construction of the José María Morelos Dam was completed on November 8, 1950. This dam is the hydraulic infrastructure that receives the Mexican quota of Colorado River water and where the enormous net of channels in the Mexicali Valley is born, giving life to the whole northern region of Baja California.

Five levels of authority manage the water on the Mexican side of the delta.[8] It allows the operation of a 2,552km-long network of channels with the participation of the 14,126 users that comprise Irrigation District 014, Colorado River. Because of its 207,935 hectares of water rights, a great diversity of crops (more than 100 species) and high level of productivity, this irrigation district is considered the third most important in Mexico. The 470km-long main channels maintain flows of 50m^3 per second and an absolute maximum value of 159.6m^3 per second. From the network of main channels, 328km are concrete lined and 142km are not protected. Some 2,082km of the network is comprised of secondary channels, 93% of which are lined. It also has 6,443 water flow measurement structures within the irrigation modules.

The 1,492km network of open drains is made up of 422km-long main drains and 1,070km-long secondary drains. The open drainage network is insufficient for controlling soil salinity and drainage water. Consequently, these agricultural drainage waters are controlled by 1,288 hydraulic structures. The artificial drainage network in the Mexicali Valley is hardly 722km. Although some technicians who have researched the situation claim that soils in the Mexicali Valley do not require artificial drainage, a great many of them require the installation of artificial drainage systems due to the shallowness of the well water level. The road drainage network is 2,422km long, 1,378km of which are paved.

Hydraulic Network Infrastructure of the Imperial Irrigation District

The Imperial Dam is the most important hydraulic infrastructure in the Colorado River delta region. The Imperial Dam, through the framework of the AAC, the Gila Main Canal, and the natural course of the Colorado River, regulates the water supply of the Arizona valleys of Yuma, Gila, and Wellton-Mohawk; the Imperial and Coachella valleys in California; the San Luis Valley in Sonora; and the Mexicali Valley in Baja California. All of them are located on a surface of more than 500,000 hectares, which have agricultural irrigation. The Imperial Dam also supplies water to a population of 2.8 million inhabitants. The IID, founded in July 1911, is operated by a civil user association.

IID network channels are 2,573km in length, including main and lateral channels. Also, there are 2,336km of drains captured by an immense network of pipes of nearly 50,000km that forms the system of artificial tile drainage. This system covers 93% of the cultivation surface of the Imperial Valley.

For the IID, there is a fundamental need for an artificial drainage system, mainly because most of its agricultural lands are situated below sea level and flows of internal drainage cause shallow well-water levels and salinated soils. This situation is made worse by surplus water that comes from urban and agricultural uses from the Imperial Valley's cities and from Mexicali through the New River and El Alamo Canal, which frequently divert waters from agricultural irrigation and water drainage.

The All-American Canal

The AAC is the main conduit for delivering water and energy to the region that includes the agricultural valleys of Coachella and Imperial, where nine small cities with 142,000 inhabitants and 500,000 acres of agricultural lands are located. For operational purposes, the AAC is divided into three large branches that include East Highline Canal, Central Main Canal, and Westside Main Canal. They feed all irrigation areas by gravity. More than $3Mm^3$ of water are managed in the Imperial Valley every year. This channel has a

total length of 132km. Its width varies from 46m to 61m, and its depth varies from 2.1m to 6.1m; its topographical gradient presents a difference of 53.3m. Over its course it moves more than $3.8Mm^3$ of water at a rate of $488.3m^3$ per second. This channel also diverts water toward Arizona's Yuma Valley at a rate of $56.6m^3$ per second and toward California's Coachella Valley at $70.7m^3$ per second.

Besides being the main vein of water supply, the AAC is important because of the water volume filtered to the aquifer. The AAC crosses the Yuma Sand Dunes for 38km. This geologic formation has characteristically high permeability because of the sandy-textured soils and surpasses the basic infiltration speed of 7.6 centimeters per hour, which is the technically recommended maximum level for gravity irrigation methods in agricultural uses (Román 1990). Under normal operation, AAC requires a permanent water volume because it delivers water to cities and agriculture. This situation and the electricity generation at five generating stations located along AAC forces IID authorities to maintain a constant hydraulic load, which supports turbine operation and water delivery services for agricultural lands and communities. In the dunes area, most of the filtered water flows underground naturally toward the south and becomes a very important part of the water recharge of the Mexicali Valley aquifer.

In December 1988, IID and MWD authorities signed an agreement for the sale of $123Mm^3$ for $28 per acre-foot for a 55-year period, with the option to renew the agreement (Román 1991a). The water volume sold was determined in light of expected water savings that would be achieved via the concrete lining of most of its irrigation channels and the lining of AAC over 38km of its course.

The Alamo Canal

The course that today is known as the Alamo Canal is a natural channel formed by the large water volume that comes from the Colorado River. Due to its strategic location and important route, this canal was essential to the development of the Imperial Valley. It travels 67km in the northern part of Mexicali Valley and 60km into Imperial Valley until it reaches the Salton Sea. Because of the lack of economic resources that made driving water to Imperial Valley

impossible, the Alamo Canal was used to transport water (Huntley 1966).

Originally, half of the water in the Alamo Canal was assigned to irrigate lands in Mexicali Valley and the other half was assigned to the Imperial Valley. This situation was not welcome by the Imperial Valley producers because they felt dependant on the water coming from Mexico. As soon as construction of AAC was finished, the growers' position changed. In 1940 the first water deliveries began, and by 1942, the Alamo Canal had stopped delivering water to Imperial Valley farmers. This was negotiated and resolved for the first time by the 1944 water treaty.

Today, the Alamo Canal has become one of the three main channels of the Mexican Irrigation District, which is known as Canal Principal Reforma. Its initial route, near Morelos Dam, has been transformed the most; however, some sections of the old branch still receive water that Mexicali Irrigation District technicians put on its course, mainly in order to recharge the aquifer when surplus water volumes are present in the Colorado River.

Because the water taken from the Alamo River is not used, a detailed registration of its volume does not exist, with the exception of that registered at the border crossing with the United States 11.3km east of Calexico, California. At this point, IID technicians have placed a stream gauging station that permanently measures the water flow crossing the border. Registered flows correspond to direct filtrations of AAC and waters of agricultural drainage from the Mexican side. Registered flows are not significant, as is pointed out in the registrations from 1946 to 1998 that Comisión Internacional de Límites y Aguas (CILA) provided in its annual bulletin. Runoff values vary from 50 liters per second to 100 liters per second, which, from the point of view of agricultural irrigation flows, is considered irrelevant.

Water from Wells

The original, historic delta's formation process, principally its sedimentary filling, was carried out by two fundamental activities: depositing of marine silts, caused by the Gulf of California coming from its southern flank, and depositing of silts of a continental origin, carried by the Colorado River (Van Der Kamp 1973). The Imperial Valley's formation is the most exposed ancient formation attributed to the historic delta of marine origin, and it confirms the incursion of the Gulf. The Upper Cenozoic deltaic sediments and non-marine sandstones and clays that appear in the northern and western portions of the basin confirms the continental contribution of the Colorado River. During the middle Pliocene, possibly during a period in which the sea level was lower, the Colorado River built its delta and thus created the crest located in Yuma city, the Cerro Prieto Volcano, and the Cocopah Hills (U.S. Department of the Interior [USDI] 2000). This crest formed a barrier that split the Salton Trough into two sections: one to the South of the delta, in close contact with the Gulf of California, and another to the North, from the depositional and topographical point of view, to the Salton Basin. The latter is occupied in its central part by the Salton Sea (Muffler and Doe 1968). The historic delta was characterized by Colorado River discharge through ephemeral drainage channels that were quickly filled with sediments, which created a new course downstream from the deltaic cone. In most cases, there was a lateral ramification that finished at the Gulf of California. Occasionally, the river forked toward the northwest and flowed toward the Salton Basin, depositing clays and sands in deltaic and lacustrine phases (USDI 2000).

Sedimentary filling was saturated with Colorado River water and marine origin water, forming an aquifer body that in the central part of Mexicali Valley is more than 5km thick. Regional flow in the aquifer shows two main directions. One goes northeast of the Mexicali Valley into the entrance of the Colorado River, to the Trough, and then moves toward the Gulf of California in a southwesterly direction. In the other direction, it flows from the northern border of the crest of the delta, heading southwest to the Cucapah Hills, then rotates to the northwest toward the basin of the Salton Sea.

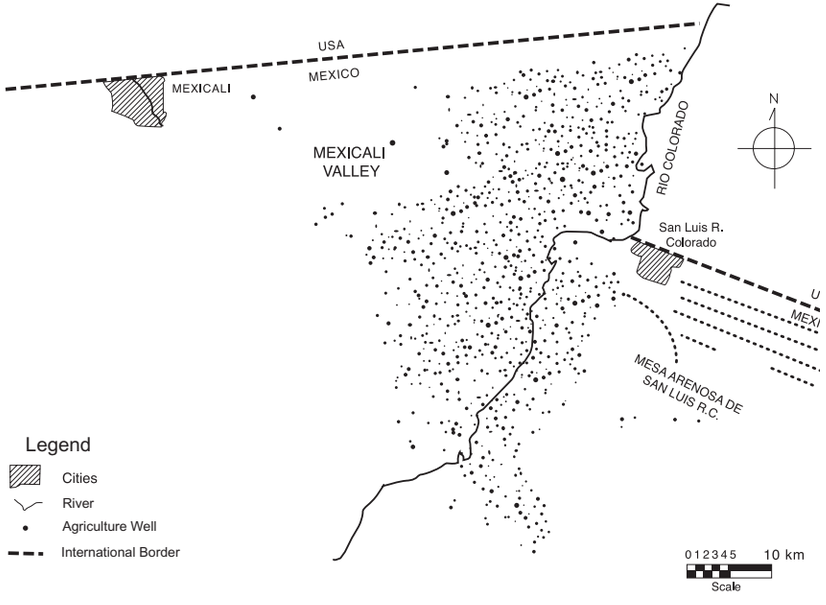
Geohydrological studies have estimated that original aquifer recharge came from Colorado River infiltration. At the present time, recharge is directly related to infiltration from irrigation channels, return of irrigation water, and infiltration from the Colorado River.

In Mexicali Valley, three fronts of horizontal underground

recharge can be identified. The first one comes from AAC infiltration, the second comes from the Arizona-Sonora border toward the San Luis sandy table; and the third comes along the bed of the Colorado River on the border between Arizona and Baja California.

The delta's depositional process was influenced directly by the chemical water quality. Colorado River water created an aquifer with low saline concentrations. Nevertheless, the gradual decrease in water volume and quality of the recharge has increased the water's salt concentration. For that reason, it is possible to find wells with salt concentrations between 800ppm and 2,200ppm. The beginning of the 1930s witnessed the first well drillings to obtain additional aquifer water for agricultural purposes; however, that ended in 1955 when Mexicali irrigation district authorities "froze" users at 207,935 producers, the same number there are today (Figure 3).

Figure 3. Location of Agriculture Water Wells in Mexicali Valley



Source: Modified from Ramírez-Hernández

Because the water volume assigned to Mexico in the 1944 Water Treaty is limited to 74Mm^3 (1.5MAF) it was necessary to establish a program of well drilling that enabled the granting of water to those users. This amount of water is only enough to irrigate 136,400 hectares, pending the granting of water to 69,335 hectares. Those growers, at present time, form part of the wells area. The actual number of wells is 725, of which 468 were built by the federal government; the rest were built by private producers.

Imperial Valley aquifer water is not used for two reasons. First, the low quality makes it unsuitable for agricultural uses. Second, the growers receive enough Colorado River water for their half-million acres of agricultural land. Therefore, aquifer water in this region is the only reliable contributor to water volume,[9] which is why the Mexicali Valley aquifer is the most important source of local water available to Baja California. Consequently, any actions that affect aquifer recharge water volumes, such as the lining of AAC or a decrease in Colorado River natural runoff, will directly impact the availability of water to the region.

Managing Water Resources

Agricultural Water Management in the Imperial Valley

The IID encompasses nearly 500,000 acres of agricultural land—the largest land use dedicated to agriculture in the United States. When it was first developed into farmland, agricultural land exploitation was not easy. Lack of water infrastructure was one of the most important problems to solve. Soil salinization problems due to a phreatic low level made developing the Imperial Valley into an agricultural area harder. But with the help of Mexican laborers, hundreds of canals were constructed and in July 1911, IID began to operate an enormous irrigation district. Today, in spite of all kinds of technology, water delivery is not efficient. More than 50% of the irrigated land is used to forage crops, mainly alfalfa, which need a large amount of water to grow. Irrigation practices that control the amount of salt in the soil are not widespread. Because Colorado River water is available at any time, agricultural lands are cultivated year round, which means that depending on vegetative cycle crop,

one surface can be used several times. This contrasts significantly with Mexicali Valley farmers, who can use land only once each year. Since almost all lands in the Imperial Valley are below sea level, 92% of the total irrigated land requires tile drainage to avoid saline problems. All agricultural drainage is directed to the Salton Sea, which at 27 meters below sea level receives water that varies in quality.

The Imperial Valley population rate has increased dramatically. In 2000 it was 142,361, having increased at a rate of 30.2% since 1990. When compared to California as a whole, the population has risen 13.6% (U.S. Census Bureau 2000).[10] Notably, in 1940, the decade the 1944 treaty was signed, the Imperial Valley had a population of just 59,740, which was only 17,000 more people than Mexicali (U.S. Census Bureau 2001).[11]

Management of the Mexican Quota: The Irrigation Modules

Legal issues surrounding the availability and assignment of water rights are complex and different in each country. While the Mexican Constitution settles everything related to land and water in a single article, in the United States, each state handles and administers these resources independently. Article 27 of the Mexican Constitution assigns lands and waters to the federal government because this property is inside the limits of the national territory, and the Republic is entitled to transmit the domain of lands and waters directly to people as private property.

Because the topic of water rights has grown in importance in Mexico, in December 1992 the Congress of the Union published the Ley Nacional del Agua (Law of National Waters, or LNW), and in January 1994, its regulation was published (CNA 1999). Until that moment, no legal instrument existed in Mexico to allow private users to hold their water as property, since it was the government that decided on the forms of use and assignment of water rights.

The LNW settles in Articles 13 and 14 a new form of management for water and agricultural lands in Mexico. *Consejos de cuencas* (watershed councils) were formed at the national level in 1992. The objective was that Mexican irrigation districts with 5.8 million hectares would be administered by their own users because it was too expensive

manage them (Cortéz and Whiteford 1999).

In 1993, CNA began the process of transferring administration of the Colorado River rights in Baja California to Irrigation District 014 users, establishing the first three irrigation modules (CNA 2000).[12] An irrigation module is a parcel of land constituted as a civil association of agricultural producers located in a specific area. Growers give their water and land rights to the director of their association, who administers the available resources to his partners' benefit. In Mexico, water rights are assigned directly to each producer.

The water volume of each water right depends on the total water availability as determined by the irrigation district. In the Mexicali Valley in 1944, water rights were granted to each farmer at a volume of 19,576m^3 per hectare (15.87af). At present, due to demographic growth, the water rights have been reduced to 10,700m^3 per hectare (8.35af).

This water volume of 10,700m^3, in real terms, is not sufficient because water demand for each crop varies. For example, perennial crops, such as alfalfa and asparagus, demand a high water volume while crops on short vegetative cycles demand less. An additional issue that affects water availability is that according Mexican law and local regulations of the irrigation district, each water right can only be used once per year, independent of the water demand of the crop (Román 2001b).

Civil associations formed by groups of agricultural users were called irrigation modules (CNA 2000). They, in turn, are supervised by a Modules Coordinator[13] called the Society of Limited Responsibility (SLR), which is an administrative structure named by the governor of the state to oversee and evaluate the operation of the modules. This supervision also includes technical support of the Irrigation District of the CNA.

For crop irrigation, the director of each irrigation module presents to CNA, SLR, and the Irrigation District a breakdown of the module users' water needs. The water volume is assigned depending on the cultivation, distance of the land from the points of hydrometric control, and their programmed demand. For 1998, average water volume per hectare was 10,300m^3, yet in 1950, farmers were allotted an average of 12,290m^3. This drastic decrease in water availability was caused by the increase in irrigated surfaces as much as by the decrease in the water

volume available. Table 2 shows the relation of total irrigated area, the number of users, and allocated water volume per year for each irrigation module during year 2000.

Table 2. Governance of the Baja California Peninsula

Irrigation Module	Land Surface (ha)	Users	Allocated Water Volume (million cubic meters)
1	11,000	762	100.099
2	6,498	474	55.448
3	9,335	582	95.950
4	13,040	869	95.884
5	9,965	594	99.238
6	5,836	430	59.975
7	12,676	751	71.337
8	10,151	833	101.159
9A	9,080	631	76.275
9B	9,569	622	73.410
10	13,265	968	158.396
11	9,324	584	112.236
12	9,683	646	116.558
13	7,351	576	87.711
14	8,363	524	101.056
15	9,935	605	119.591
16	6,686	700	80.482
17	8,949	644	106.172
18	7,891	650	95.197
19	8,946	629	107.717
20	6,388	528	76.894
21	5,578	494	83.293
22	4,985	405	61.122
Total	204,494	14,501	2,135.200

Source: CNA

Handling the transfer of the administration of the irrigation district to the modules raises the possibility of changing the policy of traditional water assignment, also known as the water volumetric delivery. Delivering water criteria through the volumetric delivery method assures that each module receives a volume that corresponds to 10,700m^3 per hectare for each water right registered in the module

during 2000.

Water is delivered to the hydrometric control point of each module. The module's technicians then take charge of their internal water distribution and each user quantifies and controls the water received on their parcels. The water savings obtained from each irrigation module is reported to the module headquarters and this savings is counted as water volume in favor of that user. When users take more water than their water rights, they are subject to an additional charge. This new way to deliver water creates incentives for saving water, as well as a water market that could be sold in the same module, other modules, or for urban and industrial uses.

Agricultural Water Use Efficiency

Of the total water available in both valleys, most of it is used for agriculture. Some 90% of the water in Mexicali and 98% of the water in the Imperial Valley is used for agricultural purposes. Unfortunately, efficiency of water use in both cases is very low—only 50% in Mexicali and 55% in Imperial Valley. In spite of high-tech agricultural developments in the Imperial Valley, agricultural use of water is the main cause of increasing soil salinity. Sprinkler irrigation systems are the most-often recommended solutions, however in most cases, these systems are used only in the first stage of cultivation. After that, gravity watering is used in an open furrow mode.

In the Mexicali Valley, gravity irrigation systems are used most often despite the variety of irrigation systems available. Only vegetable cultivation uses sprinkler and drip irrigation systems, and they do so over a minimal surface area. In both valleys the cost of water is lower than the other costs of the productive process, including seeds, fertilizers, machinery, and equipment. Cost, use, and value of water differ significantly across the border (Table 3).

Water in the Imperial Valley is priced at $12 per acre-foot, which is equivalent to $0.01 per cubic meter. In Mexicali, water is sold by 24-hour rates. Farmers pay $6.35 Mexican pesos for every liter per second delivered during 24 hours, a total of 86.4m^3 per day. The cost of this water translates into 7.3 centavos, or about $0.007 per cubic meter.

Table 3. Cost, Use, and Value of Water

	Imperial Valley	Mexicali Valley
Cost ($/m^3)	0.01	0.01
Cultivated Land (thousand hectares)	202.50	208.00
Water Need (Mm^3)	3.07	2.55
Revenues (million US$)	1400.00	4.25
Production Coefficient ($/m^3)	0.45	0.16

Source: Authors

The Mexicali Valley has 207,935 hectares under cultivation each year. To farm this land, 2.55 billion cubic meters of water is needed. The total revenue produced with this volume of water is $425 million per year, which leads to a productivity coefficient of $0.16 per cubic meter used. Although Imperial Valley farmers cultivate less land—only 202,500 hectares—they use significantly more water, an annual total of 3.065 billion cubic meters, and have higher revenues per year, at $1.4 billion. As a result, Imperial Valley's productivity coefficient is $0.45 per cubic meter used.

When comparing the cost of water to the revenues generated, it is clear that water appreciates substantially in value based on its rate of return. Water profitability in the Imperial Valley is 45 times the cost of water because a farmer is able to generate $0.45 for every $0.01 spent per cubic meter. Although less extreme than in the Imperial Valley, water profitability in Mexicali is also high at 22 times the cost of water. Mexicali farmers generate revenues of $0.16 for every $0.007 spent per cubic meter of water. Thus the ratio of water productivity of Imperial County to Mexicali is $0.45 to $0.16 or 2.8:1 for each cubic meter.

Under these circumstances, it is clear that agricultural water use in this region, when compared with domestic and industrial uses, has an extremely low index of economic productivity. Agricultural water uses that report the lowest yields and/or low water use efficiencies should be abandoned in favor of more profitable uses. Crops with high water demand, like alfalfa and asparagus, also must be regulated.

Interdependencies Between Water Use and the Environment

Salton Sea: A Dead Sea?

Today, the Salton Sea is the biggest inland lake in California, extending 360 square miles at an elevation of 228 feet below sea level. The maximum depth of sea is 51 feet but the average depth is 31 feet (Cohen, Morrison, and Glenn 1999). Approximately 75% to 80% of the 1.35MAF of water that enters into the Salton Sea is drainage water coming from the IID. Much of the agricultural water that empties into the sea, including tail drainage system water, has high saline concentrations (Pitt 2000). It has been estimated that average surface water drainage inflow to the Salton Sea is approximately two-thirds tail water and one-third drainage water (Amrhein 2001). The very nature of the basin, taken together with high evaporation rates, have increased salt concentrations to 44,000ppm. In the absence of restoration efforts, salinity will continue to increase gradually over time.

In addition, agricultural wastewater and the water that comes from the city of Mexicali has a higher-than-normal load of organic matter, boron, and selenium, among other heavy metals (Pitt 2000). Some 35% of the total water that enters into the Salton Sea comes from the New River, one-third of which originates in Mexicali.

Investigators have identified the organic load of the water that enters the Salton Sea as the cause of the eutrophic conditions that result in fish mortality even more so than increased salinity. This intense deterioration of environmental quality of the Salton Sea has, since 1992, caused the death of hundreds of thousands of birds. In fact, during the first four months of 1998 17,000 birds of 70 different species died (Cohen et al. 1999).

Researchers have considered solutions to the problem of growing environmental deterioration and the massive death of fish and birds for more than 30 years. The problem has even attracted the attention of the federal and state governments, which have dedicated more than $20 million to studying and defining the problems at the Salton Sea during the last several years.

Although this investment seems substantial, in reality it is quite

insignificant compared with the enormous income earned through agricultural activities in the Imperial Valley. And, the magnitude of the problem has not been sufficiently evaluated. The Salton Sea Restoration Project only focuses on stabilizing the water level at 232 feet below sea level and reducing salinity to 40,000ppm. The Salton Sea is a valuable natural ecosystem that cannot be ignored. It provides a habitat to more than 380 bird species, three endangered species (the desert pupfish, the Yuma clapper rail, and the California brown pelican), and gives refuge to migratory birds on the Pacific route (Pitt 2000). As a recreational area for fishing, hunting, bird observation, photography, and other activities, more than 250,000 peopled visited the area between 1997 and 1998 (USDI 2000). However, agricultural activities, from which water drainage contributes most of the water that enters the Salton Sea, generate more than $1.4 billion in annual revenue and provide work to one in three employees in the area (Pitt 2000).

The U.S. Department of the Interior, working in partnership with the Salton Sea Authority and many other federal, state, tribal, local, and academic entities, conducted environmental feasibility and scientific studies in the preparation of a Draft Environmental Impact Statement/Environmental Impact Report (DEIS/EIR) on the Salton Sea. In the DEIS/EIR, it is already a given that the Salton Sea is an important part of a much larger and more complex ecosystem and that it is intimately bound to the ecosystem of the Colorado River, which includes the delta of the Colorado River and upper Gulf of California. Therefore, the Salton Sea restoration efforts should be connected to all those ecosystems and their restoration should be seen as one unit. The objective of the DEIS/EIR is to maintain a sustainable, long-term balance, conserving the Salton Sea as a holder of agricultural wastewater but looking to improve ecological conditions and provide a safe refuge for birds and fish, as well as an area for recreational use. In short, the goal is to maintain equilibrium among economic activities, the natural ecosystem, and recreational activities. At this moment, that is a difficult objective to reach.

Nevertheless, achieving this balance would require a study of the relationships between components of the ecosystem and the most critical factors (salinity, loads of organic matter, water level, infestations, etc.) in these relationships. This would involve carrying out an enormous research effort, obtaining financial support, and redefining goals and objectives in the understanding of the ecosystem. The formation of a scientific subcommittee for the creation of a strategic scientific plan with objectives for the short-, medium-, and long-term undoubtedly constitutes the most important achievement in the restoration of the Salton Sea, as is provided for in the DEIS/EIR.

It is interesting to consider that the U.S. government recognizes the importance of carrying out intensive studies on the Salton Sea as part of the ecosystem of the Colorado River (USDI 2000). But at the same time, in the Environmental Impact Statement for the Colorado River Interim Surplus Criteria, the United States refuses to take any responsibility for the impact to the environment in Mexican territory due to the interruption of flows of fresh water in the low portion of the delta region and the discharge of polluted waters to the Santa Clara Slough (USBR 2000). In both cases, these fresh water flows are an important part of the sustainability of this enormous binational region and the ecosystem itself.

Wellton-Mohawk and the Santa Clara Slough

Wellton-Mohawk (WM) is a deviation channel that was built for the USBR as part of the solution to the Colorado River salinity problem, which was first discussed between Mexico and the United States between 1961 and 1977.[14] The delivery water was established on June 23, 1977. The volume diverted to the Santa Clara Slough has averaged 160Mm^3 (130,000af) of polluted water annually (Luecke 1999). This has been an important factor in the contamination of the region's land and water for the last 25 years. The presence of this drain water, which has saline measurements of between 3,800ppm and 5,200ppm, enlarged the coastal wetland of the Santa Clara Slough, which covers 20,000 hectares (50,000 acres). Currently, it is a natural refuge for the largest population of Yuma clapper rail and desert pupfish.

Before 1973, there was no direct water contribution from the Colorado River and brackish water was not present in the Santa Clara Slough. In fact, the only tributaries that fed this topographi-

cal trough were the artesian wells and agricultural water drainage that comes from Ríito, Sonora. The surface of the Santa Clara Slough was only about 500 acres.

Depositing this waste water in the Santa Clara Slough was an excellent and "temporary" solution for both sides of the border until the Yuma Desalting Plant entered the picture. The plant was finally constructed in 1992 but it has never really operated because, among other reasons, it would have to file a declaration of environmental impact. It spills an average of 560,000 metric tons of salt into the Santa Clara Slough annually[15] (Burnett et al. 1997), and also contributes other pollutants such as insecticides, herbicides, and fertilizers that have never been quantified.

Nevertheless, several researchers (including Cohen, Galindo, and Campoy) studying the binational border have pointed out that this brine has been beneficial for the development of the Santa Clara Slough. The level of contamination in this wastewater is higher than the contamination found in the original water poured onto this site in the past from the original tributaries.

In its time, the Wellton-Mohawk deviation channel was a convenient exit for both governments and its negotiation was framed in a sense of good neighborliness within overall bilateral cooperation. However, 25 years later, and after the millions of tons of salt discharged in the area, Mexico now has the right to demand that, before discharge into the slough, these waters be treated independently from the water Mexico receives from the 1944 treaty. Clearly, this "temporary" solution settled back in 1973 should reconsider the depositing of these fossil waters in Mexican territory.

Colorado River Delta: The Forgotten User

The Lower Colorado River Compact, signed at Santa Fe in 1922, marked the beginning of the deterioration of the natural hydrological system of the Colorado River. Although the construction of Hoover Dam was completed in 1934 and construction of Glen Canyon Dam at the end of 1960, some argue that the real beginning of Colorado River Delta deterioration was in 1909, when Laguna Dam, near the Imperial Valley, was completed. They also say the irrigation of Imperial Valley agricultural lands was another factor in

the lower delta's deterioration. However, impacts to the lower delta from these diversions were not significant because after this, Colorado River water was still running to the Mexican side of the border and its natural flows reached the Gulf of California.

In the Lower Colorado River Compact, six of the seven states in the hydrological basin agreed to distribute the water of the river, and they did so without regard for environmental sustainability. With the completion of the Hoover Dam in 1934, the natural conditions of the river were altered, drastically impacting the riparian ecosystems. Today, there are 10 major dams along the river with a total storage capacity that controls flow by nearly four times the river's natural annual flow, thereby creating a situation of total dependence for downstream users (Román 1990).

The concept of the natural user emerged in the United States after the ecological accident at the Cuyahoga River in 1967 (Cuyahoga River Remedial Action Plan Coordinating Committee 1992) when the river caught fire because it had been polluted with so many flammable substances. This marked the beginning of the development of an environmental conscience in the United States. Some might argue that this environmental conscience began earlier (see *Silent Spring* by Rachel Carson). However, the Cuyahoga River's accident gave the United States the opportunity to create true environmental institutions like the U.S. Environmental Protection Agency (EPA) and true environmental policies like the National Environmental Policy Act (NEPA).

In developing countries like Mexico, concern for the environment and sustainable development of ecosystems came later. The first international efforts began in 1983 with the La Paz Agreement, the Integrated Border Environmental Plan in 1992, and continued through the Border XXI program. In March 1993 a proposal to declare the upper gulf and lower delta a biosphere reserve was presented to the Government of Mexico by a group of non-governmental organizations. Due to the extraordinary biological and cultural importance of these ecosystems and the increased international pressure to protect the endemic vaquita porpoise and totaba, the Mexican government declared this region a Biosphere Reserve in June 1993 (Brusca et al. 2001).

At almost the same time, the LNW and the General Law of

Ecological Balance and Protection to the Environment were created. These documents recognize that a minimum flow of surface water is necessary to maintain an ecological balance.

The combination of demographic and economic growth in the Lower Colorado River Delta, in addition to a complete absence of an environmental conscience, required the planners take into account environmental concerns as an essential part of the whole system. As a result, the Colorado Delta "natural user" suffered enormous pressure. During the twentieth century, on the delta's Mexican side, Colorado River water flows were decreased by 75%. Between 1896 and 1921, the annual average flow of Colorado River water to the lower delta in Mexico was 16.7MAF (20.7 billion cubic meters). From 1984 to 1999, however, the annual average was reduced to 4.2MAF (5.2 billion cubic meters) (Luecke 1999).

Consequences that resulted from this greatly reduced flow include morphology changes in the natural course of the river, decreases in silt transport, polluted silts, soil erosion, and high salinity in soil and water. Overall, these changes have adversely affected the lower delta and altered its ecosystem. Furthermore, the decrease in fresh water volume to the lower delta and the conversion of land to agricultural uses have diminished the wetlands to 5% of their original area. Although the estuary in the lower delta has not been taken over by agriculture, it has been adversely affected by the lack of fresh water.

Non-native species and invaders have reduced the population of native species. For example, the poplars, shallows, and willows have been supplanted by the salt cedar, the cachanilla, and the chamizo (USDI 2000). The different sources of water filling the lower delta carry a variety of contaminants that are toxic to wildlife and humans. There is no program in place that systematically monitors for a variety of pesticides on the lower delta. In the 1970s, levels of DDE, the most persistent metabolite of DDT, in clams from the Mexicali Valley were as high as 11ppm (wet weight); in the mid-1980s the amount was less than 0.2ppm. Selenium levels 1.8 times to 14.2 times higher than the EPA's criterion of 5 micrograms per liter have been reported in lower delta waters and sediments. Several studies have indicated the presence of DDE and selenium in low concentrations in the lower delta's riparian system and at greater

levels higher in the food chain, especially when periodic adequate flushing from the Colorado River does not take place (Brusca et al. 2001).

Nevertheless, a century of development has not been able to kill the lower delta's ecosystem. As is true with the Salton Sea, the lower delta continues to be a refuge for migratory birds along the Pacific flyway during winter. It includes an estuarine environment that stimulates the development of marine fauna, including various species of shrimp, the totaba, and the vaquita porpoise in the Upper Gulf of California. The lower delta also includes important riparian areas along the waterways of the Colorado River—from the border to the lower delta these waterways include the Rio Hardy wetlands at their fork with the Colorado River, the intertidal wetlands, and the Santa Clara Slough (Luecke 1999).

For the past 15 years, various U.S. federal agencies and several state governments on the Upper Colorado River basin have begun to implement conservation measures for the natural habitat and endangered species by assuring a permanent flow from the Colorado River. In 1994, a plan was proposed with the overall aim of lessening the adverse impact the controlled flow of the river has on endangered species. In 1996, fresh water was released from the Glen Canyon Dam to redistribute silt and sand in the Grand Canyon and to reestablish sandy areas at recreational sites along the river.

These concrete restorative actions of the upper and lower basin clearly reflect the power of the Endangered Species Act and the threat of litigation. Although it is clear that the impact on the lower delta is a product of the regulation and diversions of the flow of the river, it has not been the object of the same concern as the Salton Sea has been. Until very recently, it has been considered a completely separate ecosystem from the Salton Sea. As a result, restoration programs have not included the lower delta in their plans.

According to Luecke and colleagues (1999), if Mexico demanded an increased quota from the Colorado River, it would create friction between users from the United States and Mexico.[16] Instead of demanding more water, they recommend that lower delta rescue efforts concentrate on the protection of existent, but not regulated, flows. They also mention that recovery of the short-term lower delta could be reached if the flows registered in recent years continued.

The surplus flows of the last years are currently being assigned to the users in the United States without considering Mexico (Luecke 1999). The regulation of surplus water among United States users will lead to a drastic reduction in surplus flows to Mexico. It is clear that competition for Colorado River water will be more intense for the short and medium term.

Restoration and conservation of the natural habitat of the Lower Colorado River Delta and Upper Gulf of California is an unresolved subject even today. However, countries all over the world are beginning to understand that sustainable development does not end at their borders and that the responsibility to conserve ecosystems is not just a national concern.

It should be understood that a permanent flow to the lower delta is vital to guarantee the survival of the wetlands, the natural river course, the Santa Clara Slough, and the Upper Gulf of California ecosystems. Preliminary findings suggest that the riparian corridor requires 260,000af every four years to regenerate trees. To create a perennial flow of water, 50,000af per year is required. This total 115,000af on an annualized basis is less than one-twelfth of Mexico's annual appropriation of Colorado River water (Varaday et al. 2001).

If there is no consensus about the water volume necessary to restore the lower delta, the quality required is even more complex to define. Quality must be measured in multiple ways. Salinity, microbial contamination, chemical pollution, and pH levels all influence the marine and estuarine organisms. The Mexican government faces three quality-related challenges: rising levels of water salinity, high concentrations of nutrients from agricultural drainage, and contamination from heavy metals, especially selenium[17] (Varaday et al. 2001).

Brusca and collaborators (2001) affirm that the only way water can be allocated to meet the environmental needs of the lower delta will be at the expense of agriculture on both sides of the U.S.-Mexican border. The first step toward this is making users of Colorado River water recognize the lower delta as a tenth user.

Interim Surplus Water Criteria

Management of Colorado River water is governed by a wide and complex group of documents and agreements that are collectively known as "Law of the River." Handling the main watercourses of the Colorado River's lower basin is the responsibility of the secretary of the USDI, which acts through the USBR.

The Upper and Lower Colorado River Basin States Water Compact, signed in 1922, divided 15MAF per year between the Upper and Lower Basins and seven U.S. states.[18] Average flow of the river was estimated based on data from 1910 to 1920, which was one of the wettest decades. Averaged out over many decades, the mean flow of the river is close to 13.2MAF per year. In 1944, when the Water Treaty was signed with Mexico to guarantee 1.5MAF of Colorado River water per year, it included the two Mexican states of Baja California and Sonora. It is clear that with the demographic, agricultural, and industrial growth of the lower basin states, the volume of 7.5MAF that was assigned in 1929 is no longer sufficient.

This Colorado River water over-assignment has created a crisis. For decades, California has dipped freely into the Colorado River to the tune of approximately 5.2MAF annually. This was allowed because California was the first state to have a water distribution system. In recent years, however, three significant events greatly altered California's favorable position. First, under a 1963 decision of the U.S. Supreme Court, California's entitlement was set at 4.4MAF annually. Second, Arizona is approaching its full entitlement because of the completion in the late 1980s of the first phase of the massive Central Arizona Water Project (Eugene 2000). Third, Nevada reached its allotment in 2000.

This situation was the main reason the USBR was obligated to implement diverse actions of technical and political character—among them the Colorado River Interim Surplus Criteria strategy.[19] This strategy consists of criteria under which surplus water volume in the lower basin of Colorado River could be declared during the next 15-year period (USBR 2000). Interim surplus criteria (ISC) are used annually to determine the conditions under which USDI may declare the availability of "surplus" water for use within the states of Arizona, California, and Nevada.

The Long Range Operating Criteria (LROC) for the Colorado River define a normal year as one in which annual pumping and release from Lake Mead is sufficient to satisfy the 7.5MAF of consumptive use in accordance with the decree. A surplus year is defined as a year in which water in quantities greater than normal (7.5MAF) is available for pumping or release from Lake Mead. USDI is authorized to determine the conditions upon which such water may be made available. The USDI must comply with and carry out the provisions of the Colorado River Compact of 1992, the Colorado River Storage Project Act of 1956, the Boulder Canyon Project of 1928, and the 1944 Water Treaty. Article 10(a) of the 1944 treaty states that Mexico is entitled to an annual allotment of 1.5MAF of Colorado River Water. Under Article 10(b) Mexico may schedule up to an additional 200,000af when a surplus of water exists in the Colorado River in excess of the amount necessary to supply the United States. As a result of current operating experience, particularly during recent years when there has been an increase in demand for surplus water, the USDI has determined that there is a definite need for specific surplus criteria. The ISC could help implement the specific provisions.

Thinking in purely U.S. terms, it seems reasonable to adopt a new approach for assigning surplus water in order to allocate more water to its U.S. users. Mexico, however, also a member of the lower basin of the Colorado River and a consumer of Colorado River water, should be taken into account. The U.S. government is concerned only with complying with the 1944 treaty and argues that this ISC does not affect the water volume that should be delivered to Mexico.

In the United States, this kind of decision must be supported by an Environmental Impact Statement (EIS), which must include a public comment period open to anyone around the world. Several Mexican organizations, including public universities like the Universidad Autónoma de Baja California, sent letters to the committee pointing out the disadvantages of reducing the flow of water to the Gulf of California. There were two arguments. First, this surplus flow is used to recharge the Mexicali aquifer and dilute its salinity, which affects the economic activities in Baja California and Sonora, who are the eighth and ninth users. Second, an ecological flow along the Colorado River from the border to the lower delta is

necessary to support the marine ecosystem of the Gulf of California, the tenth user. The EIS of the Colorado River Interim Surplus Criteria outlines the potential transboundary effects of reduced flood flow frequency in section 3.16.5.3.

According to the EIS there are positive and negative effects of excess flows to Mexico. On the positive side, the excess flows to Mexico produce lower salinity in the Colorado River. This reduced salinity cancels the adverse effect of the seepage from farm irrigation, groundwater, and drainage recharge. On the negative side, however, increased flow carries sediments that are deposited in the river channel. Furthermore, the increased groundwater level damages crops, which subsequently lowers yields.

The effects of reduced frequencies of excess flows include the following:

- Mexico will not be able to use excess water to recharge and dilute the aquifer, which supplies more than 700 agricultural and urban wells. Currently, salts are leached from farmland on the left bank of the river. This lack of water recharge would induce a draw-down of the piezometric level of the aquifer and consequently lead to an increase in the salinity of its waters.
- ISC and the proposed CA Plan—including lining of the AAC and Coachella Canal—further complicates matters. This would result in the recovery of 67.7MAF per year from the AAC and 26MAF per year from the Coachella Canal. At present, the 67.7MAF per year infiltrates to aquifers in the Mexicali Valley and is used in agriculture, delivered through deep wells.

Conclusions

Development activities for more than 150 years along the enormous borderland that Mexico and the United States share has given rise to a great interdependence among both communities. Their advanced political maturity has created initiatives designed exclusively for this region, where a complex mix of hydrological basins, entry points, and deserts have turned the binational coexistence phenomenon into something more than simple, everyday activities. The Mexicali and

Imperial Valleys are good examples of this interdependence. Colorado River water is shared between two nations and nine states, and recently both countries have been begun giving attention to a tenth user, the ecosystem.

Several issues have been discussed in this chapter, some of which are being solved, others of which have been identified and quantified. Still others must be recognized as binational problems, including the:

- Residual waters that flow through natural courses end as deposits in the Salton Sea and the Santa Clara Sludge
- Intrinsic hydrodynamic relationship between the Mexicali aquifer and the All-American Canal
- Need for an ecological flow along the Colorado River from the international border to the lower delta and to the Gulf of California
- Need for extra flow to maintain the salinity levels in the Salton Sea to guarantee the ecosystem's preservation
- Growing water demand from agriculture, urban, and industrial sectors creating a situation of over-allocation of water among users of the Lower Basin of the Colorado River
- Tension between agriculture and urban users
- Need for a definite and unilateral Colorado River interim surplus criteria

Today in both countries the perception of borderland problems has come into a wider focus than it was 100 years ago. Its origins, effects, and impacts must be analyzed with an integrated vision and with equal consideration of political, ecological, social, and economic issues. Sustainable development is not conceived of only in a friendly environment where geography is considered a unique ecosystem, where the benefits of biodiversity are appreciated, and where borderlines are not distinguished, because all are linked to each other.

Mexico and the United States have learned that reasoning and respect among neighbors is the only way to develop solutions. In December 2000, the first diplomatic agreement, IBWC Minute 306, was signed to demonstrate the intent of both countries to protect

the Colorado River Delta ecosystem. Since 1889, IBWC-CILA has played an important role in creating these agreements and they are the government office responsible of promoting amendments to the 1944 treaty.

Endnotes

[1] To use these waters, Mexico's government must mix them in a place known as the "licuadora" (blender) with water from the wells and the Colorado River because the level of salinity of the water that arrives in Mexico is 1,850ppm.

[2] At that time, the construction of an aqueduct that supplied Tijuana from the City of Mexicali was not considered, given the magnitude of the investment and work—since the natural barrier of the Sierra of Juárez, a topographical difference of more than 1065m in height, was in the way.

[3] The complex over-assignment of water to Los Angeles created serious confrontations between USBR and users. The implementation of a policy for the interim approach to handling surpluses of water from the Colorado River and the CA Plan meant that the parties would not have to revisit this issue for at least 15 years.

[4] The average annual rate of growth in Mexico decreased from 3.25% in the 1990s to 1.96% for the year 2000.

[5] This value is determined by taking annual total assignments delivered to the city and dividing them by the total number of domiciliary services registered. A crowded index is considered 4.18 members per family.

[6] In 1980, the Secretary of Agriculture and Hydraulic Resources, with the intent of planning the water demand in Baja California and the volumes that would be assigned to each city of the state, decided Tijuana would receive 88Mm^3 per year. However, the consumptions reported for 2000 were 117Mm^3 per year, delivered via the Colorado River-Tijuana aqueduct. Mexicali was assigned 82Mm^3 per year, Tecate 16Mm^3 per year, and San Luis 13Mm^3 per year. The San Luis Sonora Sandy Table, or Mesa Arenosa de San Luis, assignment was based on the extraction of 64 deep wells.

[7] In May 2001, at a meeting held by the Commission of Hydraulic Resources of the Senate of the Republic, CESPM

announced that the consumption of water per person in 2000 had been 424 liters per day. However, CNA Subsector Agua Potable y Saneamiento reported water consumptions per person per day varied between 392.3 liters in 1996 and 351.3 liters in 2000 in Mexicali.

[8] When water initially arrives in Mexican territory, the IBWC gives the water to CILA; CILA delivers it to CNA; CNA delivers it to the Mexicali Irrigation District, then the district delivers the water to each Irrigation Module.

[9] In a personal communication, Michael Cohen of the Pacific Institute said that the only reliable supply is the water allocation of 1.5MAF from the 1944 treaty because nobody knows the groundwater recharge rate.

[10] Although percent change is more than double for the Imperial Valley than for the whole of California, the distribution of the ages within the population is approximately the same.

[11] In a 60-year period the population was almost three times more.

[12] Colorado River Irrigation District 014 is comprised of 23 irrigation modules or *módulos de riego.* Each module may have a different area, number of partners, type of crops, and soils.

[13] This administrative figure appears later on in the creation of the modules because problems arose in handling them. The main argument in favor of CNA configuring this administrator is that the modules did not have any administrative experience. In January 2002, due to serious administrative problems, CNA abolished Modulate 13, the authorization to operate the hydraulic net. This module is now operated by technical personnel of Irrigation District 014.

[14] IBWC Minute 242 establishes that the United States will con–tribute the funds for Mexico to build the channel deviation for fossil waters coming from the confined aquifer in the Wellton and Mohawk Valleys. The starting point takes them from Morelos Dam to the Santa Clara Sludge.

[15] According Earl Burnett and collaborators, the Santa Clara Sludge has received, through a bypass drain, an average flow of 195 cubic feet per second with an average quality of 2,942ppm of total dissolved solids from 1977 to 1993. This results in 1,546

tons per day, or 560,000 tons per year deposited into the sludge.

[16] They argue that the water consumption of states in the Colorado River's Lower Basin is increasing competition for the water. California already uses more than its assigned quota and Nevada is next to reach its quota. Mexico will see its underground water reduced with the lining of the All-American Canal.

[17] These three challenges were pointed out by Saúl Alvarez Borrego, a researcher from the Universidad Autónoma de Baja California during the symposium and workshop "… to the Sea of Cortes: Nature, Water, Culture, and Livelihood in the Lower Colorado River Basin and Delta," held in Riverside, California, September 29 to October 2, 2000.

[18] State allotments of Colorado River Water, based on the Water Compact and in million acre-feet per year, was: California, 4.4; Colorado, 3.86; Arizona, 2.85; Utah, 1.71; Wyoming, 1.04; New Mexico, 0.838 and Nevada, 0.3.

[19] This strategy arises as an alternative solution to a difficult problem, because it is impossible to tell residents of this populous and powerful community that because there is not enough water for everyone, no one will receive any of it. This strategy is only a palliative that grants to USBR authorities a 15-year term to solve the problem of water consumption in California's big cities.

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III

Meeting the Water Needs of the Border Region: A Growing Challenge for the United States and Mexico

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Abstract

How to share and use the water resources of the border region (defined as extending 100 kilometers on either side of the border) has been an important issue in U.S.-Mexican relations during the 20th century. Increasing demand and declining availability of fresh water in the region will make the issue even more significant during the 21st century. Population growth, urbanization, and industrial development, particularly on the Mexican side of the border, will generate a steadily increasing demand for water services. Aquifer depletion, misuse of surface water resources, pollution, and climate change will all act to reduce available supplies of usable water.

Absent sustained binational efforts to change current water-management agreements, laws, and practices, each country will seek to protect its own citizens against the impact of growing shortages in a manner that harms the interests of its transboundary neighbors and thereby places increasing strains on the binational relationship. This outcome can be avoided if the stakeholders on both sides of the border can agree on a combination of measures that increase the total

amount of water services that can be produced on a long-term basis, then prioritize the allocation of these services among competing claimants through a series of political compromises involving a full range of stakeholders.

The first of these goals will require substantial additional investment in water conservation and recycling in all sectors. Crop irrigation, which accounts for more than 80% of the water consumed in the border area, should receive priority attention, followed by municipal and industrial uses. Incentives for conservation, particularly in the agricultural sector, where irrigators currently pay little or nothing for the water they use, should be strengthened. Crop irrigators, small businesses, homeowners, and other users should be given financing and technical assistance in installing more efficient water-distribution systems, equipment, and appliances.

The second goal will require a fundamentally different approach to allocation of water resources. Historically, water users have acquired rights to the water they used on an ad hoc basis. In the United States, most agricultural and other users have acquired their water rights under the prior appropriation doctrine: "prior in use, prior in right." When conflicts among holders of these rights have arisen, the courts have been required to readjudicate those rights, as in the 10-year-long court case in the 1960s and 1970s with respect to water rights in the lower Rio Grande.[1] In Mexico, water remains part of the national patrimony, but the government has accommodated withdrawals by giving irrigators and other users water rights sufficient to meet their needs at minimal cost.

Municipal and industrial users have subsequently acquired water rights from governmental and other owners through contractual arrangements. Native Americans continue to hold historical rights to water that have not been fully quantified. The U.S. Endangered Species Act and other laws in the United States and Mexico restrict withdrawals by competing users to the extent that those withdrawals threaten the survival of endangered species and ecosystems. Finally the flows of the Colorado and the rivers feeding into the Rio Grande/Río Bravo have been allocated under a set of domestic compacts and binational treaties often referred to as "the law of the river."

One thing missing from this historical accumulation of legal

rights is any systematic attempt to prioritize competing needs for water services according to any calculus of social welfare. Mexican law does provide that drinking water should have the highest priority, a provision that has been used by the National Water Commission to cut off supplies to irrigators in times of drought, but it does not provide for a more specific allocation among competing uses.[2] Texas also has a law defining six descending priorities for water use with drinking water being the highest,[3] but this law has never been used. As a result of the court case referred to above, Texas has a "Rio Grande water master," who allocates rights to lower Rio Grande Valley water among competing users on the Texas side of the river in accordance with a priority system established by the court. The water master does not, however, have authority to establish priorities on his own.

A more systematic attempt to allocate water resources has not yet been made because there has not been a crisis great enough to generate the political will required. This situation may be changing. Over the last several years, Mexico has failed to meet its treaty obligation to deliver 350,000 acre-feet of water per year from the Río Conchos to the United States. The cumulative deficit is estimated to exceed 1.2 million acre-feet. This shortfall has become a contentious issue between the two governments and has put Mexican authorities in the position of reducing water deliveries to Mexican farmers to make up part of the water expected by Texas farmers.

Although the problem is not as immediate, a similar situation is developing in the lower basin of the Colorado. Estimated total consumptive use of water in the upper and lower basins (including evaporation and transpiration), plus deliveries to Mexico, is approaching the estimated average flow of 15 million acre-feet to 16 million acre-feet per year. Any remaining cushion is rapidly disappearing as evidenced by the virtual elimination of the historical flow of water, silt, and nutrients into the Sea of Cortes. Given the projected growth of population in the lower Colorado River subregion by 50% or more from 1990 to 2020, actual shortfalls can be expected to appear soon. If unfulfilled Native-American claims and minimum unmet requirements of ecosystems in the basin are added in, the combined flows of the Colorado and its tributaries are already substantially overcommitted.

In addition, the gap between withdrawals from and recharge to underground aquifers throughout the border region is steadily growing. Unless this trend is reversed soon, irrigators and other water users dependent on these aquifers will permanently lose their existing sources of supply. The situation is particularly acute in the Paso del Norte area, including El Paso and Ciudad Juárez, where Juárez is projected to exhaust its existing water sources by 2020 or shortly thereafter. When asked where they will find the water Juárez needs thereafter, Juárez municipal officials point to the groundwater north of the border under El Paso. Juárez is already withdrawing water from the portion of the aquifers on the Mexican side of the border and is considering extending its withdrawals not only to drain aquifers to the south and west of the city, but also to drain the aquifers on the U.S. side. Pursuing this option will not be well-received in El Paso absent binational agreement on a joint long-term water-management plan.

The above trends will lead to a binational water-supply crisis characterized by shortages and conflict, absent a comprehensive effort to: increase the amount and quality of water services from available supplies through conservation, protect subsurface reservoirs by bringing withdrawals into balance with recharge, reach stakeholder consensus on how to allocate available water services to those uses with the greatest economic and social utility, and respect Native-American claims and the minimum needs of water-dependent ecosystems. Necessary components of this effort include:

- Better data and analysis of where the water comes from and where it goes, particularly in Mexico
- Creation of new economic incentives, financing vehicles, and technical assistance programs for conservation in all sectors
- Joint planning among Mexico's National Water Commission, U.S. federal agencies, state and local water authorities in both countries, the International Boundary and Water Commission (IBWC), the Border Environment Cooperation Commission (BECC), and the North American Development Bank (NADBank) to assist irrigation districts and other agricultural water users in conserving water by upgrading water-distribution and irrigation systems, shifting to crops that generate greater economic value per unit of water consumed, and reducing the amount of land being irrigated in return for appropriate economic incentives
- A political process involving all stakeholders that will produce agreement on a more realistic long-term allocation of available surface and subsurface water among competing uses, including honoring legitimate Native American claims and protecting critical ecosystems

Such agreement will only be possible if stakeholders make creative use of technology, markets, and policy reform along the lines discussed here.

Enfrentando las Necesidades de Agua de la Región Fronteriza: Un Reto Creciente para los Estados Unidos y México

William A. Nitze

Resumen

Cómo compartir y usar los recursos acuáticos de la región fronteriza (definida como la que se extiende 100 kilómetros en ambos lados de la frontera) ha sido un tema importante en las relaciones E.U.-México durante el siglo veinte. El incremento en la demanda y la reducción en la disponibilidad de agua dulce en la región harán el tema aún más significativo durante el siglo XXI. El crecimiento poblacional, la urbanización y el desarrollo industrial, particularmente en el lado mexicano de la frontera, generarán un incremento continuo en la demanda de servicios relacionados con el agua. El agotamiento de acuíferos, el mal uso de los recursos de agua superficial, la contaminación, y el cambio climático actuarán en conjunto para reducir las fuentes disponibles de agua potable.

En la ausencia de esfuerzos binacionales sostenidos para cambiar los tratados de administración del agua, leyes, y prácticas, cada país

buscará proteger a sus ciudadanos contra el impacto de la creciente escasez en una manera que daña los intereses de su vecino transfronterizo y por lo tanto coloca presiones crecientes en la relación binacional. Este resultado puede ser evitado si los actores clave en ambos lados de la frontera pueden acordar una combinación de medidas que incrementen el monto total de servicios de agua que pueden ser producidos sobre una base de largo-plazo, después priorizar la asignación de esos servicios entre los competidores demandantes a través de una serie de compromisos políticos que involucran a una gran parte de los actores clave.

La primera de estas metas requerirá una inversión adicional sustancial en la conservación del agua y reciclamiento en todos los sectores. La irrigación de cultivos, que constituye más del 80% del agua consumida en la región de la frontera, deberá recibir atención prioritaria, seguida por el uso municipal e industrial. Los incentivos para la conservación, particularmente en el sector agrícola, en donde los usuarios pagan actualmente poco o nada por el agua que utilizan, deben ser fortalecidos. Irrigadores de cultivos, pequeñas empresas, propietarios de inmuebles, y otros usuarios deberán recibir financiamiento y asistencia técnica para la instalación de sistemas de distribución de agua más eficientes, equipos, y aparatos.

La segunda meta requerirá de un enfoque fundamentalmente diferente para la asignación de los recursos del agua. Históricamente, los usuarios de agua han adquirido derechos del agua que usaron para un momento específico en particular. En los Estados Unidos, la mayoría de los agricultores y otros usuarios han adquirido sus derechos de agua bajo el derecho de apropiación por antigüedad: "primero en uso, primero en derecho." Cuando han surgido conflictos entre los poseedores [propietarios] de estos derechos, las cortes han sido requeridas para readjudicar esos derechos, como en el caso jurídico con duración de 10 años en las décadas de los 60 y 70 con respecto a los derechos del agua en la parte baja del Río Grande.[1] En México, el agua permanece como parte del patrimonio nacional, pero el gobierno ha distribuido volúmenes al otorgar a los irrigadores y a otros usuarios derechos de agua suficientes para satisfacer sus necesidades a un costo mínimo.

Los usuarios municipales e industriales han adquirido subsecuentemente derechos de agua del gobierno y de otros propietarios a

través de convenios. Las poblaciones indígenas continúan siendo poseedores de derechos históricos sobre el agua que no han sido completamente cuantificados. El Acta de Especies Amenazadas de los E.U. y otras leyes en los Estados Unidos y México restringen la extracción por usuarios competidores si amenazan la supervivencia de especies y ecosistemas amenazados. Finalmente los flujos del Río Colorado y los ríos tributarios del Rio Grande/Río Bravo han sido ubicados bajo una serie de acuerdos y tratados binacionales a menudo referidos como "la ley del río."

Un aspecto ausente en esta acumulación histórica de derechos legales, es algún intento sistemático para priorizar las necesidades que compiten por servicios de agua de acuerdo con alguna estimación del nivel de bienestar social. La ley mexicana ubica al agua potable como asunto de la más alta prioridad, argumento que ha sido usado por la Comisión Nacional del Agua para suspender el abastecimiento a los irrigadores en temporadas de sequía, pero no define alguna ubicación específica entre los usos que compiten.[2] Texas también tiene una ley que define seis prioridades descendentes para el uso del agua siendo la del consumo humano como la más alta,[3] pero esta ley jamás ha sido usada. Como resultado del caso jurídico arriba referido, Texas tiene un "Programa Maestro de Agua del Río Grande," quien asigna derechos de agua al Valle del Bajo Río Grande entre usuarios competidores para el lado de Texas del río, de acuerdo con un sistema de prioridades establecido por la corte. Sin embargo, el Programa Maestro de Agua no tiene autoridad para establecer prioridades por su cuenta.

Un intento más sistemático para asignar dotaciones de agua aún no se ha hecho porque no ha habido una crisis lo suficientemente grave para generar la voluntad política requerida. Esta situación puede estar cambiando. En el transcurso de los últimos años, México no ha cumplido con su obligación del tratado de entregar 350,000 pies-acre de agua por año del Río Conchos hacia los Estados Unidos. Se estima que el déficit acumulativo excede los 1.2 millones de pies-acre. Esta deuda se ha convertido en un tema polémico entre los dos gobiernos y ha puesto a las autoridades mexicanas en la posición de reducir las entregas de agua a agricultores mexicanos para proveer parte del agua esperada por los agricultores tejanos [texanos].

Aunque el problema no es tan inmediato, una situación similar

se está desarrollando en la cuenca baja del Colorado. El consumo de agua estimado en la cuenca alta y baja (incluyendo evaporación y transpiración), más las entregas a México, se acerca al flujo promedio estimado de 15 a 16 millones de pies-acre por año. Cualquier reserva restante está desapareciendo rápidamente como se aprecia en la eliminación virtual del flujo histórico de agua, sedimento, y nutrientes hacia el Mar de Cortés. Dado que el crecimiento poblacional proyectado en la subregión de la parte baja del Río Colorado es de un 50% o más entre 1990 y el 2020, se puede esperar que desabastos aparezcan pronto. Si se añaden los reclamos de Las poblaciones indígenas y los requerimientos mínimos no cumplidos para los ecosistemas de la cuenca, los flujos combinados del Colorado y sus afluentes se encuentran ya sustancialmente rebasados.

Además, la diferencia entre las extracciones y las recargas a los acuíferos subterráneos a lo largo de la región fronteriza, está creciendo constantemente. A menos que esta tendencia sea revertida pronto, los regadores y otros usuarios del agua dependientes de estos acuíferos, perderán permanentemente sus fuentes de abastecimiento existentes. La situación es particularmente crítica en el área Paso del Norte, incluyendo El Paso y Ciudad Juárez, en donde se proyecta que Juárez agotará sus fuentes existentes de agua para el año 2020 o un poco después. Al cuestionar a las autoridades municipales de Juárez sobre donde encontrarán el agua que Juárez necesitará posteriormente, estos apuntan hacia el agua subterránea ubicada al norte de la frontera debajo de El Paso. Juárez ya está bombeando el agua de la porción de acuíferos en el lado mexicano de la frontera pero está considerando extender sus extracciones no solo para drenar acuíferos al Sur y Oeste de la ciudad, sino también aquellos ubicados en el lado de los E.U. El buscar esta opción no será bien recibido en El Paso ante la ausencia de un acuerdo binacional sobre un plan de manejo compartido del agua a largo plazo.

Las tendencias anteriores conducirán a una crisis binacional de abastecimiento de agua caracterizada por recortes y conflictos, en la ausencia de un esfuerzo para: incrementar a través de la conservación la cantidad y calidad de los servicios de agua a partir de fuentes disponibles, proteger reservas subterráneas manteniendo un balance entre el bombeo y la recarga, lograr el consenso de los actores clave sobre cómo asignar las dotaciones del agua disponible

a aquellos usos con la más alta utilidad económica y social, y respetar los reclamos de Las poblaciones indígenas así como los requerimientos mínimos para ecosistemas dependientes del agua. Los componentes necesarios para lograr este esfuerzo incluyen:

- Mejores datos y análisis de dónde proviene el agua y a donde se va, particularmente en México.
- Creación de nuevos incentivos económicos, vías de financiamiento y programas de asistencia técnica para la conservación en todos los sectores.
- Planeación conjunta entre la Comisión Nacional del Agua de México, agencias federales de los E.U., autoridades del agua-locales y estatales en ambos países, la Comisión Internacional de Límites y Aguas (CILA), la Comisión de Cooperación Ambiental Fronteriza, y el Banco de Desarrollo de América del Norte (BANDAN) para brindar asistencia a los distritos de riego y otros agricultores usuarios de agua para conservar agua actualizando sistemas de irrigación y distribución, cambiando a cultivos que generen mayor valor económico por unidad de agua consumida, y reduciendo la cantidad de terreno siendo irrigado a cambio de incentivos económicos apropiados.
- Un proceso político, involucrando a todos los actores clave, que producirá el acuerdo sobre una asignación mas realista a largo plazo del agua superficial y subterránea disponible entre usuarios competidores, incluyendo el honrar los reclamos legítimos de Nativos Americanos y proteger ecosis temas críticos.

Dicho acuerdo solo será posible si los actores clave hacen uso creativo de la tecnología, los mercados, y reforma de políticas dentro del marco aquí discutido.

An Historical Perspective

Binational diplomacy concerning water in the border region dates back to the convention of March 1, 1889, between the United States and Mexico establishing an International Boundary Commission.[4]

The 1889 convention was followed by the convention of May 21, 1906,[5] providing for the distribution between the United States and Mexico of the waters of the Rio Grande above Fort Quitman, Texas, for the 89-mile international boundary reach of the Rio Grande through the El Paso-Juárez Valley. The convention allotted 60,000 acre-feet per year to be delivered to Mexico's Acequia Madre just above Juárez. To bring water to irrigators in southern New Mexico and far west Texas and to facilitate those deliveries, the United States constructed, at its expense, the Elephant Butte Dam in its territory. The convention further provides that deliveries to Mexico and to U.S. irrigators downstream of the Elephant Butte Dam should be reduced proportionately in the event of a serious drought or irrigation accident.

The 1906 convention was a response to the impact on Mexico of the reduction of Rio Grande flows resulting from the rapid expansion of irrigated agriculture starting in the San Luis Valley in the 1870s. This expansion accelerated on the U.S. side of the border as dams and other water-supply infrastructure were built in response to the Reclamation Act of 1902. As water resources on both sides of the border were increasingly appropriated to transform the desert into farms, orchards, and cities during the first part of the twentieth century, it became apparent that the allocation of water resources between the two countries needed to be better defined and the commission given greater authority and resources.

Accordingly, on February 3, 1944, the United States and Mexico entered into a treaty relating to the "(u)tilization of the waters of the Colorado and Tijuana Rivers and of the Rio Grande."[6] The 1944 treaty allocates to Mexico all of the waters reaching the Rio Grande from the San Juan and Alamo Rivers, two-thirds of the flow in the main channel of the Rio Grande from the Río Conchos and five smaller tributaries from Mexico, and one-half of all other flows occurring in the main channel of the Rio Grande downstream from Fort Quitman.

The treaty allocates to the United States all of the waters reaching the main channel of the Rio Grande from the Pecos and Devils Rivers and five smaller tributaries from the United States; one-third of the flow reaching the main channel of the river from the Río Conchos and the other above-mentioned tributaries from Mexico, providing that this third shall not be less, as an average amount in

cycles of five consecutive years, than 350,000 acre-feet annually; and one-half of all other flows occurring in the main channel of the Rio Grande downstream of Fort Quitman.

The 1944 treaty further commits the United States to deliver to Mexico a guaranteed annual quantity of 1.5 million acre feet of Colorado River water and an additional 200,000 acre-feet per year in times of surplus. In accordance with the Colorado River Compact of 1922, the upper and lower basins of the Colorado were each to supply half of the amount of Colorado water allocated to Mexico under the treaty. The treaty said nothing, however, about the quality of this water, an issue that was not explicitly addressed until 1973 in a separate agreement.

It is the provision of the 1944 treaty allocating 350,000 acre-feet annually from the Río Conchos and other specified Mexican tributaries to the Rio Grande that has given rise to Mexico's current water debt to the United States. Although for many years flows from the Conchos were sufficient to provide the United States with substantially more than that amount, drought conditions during the last five years have caused Mexico to substantially under-deliver and build up a cumulative water debt to the United States that was as high as 1.8 million acre-feet (it has subsequently been reduced to 1.2 million acre-feet). Since, under normal rainfall conditions, the Conchos provides two-thirds of the surface water required to sustain the economy and ecology of the lower Rio Grande basin, this ongoing shortfall presents a challenge to both countries. On the institutional side, the treaty changed the commission's name to the International Boundary and Water Commission (IBWC) and assigned to the IBWC the task of carrying out the principles of all past and present treaties. The IBWC maintains the status of an international body and is composed of two independent sections, one in the United States and one in Mexico.

During the years following the World War II, the process of transforming the desert along the U.S.-Mexican border accelerated. Agricultural and municipal demands steadily increased with the growth of irrigated agriculture and cities. Industries such as mining, smelting, and metalworking had existed for some time in the border region. They were joined by new manufacturing industries responding to growing demand for consumer products in both countries. The Mexican maquiladora (maquila) program, under which products

could be assembled in Mexico from imported components and then shipped to the United States without payment of duty, greatly accelerated this process from the late 1960s on. The new maquila plants and the housing required for their workers not only use significant amounts of water but also generate large amounts of water pollution.

By the end of the twentieth century, the border region had been transformed from a sparsely populated desert region characterized by irrigated agriculture and small cities (with the exception of San Diego) to an increasingly industrialized region of more than 10 million people concentrated in 14 sister-city pairs, characterized by industrial areas full of factories and maquila plants and, at least in Mexico, rapidly growing cities, several of which had more than 1 million inhabitants. One thing that had not increased was the supply of usable water.

The impacts of these changes on water availability and quality did generate a number of legal, institutional, and physical responses during this period. One such impact, referred to above, is the deterioration in quality of the Colorado River water crossing the border into Mexico. The water-quality problem was caused in large part by the Wellton-Mohawk Irrigation District development in Arizona and the dumping of its agricultural drainage waters into the Colorado River. The salt content of river water entering Mexico increased from approximately 800 parts per million (ppm) to approximately 1,500ppm.

An effort was made to solve the resulting dispute through an addendum to the original 1944 U.S.-Mexican treaty titled Minute 242,[7] stipulating that the water received by Mexico should have salinity levels no more than 115ppm higher than the water arriving at Imperial Dam. To help meet the Minute 242 obligation, Congress passed the Colorado Basin Salinity Control Act of 1974, which, among other things, authorized construction of desalting plants at Yuma, Arizona, as well as a 10,000-acre reduction in irrigable acreage in the Wellton-Mohawk Irrigation District.

The post-war period also witnessed continued construction of dams and other infrastructure designed to supplement or redirect flows of the Colorado that were no longer sufficient to cover commitments made in the Colorado River Compact of 1922, which assumed an average annual flow at Lee's Ferry of 18 million acre-

feet. The Colorado River Storage Project Act of 1956, which authorized construction of the Glen Canyon Dam, and the Colorado River Basin Project Act of 1968, which authorized construction of the Central Arizona Project, were milestones in this effort. Similar efforts, although on a much smaller scale, were mounted on the Mexican side of the border. A common characteristic of all of these projects is that the irrigators and other users of the water supplied by the projects have paid only a small fraction of the projects' cost.

Starting in the 1970s, attention in the United States began to shift from simply providing the water required to accommodate further development to addressing some of the environmental problems associated with the development that had already taken place. In addition to the salinity problem in the lower basin of the Colorado discussed above, the environmental community and other concerned citizens in the United States pressed for greater attention to other negative impacts of existing water-rights allocations, dam operations, or water management procedures on aquatic habitats and species and other environmental resources. U.S. federal environmental statutes, including the Clean Water Act, the Endangered Species Act, and the National Environmental Policy Act (NEPA), were increasingly referred to in strengthening the case for maintaining in-stream flows at levels sufficient to protect aquatic species and water-dependent ecosystems.

In 1989, for example, the U.S. secretary of the interior called for a full assessment of the environmental impacts of the operation of the Glen Canyon Dam. The resulting expanded Glen Canyon Environmental Studies Research Program was a critical factor in the passage of the Grand Canyon Protection Act of 1992, which ensures that water released from the Glen Canyon Dam will stay within a range that protects the safety of Grand Canyon river rafters and boaters and better maintains the sand beaches along the river used by the these boaters. This legislation marks the first time that protection of downstream river resources was identified as a primary purpose of a Colorado River dam.

Also, starting in the 1970s, the Mexican federal government began to pay greater attention to the environmental consequences of rapid post-war development. In 1971, the federal government promulgated its first comprehensive anti-pollution law, the Law for Environmental Pollution Prevention and Control, which strength-

ened and enlarged the scope of prior ecological standards. In 1982, a more comprehensive Federal Law of Environmental Protection was enacted, and the first ministerial-level environmental agency, the Urban Development and Ecology Ministry, was established.

In 1987, the Mexican Constitution was amended to impose ecological obligations on private property owners and to empower the national Congress to pass laws that established common standards at the federal, state, and municipal levels. Based on this amendment, the Ley General del Equilibrio Ecológico y la Protección al Ambiente (General Law of Ecological Balance and Environmental Protection, in Spanish LGEEPA), which consolidated and strengthened prior laws and standards, was promulgated in 1988.

In an effort to improve water management, the Comisión Nacional del Agua (National Water Commission, in Spanish CNA) was established in 1989 with sole authority in matters of water management within the federation. In 1992, the Territorial Waters Act was amended to regulate the use of territorial waters and to protect their quality. Since 1992, Mexico has modernized its water-management and planning systems with the help of a World Bank loan. Specifically, it has greatly improved its water-rights registry, which should help quantify who holds what water rights and thereby provide the basis for the market-based transfers proposed below. Although additional political resolve will be required to implement these laws, and additional resources will be required to make them effective, it is clear that water development and management in Mexico, including the border region, is increasingly subject to ecological constraints.

Against this backdrop of increased attention to the environmental consequences of historical water-development practices at the national level, the 1980s witnessed growing binational cooperation in addressing the environmental problems of the border region, including those related to water. During his campaign for president in 1980, then-Governor Ronald Reagan of California was confronted with sewage flowing north from Mexico onto the beaches south of San Diego, and he was asked what he was going to do about it if elected president. His campaign pledge to clean up the mess led to the negotiation of the La Paz Agreement[8] on the protection and improvement of the environment in the border area, signed by Presidents Reagan and Miguel de la Madrid in 1983.

The La Paz Agreement established a basic framework for binational cooperation for addressing the environmental problems of the border region; more specific obligations were spelled out in a series of annexes. The first such annex addressed the municipal wastewater issue and led to the construction more than 10 years later of an international sewage-treatment plant south of San Diego, which is today treating a substantial portion of the sewage generated in Tijuana. Four subsequent annexes deal with preparedness and response in the case of industrial accidents, transboundary movement of hazardous waste, copper-smelter emissions, and air pollution.

The La Paz Agreement also led to the creation of a series of permanent binational working groups to address environmental issues in specific media (air, water, chemicals) or subject areas (waste management, emergency response, enforcement). Although these working groups made progress in understanding and addressing specific environmental problems in the border area, it became apparent as the decade progressed that environmental conditions along the border would continue to deteriorate absent a much greater investment in environmental infrastructure than had taken place to date.

The event that made much of that investment possible and set the stage for addressing the water and other environmental problems of the border region in a more comprehensive fashion was the negotiation of the North American Free Trade Agreement (NAFTA).[9] When Presidents George Bush and Carlos Salinas announced their determination to negotiate an agreement extending the U.S.-Canada free trade agreement to Mexico and thereby transforming all of North America into a free trade zone, the U.S. environmental community saw an opportunity to exert political leverage toward requiring Mexico to bring its environmental performance up to the U.S. levels. By allying themselves with the labor unions, which opposed the agreement as posing a threat to U.S. jobs, U.S. environmental organizations did, in fact, achieve considerable leverage and caused certain environmental provisions to be inserted into the treaty text.

With the election of President Bill Clinton in 1992, this leverage was greatly enhanced by the new president's need to deal with the labor and environmental movements as core constituencies of the Democratic Party. As a result, President Clinton forced Mexico and Canada to accept side agreements on labor and the environment and

somewhat stronger language in the treaty itself as the price for agreeing to sign NAFTA. The environmental side agreement[10] created a North American Commission for Environmental Cooperation (CEC), which is empowered to develop and implement environmental cooperation programs, to consider submissions from citizens groups asserting that one of the three countries is failing effectively to enforce its environmental laws, to prepare factual records in response to those submissions (Articles 14 and 15 of the side agreement), and to issue reports initiated by the secretariat on specific environmental problems (Article 13). The secretariat has already addressed water-management issues in the border region in its report on the San Pedro riparian area straddling the Arizona-Sonora border. The report describes an approach to water management in the area that would both meet human needs for water and protect the San Pedro ecosystem (CEC 1999).

Another group that exerted leverage during the NAFTA negotiations in a manner even more relevant to the water problems of the border region is the Congressional Border Caucus. Led by Congressmen Esteban Torres and Kika de la Garza, the Border Caucus insisted that new financial resources be dedicated to improving social and environmental conditions in the border region by providing adjustment assistance to U.S. workers who lost their jobs because of NAFTA and by financing needed environmental infrastructure on both sides of the border. In order to gain the support of these members for the NAFTA package, in 1993 the U.S. and Mexican governments entered into an agreement creating two new binational institutions to help develop environmental infrastructure in the border region: BECC and NADBank.[11]

BECC and the NADBank were given complementary missions. The two main functions of BECC are to:

- Assist states, localities, public agencies, and private investors in developing environmental infrastructure project proposals by helping them analyze the technical, environmetal, and financial aspects of the projects, evaluate their social and economic benefits, and arrange financing for the projects in concert with the NADBank
- Certify applications for project financing to the NADBank and other sources

The BECC also provides technical assistance for project planning and design through the Project Development Assistance Program (PDAP) funded by the U.S. Environmental Protection Agency (EPA). Finally, BECC promotes public participation in the project certification process by holding public meetings to hear comments on projects being considered for certification, organizing public participation mechanisms at the community level, and conducting other outreach activities.

The three main functions of NADBank are to:

- Provide technical assistance for project financing and implementation
- Promote public and private investment in border projects
- Supplement such investment with NADBank loans and guarantees

The United States and Mexico have each pledged to contribute $1.5 billion of capital to NADBank for a total capitalization of $3 billion. Of this amount, $450 million is paid-in capital, and the remainder is callable capital. To date, $303 million of the $450 million has been paid in.

Through its Institutional Development Cooperation Program (IDP), NADBank promotes the long-term financial health of water utilities through initiatives such as management assessments and user-rate studies. In 1999 NADBank used the IDP to create the Utility Management Institute, which trains border community utility professionals in long-term utility organization, administration, finance, and management. Finally, NADBank has recently set aside a portion of its retained earnings to subsidize solid-waste projects, which are ineligible for grant funds from the EPA.

BECC and NADBank have accomplished much since they began operations in 1994. As of March 31, 2002, BECC has certified 57 projects with a total value of approximately $1.2 billion, of which 12 have been completed and are in operation and 21 are under construction. Thirty projects have been certified in Mexico and 27 in the United States with 55% of the total funding going to U.S. projects and 45% to Mexican projects. Wastewater treatment plants and associated infrastructure account for the largest number of projects, followed by drinking-water systems and municipal solid-waste projects.

In addition to moving a number of projects through the pipeline

and thereby substantially improving environmental conditions in the border region, BECC and NADBank have provided millions of dollars of technical assistance to smaller communities on both sides of the border and thereby enhanced their capacity to plan, build, operate, and maintain water-treatment and drinking-water systems. Through its public participation process involving the users and providers of water services, BECC has given citizens groups and community representatives opportunities to voice their concerns and influence investment decisions affecting their communities, which they had never had before, particularly in Mexico. Finally, the sustainable development criteria included in the BECC project certification guidelines represent the first such criteria adopted by any international organization.

Despite these accomplishments, the first six years of experience with BECC and NADBank have disclosed some shortcomings in their effectiveness. First, the charters of the two institutions focus their efforts on water treatment and drinking water. Although there is general language within the charters permitting BECC to certify and NADBank to lend for other projects that improve environmental conditions within the border region, the two institutions have, to date, interpreted their mandates narrowly. Therefore they have not addressed air quality, hazardous waste, and other environmental problems that have a negative impact on the health and quality of life of border residents. Even with respect to water, the two institutions have focused their efforts on improving water quality rather than increasing the quantity of available water services.

There are a number of reasons for this limited focus. Water pollution and lack of potable water are immediate problems requiring a political response. Helping border communities to build needed wastewater and drinking-water infrastructure is politically easy, provided that projects are sufficiently subsidized to keep rate increases, particularly for poor users, small. Changing the status quo regarding the allocation, cost, and method of delivery of water services more broadly, on the other hand, is bound to meet resistance from existing users. It is for this reason that the two governments have not given BECC or NADBank authority over water-rights allocation or administration. Finally, there is a backlog of $1 billion to $3 billion in needed wastewater and drinking-water projects in the border area that could be worked through without addressing broader water issues.

Nevertheless, in 2000, BECC and NADBank did decide in principle to expand their respective mandates to address other environmental problems, including water-management issues. The reason for this decision was NADBank's failure to use more than a tiny fraction of its lending capacity on BECC-certified projects. The U.S. communities in which those projects have been built have been able to find lower-cost funding from the municipal bond market and other U.S. lenders. The Mexican communities with projects have not been able to afford the currency-risk adjusted rates charged on NADBank loans. Therefore the bulk of the public funding for projects on both sides of the border has come from grants from the EPA. Through March 31, 2002, EPA has channeled $330 million in water-infrastructure grant funds to border projects, $305 million of which has already been disbursed or committed. In comparison, NADBank loans for these projects have totaled only $23 million.

NADBank's inability to use its more than $2 billion dollars in lending capacity gave rise to criticism on both sides of the border. The Mexican government in particular became concerned that an institution to which it had contributed more than $150 million in paid-in capital was not making a greater contribution to addressing Mexico's unmet social needs. During his 2000 presidential campaign, then-candidate Vicente Fox presented a vision of economic and social integration of Mexico with the United States, assisted by transition funds flowing from the United States to Mexico, following the model of the European Union. Fox pointed toward using NADBank to perform this function.

In response to this political interest, the NADBank board discussed how the bank could make better use of its lending capacity by offering to finance other types of environmental projects. At its meeting on November 16, 2000, the board agreed to set aside $50 million of its capital to lend at subsidized rates for projects in key sectors and to give management authority to make equity investments in certain types of projects on a case-by-case basis. Among the new types of projects approved for future certification and funding are water-conservation projects in the agricultural sector. NADBank is already exploring projects that would finance investments to improve the efficiency of irrigation in Texas irrigation districts through the sale of conserved water to nearby municipalities, and it hopes to explore similar projects on the Mexican side of the border.

The U.S. and Mexican governments have been engaged in ongoing discussions about how to reform BECC and NADBank in order to enable the two institutions to work more effectively together. The two governments seriously considered merging the two into a single institution but backed away from the idea in the face of strong pressure from border states and community groups. Two changes that have been preliminarily agreed upon are to combine the boards of the two institutions and to extend the geographic area for projects eligible for market-rate loans from 100 kilometers to 300 kilometers south of the border.

The two governments have not, however, reconciled their different agendas for the two institutions. From a U.S. perspective, the primary role of BECC and NADBank is to reduce the environmental and social impacts of current patterns of economic activity and resource use in the border region. From a Mexican perspective, the primary role of the two institutions is to expedite the economic and social development of northern Mexico, making up the shortage of infrastructure funding from Mexican public sources with as much U.S. grant funding as possible. The tension between these two perspectives is inherent in the basic difference in economic circumstances between the two countries and it is unlikely to be resolved in the foreseeable future.

The Current Situation

These developments could mark a turning point in moving toward a less-fragmented approach to water management along the border. Management of water resources in the border region is fragmented in three respects.

First, it is fragmented geographically. The Colorado draws from two separate basins whose water resources have been allocated among competing U.S. jurisdictions with a residual amount committed to Mexico. The Rio Grande/Río Bravo has two different flow regimes upstream and downstream of the Río Conchos.

Upstream of the Río Conchos the river's flow has derived primarily from the melting of snow in the Rocky Mountains. This flow has been captured by a series of dams, reservoirs, and diversions, most notably the Elephant Butte Dam, to provide water for irrigation and municipal uses. After flowing through El Paso and Ciudad Juárez,

where substantial additional quantities are withdrawn, the river enters the 80-mile reach to Fort Quitman, which is substantially dewatered and has to be periodically dredged to maintain its flood capacity. The subsequent 180-mile reach between Fort Quitman and Presidio (the "Forgotten" River Reach) has very little flow and is a shadow of its predevelopment state.

Only when it is joined by the Río Conchos flowing out the Mexican highlands after the Presidio does the Rio Grande/Río Bravo again become a great river worthy of its history. Thus the river can conveniently be divided into two discrete hydrologic segments: an upstream segment, in which the United States is the upper riparian nation with treaty obligations to deliver a quotient of water to Mexico; and a downstream segment starting with the Río Conchos confluence, in which Mexico is the upper riparian nation with treaty obligations to deliver a quotient of water to the United States.

Second, management of water resources along the border is fragmented legally and institutionally. As mentioned above, allocation of these resources, is governed by a kaleidoscope of binational treaties, interstate compacts, reclamation projects, water rights, and contracts. In the Paso del Norte area alone, water management is governed by binational treaties; the federal laws of the United States and Mexico; the laws of Texas, New Mexico, and Chihuahua; and the legal regimes of El Paso, Ciudad Juárez, and Las Cruces.

These treaties, laws and regimes are implemented by a plethora of government institutions, including the Texas Commission on Environmental Quality, Texas Water Development Board, New Mexico Office of the State Engineer, Interstate Stream Commission of New Mexico, CNA, Rio Grande Compact Commission, and IBWC. Also, a plethora of water providers are involved, including El Paso Water Utilities, El Paso County Water Improvement District, Las Cruces Water Resources Department, Junta Municipal de Agua y Saneamiento de Ciudad Juárez, and Distrito de Riego 009, a division of CNA dedicated to delivering irrigation water to members of its district (Paso del Norte Water Task Force 2001).

These institutions and an even larger number of private organizations are all stakeholders in the process of transforming the current fragmented system into a more integrated decision-making process for managing the border's water resources, which recognizes the real value of those resources and prioritizes their uses on the basis of

some calculus of social welfare.

The final discontinuity in the management of water resources along the border is that water-user communities and the other stakeholder communities simply do not communicate with each other enough. This is particularly true with respect to the water needs of the threatened ecosystems and the rights of Native-American communities. Private institutions such as Instituto Tecnológico y de Estudios Superiores de Monterrey (ITESM), the Universities of Texas at Austin and El Paso, the Pacific Institute, the Texas Center for Policy Studies, Environmental Defense, and the Natural Heritage Institute are working to develop comprehensive hydrological analyses and management options that could be the basis for stakeholder dialogues on a regional basis, but they have not yet received sufficient support from the two governments or binational institutions (ITESM 2001).

Partially as a result of the fragmented management structure described above, the cost of water to most users in the border region is only a small fraction of its true value. Agricultural irrigators, which account for more than 80% of the water consumed on both sides of the border, pay almost nothing for their water in Mexico (50 centavos per cubic meter) and only a small fraction of its marginal cost in the United States. Municipal users pay more, but their rates are subsidized, particularly for poor households. In Mexico, failure to meter water use in a majority of households means that many people do not even pay the subsidized price. Larger industrial users frequently pay prices that reflect the market value of the water they use, but they often cannot obtain the additional water supplies they need to expand their operations because there is no market mechanism for obtaining those supplies.

The predictable result of this underpricing is lack of investment in maintaining and upgrading water systems and massive waste. CNA estimates that 60% of the water supplied for irrigation in Mexico is lost through evaporation, seepage, or other unplanned diversions (CNA 2001b). The situation is somewhat better in the United States, but irrigation losses are still close to 50% on average. In a report completed as part of the Texas Senate Bill 1 regional water-planning study for the Rio Grande region (Region M), Professor Guy Fipps of Texas A&M University determined that there was significant potential for water savings in irrigated agriculture in

the region's 28 irrigation districts (2000).

Professor Fipps determined that the average conveyance efficiency in the 28 districts was only 70.8%. Out of a total of 1,459 miles of distribution canals, 552 miles were lined, 613 were unlined, and 294 were unknown. The condition of the lined canals was rated as poor, with many canals showing high rates of seepage loss due to poor construction and inadequate maintenance. Farm practices and methods also had much room for improvement with 34% of the irrigated acreage in five larger districts still using field ditches to deliver water to their crops as opposed to tubing, pipes, or drip-tape.

His overall conclusion was that, out of average annual diversions by all districts in Region M of approximately 900,000 acre-feet, the combined water-saving potential from improving district conveyance efficiency from 70% to 90% and improving on-farm practices and methods was 354,000 acre-feet, or nearly 40% (Fipps 2000). Based on a capital cost of $127 per acre-foot (in 1988 dollars) for the Imperial Irrigation District's comprehensive water-conservation program with the Municipal Water District, and assuming that the capital investment would be written off over 10 years, such savings could be realized at a cost equivalent to buying the water for $10 to $20 per acre-foot, which is well below the subsidized price for incremental supplies today.

The agricultural sector's combined water-saving potential is even greater on the Mexican side of the border where conveyance efficiency is lower and on-farm practices and methods are less advanced than in the United States. CNA has a plan to upgrade Mexico's water-conveyance infrastructure for the agricultural sector at an estimated cost of 40 billion pesos. It estimates that the planned investments will generate annual water savings of 10 billion cubic meters (CNA 2001a).

These estimates translate into a cost of 4 pesos per cubic meter. With municipalities and industry willing to pay 5 pesos to 15 pesos per cubic meter for additional water supplies, CNA's investment could in theory be recouped in one year or less. The problem is that CNA is not likely to receive the necessary investment funds from the Mexican federal budget given the overall budget constraints and other priorities. And, the legal framework and mechanisms for raising those funds through the sale of conserved water rights to municipalities and industry are yet to be developed.

Although it accounts for only 10% to 15% of total water consumption in the border area, the municipal sector also offers significant water-saving opportunities. The greatest such opportunity is repairing the water-distribution systems in Mexican border cities. CNA estimates that on average 35% of the water delivered to such systems leaks from water pipes before it reaches intended users (CNA 2001b). In some Mexican border cities, the leakage rate exceeds 50%.

Most water utilities in Mexican border cities are caught in a vicious cycle. Lack of metering and a culture of nonpayment lead to low collection rates for water deliveries, which in turn lead to lack of investment in and maintenance of water-distribution systems, which in turn leads to a low quality of service, which reinforces the culture of nonpayment. The situation is better on the U.S. side of the border, although meaningful savings could be realized by upgrading municipal distribution systems.

There are also significant savings to be realized in the municipal sector from water conservation by end users. Conservation programs in Los Angeles, Phoenix, and Tucson, have achieved reductions in per capita water consumption of 20% or more. Similar programs should be instituted in U.S. and Mexican border cities. For such programs to succeed, particularly in Mexico, currently unmetered end users will have to be metered, enforcement will have to be strengthened, and homeowners and small business owners will have to be given technical and financial assistance in installing water-efficient equipment.

The industrial sector offers the smallest water-savings opportunities because it accounts for the smallest percentage of total water consumption and pays the highest prices for its water supplies. The greatest conservation opportunity in the industrial sector lies in recycling wastewater from the municipal and agricultural sectors, which does not have to be treated to drinking-water standards to be used in many industrial applications. There are also industry-specific opportunities to reduce water consumption per unit of output through process improvements.

Finally, it would be remiss not to mention the natural sector, which has been deprived of the water it needs by surface water and groundwater diversions to service the other sectors discussed above. As mentioned earlier, the U.S. Endangered Species Act and provisions in Mexican federal laws, as well as the public trust doctrine,

prohibit or restrict water withdrawals for human activities when they would threaten the existence or health of endangered species or ecosystems. It has proven difficult to enforce these laws, however, in the face of political pressure from people benefiting from those withdrawals. Fortunately, water conservation in other sectors may provide an opportunity to provide additional water to the natural sector.

Instruments for Change: Technology, Markets, and Policy Reform

The instruments to bring about conservation and thereby provide additional water resources to meet the needs of competing users without further depletion of groundwater reservoirs in a manner that maximizes social welfare are at hand. These instruments are technology, market mechanisms, and policy reform.

Technology

As indicated above, this is already enough technology to conserve a substantial portion (at least 35% to 40%) of the water diverted for agricultural, municipal, and industrial uses in the border region. The bulk of those savings can be achieved by rebuilding and properly maintaining water-conveyance, distribution, and storage systems and by metering water deliveries from those systems to end users. The concrete, liners, pipe, pumps, gates, meters, and other components of such systems are easy to obtain. More difficult to obtain is the equity and loan capital to rebuild the systems. Most difficult of all is to create operator and user communities that have internalized a culture of social accountability, prompt payment, regular maintenance, and long-term planning.

Additional savings can be achieved by deploying more sophisticated irrigation technologies. Irrigation efficiency can be improved even beyond the results achieved in the Imperial Irrigation District in California by deploying computer integrated underground drip irrigation systems. In these systems daily, weekly and monthly weather projections are fed into software that has already been programmed with optimal water-delivery cycles for the crop in question. This software then generates instructions for timed water

releases under the root systems of each plant to optimize plant growth and seed creation per unit of water released. Unfortunately the high capital and operating costs of these systems can only be justified with higher marginal water prices and higher value-added crops than exist in most border irrigation districts today.

Further savings can be obtained in the municipal and industrial sectors by deploying more efficient end-use technologies. In the municipal sector, these technologies include low-flow faucets and showerheads, low-flush toilets, water-efficient dishwashers, and more efficient chillers in cooling systems. The savings from these technologies can be enhanced by improved operating practices such as restricting lawn irrigation and car washing and encouraging reuse of sheets and towels in hotels. In the industrial sector, enterprises should be encouraged to conduct water-conservation audits similar to the energy-efficiency and pollution-reduction audits that have already produced eco-efficiency improvements in the refining, petrochemical, metal plating, and other industries. In both sectors, governments and binational institutions such as NADBank will have to provide technical and financial assistance to ensure that the potential savings identified are actually achieved.

In addition to technologies that can reduce the demand for water, there are desalinization technologies that can increase the supply of usable water. As these technologies have improved and their cost has declined, they have become a viable option for some communities in areas with little rainfall or access to surface water or groundwater supplies. The City of Hermosillo in Sonora is finalizing a $250-million contract with Aguas de Saltillo, S.A., to purchase water from a reverse osmosis desalinization plant 150 miles away at a cost of 8.22 pesos per cubic meter (Aguas de Saltillo, S.A. 2001). The cost of transporting the water this distance uphill via aqueduct accounts for about half of the total cost, with the cost of desalinization accounting for the other half.

Market Mechanisms

A necessary condition to capturing the water-saving potential of the technologies discussed above is the creation of market mechanisms that place an economic value on each unit of water used or saved at the margin that approximates its true long-term social value. These

mechanisms will have to be created within the interstices of the existing fragmented structure of water rights within the border region. A broader renegotiation of water treaties, compacts, laws, allocations, and practices may, in the end, be necessary,[12] but this can only be achieved incrementally. The initial steps in this process should be designed to give existing water users economic incentives to make additional supplies available for higher-value uses through a combination of conservation and transfer of water rights.

The legal rules governing water rights that have developed in the United States and in Mexico have not encouraged conservation or market-based transfers. In the United States, the "first-in-time, first-in-right" prior appropriation doctrine developed in the western states to give farmers, miners, and other appropriators clearly defined property rights to water has increasingly been circumscribed by court decisions and state regulation based on the riparian doctrine borrowed from English common law. Initially, miners and irrigators used the prior appropriation doctrine to create private water markets in which rights could be bought and sold from one use to another. Private institutions, notably commercial and mutual irrigation companies, were created to develop the water resources needed for their operations. The resulting system gave participants the ability to determine, and the incentive to pursue, the uses of water most beneficial to them at the time.

Starting in the 1880s, however, courts and legislatures in western states began to restrict the free operation of water markets by using the riparian doctrine that each user of water from the stream has only the temporary right to use part of a common resource. States passed laws providing that water rights could only be established by diverting water from a stream and that claims to water left in the stream were not legitimate rights. The "use-it-or-lose-it" rule requires appropriators to use their entire water right or risk forfeiting it. The "salvaged water rule" prohibits users from keeping or selling water that became surplus through conservation efforts such as lining ditches, repairing pipes, or installing more efficient irrigation systems. Under the "beneficial use" doctrine, states determine which uses of water were "beneficial" and which were not. Until recently, for example, maintaining in-stream flows was not recognized as a beneficial use. States and counties have begun passing area-of-origin protection laws that prohibit or limit transfers of

water out of originating basins. Finally, courts have used the public trust and federal reserved rights doctrines to override legally established water rights to protect the environment or to uphold claims to water for Indian reservations, national parks, and other federal lands.[13]

These restrictions on private water rights and the operation of water markets have been justified on public interest grounds such as protecting downstream water users, conserving the environment, and Native American rights, or avoiding speculation and monopoly control. Their actual effects, however, are often contrary to their alleged purposes. By removing economic incentives to conserve water, these restrictions have encouraged waste and reduced the amount of water available to other users. By denying appropriators any legal rights to water returned to the stream or even prohibiting such return as a "nonbeneficial use," they have damaged water-dependent ecosystems. By preventing market forces from allocating water, they have enabled users to capture above-market rents by persuading political authorities to protect and subsidize uneconomic uses.

Mexican water law derives from a continental European legal tradition very different from the Lockean "labor theory of value" law tradition upon which the prior appropriation doctrine is based. Under the Mexican Constitution and relevant statutes, water is part of the national patrimony and cannot be owned or transferred as private property. CNA, on behalf of the state, grants irrigation districts, municipalities, and other users temporary rights to use a portion of this patrimony for their private purposes.

But what the state grants it can take away without payment or compensation. This is precisely what has happened to irrigation districts in the Río Conchos basin in order to pay back a portion of the water debt to the United States. The districts have received a small voluntary payment from CNA for the reduction in deliveries, but are not entitled to demand compensation equal to the economic value of the water withdrawn from their use as they would be in the United States.

CNA's authority to allocate temporary water rights to users as it sees fit has led to the use of water as a political patronage tool. The government in power has had an incentive to keep the prices charged to farmers and poorer urban residents low in order to retain their

political support. Low prices have in turn contributed to the waste of water in the agricultural and municipal sectors described above. The conservation investments and market-based transfers needed to correct this situation will therefore require at least a partial "depoliticization" of, and reduction of CNA control over, water rights in Mexico.

The legal and political disincentives to promoting water conservation through the market mechanisms described above have been compounded in both countries by federal water subsidies. In the United States, the federal government began to subsidize construction and operation of massive water-storage and delivery projects starting with the Reclamation Act of 1902. The New Deal accelerated this process as the federal government built hundreds of dams for flood control, irrigation, and hydropower production through the Tennessee Valley Authority, the Public Works Administration, and the Columbia Basin Project.

Initially, the costs of these projects were to be repaid within 10 years by the recipients of the water, but the political temptation to accommodate vocal beneficiaries in western states by spreading these costs over all taxpayers became irresistible and interest-free repayment schemes, together with deferrals and extensions of the repayment period, raised the value of the subsidy to more than 90%. The political attraction of these subsidies was demonstrated by Congress's refusal to allow President Carter to stop funding a number of subsidized water projects in 1979. As recently as 1993, Congress authorized construction of the Central Utah Project, which will charge irrigators $8 per acre-foot for water that it costs $300 to $400 per acre-foot to deliver.

Following the U.S. example, the Mexican government has also subsidized dams and other water-storage infrastructure for irrigation, flood control, and hydropower. These projects have been characterized by many of the same economic and environmental problems as in the United States. In the state of Nuevo León, for example, CNA has constructed several dams that have failed to store water in periods of drought, caused rapid buildup of silt, and damaged local ecosystems. If the billions of pesos spent on these dams had been spent to upgrade the existing conveyance and storage infrastructure in the area, water users and the environment would both have been far better off.

Despite these impediments, there have been a number of cases where water prices have been allowed to rise and conservation and higher-value uses thereby encouraged. In 1989, for example, the California State Water Resources Control Board found that Central Valley cotton growers who paid for federal water from the Central Valley Project used 20% less water and produced 20% more output than did nearby growers who received their water at no cost under senior water rights (Anderson and Snyder 1997). Between 1985 and 1995, the price of water delivered to farmers in California's Westlands Water District rose from $16.25 to $58.11 per acre-foot in response to declining supplies. Farmers responded by fallowing all but their best lands, growing crops that yielded higher returns, and installing drip irrigation systems (Anderson and Snyder 1997).

Water banks have proven to be an effective mechanism for encouraging transfers and promoting conservation. Because they are sanctioned by government and set prices, water banks are more politically acceptable than unregulated private markets. Idaho's water market has been functioning since 1979 and several hundred thousand acre-feet change hands annually. In 1991, California established a Drought Water Bank that purchased 800,000 acre-feet of water at $125 per acre-foot and sold half of it for $175 per acre-foot. The success of this experiment led California to repeat it in 1992 and 1994 and to consider establishing a permanent State Drought Water Bank (Anderson and Snyder 1997).

Policy Reform

The power of market mechanisms to encourage conservation and to allocate scarce water resources to higher value uses has been demonstrated in many individual cases, including the examples cited above. The challenge is to make these mechanisms the norm rather than the exception. The critical step in meeting this challenge is to allow water prices to rise at the margin. As long as water is free or priced far below its real value, users will have little or no incentive to conserve water or to apply it to the highest-value uses. In the United States, the price of marginal water supplies has been rising in many agricultural areas and cities in response to declining availability and increasing demand. As a result, all four U.S. border states project only modest growth in total water use over the next 20 years

with growth in municipal consumption being partially offset by declines in agricultural use.

The long-term state water plans upon which these projections are based, however, are unrealistic in three respects. First they assume unsustainable rates of groundwater withdrawal. If the aquifers supplying the Paso del Norte and other populated areas along the border continue to be depleted at current rates, the groundwater supplies assumed in state water plans will simply not be available in the out years. Second, they make no allowance for returning water to streams for ecosystem protection or honoring Native-American claims. Third, they make no allowance for the higher temperatures or changes in precipitation and soil moisture likely to result from climate change. Once these three factors are taken into account, much greater reductions in surface and groundwater withdrawals for irrigation and municipal use will be required to bring water budgets into balance.

Achieving these reductions will require far more extensive use of market mechanisms than has taken place to date. Government authorities responsible for water-delivery and storage infrastructure, irrigation districts, and other users need to create mechanisms that will compensate suppliers and users for conserving water or transferring it to higher-value uses. The optimum theoretical model for such mechanisms might be regional water exchanges for each of the three most populated regions along the border (California-Baja California, Paso del Norte, and the Lower Valley) in which water rights could be as freely traded as stocks in New York or pork bellies in Chicago.

In such an exchange, holders of historical water rights would enter the market with their rights intact but would be free to sell those rights or buy additional rights as they saw fit. Futures, hedges, and other contractual devices could be created to manage risk and to improve market efficiency. The exchange would be subject to government regulation to ensure transparency and to prevent fraud and manipulation, but the regulatory authority would not attempt to control the prices at which rights were traded or the purposes for which the water was used.

The need to reserve water for public purposes such as ecosystem protection, negative attitudes toward treating water as a market commodity, and the history of government regulation and subsidiza-

tion discussed above make this model difficult to implement on a regional scale. It should, however, be implemented through pilot projects on a local scale. California and Texas have created precedents for such projects through the Imperial Valley-Municipal Water District agreement discussed above, the California Drought Water Bank, and several conservation projects being implemented by the Texas Water Development Board with local irrigation districts. No such projects have yet been implemented in Mexico, but CNA, other Mexican federal agencies, and local governments have all expressed support for the concept, and several large irrigation districts in Tamaulipas have shown interest.

The central elements in the U.S. projects implemented to date are:

- Transfer of a specific quantity of water at a negotiated price from an irrigation district to a nearby municipality
- Use of all or a portion of the proceeds to conserve water by financing improvements in delivery and storage systems and on-farm practices
- Presence of a government intermediary with control over volumes and prices

Future projects could improve on these precedents by including additional participants such as other districts and municipalities, local industrial enterprises, conservation organizations, and state agencies themselves, which could sell additional water rights in the local area and use the proceeds to invest in conserving water locally or elsewhere in their systems. Including additional parties would allow greater scope for true market transactions based on competitive bids and offers and constitute an initial step toward creating the broader markets discussed above.

Providing greater scope for market forces to influence water allocation in the border region will be controversial. Irrigators and their advocates in state and local governments are already concerned that more and more water is being allocated to municipalities and less and less to agriculture. Market-based reforms are perceived as accelerating this trend. Citizens groups are concerned that permitting water rights to go to the highest bidder will deprive many poorer agricultural workers in the border region of the low-cost water that sustains their livelihood and force them to move into the cities.

More broadly, many people with roots in the region are saddened by the prospect of losing a way of life built around farms and ranches that "made the desert bloom."

Giving greater scope to market forces also contradicts the basic philosophy underlying the Reclamation Act of 1902. In the words of the Western Water Review Advisory Commission, "(a)chieving these efficiency benefits through the reduction or elimination of irrigation subsidies…would fundamentally undermine the historic justification of the western reclamation program and would negatively impact many farming communities, suggesting that the true value of water in the West can only partially be understood by the concept of pricing" (Western Water Policy Review Advisory Commission 1998). These communities are capable of exerting considerable political leverage to protect their access to subsidized water, as demonstrated by the resistance to withdrawal of federal water from irrigators in the Klamath Basin in Oregon and Northern California.

These concerns do not, however, justify stopping or delaying the pursuit of market-based policy reforms in the border region for a number of reasons. First, there is no realistic alternative. Water conservation in the agricultural sector is a critical element in meeting the future water needs of the border region, and the investment necessary to achieve that conservation is not likely to be forthcoming from government sources, particularly in Mexico. Second, Mexican irrigators already face a reduction in available water and have a strong incentive to support projects that will enable them to generate greater value from less water. Third, any transfers from agricultural to urban uses will be voluntary and will only result in reductions in agricultural production if the producers involved choose that outcome.

Finally, a continuing shift of rural population out of agriculture into other occupations is a necessary component to improving the quality of life of border residents. To suggest that the sons and daughters of current agricultural workers do not have better choices for their future is to deny them the economic opportunities they want and deserve. The challenge is to work together toward a pattern of economic growth in the border region that creates those opportunities while at the same time protecting the environment and providing necessary social services. Viewed through the prism of water, the challenge is to generate the greatest amount of social wel-

fare from a limited supply of water. Market-based mechanisms have an important role to play in meeting that challenge.

The concerns expressed above should, however, be addressed in developing those mechanisms in three respects. First, they should be developed through a transparent, participatory process involving all relevant stakeholders. New market-based approaches to water management cannot be imposed from the top down and will succeed only if all affected parties are involved in developing them. Second, the market transfers involved will have to have direct government involvement and sanction, particularly in Mexico where CNA has the sole legal authority to create and transfer water rights. Third, these market-based approaches will have to be tested in carefully selected pilot projects before they are applied more generally.

To maximize the utility of these pilot projects, however, four prior steps need to be taken. First, government agencies and other key stakeholders require a better understanding of where water is coming from and where it is going in the border region, particularly with respect to return flows. This is especially true in Mexico, which does not yet have water data of the same quality and reliability as the United States. Texas Senate Bill 1 has appropriated funds to gather and analyze such data, and the state government has contracted with Texas universities to carry out this task. The U.S. federal government, other U.S. border states, and the Mexican government should do the same, using the expertise of border institutions such as ITESM. U.S. charitable foundations and other private funding sources should also be asked to contribute to this effort.

Second, this data should be analyzed to identify specific opportunities to conserve water or to transfer it from one use to another that will achieve the greatest benefit at the lowest cost. Such an effort is being mounted by a binational private-sector consortium of universities, environmental organizations, and other institutions with relevant expertise (Instituto Tecnológico y de Estudios Superiores de Monterrey and the National Heritage Institute 2001). The consortium will use sophisticated software called River Ware to model water sources and uses in the border area and to identify opportunities for conservation or transfers to higher-value uses. The U.S. and Mexican federal governments, and international organizations such as the NADBank and the Inter-American Development Bank should also support this work.

Third, water budgets incorporating the conservation and transfer opportunities identified through the efforts described above should be developed for each of the three most populated areas along the border. These budgets should provide for a balance between groundwater withdrawals and recharge and set aside appropriate quantities of water for ecosystem rehabilitation and Native-American claims. They should also make realistic assumptions about users' responses to price signals, including shifting from cotton and alfalfa to higher-value crops, fallowing acreage, transferring water from agricultural to municipal uses, and end-use conservation in urban areas.

Finally, existing institutions need to be better coordinated, and laws and regulations may in some cases need to be modified to create the space necessary for the pilot experiments with market mechanisms proposed above to take place.

The Way Forward

The question is how to make the changes in the existing legal framework and to create the institutional arrangements necessary to enable market mechanisms to achieve their potential for conservation and reallocation of water to higher-value uses. A first step is to conduct the data-gathering and analysis of conservation and reallocation opportunities described above. The results of this effort could then be combined with a number of existing regional studies of how those mechanisms might operate and what their results might be.

In its study on the sustainable use of water in the Lower Colorado River Basin, for example, the Pacific Institute describes how improvements in irrigation efficiency, shifts in cropping patterns, and fallowing of irrigated land could save 1.24 million acre-feet of water per year in Arizona alone (Morrison, Postel, and Gleick 1996). The study recommends that market mechanisms, including properly designed pricing structures, water-depletion taxes on groundwater overdraft, and voluntary water transfers from lower- to higher-value uses, be used to help achieve those savings and that a portion of the water saved be allocated to maintaining minimum flows in the Ciénega de Santa Clara and the Colorado River Delta (Morrison, Postel, and Gleick 1996).

A next step would be to feed the results of those analyses and studies into regional planning projects at the state level. Texas has

taken the lead among U.S. states by establishing regional water-planning entities with participation by all interested stakeholders and support from the Texas Water Development Board. The Far West Texas Planning Group and the Regional Water Planning Group for the Lower Rio Grande Valley are already developing water plans for their sub-basins. Other U.S. border states and the Mexican federal and state governments should follow the Texas example. (Mexico has established a consultative council for the entire Río Bravo basin, but it has inadequate resources and has not yet engaged in water planning.)

But, it is not sufficient to create water-management plans on a state-by-state basis when critical water resources are shared between states and between the United States and Mexico. The two countries must create binational fora in which integrated regional management plans and budgets for both sides of the border can be developed. Three nongovernmental institutions—the Houston Advanced Research Center, New Mexico State University, and the Universidad Autónoma de Ciudad Juárez—have shown the way by creating the Paso del Norte Water Task Force. The task force will develop policy recommendations for integrated water management in the region after fact-finding and consultations with stakeholders, according to the agreement that established BECC and NADBank.

To transform private initiatives such as this into public processes with the ability to make binding recommendations or decisions will require a binational public institution with authority to coordinate the activities of existing public institutions at all levels of government. Some commentators have suggested creating an entirely new institution or institutions to perform this role. The Pacific Institute study referred to above, for example, recommends the formation of "an Overarching International River Basin Commission" with authority to develop a comprehensive, integrated, environmentally sustainable, long-term management plan for the Colorado River (Morrison, Postel, and Gleick 1996).

Another approach, which may be more politically feasible, would be to give an existing binational institution the additional powers and resources it needs to create and coordinate the implementation of integrated regional water plans and budgets. Dr. Jurgen Schmandt, director of the Houston Advanced Research Center, recommends that the IBWC be used for this purpose (Schmandt 2001).

In addition to its current functions—river water allocation, reservoir management, and flood control—the IBWC would, among other new functions, be given the authority to establish a Rio Grande Basin Council (or, perhaps, Rio Grande-Lower Colorado Basin Council). The council would have reporting to it the binational regional water task forces for each of the four hydrological sub-basins of the Rio Grande, perhaps even the lower basin of the Colorado task force. Based on advice from these task forces and other subsidiary bodies, the expanded IBWC would then develop and submit action and project recommendations to other binational institutions in the border area.

The two binational organizations best qualified to act on these recommendations are BECC and NADBank. BECC would then develop specific project proposals to implement the recommendations after consultation with public and private stakeholders, and then submit those proposals to a certification process with full public participation. NADBank would assemble the technical assistance and financial resources necessary to implement the project.

One critical element not referred to in Dr. Schmandt's paper is removal of obstacles in current laws and agreements to using market mechanisms to promote conservation and transfers to higher-value uses. Rather than negotiating ad hoc regimes or amendments for each project, amendments to existing laws and agreements that would achieve minimum consistency between the United States and Mexico should be developed and submitted to federal and state legislatures in both countries. Only with this legal integration and consistency will market mechanisms be able to fully contribute to achieving the goals of the integrated binational water plans and budgets discussed above.

Conclusion

The United States and Mexico have an opportunity to transform water management in the border region from a source of strain and possible conflict in their relationship to a source of cooperation and mutual benefit to their citizens. They have the technology, the resources, the institutions, and the policy tools to make this transformation a reality. The journey will be long and challenging, but the time to start is now.

Endnotes

[1] In the United States, the river is referred to as the Rio Grande; in Mexico as the Río Bravo.

[2] Ley Federal de Aguas, 1972, Article 27.

[3] The Wagstaff Act 1031 established seven priorities: domestic and municipal, industrial, irrigation, mining, hydroelectric, navigation, and recreation. It was amended in 1985 to add an eighth-priority, bays and estuaries.

[4] Convention between the United States and Mexico to Avoid the Difficulties Occasioned by Reason of Changes that Take Place in the Beds of the Rio Grande and Colorado River, signed March 1, 1889, 26 Stat. 1512.

[5] Treaty between the United States and Mexico Relating to the Waters of the Rio Grande, signed at Washington, D.C., May 21, 1906; entered into force January 16, 1907; 34 Stat. 2953; Treaty Series 455.

[6] Treaty between the United States and Mexico Relating to Utilization of Waters of the Colorado and Tijuana Rivers and of the Rio Grande, signed at Washington, D.C., February 3, 1944; protocol signed at Washington, D.C., November 8, 1945; Stat. 1219; Treaty Series 944.

[7] Minute No. 242 of the International Boundary and Water Commission, United States and Mexico, approved by the governments of the United States and Mexico on August 30, 1973.

[8] The United States-Mexico Agreement on Cooperation for the Protection and Improvement of the Environment in the Border Area, signed at La Paz; Baja California Sur, Mexico, August 14, 1983, T.I.A.S. 10,827.

[9] North American Free Trade Agreement, signed December 17, 1992, reprinted in 32 I.L.M. 289 (1993).

[10] North American Agreement on Environmental Cooperation, signed September 1, 1994, reprinted in 32 I.L.M. 1489 (1993).

[11] Agreement Concerning the Establishment of a Border Environment Cooperation Commission and a North American Development Bank, signed November 18, 1993, entered into force January 1, 1994, reprinted in 32 I.L.M. 1545 (1993).

[12] Mexican commentators have already proposed a renegotiation of the 1944 treaty to allocate total water resources in the Río Conchos Basin between the two countries on a more equitable basis.

[13] For an excellent discussion of the evolution of water law in the western United States, see T.L. Anderson and P.S. Snyder, "Priming the Invisible Pump," *Political Economy Research Center Policy Series*, Issue Number PS-9, February 1997.

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IV

The Challenge of Balancing Water Supply and Demand in the Paso del Norte

Charles Turner, Edwin Hamlyn, and Oscar Ibáñez Hernández

Abstract

The Paso del Norte, a region that includes the sister cities of El Paso, Texas, and Ciudad Juárez, Chihuahua, is faced with a complex set of water supply problems that embody the range of water issues found elsewhere along the U.S.-Mexican border. Many circumstances in the Paso del Norte are generally the same for the entire U.S.-Mexican border region, including the facts that:

- Water is scarce, and competition for water resources is intensifying
- Per capita water use is higher on the U.S. side of the border than the Mexican side
- Agricultural water use is relatively constant; increased water demand is being driven by urban growth
- Upstream surface water irrigation reduces downstream flow and degrades downstream water quality by concentrating dissolved minerals
- Intensive human use of water resources has impoverished natural ecosystems
- The quality of existing water resource infrastructure, financial capability, and technical capability is greater on the U.S. side of the border than the Mexican side

Urban populations are increasing on both sides of the border, but more so in Ciudad Juárez where industrial expansion has acted as a magnet for in-migration and spurred rapid population growth. Because in-migrants tend to be relatively young, the intrinsic rate of growth of Ciudad Juárez is higher than that of Mexico as a whole, suggesting that, even absent further in-migration pressures, the city's population will continue to grow rapidly. Population growth will increase the demand for water.

Both El Paso and Ciudad Juárez are heavily dependent on groundwater. Underneath the two cities is the Hueco Bolson, an extensive aquifer, but one that receives limited recharge. Groundwater extraction from this aquifer by both cities has caused a dramatic decline in the water table, and the fresh water fraction of the aquifer is being depleted. El Paso has developed well fields in a different aquifer, the Mesilla Bolson—but the preponderance of this second aquifer is in New Mexico, not Texas, thus restricting El Paso's access to this source of water. By contrast, Ciudad Juárez remains totally reliant on the Hueco Bolson. The portion of the Hueco Bolson beneath Ciudad Juárez is relatively "pinched-out." The useful life of Mexico's portion of the Hueco Bolson is limited, though officials on opposite sides of the border differ in their projections of the volume of fresh water remaining. The asymmetry of information regarding shared aquifer systems constrains joint management of the region's groundwater resources. Currently, both El Paso and Ciudad Juárez are investigating the feasibility of importing groundwater from outlying areas, but legal and political restrictions impede El Paso, and Ciudad Juárez has neither technical documentation of the extent of groundwater resources available, nor the financial capability of aggressively pursuing this option.

Due to diminished supplies of groundwater, both El Paso and Ciudad Juárez are seeking greater access to replenishable surface water. However, surface water use is constrained by a complex set of water laws, allocation systems, international treaties, and interstate compacts. Consequently, while the conversion of surface water from agricultural to municipal/industrial use is beginning, the process is somewhat tortuous, and progress has been slow.

Underlying the fresh water portion of the region's aquifers is a substantial, though poorly documented, amount of brackish water.

Desalination technologies have matured over the last several decades, but using this water resource will be expensive. The disposal of concentrate from desalination poses a challenge given the region's inland location. Nonetheless, both El Paso and Ciudad Juárez are currently investigating this option.

The challenge of securing adequate water supplies requires both "supply-side" and demand-management strategies. Water reuse systems and aggressive demand management strategies have been implemented in El Paso, and per capita water use has been reduced by more than 25% over the last two decades—yet El Pasoans, on average, continue to use considerably more water than their Juarence counterparts. Further reductions in per capita water use will be necessary, though challenging, to secure. Because per capita water consumption is already considerably lower in Ciudad Juárez than in El Paso, water conservation campaigns and other demand-management strategies are likely to be less effective in reducing water needs in Ciudad Juárez.

The chapter concludes with a brief analysis of future scenarios and challenges to binational planning in the El Paso-Ciudad Juárez region.

El Reto de Equilibrar el Abastecimiento y la Demanda de Agua en el Paso del Norte

Charles Turner, Edward Hamlyn y Oscar Ibáñez Hernández

RESUMEN

El Paso del Norte, la región que incluye las ciudades hermanas de El Paso, Texas y Ciudad Juárez, Chihuahua, enfrenta un conjunto complejo de problemas sobre el suministro de agua que demuestra la variedad en los asuntos de agua que se encuentran en otras partes de la frontera México-Estados Unidos. Muchas circunstancias en el Paso

del Norte son representativas de la frontera México-Estados Unidos en su totalidad, incluyendo los hechos que:

- El agua es escasa y la competencia por el agua está intensificando
- El uso per cápita del agua es mayor en el lado estadounidense que en el lado mexicano
- El uso agrícola de agua es relativamente fijo; el incremento en la demanda de agua está siendo impulsado por el crecimiento urbano
- La irrigación con aguas superficiales río arriba reduce el flujo río abajo y degenera la calidad del agua río abajo por concentrar los minerales disueltos
- El uso humano intensivo de los recursos agua ha empobrecido las ecosistemas naturales
- La calidad de la infraestructura existente del recurso agua, la capacidad financiera y la capacidad técnica es mayor en el lado estadounidense de la frontera que en el lado mexicano

Las poblaciones urbanas están aumentando en ambos lados de la frontera, pero aun más en Ciudad Juárez donde la expansión industrial ha atraído migración y ha fomentado el crecimiento rápido de la población. Porque los itinerantes son jóvenes, la tasa natural del crecimiento en Ciudad Juárez es mayor que la tasa nacional de México, lo que sugiere que aun si no hubiera las presiones de más migración dentro del país, la población de Ciudad Juárez seguiría creciendo rápidamente. El crecimiento de la población causará el aumento en la demanda de agua. El Paso y Ciudad Juárez dependen en alto grado del agua subterránea. Debajo de las dos ciudades está el Hueco Bolson, un acuífero extenso que recarga poco. La extracción del agua subterránea de las dos ciudades ha resultado en un declive dramático en la tabla del agua y la fracción de agua dulce del acuífero está disminuyendo. El Paso ha desarrollado campos de pozos en el acuífero Mesilla Bolson. Sin embargo, la mayoría de este segundo acuífero está ubicada en New Mexico y no en Texas, así que restringe el acceso de El Paso a esta fuente de agua. En contraste, Ciudad Juárez depende totalmente en el Hueco Bolson. La porción del Hueco Bolson que está debajo de Ciudad Juárez está relativamente estrechada. La vida útil de la porción del Hueco Bolson que pertenece a México es limitada, aunque los funcionarios en los lados opuestos de la frontera difieren en sus proyecciones para el volumen de agua dulce que queda. La asimetría de información con respeto a los sistemas compartidos de acuíferos restringe la gestión compartida de los recursos de agua subterránea de la región. Actualmente, El

Paso y Ciudad Juárez están investigando la posibilidad de importar agua subterránea de las áreas de la periferia, pero las restricciones legales y políticas dificultan el progreso de El Paso, y Ciudad Juárez carece de los documentos técnicos de la cantidad de los recursos disponibles de agua subterránea y de la capacidad financiera para avanzar agresivamente para implementar esta posibilidad.

A causa del suministro disminuido del agua subterránea, El Paso y Ciudad Juárez están buscando acceso a las aguas superficiales que se reabastecen. Sin embargo, el agua superficial está limitada por un conjunto complejo de leyes de agua, sistemas de asignación, tratados internacionales y convenios Interestatales. Por consecuencia, aunque la transformación del agua superficial del uso para agricultura a uso municipal e industrial es un paso inicial, el proceso es un tanto tortuoso y el progreso ha sido lento.

Debajo de la parte de los acuíferos que contiene agua dulce, hay una cantidad sustancial, aunque no está bien documentada, de agua salobre. Las tecnologías de desalinización han madurado durante las últimas décadas, pero aún así el uso de este recurso de agua es caro. El desecho del concentrado del proceso de desalinización presenta un desafío considerando la ubicación de la región al interior. Sin embargo, El Paso y Ciudad Juárez están investigando esta posibilidad actualmente.

El desafío de asegurar el suministro adecuado del agua requiere de estrategias que tratan el suministro y el manejo de la demanda. Sistemas de reuso del agua y estrategias agresivas de manejar la demanda se han implementado en El Paso y como consecuencia el uso per cápita del agua se ha disminuido por más de 25% durante las últimas dos décadas. Sin embargo, en promedio, elpasoanos todavía usan considerablemente más agua que sus vecinos juarense. Más reducciones en el uso per cápita serán necesarios, aunque difícil, para asegurar. Como el uso per cápita del agua ya es considerablemente menor en Ciudad Juárez que en El Paso, es probable que las campañas de conservación del agua y otras estrategias para reducir la demanda no serán muy eficaz en reducir las necesidades de agua en Ciudad Juárez.

El capítulo concluye con un análisis breve de escenarios en el futuro y los desafíos para la planeación binacional en la región El Paso-Ciudad Juárez.

Introduction

The U.S.-Mexican border extends from the Pacific Ocean to the Gulf of Mexico, a distance of more than 3,100 kilometers (km). More-or-less at the midpoint of the U.S.-Mexican border, at the juxtaposition of the U.S. states of New Mexico and Texas and the Mexican state of Chihuahua, is a region known as the Paso del Norte. Flowing through the region is the Rio Grande, which is known as the Río Bravo in Mexico. Today, the river that flows through the Paso del Norte is neither *grande*—large, nor *bravo*—wild. Instead, its flow is regulated by a series of upstream dams, it is confined within a straightjacket of levees, and its flow is significantly reduced by the time it leaves the region.

The Paso del Norte consists of a mix of agricultural and urban development surrounding a segment of the Rio Grande/Río Bravo that extends from Elephant Butte Dam in southern New Mexico to Fort Quitman in far west Texas on the international border. Within this region are located the "sister" cities of El Paso, Texas, and Ciudad Juárez, Chihuahua. West of El Paso and Ciudad Juárez, the international boundary is a land boundary delineated by 276 permanent monuments; to the east, the border is defined by the meandering course of the Rio Grande/Río Bravo as it makes its way to the Gulf of Mexico.

Systems of allocation of water resources throughout this region were developed in the early 20th century based on the irrigation needs of what was then a predominantly rural area. Today, the character of the region is different. Economic opportunities made possible by cross-border commerce have fostered the growth of an urban population. Currently, more than 2 million people reside within the Paso del Norte. Cities in the region have traditionally relied on groundwater, but the region's aquifers receive limited recharge and the principal aquifer serving El Paso and Ciudad Juárez is being depleted. Surface water from the Rio Grande/Río Bravo represents an alternative and replenishable source of drinking water, but the vast majority of the river's water is devoted to agricultural use.

Paradoxically, the Paso del Norte is continuing to experience rapid population growth despite its diminishing water resources. Institutional fragmentation in this binational, tri-state region

impedes cooperative water resource management, and the unequal distribution of water resources is resulting in growing disparities and conflict. Furthermore, jurisdictional conflicts are tending to obscure the implications of the unsustainable mining of the region's groundwater resources, and thereby forestalling difficult choices.

The range of water-related issues in the Paso del Norte are the same water problems found elsewhere along the international border. In addition to diminishing supplies of groundwater issues include: difficulties converting surface water from agricultural to municipal and industrial use, legal disputes over water rights, impaired surface water quality, water scarcity and drought susceptibility due to climatic conditions, impacts on surface water flows due to groundwater pumping, and impoverished natural ecosystems attributable to intensive water use. Of particular concern are issues that underscore the disparities between the United States and Mexico. Differences are evident in water resource infrastructure for both municipalities and irrigators; asymmetries in financial capabilities; different information about the region's aquifers; and legal and institutional differences which, in the instance of the Paso del Norte, include not only differences between the United States and Mexico, but also between Texas and New Mexico.

It is not accurate to characterize the immediate water supply situation facing communities in the Paso del Norte as a crisis. The supplies of water being depleted are the high-quality groundwater sources; other, lower-value water is available, though treating it to meet drinking water standards will be expensive. In that sense, communities in the Paso del Norte are not running out of water so much as they are running out of "cheap" water. But that is only the immediate, short-range problem. From a mid-range perspective, the region is faced with the dilemma of a potential reallocation of water among its jurisdictions and users. Thus far, this highly political issue has tended to promote parochial attitudes. But, technological fixes and political solutions cannot manufacture new water in this arid region. The long-range reality facing the Paso del Norte is one of recognizing that the finite supplies of replenishable water constitute a limit to population growth in the region.

The complex water challenges of the Paso del Norte are, in many respects, relative to other regions of the border. In a broader con-

text, however, the challenges facing the Paso del Norte are a microcosm of the water problems faced by communities throughout the U.S.-Mexican border region. When scarce water resources must be shared, particularly in times of shortage, competition for and conflicts over water are inevitable. More importantly, economic pressures and differences between the two countries complicate a rational approach to sustainable development.

Historical Development

The morphology of the Rio Grande/Río Bravo 500 years ago was very different from what is visible today. Historically, the river had a shallow, meandering, shifting channel with a sandy bottom, and it was prone to periodic flooding, during which it would become a raging river (Stotz 2000). The shifting river formed braided channels giving rise to a dynamic mosaic of habitat types, including sedges and marsh grasses, and bosques of willow, cottonwood, and mesquite (Dick-Peddie 1993).

Archeological evidence indicates that the river valley in the Paso del Norte was inhabited in the late Pleistocene/early Holocene between 10,000 B.C. and 6,000 B.C. The first evidence of village settlements and horticultural activity date from 900 B.C., but year-round occupation of sites appears to have shifted to more dispersed hunting and gathering lifestyles circa 1375 A.D., possibly in response to an extended period of drought (Peterson et al. 1992).

In 1598, Spanish explorer Don Juan de Oñate led a colonizing expedition of approximately 600 people north from the frontier settlement of Santa Bárbara in southern Chihuahua. Oñate arrived in the Paso del Norte in May of that year, and gave the region its name—*El Paso del Río del Norte*, the Ford of the River of the North. The passage blazed by Juan de Oñate would subsequently become part of the Camino Real, the principal trade route that extended from Mexico City in the south to Santa Fe and the Spanish territories in the north.

When the Spanish explored the upper Rio Grande/Río Bravo basin, they encountered permanent settlements of Pueblo Indians that were using river water to irrigate crops along the riverbanks. The Native Americans had developed systems for sharing water at a

local level. During the subsequent period of Spanish colonization, the Spanish introduced water rights management as practiced in Spain. The system was supposed to leave Pueblo irrigated lands intact while Spanish land grants developed on nearby lands. Since the Pueblo Indians often had the best land, encroachment gradually took place over time. A hybrid system of water allocation evolved based on Spanish law and water needs of land grant owners. The Spanish system incorporated some elements of the prior appropriation doctrine but gave highest priority to municipal water uses. Under the Spanish system, irrigation rights were reduced as needed to meet the demands of settled villages. Water rights of Native Americans were often incorporated into the evolving system. Only in a few cases do Native American rights remain intact to this day (Clark 1987).

Permanent settlement in the Paso del Norte did not begin until the latter half of the 17th century when a mission church was constructed in what today is Ciudad Juárez. Development north of the river only began in the early 19th century when a hacienda was built at a site that today is occupied by downtown El Paso.

Population growth in the Paso del Norte was slow during the 18th and 19th centuries because the area was mostly a stopover for travelers. Irrigated agriculture was practiced in the river floodplain, but the vagaries of the river flow and annual surges of flood waters limited development. Initially, diversion structures were primitive and temporary, as permanent fixtures risked diverting flood water into the fields (Horgan 1954). Nonetheless, agricultural development expanded throughout the El Paso and the Mesilla valleys, the latter being predominantly in Doña Ana County, New Mexico.

Urban development in El Paso accelerated with the completion of the Southern Pacific railroad line in 1881, and between 1880 and 1890, the population in El Paso County quadrupled. The city of El Paso became the county seat and quickly emerged as the dominant city in the region. Despite urban growth, however, the region continued to be largely rural in character. By the turn of the century, the combined population of El Paso County and the Juárez Municipio was less than 35,000, 75% of which lived north of the border.

In the 19th century, both El Paso and Ciudad Juárez depended on

surface water for their drinking water supply, and though El Pasoans also imported water from Deming, New Mexico, this water was being hauled in barrels. In 1892, growth pressures prompted the first water well in El Paso, a 14-meter (m) deep hand-dug well that tapped into the river alluvium (Rittmann 2003). Approximately 10 years later, the city drilled its second well in the upper mesa; this second well was drilled into an aquifer known as the Hueco Bolson. Thus, a pattern began to be established whereby cities in the Paso del Norte became reliant on groundwater, while agriculture relied on the surface waters of the Rio Grande/Río Bravo.

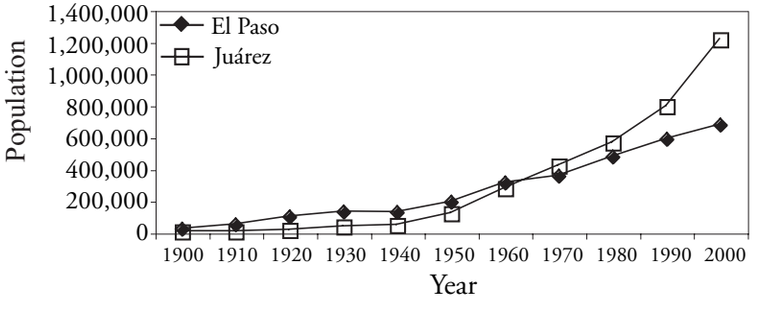
Until the modern era, primitive technology limited the amount of river water that could be diverted, and irrigation use had only a nominal impact on stream flow. Irrigation demands on the river have increased greatly in the last 150 years, causing a substantial diminution in the surface flow. By the end of the 19th century, ever greater amounts of water were being diverted for irrigation throughout the watershed, particularly in the San Luis Valley of Colorado, some 600km to the north (Clark 1987). As a consequence, water shortages in the Paso del Norte became ever more common, and the Mexican government protested to the United States. An international treaty and an interstate compact would follow, presumably imposing a permanent settlement on the allocation of the river's water. These negotiated water allocation settlements were reflective of the irrigation needs of what was predominantly a rural area.

Today, the character of the region is changing. Economic opportunities made possible by cross-border commerce are fostering rapid urban population growth—a kind of growth not anticipated when the interstate compacts and international treaties were negotiated. The sister cities of El Paso and Ciudad Juárez are turning to the Rio Grande/Río Bravo to meet their water needs, and pressures are building to transfer water from agricultural to urban uses.

Population Growth in the Paso Del Norte

Recent population growth and expectations of continued growth are incongruent with the rapid depletion of the region's groundwater. Figure 1 shows population growth in the Paso del Norte over the last century. Over the last 50 years, El Paso County has had an average annual growth rate of 2.5%, more than tripled in size, and increased from a population of fewer than 200,000 in 1950 to a population approaching 680,000 in 2000. During those same years, the Juárez Municipio experienced an average annual growth rate of 4.6% and mushroomed from a population of 122,000 to more than 1.2 million—nearly a 10-fold increase. Recent growth trends are especially imbalanced. El Paso continues to increase in population, but it has exhibited a declining rate of growth over the last 30 years, whereas the population of Ciudad Juárez has continued to increase at nearly 4% annually, and today it is almost twice the size of El Paso. Of particular note is the growth that has occurred over the last 20 years. During this time, the combined populations of El Paso and Juárez have added more than 850,000 residents—nearly doubling the population. This two-decade span coincides with a relatively "wet" period during which irrigators enjoyed full water allocations from the Rio Grande/Río Bravo, and therefore were less reliant on supplemental pumped groundwater.

Figure 1. Historic Population Growth in the Paso del Norte



Sources: U.S. Census Bureau; Instituto Nacional de Estadística Geografía e Informática (INEGI)

Although fertility rates are higher in Mexico than the United States, the principal factor of the population growth of Ciudad Juárez has not been natural increase; the rapid population growth has been driven by in-migration. Over the last 20 years, Ciudad Juárez has experienced an expansion of industries that have lured migrants into the border region. The border industrialization program of the 1960s promoted increased manufacturing employment along the border, and implementation of the North American Free Trade Agreement (NAFTA) in 1994 further accelerated this trend. The term "maquiladora" refers to an industry established under a special Mexican industrial program that permits, under a special customs allowance, mostly non-Mexican operations to establish manufacturing plants in Mexico that are allowed to import duty-free raw materials, equipment machinery, and replacement parts (Solunet Info-Mex Inc. 2002). Between 1980 and 2000, the number of maquiladoras in Ciudad Juárez more than doubled, and the number of employees at maquiladoras increased six-fold (Table 1). The economic slowdown in the United States since mid-2001 has caused massive layoffs of maquiladora workers, and this may have, at least temporarily, lessened in-migration pressure.

Table 1. Maquiladora Employment in Ciudad Juárez

Year	Number of Plants	Number of Employees
1980	121	42,412
1990	248	120,854
1995	249	–
1999	–	222,866
2000	312	255,740
2001	303	209,247

Source: Plan Municipal de Desarrollo Urbano, Diagnóstico Integral, Instituto Municipal de Investigación y Planeación (IMIP)

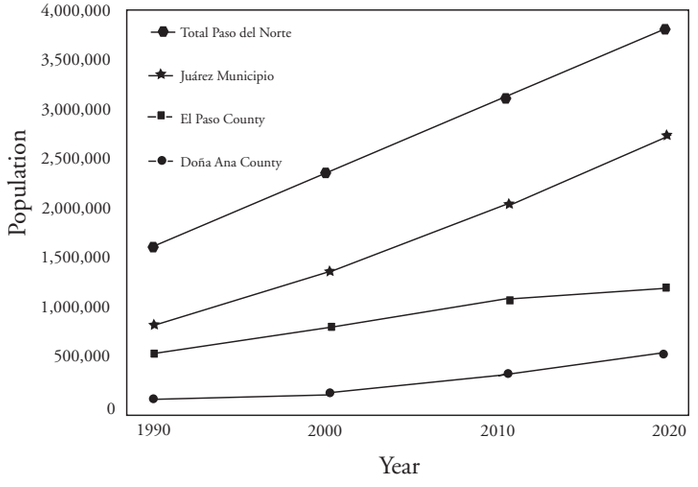
Migrants are apt to be relatively young adults seeking improved economic opportunity. As a consequence, positive migration promotes continued population growth by increasing the percentage of people starting families. Thus, the intrinsic rate of growth of a population increases as a consequence of positive net migration (Namboodiri 1996). Even if migration pressures were to cease, Ciudad Juárez is still positioned to continue to grow rapidly. By contrast, the 2000 U.S. Census showed that El Paso, although still increasing in population, was experiencing a net out-migration of young adults, most likely lured by better economic opportunities elsewhere. The age cohort of people between 18 and 34 years of age declined by 11,810 in El Paso from 1990 to 2000 (Ramírez-Cadena 2001). These countervailing trends suggest that the future will see a widening gap in population size between El Paso and Ciudad Juárez.

Demographic projections of future populations necessarily rely on a number of assumptions. If migration could be disregarded, future population could be reliably predicted based on knowledge of the existing population's age distribution coupled with forecast changes in rates of fertility and mortality. But, population projections must also take into account future in- and out-migration, and commonly these variables are simply extrapolated from past trends. Given its water supply problems, the past may not be protocol in the Paso del Norte. The projected combined populations of the Juárez Municipio, Chihuahua; El Paso County, Texas; and Doña Ana County, New Mexico, as developed by various local agencies, are shown on Figure 2.

Water Supply for the Paso del Norte

The Paso del Norte depends on both groundwater resources and surface waters from the Rio Grande/Río Bravo. Overall, adequate water would appear to be available to satisfy the needs of a growing population. Access to water, however, is constrained by jurisdictional boundaries, systems of allocation, and radically different water laws and institutional frameworks, none of which are amenable to change. These factors complicate water planning in the Paso del Norte. Figures 3 and 4 are maps depicting the water resources of the Paso del Norte.

Figure 2. Projected Population Growth in the Paso del Norte

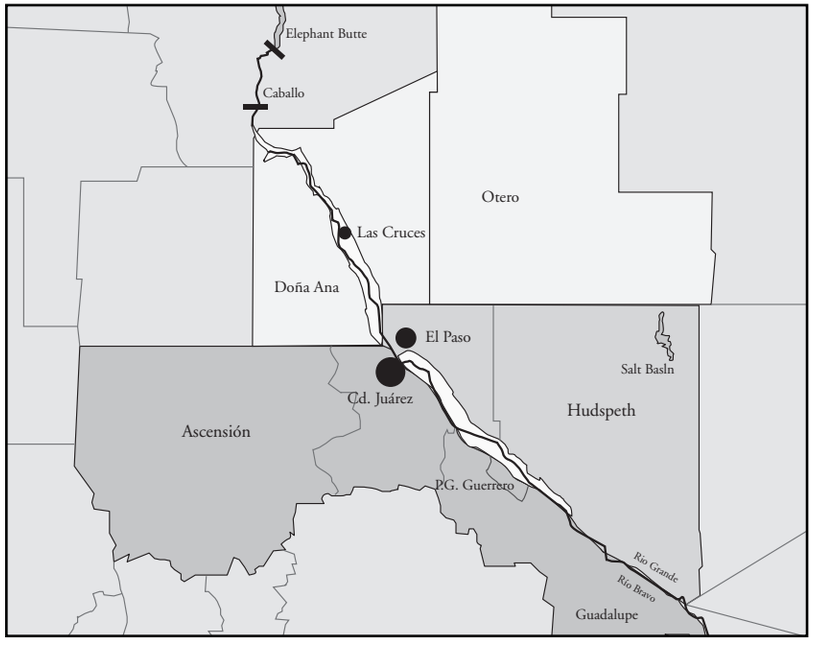


Sources: U.S. Census Bureau; INEGI; IMIP; Texas Water Development Board; City of Las Cruces

Hueco Bolson

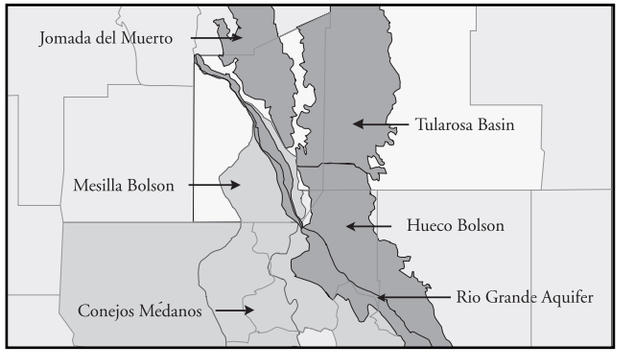
Beneath the cities of El Paso and Ciudad Juárez is the Hueco Bolson, an extensive aquifer located in the southern portion of a rift basin that extends for approximately 320km in a north-south direction and has a width of 64km at the broadest point. The northern portion of this rift basin, known as the Tularosa Basin, lies in southern New Mexico, and is separated from the Hueco Bolson by a minor topographic divide near the New Mexico-Texas boundary. Fresh groundwater, defined as water with total dissolved solids (TDS) less than 1,000 milligrams per liter (mg/l), is found within the Hueco Bolson in an irregularly shaped wedge that borders the Franklin Mountains and the Organ Mountains of southern New Mexico. The fresh water overlays brackish water and, over a geologic time span, it is thought to have remained fresh due to mountain-front recharge. The zone of fresh water extends southward beyond the Franklin Mountains into the area beneath El Paso and Ciudad Juárez (Texas Water Development Board and New Mexico Water Resources Research Institute 1997).

Figure 3. The Counties and *Municipios* of the Paso del Norte



Source: Creel et al.

Figure 4. Groundwater Resources in the Paso del Norte



Source: Creel et al.

The Hueco Bolson began to be used for drinking water purposes during the first decade of the 20th century. It has been heavily exploited for municipal and industrial purposes, and groundwater withdrawals vastly exceed natural recharge. As a consequence, the water table has been drawn down, and a number of wells in the central portions of both El Paso and Ciudad Juárez have had to be taken out of service due to the intrusion of brackish water. In 1979, the Texas Department of Water Resources published a report on groundwater availability which projected that the Texas portion of the Hueco Bolson would be virtually exhausted of all economically-retrievable fresh water by the year 2030, (Muller and Price 1979). To forestall such an outcome, El Paso Water Utilities (EPWU), the quasi-independent municipal entity that provides water and wastewater services for the city of El Paso and some outlying Texas communities, has sought to develop alternative sources of water supply and lessen water demand. Nonetheless, the Hueco Bolson continues to provide a significant portion of El Paso's water supply. Currently, EPWU has 69 operational and 13 blendable production wells in the Hueco Bolson that have a total capacity of 0.55 million cubic meters per day (Mm^3/day). During the year 2000, the utility extracted 73.28Mm^3 of water from the Hueco Bolson, this representing approximately 47.1% of the total water demand in El Paso that year (EPWU 2002).

The Junta Municipal del Aguas y Saneamiento (JMAS), the agency charged with providing water and wastewater services to Ciudad Juárez, relies solely on the Hueco Bolson for the city's drinking water supply. As of 1999, JMAS had 131 wells in production with depths varying from 200m to 400m. Groundwater withdrawals increased from 145.5Mm^3 in 1998, to approximately 150Mm^3 in 1999. Aquifer depletion is evidenced by the production rate changes in the JMAS's primary well field, which declined from 55 liters per second (l/s) in 1977 to 41.8l/s in 1998 (Lemus 1999). To place the issue of aquifer depletion in a different context, Lemus estimated that 3,008Mm^3 of groundwater has been withdrawn from the Juárez portion of the Hueco Bolson since the inception of pumping in 1926. Estimates of the amount of natural recharge to the aquifer vary from 7Mm^3 to 35Mm^3 annually; using the "high end" estimate of recharge, this represents a net reduction in groundwater of approximately 488Mm^3 from pumping by Ciudad Juárez alone, and most of this groundwater "mining" has occurred during the past two decades.

Mesilla Bolson/Conejos Médanos

Beginning in 1951, in response to then-drought conditions, El Paso Water Utilities developed a well field in the Mesilla Bolson. The Mesilla Bolson is an extensive aquifer, but the vast majority of it lies in southern New Mexico and northern Chihuahua (Figure 4). A small portion of the Mesilla Bolson is in Texas, located in the northwestern-most portion of El Paso County, near the unincorporated community of Canutillo. Hence, EPWU's well field is locally referred to as the "Canutillo Well Field." Currently, EPWU's Canutillo Well Field consists of 19 production wells drilled to three different formations at varying depths with a total capacity of 0.16Mm^3/day. In 2000, the Mesilla Bolson supplied EPWU with a total of 30.44Mm^3, representing approximately 19.6% of El Paso's water supply (EPWU 2002). In the 1980s, EPWU sought to gain access to the New Mexico portion of the Mesilla Bolson, but this effort was blocked by legal action (see *El Paso v. Reynolds*, 597 Fed. Sup. 694, 1984). The decade-long period of acrimonious litigation between El Paso and the state of New Mexico ended in 1991 with a settlement agreement that established a basis for cooperative planning activities, but neither enabled nor totally precluded future cross-state transfer of groundwater.

While only a small portion of the Mesilla Bolson is in Texas, this aquifer does extend into Mexico, where it is known as the Conejos Médanos. It lies west of the Sierra de Juárez, whereas the developed area of Ciudad Juárez lies east of these low mountains. Limited public information is available regarding the lateral extent, saturated thickness, or water quality of the Conejos Médanos, but indications are that it may be mildly brackish. Currently, JMAS obtains all of its water from groundwater and relies solely on the Hueco Bolson, but investigations have begun considering the feasibility of using the Conejos Médanos as a supplemental source of water. Under this scenario, water would be extracted from the Conejos Médanos and then delivered to the developed area of Ciudad Juárez via a transmission line, most likely looping south of the Sierra de Juárez.

Groundwater Production Costs

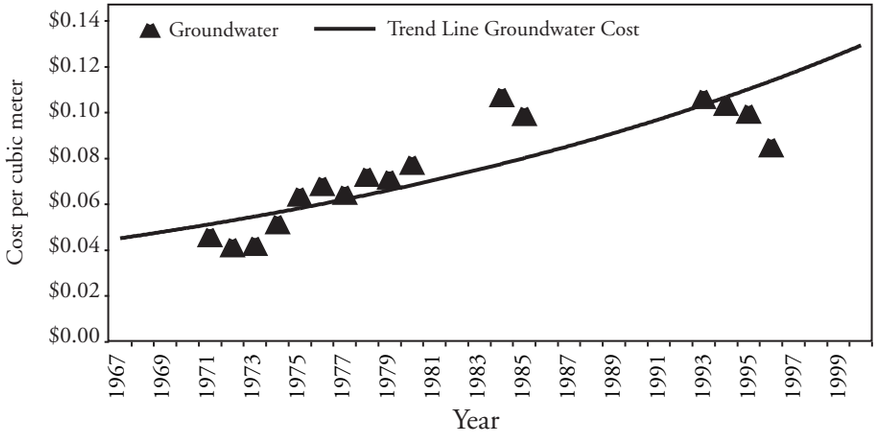
The cost of developing and maintaining well fields is a consideration in water supply. Groundwater production costs have exhibited a marked increase over the last three decades, as shown in Figure 5. Groundwater production costs, adjusted for inflation, increased from less than $0.05 per cubic meter in 1971 to approximately $0.10 per cubic meter in 1995. The primary factors influencing groundwater production costs are pumping costs and well replacement. Another factor is the increasing salinity of groundwater. Both Texas and Mexico limit salinity for public drinking water supplies to 1,000mg/l of TDS (Secretaría de Salud, E.U.M. 1999). EPWU and the JMAS each have been forced to remove approximately 25 wells from production because the TDS concentrations reached the 1,000mg/l level, thus limiting the useful life of the well and the time over which initial costs can be amortized. The JMAS laboratory reported that, as of 1999, 12% of its groundwater wells tested exceeded the TDS limit of 1,000mg/l; the maximum reported exceedance being 1,600mg/l (Paso del Norte Water Task Force [PdNWTF] 2001).

Rio Grande/Río Bravo

The Rio Grande/Río Bravo provides a replenishable source of water to the Paso del Norte. It rises in the San Juan Mountains of southern Colorado, with its headwaters lying at an altitude of more than 4,000m. Initially, the river flows easterly to the San Luis Valley in southern Colorado, then turns south and continues in a southerly alignment, bisecting the state of New Mexico. Snowmelt from the higher elevations provides the major source of water for this river. Evapotranspiration losses from intensive upstream irrigation use and evaporation from reservoir surfaces act to diminish the river's flowand degrade its quality as it makes its way to the Paso del Norte. The flow of the Rio Grande/Río Bravo is controlled by a series of upstream dams, of which the largest and oldest is Elephant Butte Dam, completed in 1916 by the U.S. Bureau of Reclamation (USBR). Releases of water from the dam are based primarily on the needs of downstream irrigators. A graph of Rio Grande/Río Bravo

flows from 1888 through 1998 is shown in Figure 6. The graph includes surface flows from both before and after the construction of Elephant Butte Dam. Note the reduced variability in flow following the completion of the dam.

Figure 5. Groundwater Production Costs for EPWU



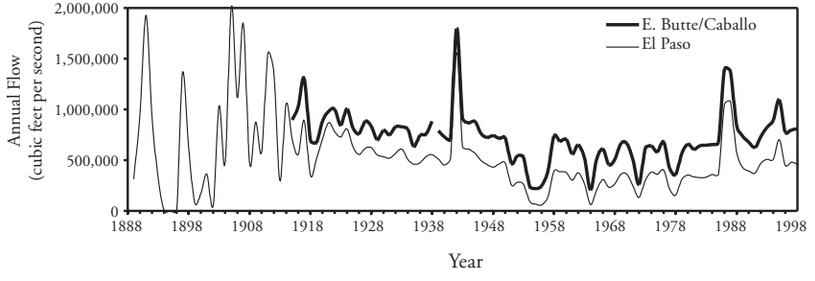
Source: Authors

Surface water in the Paso del Norte is allocated by a series of legal instruments. Internationally, water is shared between the two countries by the Mexican Water Treaty of 1906. This treaty commits the United States to deliver 74Mm^3 of water annually to Mexico (U.S. Department of State 1944). Together with its sister treaty, the 1944 Water Treaty, the two treaties allocate virtually all of the water resources of the Rio Grande/Río Bravo between the two countries from El Paso to the Gulf of Mexico. It is noteworthy that Mexico's 74Mm^3 share of the Rio Grande/Río Bravo represents only about 10% of the total surface water available in the Paso del Norte during "normal" flow years. The rational for this low allocation had to do with the amount of farmland in production in the Juárez valley at the time the treaty was negotiated, and the fact that Mexico did not financially participate in the construction of Elephant Butte Dam. Today, this small allocation limits options for providing sur-

face water to meet the municipal water needs of Ciudad Juárez.

On an interstate basis, water from the Rio Grande/Río Bravo is managed by the Rio Grande Compact that apportions the river's flow between Colorado, New Mexico, and Texas. On a local level, irrigation water is managed by the region's three irrigation districts: in New Mexico by the Elephant Butte Irrigation District, in Texas by El Paso County Water Improvement District No. 1 (EPCWID), and in Mexico by Distrito de Riego 009, a sub-unit of the Comisión Nacional del Agua (National Water Commission, in Spanish CNA). The overwhelming majority of surface water is used for irrigation purposes in the Paso del Norte.

Figure 6. Rio Grande/Río Bravo Annual Flows Between Stream Gauges at Elephant Butte and El Paso



Source: Landis

Currently, EPWU is the only municipal utility that uses surface water for a portion of its drinking water supply. EPWU's first surface water treatment plant was built in El Paso in 1943. Initially it had a capacity for treating 0.7 cubic meters per second (m^3/s). It was expanded in 1967, boosting its capacity to $1.75m^3/s$. A second surface water treatment plant with a capacity of another $1.75m^3/s$ was developed and is currently being further expanded. EPWU receives surface water via the irrigation canals of the EPCWID. In 2000, EPWU diverted and treated a total of $51.7Mm^3$ of surface water for drinking water supply purposes, this representing the remaining 33.3% of its supply that year (EPWU 2002).

Discussions are underway in Ciudad Juárez about the development of a surface water treatment plant, but a number of factors impede implementation of this action. However, even if all of Mexico's $74Mm^3$ allocation were to be used for municipal and industrial purposes, this quantity would meet only half of the current water demand of Ciudad Juárez. Further constraining this option, laterally-extensive well fields serve a relatively decentralized water distribution system in Ciudad Juárez, whereas economies of scale will dictate that a surface water treatment plant feed a more centralized system. This will require upgrading portions of the distribution infrastructure of Ciudad Juárez.

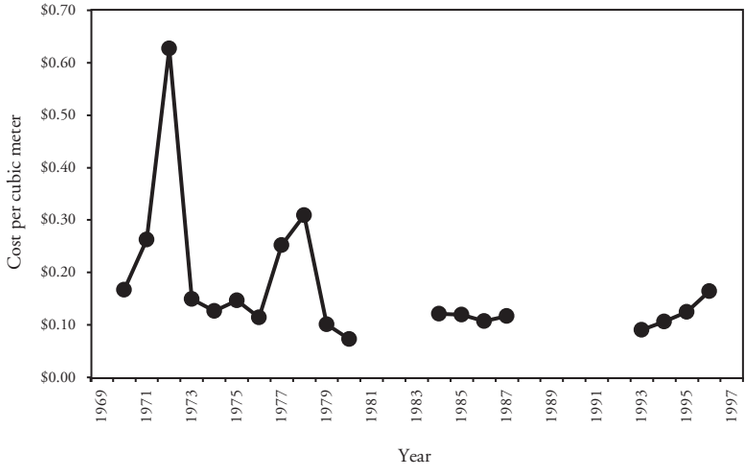
Surface Water Production Costs

While the region's fresh groundwater is of high quality, biologically inactive, and requires only chlorination before its use, surface water requires expensive treatment before it can be used for drinking water purposes. An example of the costs associated with surface water treatment, adjusted for inflation, is provided via the historic cost trend for one of EPWU's surface water treatment plants, as shown in Figure 7. Note the large year-to-year variations in cost. This is due to relatively fixed operational costs but variable inflow volume. In low-flow years, this drives up the per unit production costs. During the period of record, the costs of surface water treatment were almost always higher than ground water treatment, often markedly so. Surface water treament costs are likely to climb higher still due to escalating costs of surface water acquisition.

A problem common to both cities is that surface water releases are currently timed for delivery from late February through early October, based on the irrigation season. Consequently, EPWU is only able to operate its surface water treatment plants at full capacity for about eight months of the year. Should JMAS opt to develop a surface water treatment plant it will be faced with the same problem. During the non-irrigation season, releases from the upstream reservoirs cease and the resulting surface water flow is both too low and markedly poorer in quality in terms of TDS. Water quality improves again once water is released when irrigation resumes. The high-TDS water during the non-irrigation season is a result of return flows from upstream irrigators. The improvement in water

quality when irrigation resumes in the spring is due primarily to the dilution of return flows by copious quantities of lower-TDS reservoir water, and, to a lesser extent, a reduction of brackish baseflow as a result of high river stage (International Boundary and Water Commission [IBWC] et al. 1998).

Figure 7. Cost of Rio Grande/Río Bravo Surface Water Production, Based on EPWU Canal Street Plant



Source: Authors

Article II of the 1906 Mexican Water Treaty specifies a delivery schedule for the 74Mm^3 of water the United States is to supply to Mexico annually (U.S. Department of State 1906). The schedule provides for deliveries from February through November. Over the last 40 years, by mutual agreement, the timing of deliveries has been altered to better meet the needs of irrigators on both sides of the border. In 2002, an order from Washington, D.C., directed the IBWC to strictly adhere to the delivery schedule specified in the 1944 Water Treaty (Herrera 2002). Such a change is advantageous to neither party. Water deliveries extending into November do not meet the needs of irrigators, and the United States must absorb the "carriage losses" in making such late-season deliveries. Some water

professionals speculate that the interests of the Paso del Norte are being subordinated to the on-going controversy over Mexico's under-deliveries of water from the Río Conchos, some 320km downstream.

Despite the higher costs and limited times of operation of surface water treatment plants, El Paso and Ciudad Juárez have few other water supply options and both cities' utilities are planning to use the Rio Grande/Río Bravo to meet their future water needs. This poses a different problem: Surface waters are fully appropriated for use in irrigation. If cities in the Paso del Norte are to transition to greater reliance on the surface waters of the Rio Grande/Río Bravo, water must be converted from agricultural to municipal and industrial use. EPWU's cost of acquiring Rio Grande surface water rights from EPCWID has been contentious at times and will inevitably lead to higher municipal water rates. The cost of acquiring surface water during the 1990s was $15 per acre-foot ($12.16 per 1,000m^3), the same as that of irrigators with water rights. The agreement signed between the EPWU and EPCWID in 2001 raised the cost for additional water to more than $200 per acre-foot ($160 per 1,000m^3) (USBR 2001).

Legal constraints in gaining access to surface water may be less onerous for Ciudad Juárez. While the U.S. Constitution is silent on the subject of water, Article 27 of the Mexican Constitution, as adopted in 1917, addresses the subject in detail and declares virtually all water to be public (Bath 1977). As a result, water law is markedly different on opposing sides of the border. This has significant implications regarding the conversion of water from agricultural to municipal and industrial use. On the U.S. side, property owners possess "water rights," giving the owners assured use of surface water. Water rights are generally regarded as appurtenant to and inseverable from the land. Such rights can be "perfected" through an adjudication process. In Mexico, water rights, per se, have no meaning. Instead, the federal government, acting through CNA, grants "concessions" for the use of surface water. Consequently, the issue of converting water to municipal and industrial use is a political, not legal, issue. To address the political concern, JMAS is investigating the feasibility of using surface water to supplement its drinking water supply, then "repaying" Distrito de Riego 009 with treated

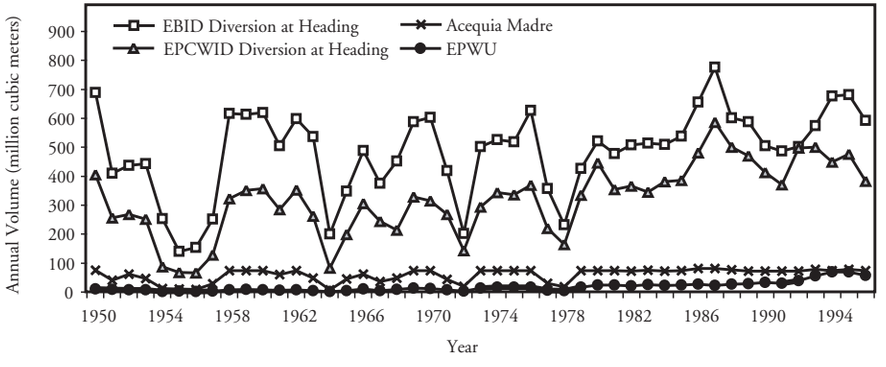
wastewater. Basically, water from the Rio Grande/Río Bravo would first be treated and distributed to meet municipal and industrial needs, and then wastewater (the source of which includes both surface and groundwater) would be collected, treated and used by Distrito de Riego 009 for irrigation.

The ability of the Rio Grande/Río Bravo to be used as a source of municipal and industrial water during an "average" flow year is not in doubt as long as the water can be transferred from agricultural use. Figure 8 shows the annual diversions from the Rio Grande to the various water users below Elephant Butte Dam between 1950 and 1996. A closer look at this figure shows that nearly all of the water is allocated to agricultural uses. The very bottom line on the graph shows the quantity of water used by EPWU. Table 2 provides a partial summary of the data shown in the figure. The table does not show water deliveries to EPWU, as EPWU receives its water from EPCWID. In 2000, EPWU received approximately 51.8Mm^3 of Rio Grande/Río Bravo water via EPCWID. EPCWID receives 444Mm^3 of water in a year of full supply (meaning years when the Elephant Butte Reservoir has an ample amount of water in storage), but, in this example, it receives only 268Mm^3 when Elephant Butte has 660Mm^3 available for release. This table and the accompanying figure suggest that, provided an agreement can be reached that facilitates conversion of water from agricultural irrigation to municipal and industrial use, El Paso has access to large quantities of water during average years from EPCWID. The JMAS options are more limited due to Mexico's lesser allocation of Rio Grande/Río Bravo water.

While the reservoirs lessen the variability in the Paso del Norte region's surface water supply, prolonged drought years present a problem that is not easily solved. The drought of record in the Paso del Norte occurred during the 1950s. The past two decades, particularly the period from 1981 to 1993, was an unusually "wet" period, and water rights holders in the Paso del Norte have enjoyed full allocations. Snowfall in the Colorado Rockies over the past three years has been meager, and inflows into the Elephant Butte reservoir in 2002 were less than 10% of average (USBR 2002). Reservoirs are commonly operated for both water conservation purposes and flood-control, this dual use meaning that a certain volume, or pool, of

each reservoir is designated for water conservation and a separate pool for flood control. The combined conservation capacity of the Elephant Butte and Caballo reservoirs is 2,776Mm^3; by mid-September 2002, the two reservoirs only impounded 340Mm^3 and Elephant Butte Reservoir was reduced to less than 11% of its capacity (USBR 2002). It seems 1992 will almost certainly be the last year of a full allocation until the current drought cycle ends.

Figure 8. Rio Grande Diversions from Elephant Butte to El Paso



Source: Authors

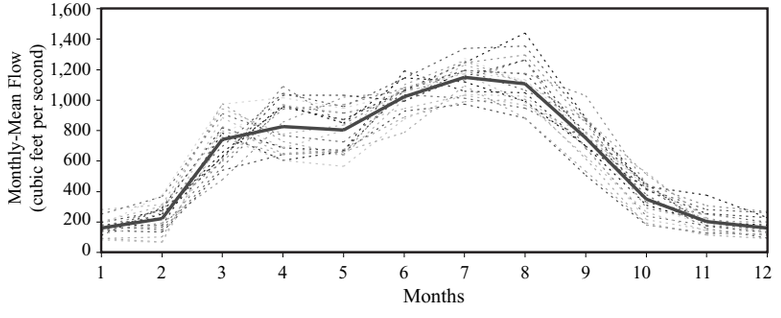
Flows in the Rio Grande at El Paso during drought periods and average flow years are shown in Figures 9 and 10. These figures indicate that flow at El Paso is reduced from nearly 1,200 cubic feet per second (cfs) (or 34m^3/s) to less than 200cfs (or 6m^3/s) during drought periods, meaning both agricultural and municipal and industrial users must rely on groundwater during these low-flow periods. Thus, the longer-term issue becomes one of allocation of groundwater resources between different users during critical drought periods, an issue made more complicated by the decreasing availability and increasing salinity of the region's groundwater.

Table 2. Summary of Rio Grande Project Water Statistics

Item	EPCWID	EBID	Mexico	Total
Land with water rights*	27,927ha	36,681ha	8,029ha	72,637ha
Percent of total	38.50%	50.50%	11%	100%
Delivered at head gates when 606Mm³ is available for release	268Mm³	352Mm³	41Mm³	660Mm³
Delivered at head gates in years of full supply	444Mm³	586Mm³	74Mm³	1,104Mm³

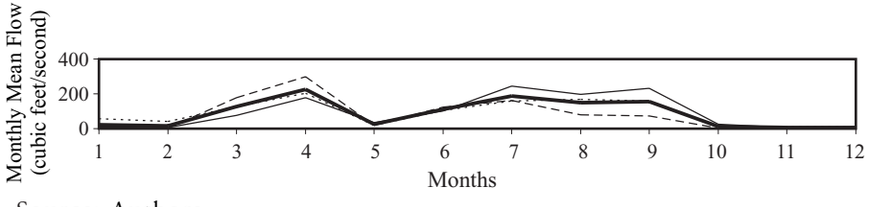
*Note: Lands in Mexico do not have "water rights" in the sense understood in the United States Rather, property owners are granted water use "concessions" by CNA.
Source: USBR

Figure 9. Average Flow Years at El Paso 1900-2000



Source: Authors

Figure 10. Drought Flow Years at El Paso, 1955, 1956, and 1964



Source: Authors

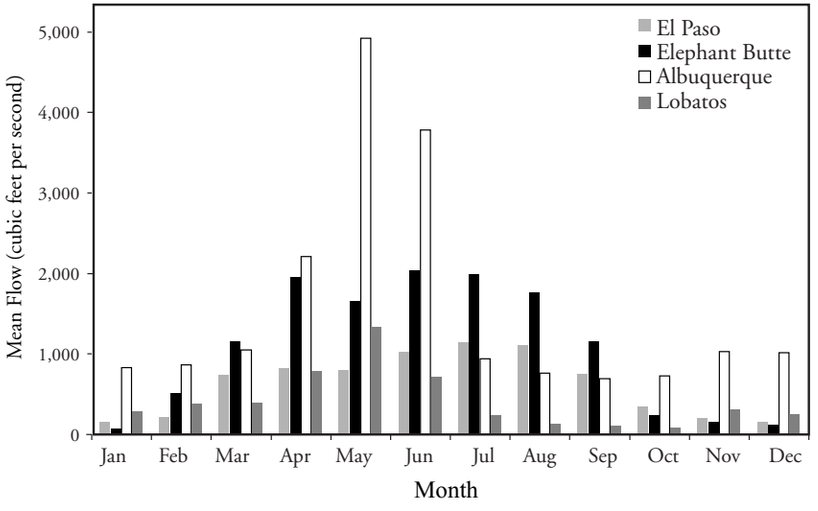
The Rio Grande/Río Bravo is a highly regulated river with many reservoirs in both Colorado and New Mexico upstream of the Paso del Norte. These reservoirs are largely operated to meet the requirements of the Rio Grande Compact, the legal agreement that allocates water between Colorado, New Mexico, and Texas. Most of the water originates in the San Juan and Sangre de Cristo mountains in southern Colorado and northern New Mexico. Historically, irrigation was widely practiced in the area between Albuquerque and El Paso long before it began to develop in the San Luis Valley of Colorado. The principle of "prior appropriation" was applied in the Rio Grande Compact, thus ensuring a surface water supply to the Paso del Norte.

The distribution of surface water flows in the Rio Grande Basin are shown in Figures 11 and 12. These figures show the mean monthly flow for selected years that are representative of average and low-flow periods at gauging stations at Lobatos, Colorado; Albuquerque, New Mexico; below Elephant Butte Dam; and at El Paso near its border with New Mexico. Figure 11 shows that flows in the Rio Grande/Río Bravo decrease as water is diverted for agricultural and municipal and industrial uses. Figure 12 shows the impact of the compact and how Elephant Butte Reservoir is used to implement its terms. The figure shows low monthly flows at the Lobatos and Albuquerque gauges, but then a sudden increase at Elephant Butte Reservoir where water held in storage from previous years is released to meet compact obligations. Water reaching the El Paso gauge diminishes between the two points due to use by the Elephant Butte Irrigation District in New Mexico as provided by the compact.

Brackish Groundwater Resources

Beneath the fresh water portion of the Paso del Norte region's aquifers are considerable, though poorly documented, quantities of brackish water. The mineral content of the region's brackish groundwater varies from 1,200mg/l to 3,000mg/l. Since 1,000mg/l is the legal upper limit for TDS for municipal water in both Texas and throughout Mexico, brackish water cannot be used without desalination.

Figure 11. Average Flows for the Rio Grande

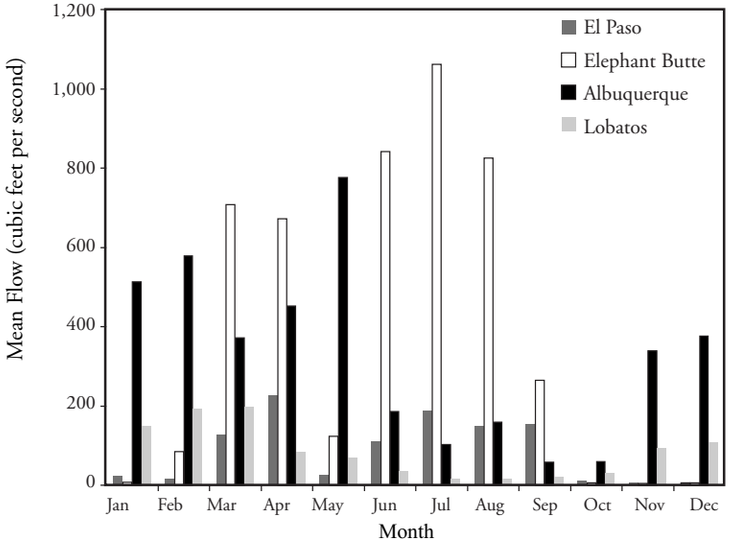


Source: Authors

Permeate, the low-TDS water product from desalination, can be blended with high-TDS well water from the same aquifer that was previously unusable because of its high salinity, to achieve a finished TDS concentration of less than 1,000mg/l. Blending these two waters enhances the yield of usable water. Membrane desalination technologies have advanced and the cost of desalination is becoming more economic. Desalination, however, generates saline concentrate, the disposal of which poses a challenge for inland locations. While membrane desalination costs less than $0.13 per cubic meter for large facilities, disposal of the resulting concentrate that contains the salts from the product water can easily triple this cost for landlocked municipalities like El Paso and Ciudad Juárez.

Thus far, two small utilities in El Paso County have used reverse osmosis treatment to exploit the region's brackish groundwater resources. Although none of the larger utilities in the region are currently using desalination treatment, recently EPWU and Fort Bliss, a U.S. Army facility in the El Paso area, entered into an agreement to develop a large-scale, 1.23m^3/s membrane desalination treatment plant to supplement their water supplies. The JMAS is also investigating desalination options.

Figure 12. Low Flows for the Rio Grande



Source: Authors

Outlying Groundwater Resources

Both EPWU and the JMAS are seeking access to groundwater resources in their outlying areas as a means of supplementing local supplies. In the mid-1990s, EPWU acquired two large ranches, the Antelope Valley Ranch and the Wild Horse Valley Ranch located in west Texas 180km east of El Paso, to secure access to the potentially significant quantities of underlying groundwater. A private investment company proposed a similar groundwater importation scheme for property in the vicinity of Dell City, Texas, a small community located 120km east of El Paso. On April 13, 2002, the *El Paso Times* reported that EPWU had taken an option on 10,000 hectares (ha) of property in the Dell City area to secure the underlying water rights (Williams 2002). While preliminary feasibility analyses have been performed for the importation of water from

these sources, EPWU contends that importation options represent only a contingency to assure future water supply for El Paso. Residents of the small nearby west Texas communities expressed vehement opposition to this proposal, and the issue of potential future groundwater importation became a major stumbling block in the final adoption of the Far West Texas Water Plan, a component of a regional planning approach that the Texas Legislature had mandated as part of an update of the overall water plan being prepared by the Texas Water Development Board. The ultimate wording of the regional water plan strategy included a statement to the effect that, prior to effectuating any groundwater transfers, further hydrological studies of the affected aquifers would be needed to fully address the potential impacts of such groundwater exportation (Rio Grande Council of Governments 2001).

JMAS is also considering importing groundwater from outlying areas. In addition to investigating the option of using groundwater from the nearby Conejos Médanos, JMAS has proposed using the groundwater from Bismark Mine, 120km west of Ciudad Juárez in northern Chihuahua, as a source of additional drinking water supplies (JMAS 2001). Unfortunately, no feasibility studies have been performed for this option, and the amount and quality of groundwater available at the Bismark Mine is largely unknown. Financial limitations hamper JMAS from fully evaluating this option.

Wastewater Reuse

Treated wastewater is a potential means of supplementing municipal water supplies. In the early 1980s, EPWU constructed a wastewater treatment plant that employs tertiary water treatment and annually re-injects as much as 3.6Mm^3 of treated wastewater into the Hueco Bolson (EPWU 2002). More recently, EPWU has instituted an aggressive water reuse program using special distribution lines from its wastewater treatment plants to provide water for irrigating parks and school playing fields. EPWU is also marketing this reclaimed water for non-potable industrial uses. JMAS's initial foray into wastewater reuse has been to provide treated wastewater for use in irrigating the large Chamizal Park. More extensive reuse of treated wastewater by JMAS will be limited by the poor quality of treated

effluent, as JMAS's two recently completed wastewater treatment plants provide only primary treatment.

All water has value in arid regions. Obviously, throughout the length of the Rio Grande/Río Bravo, irrigation return flows and wastewater discharges into the river are put to beneficial use downstream. Over time, wastewater discharges from municipalities have represented a supplement to streamflow because most cities' water supplies are drawn from groundwater. As cities throughout the length of the Rio Grande/Río Bravo transition to use of both surface and groundwater, the net effect will be a reduction in streamflow. And, just as cities are recognizing the potential value of their treated wastewater, downstream irrigators are becoming concerned about the potential consequences of reduced wastewater discharge and they are seeking to protect this source of water. Recent tri-party contracts between USBR, EPWU and EPCWID, whereby EPWU is able to purchase additional surface water, also obligate EPWU to discharge part of its wastewater into EPCWID's irrigation canals, thus reducing the amount of treated effluent available for its urban water reuse program (USBR 2001). JMAS may be faced with a similar challenge, as some industries have expressed interest in using its treated wastewater, and this will reduce the amount of such water JMAS can provide to downstream Distrito de Riego 009 irrigators.

Impacts of Water Use

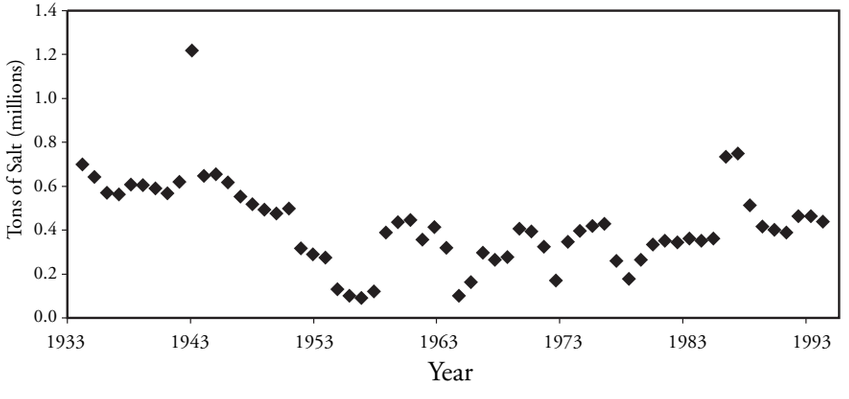
The human appropriation of water resources has repercussions on both physical and natural systems. Water management must always be cognizant of the impacts of water use.

Water Quality Impacts

Discussion of water quantity is incomplete unless it is coupled with a discussion of water quality. The water quality parameter of greatest interest is salinity as represented by TDS. Snowmelt runoff from the Rio Grande/Río Bravo headwaters in the mountains of Colorado is nearly free of dissolved minerals. By the time the water reaches

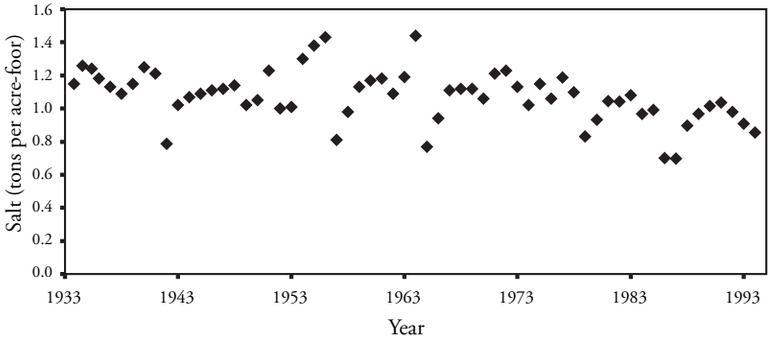
Elephant Butte Reservoir, the TDS has reached approximately 300mg/l. A TDS concentration of 300mg/l contains a solids mass of 0.4 tons per acre foot (1.46 kilograms per cubic meter [kg/m^3]) of water. This value can be contrasted with values seen in Figures 13 and 14. The total salt load graph shows a distinct decrease in total salts at El Paso from approximately 1950 onward. Large increases in the use of groundwater occurred about this time and continue to the present. Since groundwater pumped for irrigation generally has a higher TDS than surface water from the Rio Grande/Río Bravo, the salt load would be expected to have increased. The cause of this anomaly is unknown at this time. Figure 14, showing tons of salt per acre-foot of water, indicates this trend with salt load averaging about one ton per acre-foot (3.6kg/m^3) of water. This represents an increase of 250% between Elephant Butte Reservoir and El Paso. This salt load significantly impacts both agricultural and municipal and industrial uses, as agricultural productivity is impaired and the value of the water for municipal and industrial uses decreases with increasing salt concentrations.

Figure 13. Total Annual Salt Load at El Paso, 1933-1994



Source: Authors

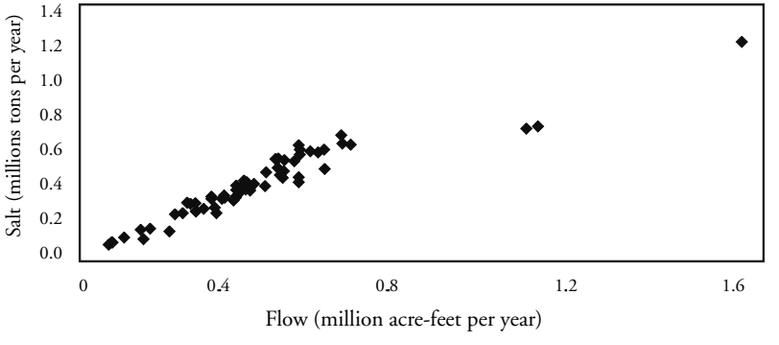
Figure 14. El Paso Annual Mean Salt Load in Tons per Acre-Foot, 1933-1994



Source: Authors

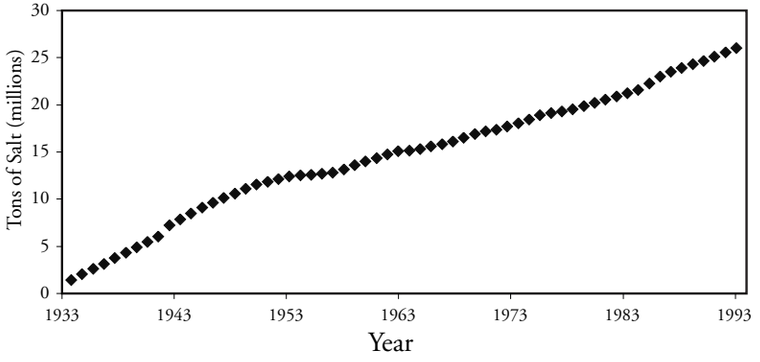
Figure 15 shows the variability of salt load with total annual flow. The linear relationship indicates a relatively constant salt load for similar total annual flows measured in acre-feet. Figure 16 shows the sum of salts at El Paso when totaled for each successive year. A straight-line relationship with a constant slope would indicate that the salt load has remained constant over time. There is some variability, however, and a change in slope can be seen in about 1950.

Figure 15. Flow vs. Total Salts at El Paso, 1933-1994



Source: Authors

Figure 16. Cumulative Salt at El Paso, 1933-1994



Source: Authors

Ecosystem Concerns

In July of 1998, then-President William Clinton, by Executive Order 13061, designated the Texas portion of the Rio Grande/Río Bravo as an "American Heritage River." Such a designation was to be based, in part, on "characteristics of the natural, economic, agricultural, scenic, historic, cultural, or recreational resources of the river that render it distinctive or unique" (Clinton 1998). For such a designation to be given to the reach of the river in the El Paso-Ciudad Juárez region reflects support for efforts to restore the river, rather than a statement of the river's current condition.

Elephant Butte Dam, completed in 1916, is located in Sierra County, New Mexico, 160km upstream of El Paso. The dam provides flood protection, and the storage and controlled release of impounded waters from both Elephant Butte Reservoir and Caballo Reservoir (completed by USBR in 1938 and located immediately downstream of Elephant Butte) facilitated the agricultural development of the river floodplain.

The managed release of water for irrigation purposes has consequences for both the rate of flow and the quality of the water. The flow rate, measured at a gauging station upstream of El Paso, during the peak of the irrigation season in July averages more than 34m^3/s; in January, flows at this same station are reduced to 8.5m^3/s and represent primarily return flows from irrigated lands upstream of the cities but downstream of the reservoirs (Turner, Quezada, and Troncoso 1998). Water quality in this reach of the river varies with the flow rate in an exponential manner: TDS range from less than 500mg/l for flows greater than 40m^3/s, to more than 1,000mg/l for flows less than 10m^3/s (Bahr, Keyes Jr., and Kenny 1998). The seasonal fluctuation in flow and water quality not only limits the time periods during which surface water treatment plants can operate, but it stresses aquatic life. Today, the river supports only a fraction of the number of species once present.

The Rio Grande/Río Bravo channel in the Paso del Norte has been considerably altered. In the mid-1930s, two projects, the Rio Grande Rectification Project along the international border and the Rio Grande Canalization Project in southern New Mexico, eliminated the river's meanders and forever altered the riparian habitat throughout approximately 200km of the river valleys of Doña Ana County, New Mexico, and the reach between the Texas counties of El Paso and Hudspeth and the Chihuahuan municipios of Juárez, Guadalupe, and Praxedis G. Guerrero.

In the mid-1960s, the Chamizal Settlement (a resolution to a 100-year old boundary dispute between the two countries) resulted in the relocation of the river channel between the central, most densely settled portions of both El Paso and Ciudad Juárez. The new realigned segment of the river now flows through a 5km-long, concrete-lined, trapezoidal channel. Immediately upstream of this reach of the river, the American Dam and International Dam divert surface flows into the principal irrigation canals serving El Paso and Juárez respectively. The river below is depleted of water—so much so that EPWU sought to commission a study to have the Rio Grande/Río Bravo, from the area of the International Dam diversion to below the utilities' Haskell Street Wastewater Treatment Plant, classified as "intermittent," meaning that it has a flow of less than 0.003m^3/s at least once every two years (Texas Administrative Code 2002). The utilities' interest in this classification is understandable since, by so doing, it will have to meet less stringent discharge standards for its wastewater treatment plant. Yet, such a designation for an "American Heritage River" is ironic.

Downstream of the two cities, irrigated farmland makes extensive use of the available water. By the time the Rio Grande/Río Bravo passes the Fort Quitman gauging station in eastern Hudspeth County, the river's flow is substantially depleted and its quality is significantly impaired. This marks the beginning of a reach of the Rio Grande/Río Bravo that is commonly referred to as the "Forgotten River." From this point, the main stem of the river does not have any significant stream inflow until it is joined by the Río Conchos, some 320km downstream. Water quality in this lower reach commonly exceeds 2,000mg/l. Unable to transport sediment, the low flow rates cause aggregation of the river channel. The lack of disruptive flood waters and the poor quality of the water have accelerated the spread of invasive Saltcedar (*Tamarix, sp.*), further impoverishing the habitat.

An example of the continued impact of competition for water resources is the Rio Bosque Wetlands Park, located in the southeast portion of El Paso County. The park, approximately 150ha in size, lies adjacent to the Rio Grande/Río Bravo and in fact, prior to the river rectification project, the site was part of one of the river's meanders. Cut-off by the rectification project, the site was left undeveloped and remained federal property until 40 years later when the title was conveyed to the city of El Paso to enable the development of a park. No development ensued until the late 1990s when IBWC approached the city with the concept of developing a wetlands park, as the IBWC was obligated to "mitigate" other wetlands being disrupted by a canal extension project (Watts, Sproul, and Hamlyn 2002). It was anticipated that water would be provided to the park from an adjoining EPWU wastewater treatment plant. Unfortunately, the wastewater plant's effluent is allocated to EPCWID, and generally, the wetlands park only receives water during the non-irrigation season. The lack of water during the spring and summer months all but precludes the reestablishment of native riparian plant species. In the future, water supplied to the park may be further reduced as EPWU's water reuse program is expanded.

Groundwater and Surface Water Interaction

Historically, water laws have treated surface water and groundwater as though they were distinct. In rare instances, surface water flows are separate from underlying groundwater by virtue of intervening aquicludes, defined as extreme low-permeability soil stratum that will not transmit groundwater. More commonly, groundwater and surface water "communicate." Examples of the interrelationship of groundwater and surface water in the Paso del Norte include the diminished surface flows in the vicinity of EPWU's Canutillo well field due to a lowering of the water table, as well as a noticeable lowering of the water table in the central portion of El Paso and Ciudad Juárez. This happened after the concrete lining of a reach of the Rio Grande/Río Bravo described previously, an action that stopped the surface water from being able to recharge the groundwater (Walton and Ohlmacher 2000).

Water laws are evolving to account for the interaction of groundwater and surface water. New Mexico water law expressly acknowledges groundwater/surface water interaction and applies the principle of "prior appropriation" to both surface water and groundwater. Texas water law applicable to groundwater is based on the "right of capture." This allows landowners the unfettered right to pump groundwater from their property without regard for the impact on neighboring groundwater users and keeps them from being held accountable for the impact on hydraulically-connected surface waters. This somewhat antiquated system may cause problems in the future. Although Texas water law does not acknowledge the interaction of groundwater and surface water, recently negotiated agreements between EPWU and EPCWID have taken this factor into account (USBR 2001). Mexico, by virtue of public control of both surface and groundwater, is positioned to be able to manage the interaction of groundwater and surface water.

Water Demand in the Paso del Norte

Basic Principles

Water demand for any given geographic area is the aggregate of all categories of human water use, including irrigation water for agriculture, livestock use, electrical power cooling, manufacturing and industrial use, domestic use, and other urban uses. To the extent that the native riparian environment is valued, this element may be incorporated in minimum in-streamflow requirements, but generally it is not recognized as a source of water demand. Water use, however, need not imply water consumption. Consumptive water use, in the most complete sense of the term, involves a change in the state of water—namely the conversion of H_2O from either a solid (ice) or liquid to a gas (water vapor)—because once vaporized, water is lost to the atmosphere. The dominant water "sinks," or absolute loss of water from a region, are evaporation from reservoir surfaces and evapotranspiration—this term including both the loss of water from soil by evaporation and by transpiration from the leaves of plants. The amount of loss from evaporation at surface reservoirs is not trivial.

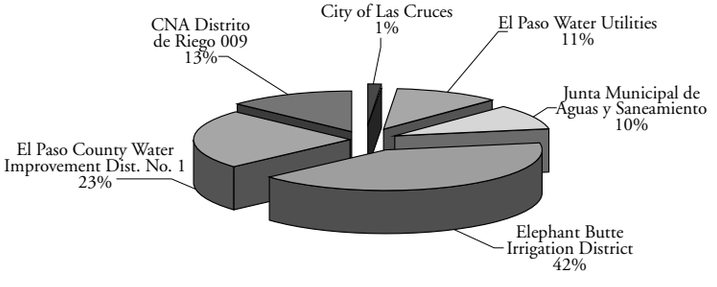
When Elephant Butte Dam was built, it impounded a reservoir more than 65km in length that was touted as one of the largest manmade lakes in the world. Pan evaporation data for this location averages almost 3m annually (New Mexico State University 1995). The reservoir's vast surface area results in a significant evaporative loss of water. While evaporation is a factor in a number of variables, such as temperature, humidity, solar gain, wind speed, and reservoir pool size, annual evaporative loss from Elephant Butte and Caballo reservoirs generally approximates 7% of the average volume in storage (Landis 2002).

Water contamination—whether from natural sources like minerals dissolved in groundwater or human sources like pesticides and high levels of nutrients from agricultural runoff, pathogens from human waste, or heavy metals and anthropogenic chemicals in urban runoff—limits the range of potential uses of water. Technologies exist that can "treat" water to remove contaminants, but the level of treatment and cost thereof, vary depending on the intended subsequent use of the treated water.

Agricultural Water Demand

The adopted Far West Texas Region Water Plan noted that, although irrigated land represents less than 1% of the total land in its seven-county planning area, this category is the largest source of water demand (Rio Grande Council of Governments 2001). The generalization that irrigation is the dominant user of water is relevant to the Paso del Norte, as collectively the three jurisdictions contained therein form a geographically comprehensive area of the region's water resources. As part of a study of comparative approaches to water planning undertaken by a voluntary organization known as the Paso del Norte Water Task Force (PdNWTF), data was compiled on water use from groundwater and surface water within the region. Figure 17 shows total water use during 1999 in the Paso del Norte. Irrigation accounted for more than three-quarters of the total 1,500Mm^3 of water used that year (PdNWTF 2001). The summation of water used by the three irrigation districts exceeds the amount of water diverted from the river, primarily due to reuse of water in the form of irrigation return flows by downstream irrigators.

Figure 17. Paso del Norte Water Use in 1999



Source: PdNWTF

Of special note is the quantity of water, some 197.4Mm^3, used by Distrito de Riego. This far exceeds the 74Mm^3 of "treaty water" provided under the 1906 Mexican Water Treaty, because irrigators in the Juárez valley supplement their irrigation allotment with water

from other sources. For example, in 1998, only 38% of the water used by Distrito de Riego irrigators was surface water (i.e. "treaty water" from the Rio Grande/Río Bravo), another 38% was wastewater from Ciudad Juárez, and the remaining 24% was pumped groundwater (PdNWTF 2001). Thus, in large measure due to the limited surface water allocation Mexico receives, agriculture in the Juárez valley is also a significant user of the region's groundwater.

Whereas agricultural water use is constrained based on the amount of arable land and the historic allocation system as codified in water rights, municipal growth is relatively unconstrained, and thus the increasing demand for water in the Paso del Norte is driven by urban water use. If cities in the Paso del Norte are to transition from dependence on groundwater to conjunctive use of both surface and groundwater, surface water will have to be "converted" from agricultural to municipal and industrial use. The combined effects of agricultural displacement by urban expansion and EPWU's increased use of surface water, would be expected to have resulted in a decline in the land area devoted to irrigated agriculture in the region. Experience indicates otherwise. According to data compiled by Texas A&M University's Agricultural Research and Extension Center in El Paso, and for Distrito de Riego 009 by the Department of Rural Development in Mexico, the amount of cropped land area in the Paso del Norte from 1979 through 1999 remained relatively stable. Ironically, only cropped land area in Doña Ana County, the jurisdiction with the smallest urban population, noticeably declined, though only by about 6% (PdNWTF 2001).

A different issue concerns the type of crops that are being grown. Over the past several decades, traditional row crops grown in the region such as cotton, alfalfa, and chilies have been displaced by groves of pecan trees. Pecan trees require more irrigation water than many of the crops they replaced, but more importantly, unlike an annual crop, pecans represent a multi-year commitment. This creates a somewhat inflexible demand for irrigation water. This inflexibility is reflected in the recently negotiated tri-party agreement with USBR, whereby EPWU obtains water from EPCWID. The agreement contains provisions that place EPWU in a position analogous to a "junior water rights holder" (USBR 2001). During years of low flow, less surface water will be available to EPWU. The past two decades have

been relatively "wet" years, but during drought conditions, cities will be almost totally reliant on groundwater.

Municipal and Industrial Water Demand

Municipal and industrial water use is the summation of all categories of urban water use. Normalizing the total quantity of water used by the population served allows the water use characteristics of different cities to be compared. El Paso and Ciudad Juárez are markedly dissimilar in their rates of water use. In 1999, EPWU customers used an average of 617 liters/person/day; customers of the JMAS used an average of 321 liters/person/day (PdNWTF 2001).

The recently adopted Far West Texas Region Water Plan broke down water demand by municipal, irrigation, manufacturing and industrial, electric power cooling, livestock, and mining. Both population and demand for water were projected in 10-year intervals to the year 2050. By the end of the 50-year planning horizon, total water demand in El Paso County from all sources of water was projected to be 522Mm^3, of which 64% was municipal and industrial water use. Irrigation water use was expected to decline by approximately 20%, based on expected conversion from agricultural to municipal and industrial use. The plan notes that EPWU contends the conversion rate will be "significantly greater" than reflected in the plan (Rio Grande Council of Governments 2001).

JMAS also developed a master plan incorporating projections of population, future water demand, and needed infrastructure improvements. Indicative of a difference in perspective, whereas the Far West Texas Region Water Plan has a 50-year planning horizon, the Ciudad Juárez Plan Maestro para el Mejoramiento de los Servicios de Agua Potable, Alcantarillado y Saneamiento (Ciudad Juárez Master Plan for the Improvement of Potable Water Services, Water Storage, and Wastewater Treatment), only has a 20-year planning horizon. Similarly, public agencies in Mexico generally do not project population growth more than 20 years into the future. Among the analytical elements of the JMAS plan was a projection of the sources of water demand, as shown in Table 3. Consistent with the JMAS water billing system, household water use was broken down into four separate income categories. Non-domestic water demand was projected based

on a ratio per household. Neither a significant increase in income level nor a significant change in per capita use is implied by this analysis. This suggests a relatively low aggregate water demand—markedly lower in Ciudad Juárez than in its sister city El Paso. The lack of any significant projected change in income levels has implications for the community's expectations for its future.

Balancing Supply and Demand

Water scarcity is an issue of increasing concern for both El Paso and Ciudad Juárez. Scarcity, however, is a relative term. Scarcity of water, at least in the near term, means scarcity of "cheap water." It is the supply of inexpensive groundwater that is being rapidly depleted. Future urban water demand must be met by converting Rio Grande/Río Bravo surface water from agricultural to municipal and industrial use, desalinating brackish groundwater supplies, or importing water from outside the region. All of these options are very expensive compared to pumping and distributing high-quality groundwater.

Supply and demand can be balanced by increasing the former or reducing the latter. "Demand management" is a term that refers to an holistic approach that integrates water conservation with water resource planning, and includes evaluating the determinants of water demand, the impact of water pricing structures and financing alternatives, and the effectiveness of water conservation programs (Bauman, Boland, and Hanemann 1998). Numerous efforts and programs are underway in the Paso del Norte to effect a reduction in per capita demand for water.

Reducing Demand

Logically, it would seem that the most effective means of reducing water demand would be to increase the price of water. In fact, many empirical studies have demonstrated that consumers do respond to increasing water prices by reducing their consumption (Boland et al. 1984). Some recent research, however, argues that price increases alone have limited effect, and instead researchers advocate that a suite of coordinated, non-price conservation programs can be more effective at reducing demand than simple water rate hikes. Rate

increases themselves were found to be most effective when implemented through graduated rate structures and coupled with public education programs. Summertime outdoor domestic irrigation was found to be the most responsive, though a price elasticity of 0.2 (the percentage decrease in water use in response to a given percentage increase in cost) was the most that could be expected (Michelsen, McGuckin, and Stumpf 1998). Given the relatively low incomes of Paso del Norte residents, using large rate increases to reduce water use is unlikely to find political favor.

Table 3. JMAS Projected Sources of Water Demand

Use	Allocation (liters/person/day)	Allocation (liters/month)
DOMESTIC		
Low-income	270	
Moderate-income	339	
Middle-income	386	
Upper Middle-income	521	
COMMERCIAL		88.06
INDUSTRIAL		802.06
PUBLIC		402.30

Source: Elaborado para el Plan Maestro

The approach to educating the public about the importance of water conservation differs north and south of the border. On the U.S. side, the focus is on developing a greater awareness of water usage, educating the public about how to conserve water (e.g. using water-efficient appliances and fixtures, and landscaping with drought-tolerant plant species) and trying to instill an environmental ethic. In Mexico, much of the focus is on changing a basic attitude about water, often expressed as changing the "culture" of water. Part of this stems from Article 27 of the Mexican Constitution, which declared all the country's water resources to be public. Taken literally, if all water is public, some individuals contend that they should not have to pay for what is already theirs. In practice, water supply systems in Mexico have been heavily subsidized, and users are

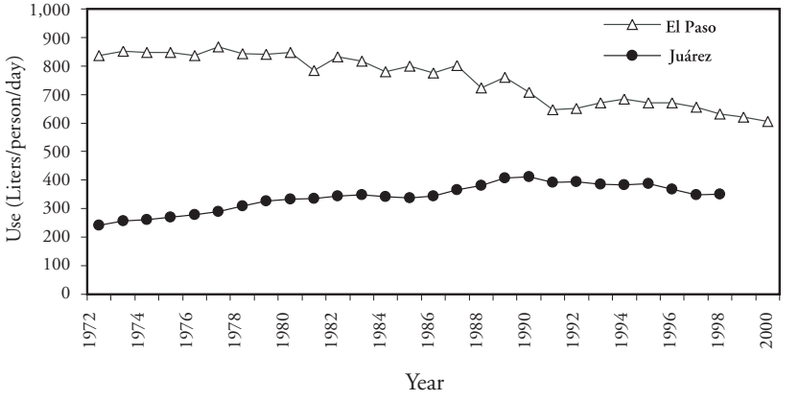
accustomed to paying very little for their water. An attitudinal change is needed to gain public acceptance for higher water rates, metering individual users, charging based on use, and accepting different levels of charges as are embodied in graduated rate structures.

EPWU has instituted a broad range of programs designed to reduce per capita consumption. Among the elements of EPWU's strategy have been changes in the local plumbing code to require more water-efficient fixtures, implementing a graduated block rate structure, enacting an ordinance that limits the time-of-day during which residents can engage in outdoor irrigation, incentive programs to encourage xeriscaping and replacement of less-efficient plumbing fixtures, and an aggressive public education campaign to raise public awareness of the need to conserve water. EPWU's approach to reducing per capita consumption appears to have had its intended impact. Figure 18 shows a comparison in changes in per capita water consumption by EPWU customers and JMAS customers over a 28-year time period. Note the reduction in water demand by EPWU customers since the advent of an aggressive demand management program in the early 1980s. The price of water cannot have been a significant factor in this change. In fact, a recent survey conducted by NUS Consulting Group found EPWU has the fourth lowest water costs among the 51 water systems surveyed across the United States (Kolenc 2001). Buoyed by its success in attaining previously established water conservation goals, the managing board of EPWU recently adopted a goal of further reducing per capita demand to 530 liters/day.

JMAS has also developed programs to reduce water demand in Ciudad Juárez. Like EPWU, JMAS promotes water conservation through various public education efforts and in partnership with a non-governmental organization (NGO) known as Aqua XXI. Some of the challenges faced by JMAS are, by American standards, very basic. JMAS has worked to meter water consumption, but many service connections remain un-metered. As of 1999, only 59% of registered users, or 92% of total accounts, had water meters, and only two-thirds of those meters were functioning properly and read on a regular basis (JMAS 2001). The relatively unchanged per capita water demand by JMAS customers, as shown in Figure 18, may not indicate a lack of effectiveness in JMAS water conservation pro-

grams. Given that the average Juarense uses less than 60% as much water as the average El Pasoan, dramatic reductions in water use should not be expected.

Figure 18. Trends in EPWU and JMAS Per Capita Water Use



Sources: EPWU; JMAS

The two cities have taken different approaches in developing graduated rate structures as a means of discouraging excessive water use. One of the issues involved in developing a rate structure is to ensure that the poorest citizenry are able to afford sufficient water for their basic needs. That poses a challenge given that the number of individuals sharing a residence (and therefore on a single account) vary from single-person households to large families. EPWU addressed this concern by tying excess volume charges to a percentage of the average winter (December, January, and February) consumption, when outdoor irrigation use is minimal. JMAS uses a different approach; it assesses water use fees based on a combination of usage and account location, the latter based on an assessment of the character (and likely household income), of the neighborhood. For billing purposes, JMAS divides Ciudad Juárez into a series of zones, and assigns each zone to one of four categories based on the assumed average household income level. Table 4 provides a summary of the number of connections based on the household economic

income level categorization as of 1999. Note the relationship of the average household consumption and economic level. Given that family size tends to shrink with rising income, this suggests a strong correlation between per capita water use and income level.

While household income and water use appear to be correlated, the rate of water consumption for families reliant on hauled water is dramatically lower than households served by public water systems. The Paso del Norte provides a dramatic illustration of this phenomenon. In Ciudad Juárez, outlying areas beyond the limits of JMAS water lines are served by water haulers, known as *pipas*, that provide between 760 liters and 1,900 liters of water per week to homes, within which typically reside an average of four or five individuals. Using the midpoint of this range, and assuming a four-person household, this represents an average domestic water use of approximately 50 liters per person per day.

A similar situation exists across the border in El Paso County. Developments at the margins of the city of El Paso sometimes lack water service or wastewater service, or both. Such developments are the legacy of the laissez-faire attitude embodied in the relatively weak land development laws of Texas that allowed unscrupulous developers to sell building lots in marginally-improved subdivisions, often by contract-for-deed, to low-income purchasers. Perhaps because many of the purchasers of these lots were recent émigrés from Mexico, the resulting developments came to be known as *colonias.* Water service to homes in *colonias* is often provided by delivery trucks, registered by the Texas Commission on Environmental Quality, that refill 9.5m^3-capacity individual storage tanks on a monthly basis (Graham 2002). Assuming a four-person household, this translates into approximately 80 liters per person per day. By contrast, documented water use by low-income households in Ciudad Juárez that are connected to public water lines averages 250 liters per person per day (Lemus 1999). Inevitably, as water lines are extended to un-served areas, water use will increase.

Table 4. Water Consumption of JMAS Household Accounts, 1999

Household Economic Level	Number of Connections (December 1999)	Annual Volume (m^3)	Average Consumption (m^3/household/month)
Low-income	80,275	28,308,600	30.15
Moderate-income	96,726	36,007,559	31.76
Middle-income	35,352	14,851,458	35.07
Upper middle-income	19,660	8,205,669	34.88
Total/Mean	232,013	87,373,286	32.97

Source: Lemus

Increasing Supply

Reducing per capita water consumption, though important, will not address the Paso del Norte region's fundamental problem of an increasing population and diminishing water resources. New sources of water will have to be developed to increase the water supply. The approaches of the two cities to this challenge differ.

EPWU, as part of its 1992 management plan, adopted a five-part strategy to cope with the region's water supply problems (Boyle Engineering Corp. 1992). The first component of EPWU's strategy is demand management, especially water conservation. The remaining four components:

- Promote water reuse, in the form of use of treated waste water for non-potable uses
- Increase the use of Rio Grande/Río Bravo surface waters, possibly coupled with an aquifer storage and recovery (ASR) option during years of high surface flow
- Desalinate brackish groundwater
- Increase withdrawals from the Mesilla Bolson

EPWU has aggressively pursued this approach and has also sought access to groundwater resources elsewhere in the west Texas area. The last option listed in the strategy, namely that of increasing

withdrawals from the Mesilla Bolson, implies a potential future attempt to gain access to groundwater from New Mexico.

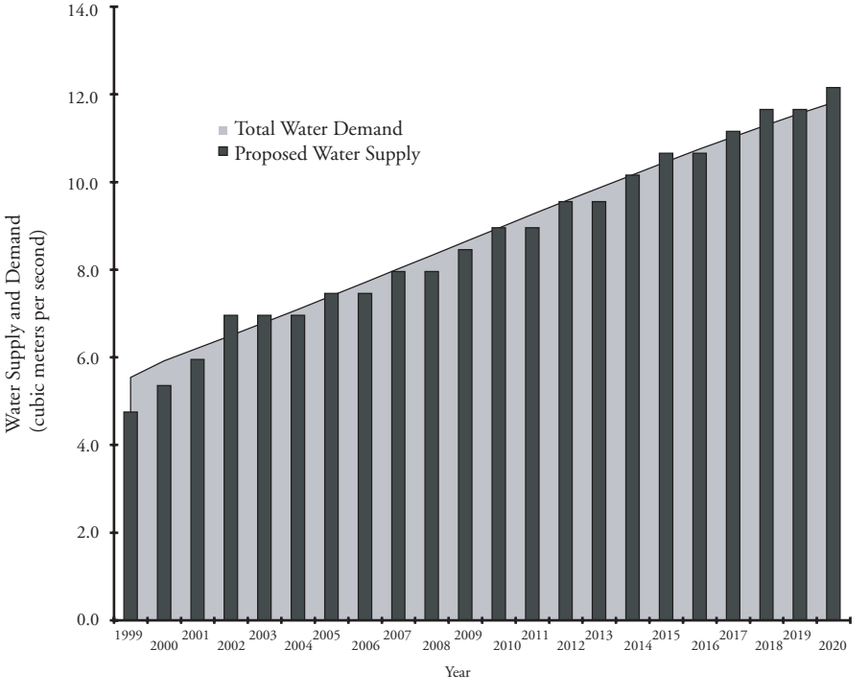
The JMAS, with the financial support of the Border Environment Cooperation Commission (BECC), developed a water master plan that was released in 2000. Long-range water planning requires taking inventory of existing facilities, evaluating the current water demand characteristics, projecting future population and water demand, and identifying sources of water and the cost and timing of needed infrastructure improvements. Figure 19, taken from the Ciudad Juárez Plan Maestro para el Mejoramiento de los Servicios de Agua Potable, Alcantarillado y Saneamiento, shows a graph of expected water demand matched with planned water supply.

Figure 19 suggests JMAS can increase its water supply enough to meet future water demand, albeit without any surplus capacity as a contingency supply. The sources of this supply, however, may be questionable. Figure 20 reproduces the same bar graph of water supply, but identifies the proposed sources of water.

In theory, JMAS proposes to meet rising demand by tapping into ever more-distant sources of water, but the plan presupposes that each water source, as developed, can be relied upon to produce a sustainable quantity of water. The plan projects that by the year 2020, more than half of the water needs of Ciudad Juárez will be supplied by sources other than the Hueco Bolson. Particularly disturbing, however, is the assumption that withdrawals from the Hueco Bolson can be increased to a level of $6m^3/s$, and sustained thereafter through the 20-year planning horizon. That assumption may be incorrect.

In February, 2000, shortly after the JMAS Master Plan was completed, the *El Paso Times* published an article stating that, based on the current and projected rates of withdrawal, the fresh water portion of the Hueco Bolson beneath Ciudad Juárez would be virtually depleted by 2005 (Simonson 2000). The article was based on statements made by EPWU officials and was given added credibility by virtue of recent groundwater modeling of the Hueco Bolson, which EPWU had undertaken with the U.S. Geological Survey. Officials from JMAS, though they declined to give statements to the press, dispute this projection and asserted that a vertical assessment of water quality of the Mexican portion of the Hueco Bolson is lacking. It well may be true that the full extent of the Hueco Bolson is not known, but, absent better information, it seems imprudent to base long-range planning on the assumption that a constant supply of water will be available from this source.

Figure 19. Projected Water Demand and Supply for Ciudad Juárez



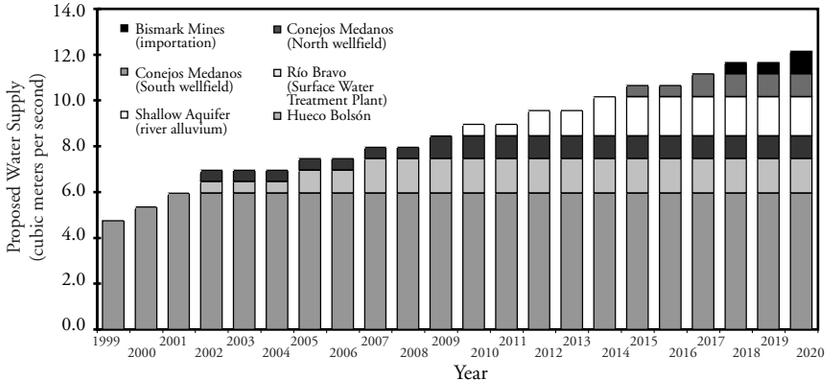
Source: JMAS Plan Maestro

The other proposed sources of water supply lack sufficient information for water management planning purposes. This will be a constraint on implementing the plan's recommendations because, before funding is committed to implement the recommendations, additional information is needed about the quality of groundwater and the extent of supply available. Thus far, JMAS has lacked sufficient financial resources to undertake this next step.

The magnitude of investment required to implement the recom-

mendations of the Master Plan is considerable. Table 5 provides a summary of the costs of different elements of the plans recommendations.

Figure 20. Sources of Water Supply for Ciudad Juárez



Source: JMAS Plan Maestro

Alternative Strategies

Projected water shortages have forced utilities in the Paso del Norte to adopt more sophisticated planning and demand management strategies, and to be more creative in identifying alternative sources of water supplies. Other approaches not currently under consideration may be needed in the future, but the impacts of such alternatives must be evaluated.

Reallocation through Water Markets

Given that ample water for municipal and industrial use is available on a regional basis provided less water is devoted to agriculture, the future may see the development of broader water markets whereby water rights holders lease their water allotment to municipalities. This is already in place with the conversion of EPCWID water from agricultural to municipal and industrial use. Not under consideration is a cross-jurisdictional water market, such as New Mexico surface water being sold for use in Texas. This approach, though controversial, could be a means by which EPWU could gain access to additional water supplies. By contrast, water law in Mexico precludes individual ownership of water, therefore open water markets cannot develop within Mexico. Water law in Mexico, however, does allow for the transfers of water concessions, so a type of water market may emerge. Unfortunately, because Mexican communities have considerably fewer financial resources than their American counterparts, an international market for water could hurt, rather than help, their situation. Even applied only within the region's separate jurisdictions, the consequences of unregulated water marketing may have other undesirable consequences, particularly for natural ecosystems.

Direct Reuse of Treated Wastewater

Currently in the Paso del Norte, most municipal wastewater is treated and then released, either into the Rio Grande/Río Bravo or into the canals of the various irrigation districts. Exceptions to this generalization are the re-injection of tertiary-treated wastewater into the Hueco Bolson by EPWU and the water reuse programs that make treated wastewater available for non-potable purposes. No wastewater, however, is treated and directly reused for drinking water purposes. Direct reuse is referred to as a "pipe-to-pipe" system, though the public sometimes disparagingly labels it as "toilet-to-tap." Technologies are available that are capable of treating effluent so that it meets the drinking water standards, but thus far, no U.S. municipality has opted for a pipe-to-pipe system. Rather, water reuse systems avoid direct connections between sewage treatment plants and public water supply systems by discharging treated effluent into a natural surface water body so that it blends with surface water before it is diverted for municipal water supply, or by means of artificial recharge of groundwater to enable soil-aquifer treatment and blending with native groundwater before being pumped out and used for drinking water.

Table 5. Estimated Costs of the Ciudad Juárez Master Water Plan Recommendations

Recommendation Number	Description	Total Investment Required	
		Millions of Pesos	Millions of Dollars
DRINKING WATER SYSTEM			
1	Development of infrastructure (well fields, transmission lines, etc.) to provide new water sources to meet future water demand of Ciudad Juárez	4,160.35	416.03
2	Rehabilitation and enhancement of the water distribution system	2,181.38	218.14
WASTEWATER COLLECTION SYSTEM			
3	Investments to the wastewater collection system	1,358.78	135.88
WASTEWATER TREATMENT SYSTEM			
4	Investments to the wastewater treatment system	380.80	38.08
REUSE OF TREATED WATER			
5	Investments for water reuse systems	104.66	10.47
OTHER STUDIES & PROGRAMS			
6	Studies to determine necessary enhancements of the administrative and technical capacity of JMAS	53.86	5.39
7	Studies of potential new sources of potable water supply for Ciudad Juárez	21.84	2.18
8	Actions and programs by JMAS to promote water conservation	76.54	7.65
TOTAL		8,338.21	833.82

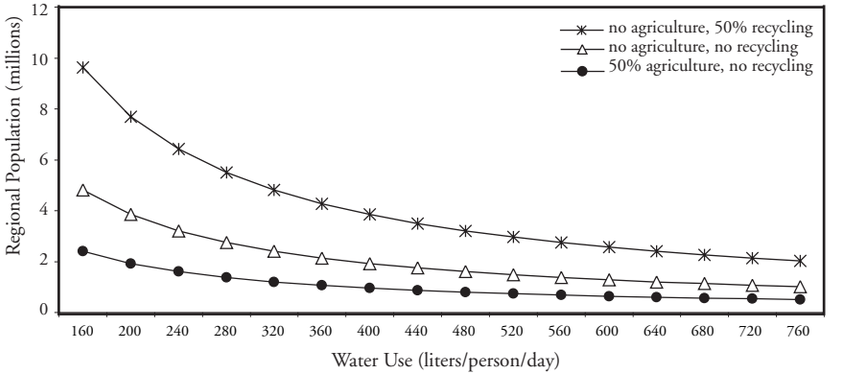
Note: Assumes a currency exchange rate of one U.S. dollar per 9.7 Mexican pesos
Source: JMAS Plan Maestro

During the first "Water Summit" that Congressman Silvestre Reyes convened in the spring of 2001, Dr. Douglas Rittman proposed that EPWU, which has side-by-side surface water and wastewater treatment plants, blend treated effluent with surface water and treat this mixture for use as drinking water (Rittmann 2001). Unfortunately, even if this idea could win political favor, under the terms of EPWU's current contractual obligations, it is not permitted to release treated effluent into EPCWID's irrigation system.

Growth Management

Growth management refers to assessing costs to new development based on the added financial burden such development imposes on an existing community, including indirect impacts. An example of this approach was proposed by means of a guest editorial written by the General Manager of EPWU and published in the *El Paso Times* on March 31, 2002. This editorial advocated the use of impact fees to offset EPWU's costs of upgrading its utility infrastructure. Local builders expressed opposition to the proposal, and the city of El Paso has not acted on this recommendation.

Figure 21. Paso del Norte Population Carrying Capacity



Source: Adapted from Tarquin

Ciudad Juárez currently assesses a fee from all new development, although the revenues collected are insufficient to meet the city's considerable infrastructure needs. Since in-migration is fundamentally a factor of the expansion of so-called "base industries," JMAS might adopt a strategy of targeting new maquiladoras and other new industries with an impact fee expressly tied to the capital costs of developing new sources of water. Such an approach, however, may not be politically feasible. Despite recent efforts to decentralize governmental decision-making, the federal government still has consid-

erable influence on local financing, and it is unlikely that all additional revenues collected from higher impact fees would be retained for local use. Nor, if this kind of strategy were adopted, would it be appropriate solely in border communities because water problems in Mexico are not unique to the border region. For example, water supply problems in Chihuahua, the capital of the state of Chihuahua, have resulted in frequent service interruptions. On both sides of the border, because one of the effects of impact fees is slowing development, compromise will be needed to balance infrastructure financing needs with economic development aspirations.

Using growth management as a means of restricting growth is contrary to current programs seeking to promote economic development. Yet, from a long-term perspective, this may be necessary. For example, while current water supply problems in the Paso del Norte could be significantly remedied by the conversion of surface water from agricultural to municipal and industrial use, that strategy has limits. Dr. Anthony Tarquin published a paper in 1998 in which he argued that the upper limit of the population carrying capacity of the region should be based solely on replenishable water supplies. From this perspective, replenishable water, in the form of average annual inflow of surface water and the estimated annual aquifer recharge, is analogous to income; groundwater that has accumulated over geologic time is analogous to stored capital. Translating the amount of replenishable water into population requires that assumptions be made about the average per capita water use—essentially choices regarding the types of land use and lifestyles. Figure 21, re-created from Tarquin's paper, shows three extreme scenarios: a 50% reduction in the region's agricultural water use with the saved water used for municipal and industrial purposes; an abandonment of all agriculture in the region with all replenishable water devoted to municipal and industrial use; and a final alternative wherein all agriculture is abandoned and 50% of all water is reclaimed and reused. The horizontal axis on this graph represents alternative per capita water use rates. (The current per capita water use in Ciudad Juárez is approximately 320 liters per day, and in El Paso it is 610 liter per day.) Disquietingly, unless a relatively extreme set of assumptions are used, the resulting "carrying capacities" from this analysis are less than the population projected to live in the region in the near future.

Regional Cooperation

Given the Paso del Norte's rapidly diminishing water resources, water issues in the region can only become more prominent. The "null alternative" is unacceptable, as inaction will only forestall the selection and implementation of actions to address the region's problems, and major water supply projects require considerable lead times to implement. Because many aspects of the economies of El Paso and Ciudad Juárez are tightly coupled, consequences of water supply problems will have repercussions for both cities.

The severity of water problems in the Paso del Norte has forced greater interaction among the many entities charged with aspects of water management in the region. Sometimes this is a negative process, as evidenced by the plethora of lawsuits regarding water resources. Other times it is positive. Examples of such positive interaction include:

- Special state legislation designating EPWU as the sole water planning entity for El Paso County
- Formation of a New Mexico-Texas Water Commission (this was an outgrowth of a settlement agreement ending a protracted series of lawsuits), which provides a forum for bi-state dispute resolution and which led to the development of the Las Cruces-El Paso Sustainable Water Project
- The seven-county Far West Texas Water Planning Group, created in response to Texas state legislation that incorporated a "bottom-up" approach to state water planning
- The Lower Rio Grande Water Users Association (initially created to help counteract El Paso's efforts at gaining access to New Mexico water), which today is coordinating water planning in Doña Ana County
- The recent BECC-funded Tri-Region Water Planning initiative that is exploring the potential of water supply projects of mutual benefit to El Paso and Ciudad Juárez

Voluntary organizations are also active, examples of which are: Aqua XXI, a non-governmental organization working to promote more dialogue regarding water issues in Ciudad Juárez; the Paso del Norte Water Task Force, which promotes regional water planning; and the Paso del Norte Watershed Council, focusing on environmental issues along the Rio Grande/Río Bravo.

Despite efforts at promoting regional water planning, numerous factors continue to impede cooperation, including existing, inflexible water allocation systems; different legal systems; different economic pressures and financial abilities; centralized versus decentralized decision-making structures; cultural differences that influence water use; differences in perspective (long-term future versus immediate needs); and a lack of complete information about the region's water resources, particularly in Mexico.

Some factors favor regional water management planning. Physically, water resources are shared; drought, when it occurs, will affect all jurisdictions; and combining resources can help attract more outside financial assistance. Futhermore, the growing economic interdependence of El Paso and Ciudad Juárez creates a shared destiny should that work to prevent extreme hardships from being disproportionately borne by some of the region's population as this will, to greater or lesser degrees, impair the quality of life of everyone in the region.

Water planning and management in the Paso del Norte could evolve in at least three different directions:

1. Dialogue and cooperation could dissipate as water shortages become more severe. Under this scenario, parochialism could lead to a reticence to share information, legal maneuvering could further drain financial resources, and opportunities for combining resources could be lost.
2. The current situation of guarded dialogue and willingness to consider projects and programs of mutual benefit could continue, interspersed with conflict and dissention. The effectiveness of the current approach will only be demonstrated if, despite diffecences, significant, mutually beneficial cross-jurisdiction projects and programs are implemented.
3. Greater trust could develop and lead to a willingness to pursue a regional approach to water management. Common systems of pricing and regional growth management could help reconcile the region's development with its resource base, and enable entities to pursue sustainable, region-based quality of life initiatives rather than have to focus on near-term crises.

Not included as a scenario is the development a regional water management authority. Any such entity would only be effective if empowered to take decisive action, including having a regulatory function. However, issues of sovereignty preclude this possibility. The region's best hope is that continued dialogue will foster a sense of a shared destiny and that this will promote a willingness to cooperate to achieve a mutually-beneficial future.

Afterword

In 1987, the United Nations-created World Commission on Environmental Development published a landmark report, *Our Common Future*, which is often referred to as the "Brundtland Report," named after the commission's Chairman, Gro Harlem Brundtland. This report gave what has become a commonly-accepted, if deceptively simple, definition of sustainable development. It reads: "Development that meets the needs of the present without compromising the ability of future generations to meet their own needs." The concept is straightforward—its application, however, is not.

Provided equitable reallocation mechanisms can be devised, sufficient water resources are available in the Paso del Norte to provide the next several generations with drinking water, though the cost of water will almost certainly escalate dramatically. More optimistically, emerging technologies may vastly increase water use efficiency, make possible the treatment of wastewater sufficient for its direct reuse, and make available previously unknown or inaccessible water resources. But in a long-term context, it may be foolhardy to dismiss the consequences of unsustainable use of natural resources by forever assuming that technology will develop an answer to the problem.

Because resources are finite, development can be sustained. Growth, however, cannot. In terms of water resources in the Paso del Norte, extracting groundwater (whether fresh or brackish, and

whether within the immediate region or imported from outside of the region) at a rate exceeding the aquifers' natural recharge rate, is inherently unsustainable. Doing so only postpones the inevitable need to balance supply and demand. Eventually, El Paso and Ciudad Juárez will have to match their consumption of water resources with the natural rate of replenishment.

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Water Without Borders: A Look at Water Sharing in the San Diego-Tijuana Region

Barbara R. Bradley and Emilio de la Fuente

Abstract

Given the aridity and growing population of the U.S.-Mexican border region, few leaders miss the fundamental connection between adequate water supply and quality of life in border communities. As dominant factors, aridity and population growth cause persistent controversies of political, economic, and environmental natures, affecting the evolution of water supplies and infrastructure. Water-related infrastructure refers to infrastructure used to manage water sources, including potable water, wastewater, and storm water. Like most infrastructure along the border, water infrastructure is physically divided into two portions, each separately serving each country.

Conventional water sources are rainfall, snowmelt, groundwater, and surface waters such as lakes and rivers. Non-conventional water sources include desalinated water and recycled water. Regardless of where they are located, many factors define the envelope of constraints for providing water infrastructure, including: demographics and land uses, water sources, land form, and the capacity of existing infrastructure. To explore the paradigm of Water Without Borders—

the transboundary sharing of water resources—each of the above constraints must be addressed to define the technically feasible options. The San Diego-Tijuana region provides an example to illustrate the engineering issues that must be answered to create physical conditions conducive to sharing water across the U.S.-Mexican border.

Despite existing constraints, two types of regional opportunities may exist for water sharing: transboundary water transfers or jointly owned and operated water infrastructure. The options for water sharing include a binational aqueduct, a binational desalination plant, transfers of recycled water, and a jointly owned and operated groundwater recharge and extraction system. A constraints analysis suggests shared aquifer storage and recycled water reuse are feasible and cost-effective opportunities for water sharing that would benefit Tijuana, Rosarito, and San Diego. By means of injection into aquifers accessible from both sides of the border, recycled water overcomes the barriers to transport caused by urban development.

Since three existing plants and four future plants could become sources of recycled water, several alternatives may emerge for large-scale aquifer storage and reuse in the San Diego-Tijuana region. One possible scenario would combine two potential projects into one conjunctive use project resulting in transboundary water sharing and multiple benefits. The first project would restore the riparian habitat along the Río Alamar in Tijuana; however, no surplus of surface waters is available for the restoration. The second proposed project would bring recycled water from across the border to the vicinity of the river where it could be discharged into infiltration basins constructed along the riverbed. Using the riverbed for recharge would simultaneously act to restore the habitat value of the riparian corridor and recharge the aquifer.

Agua Sin Fronteras: Una Mirada a la Repartición del Agua en la Región San Diego-Tijuana

Barbara R. Bradley y Emilio de la Fuente

Resumen

Con la aridez y el crecimiento de la población de la frontera Estados Unidos-México, pocos líderes desconocen la conexión fundamental entre el suministro del agua y la calidad de la vida en comunidades fronterizas. Los factores dominantes—la aridez y el crecimiento de la población—causan controversias persistentes de tipo político, económico y ambiental, las cuales afectan la evolución de los suministros del agua y infraestructura. Infraestructura relacionada con agua se refiere a la infraestructura que se usa para el manejo de fuentes de agua, agua potable, aguas negras y aguas pluviales. Como la mayoría de la infraestructura fronteriza, la infraestructura del agua está dividida físicamente en dos porciones, cada una sirviendo a cada país.

Fuentes convencionales incluyen aguas pluviales, provenientes de la nieve derretida, de las superficies acuáticas como los lagos y los ríos y agua subterránea. Fuentes no convencionales incluyen agua desalinada y reciclada. Aparte de la ubicación, los factores siguientes definen las restricciones para proveer infraestructura acuífera: usos demográficos y agrícolas, fuentes acuíferas, la topografía y la capacidad de la infraestructura en existencia. Para explorar el paradigma de agua sin fronteras, es decir el uso compartido de los recursos del agua de la frontera, hay que tratar con las restricciones susodichas para definir las opciones técnicamente posibles. La región San Diego-Tijuana provee un ejemplo para ilustrar los retos de ingeniería que tienen que ser resueltos para crear las condiciones conducentes para compartir el agua en la frontera.

A pesar de restricciones existentes, dos tipos de oportunidades regionales puedan existir para el compartimiento del agua: transfe-

rencias del agua entre la frontera o infraestructura acuífera que sea poseída y dirigida conjuntamente. Las opciones del compartimiento del agua incluyen un acueducto binacional, una planta de desalinación binacional, transferencias del agua reciclada, y una recarga de los mantos subterráneos y un sistema de extracción poseída y dirigida conjuntamente. Un análisis de restricciones sugiere una oportunidad factible y efectiva del compartimiento del agua para beneficio de Tijuana, Rosarito y San Diego—un almacenaje acuífero compartido y el reuso del agua reciclada. El inyectar agua reciclada en los acuíferos accesibles por los dos lados de la frontera, permitirá que el agua reciclada supere los obstáculos de transporte causado por el desarrollo urbano.

Con tres plantas en existencia y cuatro potenciales como fuentes de agua reciclada, varias alternativas para almacenaje acuífero en larga escala y el reuso del agua residual en la región San Diego-Tijuana. Un escenario posible combinaría dos proyectos potenciales en un proyecto conjunto con el resultado del aprovechamiento compartido del agua fronteriza y beneficios múltiples. El primer proyecto restituiría el hábitat ripario por el Río Alamar, sin embargo, no habría excedente de aguas superficiales para la restauración. El segundo proyecto propuesto traería agua reciclada del otro lado de la frontera a la vecindad del río donde se podría recargar hacia las cuencas infiltradas construidas por el lecho. Usando el lecho para la recarga simultáneamente servirá para restaurar el valor del hábitat del corredor ripario y la recarga del acuífero.

Introduction

Given the aridity and growing population of the U.S.-Mexican border region, few political leaders miss the fundamental connection between adequate water supply and quality of life in border communities. The strong, influential voices of leaders need to be anchored by the reality of what is physically and technically feasible if border communities are to meet demands for adequate potable water quantity and quality cost-effectively.

If population increases mean water resources and infrastructure are becoming a greater constraint to social and economic well-being,

then social strife, economic hardship, and local friction between nations will be inevitable. To circumvent constraints from water shortages, new sources and infrastructure are needed now. The transboundary sharing of water resources and infrastructure merits further examination given the complex and intertwined social and economic relationship between U.S. and Mexican border communities. Where traditional water supplies cross the border—and several watersheds do—the physical conditions seem to support the possibility of transboundary water sharing in new ways. Transboundary water sharing requires binational collaboration and funding. Funding will probably be successful only if benefits exist for both parties.

The concept of Water Without Borders, proposed in this chapter, means overcoming the political boundaries that are seen as physical barriers so that water sources and/or water infrastructure can be shared efficiently for the benefit of both countries. This approach keeps with the trend toward watersheds as a planning region. The watershed approach recognizes that surface water flows, groundwater aquifers, ecosystems, and biodiversity do not conform to political boundaries. Using watersheds as natural regions allows for the joint management of water supplies, water quality, flooding, and environmental health.

Binational water management is not a new concept, although transboundary water management is. This chapter offers an engineering approach that results in identification of a physically and technically feasible model within a moderately short timeframe for achievement. The San Diego-Tijuana region is used as the case study for this analysis. Engineering constraints are examined through demographics, land use, water sources, land form, and the capacity of existing infrastructure. Possible sources of water and scenarios for water sharing are discussed, as are the engineering issues that apply to each option. Although political, social, and environmental constraints exist, they are not addressed here. Finally, a scenario is examined for one of the most feasible options—aquifer storage and reuse of recycled wastewater.

Wastewater recycling is an important opportunity for water sharing. In an arid region with limited water sources, using water more than once is a common-sense method of extending water resources

and increasing the socio-economic benefits from each gallon of water. The source of water is reliable and can be used to meet demands that require lesser water quality. Like all new infrastructure, recycled water distribution could be cost-prohibitive due to interferences caused by existing infrastructure in urban areas. Alternatively, injecting recycled water into underground aquifers makes it possible to store large quantities and achieve long-distance transport through natural flow paths. By spreading the recycled water under a large region, both the United States and Mexico could access the water, producing a shared benefit and incentive for such a program. In streambeds where aquifer recharge is known to occur, stream restoration may enhance aquifer storage.

Water Infrastructure

Water-related infrastructure refers to methods used to manage water sources, potable water, wastewater, and storm water. Conventional water sources include rainfall, snowmelt, groundwater, and surface waters such as lakes and rivers. Non-conventional water sources include desalinated water and recycled water. Recycled water is water used for human purposes that is then treated to remove pollutants, enabling its safe reuse. Potable water refers to water of safe and acceptable quality in accordance with defined national standards for human drinking. Storm water is actually rain water, but once the rain lands, it is called "storm water" when managed for health and safety purposes, including flood control. Hereafter, water infrastructure refers to methods used for collection, distribution, treatment, and storage of (non-storm) water and wastewater.

Like most infrastructure along the border, water infrastructure is physically divided into two parts: the Mexican portion serving Mexico and the U.S. portion serving the United States. In the San Diego-Tijuana region, water infrastructure follows this pattern with few exceptions. Figure 1 shows the San Diego-Tijuana region with potable water infrastructure. Note how infrastructure is divided by the border. Only one pipeline—an emergency water connection initially installed to provide water to Tijuana during a period of severe drought—crosses the border. The network for wastewater collection is similarly divided although not shown in this figure. The only

infrastructure crossing the border is a wastewater interceptor from Pump Station No. 1 in Tijuana to the International Wastewater Treatment Plant (IWTP) in San Diego. At the IWTP, a connection exists to send treated water back to Tijuana, but this is non-operational as no receiving pipeline is installed.

Regardless of where they are located, the following factors define the constraints for engineering water infrastructure:

Demographics and Land Uses
- Existing and future population
- Existing and planned land uses, including how they produce water demands and how they hinder construction of water infrastructure
- Existing and future water demands based on population and land uses

Water Sources
- Natural sources and limits of water
- New sources of water

Land Form
- Distance between sources, demands, and existing water infrastructure
- Topography and relative elevation of sources, demands, and existing water infrastructure

Capacity of Existing Infrastructure
- Hydraulic capacity of existing conveyance, storage, and treatment facilities
- Water quality of natural sources, potable water after treatment, and water discharged from wastewater treatment plants

In addition to these constraints, cost and environmental protections steer engineering decisions for the provision of water infrastructure. To explore the paradigm of Water Without Borders, each of the above constraints must be addressed to define the technically feasible options. The San Diego-Tijuana region provides an example to illustrate the engineering issues that must be answered to create

the physical conditions for water to be shared. Scenarios for realistic water sharing are suggested with an emphasis on use of recycled water, particularly by way of groundwater recharge and extraction. The conditions for water sharing along other sections of the border may be different, but the same questions must be answered about the physical and qualitative conditions of the infrastructure and the water itself.

Demographics and Land Uses

A high population and a relatively rapid population growth characterize both Tijuana and San Diego. Tijuana's population is much smaller than San Diego's, but it is growing considerably faster. Table 1 shows population growth statistics for Tijuana and San Diego over the last decade.

Table 1. Population Growth Trends in the San Diego-Tijuana Area

City	1990	1995	2000	Increase 1990-2000
San Diego	2,498,000	2,626,700	2,813,800	11.3%
Tijuana	747,400	991,600	1,210,820	62.0%

Source: Ganster

In 2010, the population of this binational region will increase from 3.70 million to 5.45 million people with 60% living in San Diego and 40% in Tijuana. The population projection for 2020 is about 7 million people (Ganster et al. 2000).

Existing and planned land uses affect water demand. Figure 2 shows land uses in the San Diego-Tijuana area. Urban land uses make the expansion of infrastructure difficult and expensive, particularly for pipelines. For example, construction of a recycled water network in a developed urban area must accommodate existing buildings, pavement, and underground utilities, as well as social impacts such as traffic delays and loss of business in construction zones. The additional cost of constructing infrastructure in developed urban areas is, in fact, the major physical barrier to recycling

Figure 1. San Diego-Tijuana Potable Water Infrastructure

Source: Ganster

water on a municipal scale. By contrast, recycling water to agricultural lands is commonly practiced and less expensive to implement. This suggests that trading fresh water for recycled water could result in increases to fresh water supplied for urban uses. The feasibility of this opportunity for the San Diego-Tijuana area is examined below.

In a typical year, San Diego County imports 90% of its water while Tijuana imports about 95%. By 2010, San Diego will consume about 87% of the water in this area while Tijuana will consume 13%—if the infrastructure capacity keeps up with the growing water demand (Ganster et al. 2000). Without an increased supply of water and adequate water infrastructure, the demand will exceed capacity quickly, as shown in Figure 3. From this review of the demographic conditions, the highest unmet demand is currently, and will continue to be, in the Tijuana-Rosarito area.

For this reason, the Tijuana-Rosarito area should be the focus of increased water supply and sanitation services with serious examination of all potential sources. Conversely, per capita water consumption is so high in the San Diego area that water infrastructure needs should focus on reduction of demand for fresh water supplies through water conservation, extensive water recycling, and provision of new facilities for emergency water storage.

If agricultural land uses remain in proximity to urban areas, the cost of trading water might be feasible within the short term. For example, water from the IWTP could be transferred to farmers along the coast south of Rosarito who traditionally used raw wastewater before the conveyance canal was replaced by a pipeline. With additional treatment, this water might be acceptable for additional purposes, such as landscape and golf course irrigation at resorts developing on the coast, or for agricultural uses in the U.S. portion of the Tijuana River Valley. Agricultural users in the United States would likely prefer recycled water from the South Bay Water Reclamation Plant (SBWRP) because of the potential for industrial compounds in the effluent from the IWTP.

Long-distance water trading, such as between San Diego-Tijuana and the Imperial-Mexicali Valleys, could become feasible if the cost of fresh water were to increase substantially or the transfer and sale of recycled water were subsidized. With either scenario the cost increases for the general public, driving development of water recy-

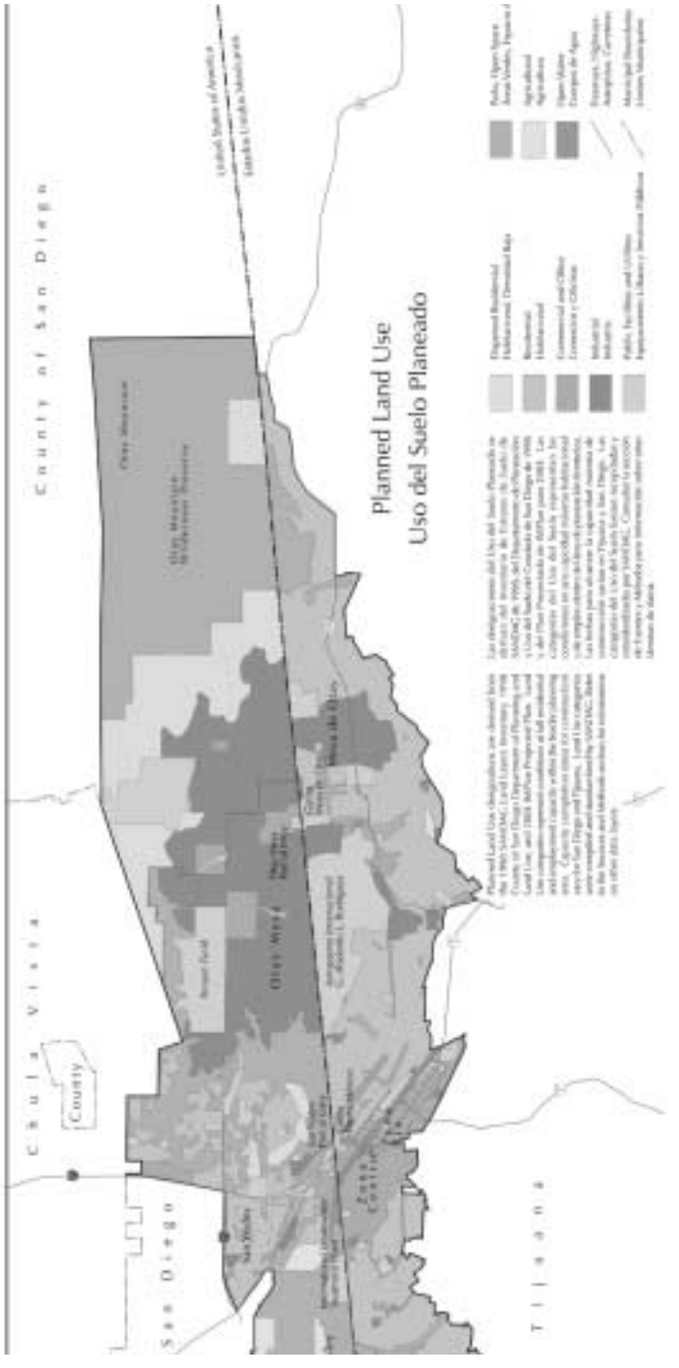
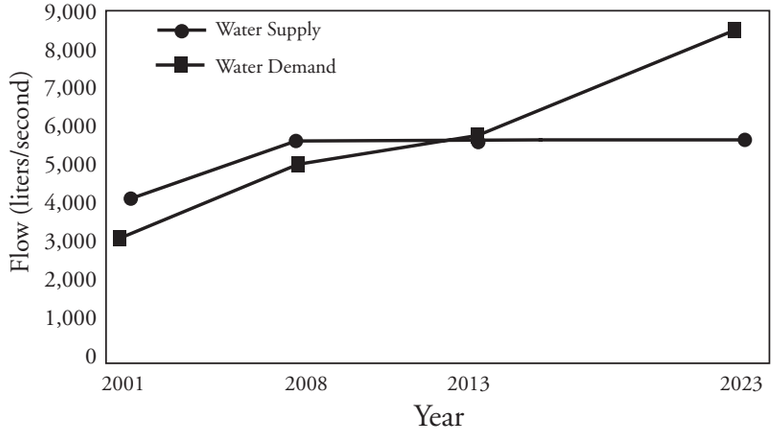


Figure 2. San Diego-Tijuana Land Use

Source: Ganster

cling infrastructure. Water quality issues would have to be addressed to protect agricultural soil quality from salts and protect consumers from biological or industrial pollutants.

Figure 3. Projection of Water Supply and Water Demand for the Tijuana-Rosarito Area 2001-2023



Source: Comisión Estatal de Servicios Públicos de Tijuana (CESPT)

Water Sources

Natural Sources and Limits of Water

In the San Diego-Tijuana region, the Colorado River, rainfall, and groundwater are the natural sources that serve both municipalities. Surface water from Northern California also supplies water to San Diego and other regions of California. Natural limits, water rights, and environmental protections require the sharing of these waters with other populations and species. These sources as allocated are not adequate for sustained or improved quality of life in the San Diego-Tijuana region. With the exception of obtaining fresh water supplies from agricultural lands, there is probably little reason to expect or justify additional importation of water to the region.

The Colorado River is the main source of shared water for San Diego-Tijuana. Water is conveyed through open channels on each side of the border. It may be possible to transfer additional Colorado River water from agricultural uses to urban uses, such as from the Imperial and Mexicali Valleys and Baja California. Ongoing plans and studies to increase the hydraulic capacity of the channels include a plan for a shared channel. This would be a form of transboundary water sharing for mutual benefit. Depending on the route taken, the channel could be located in either country or cross back and forth between the two. An advantage for locating a shared channel in the United States includes the rigorous bidding and construction practices required there. An advantage to locating the channel in Mexico is the lower cost of labor for construction.

Rainfall in natural watersheds is collected in reservoirs in the San Diego-Tijuana region. Given the low amount of rainfall in the region, the percentage of water demand met by rainfall is in decline as demand increases with population growth. Varied rainfall frequently results in below-normal water levels in reservoirs. Rodríguez Reservoir, the only reservoir for rain water catchment in Tijuana, periodically nears empty (CESPT 2002). The use of reservoirs for capturing rainfall is extensive in San Diego, resulting from several decades of water infrastructure construction. Most recently, construction has focused on emergency storage reservoirs. Opportunities for shared emergency storage could mitigate the effects of long-term drought on the San Diego-Tijuana region.

Groundwater is extracted to meet a portion of current water demands. Local aquifers offer many possibilities for shared water storage, transport, and extraction. A particularly attractive feature is the potential for transporting water underground through natural aquifers without the interferences and costs associated with transporting water through urban areas. Stream restoration can enhance groundwater supplies with storm water not captured by existing reservoirs (Dallman and Piechota 2000). Sources of water for recharge include rainfall during abundant years, recycled water, desalinated water, and, under certain circumstances, Colorado River water.

Without additional infrastructure to take advantage of the possibilities described here, groundwater levels will continue to drop and

degrade in quality. The paradox associated with the use of aquifers without stream restoration is that water from other sources will have to supplement natural groundwater resources.

New Sources of Water

Currently, the three most technically feasible sources of water are demand reduction, desalination, and recycled water. Demands are water "losses" due to agricultural, industrial, commercial, residential, and landscape uses or other leakages resulting in lost use of water. Demand reduction is simply the reduction in water demand that results in water becoming available for other uses or demands. Demand reduction is sometimes referred to as "found water," and occurs through conservation, such as using water-saving consumer devices like low-flow flush toilets and timed drip irrigation. Demand reduction also occurs through reduction in water losses in the public water distribution system. These "system losses" can be significant. In Tijuana, system losses from leaking water distribution lines have varied from 25% to 41%. These losses are the major reason why the total water quantity sent into the distribution network outstrips the total quantity recorded for billing purposes (Caloca 1997). Conservation and reduction of water losses should be a key element of any water supply program.

Desalination is an effective technology although it is rarely considered unless other sources of water are inadequate. The cost of desalinated water is often greater than 10 times the cost of water from existing sources. The cost of construction and energy for operations will continue to limit its use, despite the stability of this source, because ocean water provides a year-round source of water at a predictable flow. Desalination can also take advantage of brackish groundwater and can be used to remove salts from recycled water. Within the context of transboundary water sharing, desalination will not likely provide a significant source of water supply unless water shortages increase further or emergency conditions, such as a drought, occur. In the San Diego-Tijuana area, desalination is currently used for water supply only in Oceanside, California. The City of Oceanside extracts and desalts 8 million gallons per day (MGD) of brackish groundwater. The groundwater is combined with water

from other sources and distributed throughout the city. The San Diego County Water Authority is proceeding with plans to construct a much larger plant to desalinate ocean water in the neighboring city of Carlsbad.

Like desalination of ocean water, recycling provides a constant source of water. Recycled water is wastewater that has been treated to standards that make it safe for reuse. The level of treatment dictates the type of use. Elevated salts in recycled water may render the water unsuitable for some uses unless diluted with other water. For example, this type of water can be used to irrigate vegetation with a low salt tolerance. Most recycled water in the San Diego area is used for landscape irrigation, industrial purposes, and groundwater recharge in areas like Santee Lakes. Conjunctive management of surface, recycled, and groundwater has the potential to increase the use of recycled water and to extend surface and groundwater quantities.

Recognizing that public resistance to the use of recycled water will probably limit the number of uses for this water, the primary issue from an engineering perspective is reduced to finding adequate numbers of users in clusters to make the cost feasible for construction of a completely separate water distribution system used solely for recycled water. The cost of recycled water is high—anywhere from 1.3 times to 10 times higher than the cost of existing sources, not including the cost of the distribution system. Where opportunities for aquifer storage and recovery exist, the feasibility of using recycled water increases substantially by replenishing groundwater sources. This is because the wholesale cost of groundwater is low—about $20 per acre-foot. By contrast, the cost of imported water is about $150 per acre-foot, depending on the source (Bradley 2002).

Landform

Landform is a fundamental constraint dictating the feasibility of water infrastructure and water sharing. (Technically speaking, almost any infrastructure option is feasible, but many are not affordable. Therefore, technical feasibility actually refers to the ability or willingness of the consumers to pay for the infrastructure.) Ideally, engineering common sense dictates: gravity-moved water from areas of higher elevation to areas of lower elevations should be

considered, water demands should be met by local water sources, and water should be exposed to sunlight to allow disinfection to occur through natural ultraviolet light irradiation. In reality, the opportunities to conform with nature are often overruled by the need to speed up treatment, the location of water supplies in far-away places or deep below the ground surface, and by other unnatural conditions. Thus the engineer's challenge is to cost-efficiently provide pipelines, pumps, chemicals, mechanical treatment equipment, concrete storage structures, electrical supply, process instrumentation, electronic controls, and a host of other means to meet society's demands for water and sanitation.

The land form of the San Diego-Tijuana region is characterized by hilly terrain, requiring extensive water pumping to route water to its intended destinations (Figure 4). Tijuana's elevation is much higher than San Diego's, so by following the flow of gravity, water sharing across the border favors the flow of water from Tijuana to San Diego. But, given the higher water use and greater availability of water in San Diego than Tijuana, this probably does not make sense, except possibly for the limited agricultural uses found in the Tijuana River Valley. The difference in elevation and the hilly terrain also suggest challenges and cost increases associated with transferring water from San Diego to Tijuana.

As a political barrier, the border acts as an artificial constraint imposed on natural conditions and infrastructure options. One needs only to look at the existing wastewater infrastructure in Tijuana to understand how land form and political boundaries have conspired to exacerbate transboundary health and environmental impacts caused by raw wastewater spills in Tijuana. Historically, a large portion of the wastewater collected in Tijuana was routed to the Tijuana River where it flowed downhill to the north, into the United States, through the Tijuana Estuary, and into the Pacific Ocean without treatment. To intercept the gravity flow of renegade wastewater flows, CESPT constructed pipelines, a pump station, and a canal to keep the water at a high elevation and redirect the flow to a treatment plant to the west. Because of construction deficiencies, deferred maintenance on the conveyance structures, and the cost of continuous operation of the pump station, raw wastewater spills remained common. The sewage flows downhill into the

United States through the now-protected Tijuana River National Estuarine Research Reserve and into the Pacific Ocean on the U.S. side of the border. If transboundary sharing of water infrastructure had been envisioned when the original wastewater infrastructure was conceived, it is possible that more reliable and less-costly infrastructure could have been constructed with some facilities at the higher elevation in Tijuana, a pipeline crossing the border and paralleling the river, a treatment plant at a low elevation in the United States, and discharge of treated effluent through an ocean outfall like those typically used in the United States. Instead, decades of unpleasant, publicly criticized, and expensive efforts focused on how to make further improvements to a system that fights gravity because a political constraint opposes natural land form and common sense. Eventually, this condition of siting infrastructure contrary to nature was partially overcome through construction of the IWTP and the South Bay Ocean Outfall (SBOO). Located in the United States below and north of Pump Station No. 1, the IWTP and SBOO treat and discharge about half of the collected wastewater from Tijuana.

Capacity of Existing Infrastructure

Examination of water infrastructure in the San Diego-Tijuana region is instructive. The infrastructure components are usually separated as a result of political boundaries rather than natural boundaries, particularly within the San Diego area, where many political jurisdictions exist. Figure 5 shows the wastewater agency boundaries, which also represent infrastructure boundaries. Clearly illustrated are the main wastewater pipelines and pump stations of the San Diego Metropolitan Wastewater Department, which is the largest district. Infrastructure systems that separately serve numerous cities, sometimes by separate water and wastewater services, produce challenges for sharing water services within the region. This is particularly true with regard to recycled water. For example, the recycled water facilities located at the North City Water Reclamation Plant (North City) and at the SBWRP are not connected. This means water cannot be transferred between the two for flexibility of operation or to optimize the customer base. The cost to

connect the plants would be very high and only considered if there were a compelling benefit.

The distribution of effluent water quality is also instructive. While all water treatment plants appear to provide adequate treatment for potable uses, the quality of treated wastewater varies considerably. The lowest effluent quality from wastewater plants discharges from the San Antonio de los Buenos treatment plant while the highest quality discharges come from North City and SBWRP. The latter two plants produce high-quality water suitable for many agricultural and urban uses. Yet, only a small portion of the water is used because the cost of redistribution cannot be covered by the market price for the water. Between these two water quality extremes lie the effluents from the Point Loma treatment plant and the IWTP. The Point Loma plant lies on the coast far from most users while the IWTP lies close to many users, particularly urban consumers in Tijuana. Of concern for the use of this water are the large number of industrial compounds present in the wastewater stream that flows into the plant. Without significant additional treatment, the water will not likely be safe for most uses. However, the flow is large, making the opportunity for water recycling worthwhile.

Viewing the infrastructure as a whole, the only transboundary water sharing operations using existing infrastructure have occurred through the Otay emergency water connection from San Diego to Tijuana, the emergency wastewater disposal connection from Tijuana to Point Loma (also no longer in use but available), and the IWTP, which treats Tijuana wastewater in San Diego with the option of returning treated effluent to Tijuana.

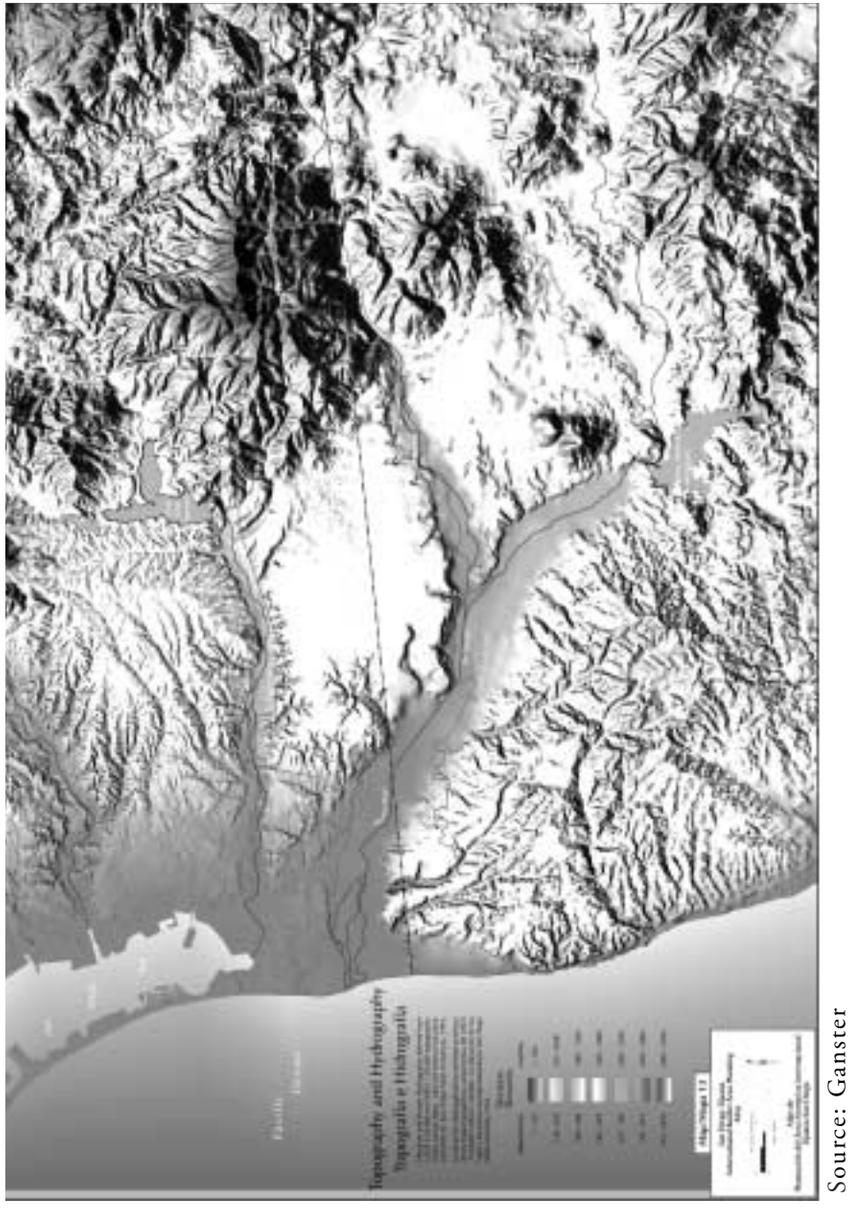


Figure 4. Topography and Hydrography

Source: Ganster

Figure 5. Wastewater Jurisdictions in San Diego

Source: San Diego Metropolitan Wastewater Department

Scenarios for Water Sharing

Given the constraints provided in the preceding sections, the following conditions shape the opportunities for water sharing across the border:

1. Two types of opportunities exist for water sharing: transboundary water transfers and jointly owned and operated infrastructure. The options for water sharing in the San Diego-Tijuana area include a binational aqueduct, binational desalination plant, transfers of recycled water, and a jointly owned and operated groundwater recharge and extraction system. Additionally, joint management of the Tijuana River watershed could lead to improved use of existing water sources, particularly if stream restoration is included.

2. Water sharing should focus on sustainability, characterized as meeting minimal standards for basic water needs and quality of life while preserving the environment. The needs of the Tijuana-Rosarito area exceed the needs of the San Diego area and therefore should be the initial focus for water sharing. However, water sharing without benefit to the San Diego area leaves little incentive for investment.

3. Additional water from the Colorado River is unlikely to arrive in the San Diego-Tijuana area for quite some time, if at all. However, a jointly owned and operated water aqueduct would strengthen the reliability of water transferred directly to the San Diego-Tijuana region; yet, the institutional and political challenges associated with this option are significant.

4. Groundwater is a shared resource of the region. Within the Tijuana River Valley, groundwater overdraft for agricultural uses has caused such degradation in water quality that it currently has limited use. In Tijuana, the groundwater wells produce water with a relatively high salt content. The continued production of the wells is unknown (CESPT 2002). Groundwater can be recharged to preserve the water-bearing capacity of the aquifer as well as the quality and quantity of the water yield. Injection of water from other sources could extend the life of the aquifers indefinitely and allow sub-surface transport of water to users.

5. Desalination offers the opportunity for unlimited water supply, but equipment and energy remain costly. It is plausible that desalination could become an avenue for water sharing in the near future. One desalination plant currently exists in the region, serving only one U.S. municipality.

6. Recycled water offers a steady supply of water but public opinion hinders the optimization of this resource. Recycled water is costly

when a separate distribution network is required and the quality limits its uses.

7. Theoretically, trading agricultural water for recycled water could provide more surface water for urban uses. Large distances and urban land uses between sources and users affect the cost and technical feasibility of trading, making the cost of pipeline installation infeasible.

8. Several potential sources of recycled water are located in the San Diego-Tijuana region. Some, such as the North City plant, are not hydraulically connected nor feasible sources for transboundary water sharing.

9. Elevation differences and urban land uses make water transfers from the San Diego area to the Tijuana-Rosarito area both challenging and costly. The IWTP and the SBWRP represent the best water quality from existing plants. The plants are well-located for this purpose.

The described engineering constraints and summary of shared water options point to many challenges for technically feasible and cost-effective water sharing benefiting both Tijuana-Rosarito and San Diego. It is possible that one option—shared aquifer storage and reuse of recycled water—could be implemented in the near future because of the relatively small amount of new infrastructure needed to transport the water. Recycled water injected into an aquifer that straddles both sides of the border and is accessible from both sides offers advantages by overcoming the cost of long-distance conveyance through highly developed urban areas. Recycled water is a reliable stream of water and injection into aquifers may meet with less public resistance than other routes for reuse.

Possible Sources of Recycled Water

By focusing on water sharing for urban uses, three existing plants and four future plants could become sources of recycled water: the IWTP, SBWRP, San Antonio de los Buenos Water Treatment Plant, and the four water reclamation plants to be built by the Comisión Estatal del Agua (CEA) as part of a large infrastructure project financed in part through a loan from the Japan Bank for International Cooperation.

International Wastewater Treatment Plant

The IWTP was built on the U.S. side of the international border by agreement between the United States and Mexico (International Boundary and Water Commission [IBWC] Minute No. 283) to end decades of pollution in the Tijuana River estuary caused by spills from Tijuana's sanitary sewer system. Although the agreement specifies that secondary treatment will be provided at the IWTP, the first phase of this facility provides only advanced (i.e. chemically assisted) primary treatment. Effluent that has not been disinfected is discharged into the Pacific Ocean through the SBOO. The plant has difficulty meeting U.S. discharge standards for toxicity for aquatic organisms. The first phase of the international plant treats an average dry weather flow (ADWF) of 25MGD and a peak wet weather flow (PWWF) of 50MGD.

Under the terms of IBWC Minute No. 283, Mexico is entitled to the treated effluent from the IWTP for the uses it deems appropriate; thus, provisions have been made in the plant's effluent structure to connect to a future pump station and pipeline that would return the flow to Tijuana should Mexico request it. However, until additional treatment is provided, the toxicity of the effluent may deter recycling efforts.

South Bay Water Reclamation Plant

The SBWRP, located adjacent to the IWTP, is part of the City of San Diego water reclamation system and was designed to provide 15MGD of tertiary treated effluent, complying with the require-

ments of Title 22 of the California Code of Regulations, making it suitable for unrestricted landscape irrigation. Plant effluent not used for irrigation or other purposes is discharged through the South Bay Ocean Outfall.

The plant capacity was expanded from 7.5MGD to 15MGD during construction with the expectation of selling the additional flow of recycled water to Mexico. The potential market would be identified through a survey of possible industrial, commercial, and institutional users. This survey was not conducted and thus the potential demand for recycled water in Tijuana is not quantified.

San Antonio de los Buenos Water Treatment Plant

This treatment plant began service in 1989 to treat wastewater transported from Tijuana Pump Station No.1 and is designed for 17MGD ADWF and 25MGD PWWF. (Before the IWTP was built, flows exceeding these maxima routinely bypassed the treatment plant and were combined with treated effluent prior to discharge.) Effluent is discharged at the shoreline—there is no outfall into the Pacific Ocean to allow for dilution of the effluent in deep water. A construction contract was recently awarded to expand the capacity of the plant from 17MGD ADWF to 25MGD ADWF and to correct deficiencies of the existing treatment units. There are no current plans to construct an outfall and the effluent would continue to discharge into the ocean at the shore. Some of the effluent from the San Antonio de los Buenos Water Treatment Plant is used to irrigate a golf course and other landscapes at a nearby resort. The resort provides additional treatment in aerated lagoons prior to use.

Planned Reclamation Plants in Tijuana–Rosarito

The CEA will construct four wastewater treatment and reclamation plants under its Infrastructure Project for Environmental Sanitation and Potable Water Supply in Baja California. The plants are Monte Olivos (340 liters per second [l/s]), La Morita (150l/s), La Gloria (100l/s), and Lomas Rosarito (75l/s). These plants will be located in the vicinity of industries that consume large volumes of water. The approach taken by the CEA in siting these facilities is to provide

industrial users with recycled water to replace an equivalent volume of potable water.

Potential Uses of Recycled Water

Fresh water supplies can be extended with the use of recycled water. Potential uses for recycled water from these plants include landscape and agricultural irrigation, industrial water use, and groundwater recharge. The current status of these reuse options are examined later. Toilet flushing is also an excellent use of recycled water but is slower to gain public acceptance. Historical uses of recycled water for toilet flushing were not identified for the Tijuana-Rosarito area.

Landscape Irrigation

Tijuana–Rosarito is a high-density urban region with few parks, golf courses, cemeteries, or other green areas, limiting opportunities for using recycled water for landscape irrigation. Thus, construction of a separate water distribution system cannot be justified on the basis of providing landscape irrigation water. However, this is not to say that this application should be ignored. Currently, there are several "single-user" irrigation projects in Tijuana. These water reuse projects individually serve two golf courses, a public park (the EcoParque Project), and several hotels or resorts along the Tijuana-Ensenada tourist corridor. These are simple, low-cost water reclamation projects that could be replicated in a relatively short time to provide irrigation water to nearby soccer fields, institutional facilities, and the like. Consequently, projects like these have the potential to make small but cumulatively significant contributions to alleviating the region's serious water shortage problem.

Agricultural Irrigation

The agricultural reuse situation is similar to that of landscape irrigation: There are limited opportunities in the Tijuana–Rosarito region where urbanization has displaced most agricultural land uses. Interestingly, the only well-known case of agricultural irrigation of this type took place along the open conveyance canal between Pump

Station No. 1 and the San Antonio de los Buenos Water Treatment Plant. The irrigation practice consisted of illegal diversions of raw wastewater by farmers along the canal alignment. Since the original conveyance system was recently replaced by a pipeline, this use no longer exists.

Industrial Water Use

The large number of maquiladoras located in Tijuana both prior to and since the North American Free Trade Agreement (NAFTA) may provide a significant potential demand for recycled water. As previously mentioned, CEA has sited four planned water reclamation plants near concentrations of industrial facilities that could use the effluent from these plants; however, the cost of making this water available is undetermined. The potential demand by Tijuana's industry has not been established and thus the financial feasibility of this type of use cannot be assessed. Perhaps more importantly, industrial facilities within the city are widely dispersed. Thus, the cost of distributing recycled water to those facilities interested in using it is likely to be so high that it would render such a project infeasible.

Using Recycled Water for Groundwater Recharge

Groundwater recharge involves the use of water from other sources to supplement natural recharge where groundwater extraction creates an overdraft condition. An aquifer storage and reuse system consists of recharge and extraction wells and distribution facilities where the water is extracted. Treatment before injection and after extraction may be necessary.

Of all the possible uses of recycled water described, aquifer recharge has the greatest potential for using significant volumes of treated wastewater effluent, such as the 25MGD currently being treated at the IWTP or the 15MGD flow from the SBWRP. Tijuana's original water supply consisted of wells in the unconfined aquifer of the Tijuana and Alamar rivers. Rosarito's water was supplied from wells from La Misión aquifer near Ensenada. Groundwater supplied by 22 wells located within the Tijuana-Rosarito area and four wells from La Misión field accounted for approximately half the total

water supplied to the two cities until the 1980s (Boyle Engineering Corporation 2002). Due to water level variations in this shallow aquifer, low yields, water quality problems, and poor well conditions, water pumped from the existing wells currently comprises only a small portion of Tijuana's water supply. To raise this percentage, CESPT is implementing a phased program to rehabilitate several wells (CESPT 2000).

A parallel recharge program could aid CESPT's efforts to preserve groundwater production. Groundwater recharge using recycled water would increase well yield and improve water quality by mixing high-salinity natural groundwater with lower-salinity recycled water. Particularly noteworthy, the aquifer would serve as the conveyance medium, thus avoiding the need to build a separate recycled water distribution system. Some users (including agricultural and industrial) with access to the aquifer would simply drill wells to tap into it.

Several alternatives may emerge for large-scale aquifer storage and reuse of recycled water. The following scenario describes one approach that combines two potential projects into one conjunctive use project resulting in transboundary water sharing and multiple benefits. The scenario illustrates the value of adopting a watershed approach where several issues can be addressed holistically.

The first project, proposed by the Instituto Municipal de Planeación, the planning agency of the Municipality of Tijuana, would restore the riparian habitat along the Río Alamar (Michel and Graizbord 2002). The Río Alamar is considered an outstanding natural resource and vital recharge zone for the large aquifer that lies beneath the Alamar and Tijuana rivers (Michel 2001).

Since a surplus of surface waters is not readily or reliably available for restoration, additional projects, such as storm water retention basins or wetlands restoration, would have to be implemented before the river restoration project could proceed. The second proposed project would bring recycled water to the vicinity of the river where it could be discharged into infiltration basins constructed along the riverbed. The Río Alamar is a natural zone of recharge for an aquifer where the majority of Tijuana's existing wells are located, so the value of this second project is obvious. Using the riverbed for recharge would simultaneously restore the habitat value of the ripar-

ian corridor and recharge the aquifer. At this time, recycled water is the only logical source for this purpose because of its year-round availability.

Recycled water for a Río Alamar restoration project could be provided either by the IWTP or the SBWRP. In the case of the IWTP, at least secondary treatment is needed. Secondary treatment units could be built either adjacent to the existing facility or at a location in Tijuana. An aerated lagoon-based system was proposed to upgrade the IWTP to secondary treatment. Under this alternative, an average of 25MGD of treatment capacity could be accommodated at the existing site. This limitation does not exist in Mexico since ample land is available at several locations along the Río Alamar. Construction costs and the opportunity for tertiary treatment facilities would seem to favor building additional treatment plants in Tijuana. The actual treatment level needed will depend on Mexican water quality regulations and the quality of secondary effluent (discharges). Until secondary treatment is installed, uncertainty remains regarding the quality of the secondary effluent and its suitability for reuse. The uncertainty stems from an unenforced program requiring pretreatment of industrial waste streams before discharging into the sewer. This condition could necessitate tertiary treatment for safe reuse.

There is currently a proposal from the private sector to build the IWTP secondary treatment facilities at a site adjacent to the Río Alamar. To make this proposal work, a pump station, conveyance pipeline, and return pipeline would have to be built. The return pipeline would allow discharge of excess effluent through the South Bay Ocean Outfall if reuse does not consume all of the effluent.

This proposal prompted the U.S. Congress to pass legislation (Public Law 106-457) to provide a revenue stream to pay for construction, operation, and maintenance of a secondary treatment facility in Mexico. To implement this type of project, IBWC Minute No. 283 would have to be amended since the original document stipulates that all treatment is to be provided in the United States. At this time, both countries have agreed to enter into negotiations to amend Minute No. 283.

In the case of the other source of reclaimed water, the SBWRP will discharge tertiary-treated effluent suitable for reuse. A pump

station and conveyance pipeline would still be needed but not a return pipeline because of the SBWRP's location in San Diego. The SBWRP effluent will be more uniform in quality. However, there are still issues to be resolved, including the cost of purchasing the recyclable water, the need for a binational agreement for such a transfer, and the perceived social issue of exporting U.S. "wastewater." By contrast and per binational agreement, water treated at the IWTP is owned by Mexico, which retains sovereign rights to the water.

Aside from the clear environmental benefits of a Río Alamar recharge project, there is a social and humanitarian component that makes the project unique. Portions of the riverbed are currently occupied by unauthorized dwellings. The Río Alamar extends into the United States, where it is called Cottonwood Creek, and terminates at Barrett Reservoir. Should the volume of this reservoir be exceeded due to unusually heavy rains (such as during an El Niño event) and/or large flows of surface runoff produced in the watershed, a considerable flow could swell in Cottonwood Creek/Río Alamar with potentially disastrous consequences for the dwellings and their occupants in the riverbed (a more tragic scenario would occur if Barrett Dam were to fail during a strong earthquake). Thus, clearing the riverbed to make room for a restoration project through groundwater recharge would ultimately protect the inhabitants of these dwellings from potential harm.

From the U.S. side of the border, this option offers several benefits. The area of the aquifer that underlies the Tijuana River Valley has limited value given the decades of overdraft and increased salinity of groundwater. As recycled water presses into this area, brackish water will recede toward the coast. Groundwater levels may rise. Valley agriculture would be able to expand and plant fewer salt-tolerant crops.

Obstacles to the implementation of the conjunctive use project include:

- The use of groundwater for Tijuana-Rosarito's and San Diego's needs must be secured to ensure long-term cooperation and benefit
- The use of water from the IWTP would require improvments from primary to tertiary treatment to make the water safe (the construction of additional treatment facilities could occur adja-

cent to the SDIWTP or in the Tijuana area); alternatively or additionally, recycled water from the SBWRP, once completed, could augment water for recharge
- The removal of the existing dwellings from the Río Alamar river bed—a daunting task for both social and political reasons

Either of the treatment options and the issue of binational benefit would require approvals from the Mexican government through negotiations—a traditionally slow and sometimes difficult process—between the IBWC and its Mexican counterpart, Comisión Internacional de Límites y Aguas (CILA). The Comisión Nacional del Agua (CNA), the federal regulatory agency having jurisdiction over all groundwater in Mexico, has not yet developed standards for groundwater recharge using recycled water. Finally, the studies to determine important characteristics of the Río Alamar aquifer, such as infiltration and storage capacity, have yet to be conducted.

Conclusions

This chapter addressed the practical feasibility of Water Without Borders, a concept of transboundary water sharing that would benefit both the United States and Mexico. The San Diego-Tijuana region is an example that illustrates the value of a holistic watershed approach. Challenges include the need for higher treatment levels to recycle water, the lack of integrated infrastructure for efficient water sharing, hilly topography creating obstacles, the high cost of piping water through dense urban areas, large distances to agricultural users (often separated by dense urban areas), as well as the non-engineering challenges of public perception and the political boundary creating an institutional barrier.

While a few options exist for producing new sources of water for this arid region, recycled water is one source that can be readily shared, thanks to topographic, hydrogeologic, and infrastructure conditions. The most suitable sources of recycled water would be the SBWRP and IWTP, given the current water quality, proximity to the border, and/or status of binational agreements on water from these plants. By injecting recycled water at higher elevations of the Río Alamar, the water would become available to consumers in Tijuana

and downstream in the Tijuana River Valley in the United States. Both communities would benefit and avoid the high cost of piping the water through dense urban areas. Were stream restoration a part of the project, the cost of aquifer storage could be reduced while restoring valuable habitat and open space and mitigating flood disaster.

The constraints, challenges, and opportunities for water sharing may be similar along other portions of the border. This example illustrates some of the tough realities and shows how transboundary collaboration and engineering can reduce water deficiencies, providing improved quality of life and security for border residents.

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VI

Comparative Analysis of Transborder Water Management Strategies: Case Studies on the U.S.-Mexican Border

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Abstract

Under any circumstances the management of water supplies is a difficult task. When multiple jurisdictions are involved—especially when water flows across international boundaries—management complexities increase dramatically. Watersheds have come to be viewed as an excellent framework for integrating the social, ecological, and economic aspects of water management. The rapidly growing population in the U.S.-Mexican border region, with the concomitant increasing requirement for scarce water resources, demands that the two countries optimize their use of water. In many areas, the U.S.-Mexican political boundary divides the drainage basins. In order to overcome this fragmentation, it is essential that the two nations coordinate their efforts in addressing water problems within the framework of those watersheds that lie astride the border.

This chapter examines the approaches to binational watershed planning that are unfolding in three different parts of the border, namely, San Diego-Tijuana, Ambos Nogales, and El Paso-Ciudad Juárez. For each, water supply and demand issues, regional water challenges, and innovative cross-border cooperative efforts are examined.

San Diego-Tijuana

The San Diego-Tijuana region is unique in many ways within the border context. While both San Diego and Tijuana command comparatively high levels of development in their own national contexts, their economic asymmetries are quite large. Such differences have important implications in the financial capacity of governments on each side of the border to meet the water needs for its citizens. Both cities are dependent on imported water. In the case of San Diego, water imports from the Colorado River and Northern California account for nearly 90% of the yearly requirements. In comparison to San Diego, Tijuana's options to meet its present and future needs appear to be much more restricted. The water imported from the Colorado River represents the only real and dependable possibility for the city. Currently, this source provides approximately 95% of its yearly supply.

Water reuse is an essential part of the San Diego-Tijuana region's water future. The San Diego County Water Authority is preparing a Regional Facilities Master Plan for the county that analyzes a variety of alternative water sources such as seawater desalination, groundwater recharge, additional water from the Colorado River via a binational conveyance system, and the recycling of wastewater.

One characteristic of the San Diego-Tijuana region that is relevant to the region's water supply is the Tijuana River Watershed (TRW). The implications of the cross-border character of this watershed are numerous, for it poses challenging circumstances in terms of binational coordination and planning. As a result of natural drainage in the TRW, sewage flows from Mexico to the Tijuana River Estuary and the surf zone of the south coastal region have been a problem for many years. In 1997, the International Wastewater Treatment Plant (IWTP) was completed to provide for advanced primary treatment of Tijuana sewage. Despite improvements in the treatment of Mexican sewage, pollution from cross-border sewage flows continues to be a problem in the Tijuana Estuary and adjacent beaches.

During the past decade, a large number of binational efforts have been undertaken by universities, government agencies, and private organizations in the region. Some notable examples include:

1. The Tijuana River Watershed Progam, an undertaking that began with the development of a watershed geographic information system (GIS) in 1994 and has made possible more than a dozen projects, most of which have been bination- al and focused on water quality and quantity problems. They include the Goat Canyon/Cañón de los Laureles Vulnerability Assessment, the Bight of the Californias project, and the Alamar River Corridor study.
2. In 1996, the San Diego Association of Governments (SANDAG) formed the Committee on Binational Regional Opportunities (COBRO) to develop a binational policy, framework, and action plan for addressing water and other problems in the San Diego-Tijuana border region. Through COBRO and under the auspices of the Border Liaison Mechanism (BLM), a Border Water Council (BWC) was established in 1997. Representatives of the San Diego County Water Authority (SDCWA) and la Comisión Estatal de Servicios Públicos de Tijuana (CESPT) are the co-chairs of the council. BWC's major effort has been to encourage the exploration of options for the conveyance of water from the Mexicali and Imperial Valleys to San Diego and Tijuana. To facilitate transborder approaches in SANDAG, a high-level position of Director of Binational Planning and Coordination and a Borders Policy Committee (BPC) have been created. With this new organization, COBRO will send policy recommendations regarding binational matters to the Borders Committee, which then can elevate them to the full board.
3. Toward the goal of insuring adequate water supplies for the San Diego-Tijuana region, the State of California and the SDCWA have funded the Regional Colorado River Conveyance Feasibility Study to explore potential routes for an aqueduct from the Colorado River to be shared by SDCWA and state agencies in California. The binational alignment options study is managed by a technical committee comprised of seven U.S. and Mexican agencies. The study of transborder options is based on a recognition that a conveyance facility may be more cost-effective if multiple agencies are involved. The joint study is an excellent example of how agencies from the U.S. and Mexico can work together to determine the most effective way of meeting regional water needs.

Ambos Nogales

Preliminary population data from the 2000 census indicate that the current population in Ambos Nogales exceeds 200,000. Population increases are generating a growing need for water in the municipal and industrial sectors and a range of related water quality issues. Water resource management issues in Ambos Nogales include provision of water supply to sectors of society with competing needs, the needed infrastructure and "plumbing" to deliver water to major sectors of Nogales, Sonora, wastewater collection and treatment, and management of groundwater/surface water interactions.

Groundwater is the major source of water for the region. Wells in both the U.S. and Mexican portions of the basin affect groundwater availability and surface water flows in the river. Increasing urban groundwater extraction is impacting long-standing agricultural use of groundwater in the basin, and urban surface water is negatively impacting flows in the river. Both of these conditions raise questions concerning sustainable use of groundwater in the future. In addition, provision of drinking water is a particularly pervasive and immediate need in Nogales, Sonora, and this poses special challenges for regional approaches to regional water resource planning.

Presently, approximately 10 million gallons per day (MGD) of wastewater generated in Nogales, Sonora, are diverted to the Nogales International Wastewater Treatment Plant in the United States. The discharge of treated effluent from the plant has a major impact on surface water and groundwater dynamics within the downstream reaches of the river. The regular discharge of this effluent is the largest source of groundwater recharge in the region. Notably, while in Mexico, this wastewater is owned by the Mexican government. As wastewater, it lacks immediate value; once treated, however, this wastewater can have value as reclaimed water for a variety of uses. When the wastewater crosses the border and enters the plant on the U.S. side, it is owned by the International Boundary and Water Commission (IBWC) or the City of Nogales. After the effluent is treated and discharged into the river, it becomes an appropriable water resource within the State of Arizona.

Several significant efforts are underway in the region to address the area's water supply problems and manage regional wastewater.

These include the following transborder efforts:

1. The facilities planning process (FPP) undertaken in the Ambos Nogales region is a binational planning effort that extends technical support to regional water resource planning agencies for the construction of needed wastewater management infrastructure. Within the facilities planning process, the IBWC and its Mexican counterpart, Comisión Internacional de Límites y Aguas (CILA); the Sonora state water authority (CoAPAES); the Arizona Department of Water Resources (ADWR); the City of Nogales, Arizona; and a range of private sector consultants have cooperated over the last few years on a regional water infrastructure effort. As a result of this cooperation, approval was given for increased treatment capacity at the existing Nogales International Wastewater Treatment Plant, upgraded treatment processes, and replacement of outfall facilities. Both wastewater treatment and potable water treatment facilities are also to be built in Sonora.
2. Two efforts have developed in conjunction with the Santa Cruz Active Management Area (SCAMA) that are of relevance to the water resource management issues in the reaches of the river below Ambos Nogales: the SCAMA Groundwater Users Advisory Council and the SCAMA Settlement Group. The Groundwater Users Advisory Council is an official governmental effort where by private citizens who are active users of groundwater resources regularly meet with SCAMA staff to discuss groundwater uses in the region and various means to manage these resources more effectively. A less formal effort is the SCAMA Settlement Group. The organization is comprised of private citizens who own water rights within SCAMA, attorneys representing the legal interests of large water rights holders in the region, and various staff members of ADWR. The goal and intention of the group is to work toward resolution of water rights adjudication in SCAMA outside the legal process that has been ongoing for many years.
3. During the 2002 legislative session, legislation was introduced in Arizona, the goal of which was to establish some manner of Santa Cruz Water Management Authority. Issues concerning the ability of the authority to generate revenues for projects, the

manner by which a guaranteed flow to Mexico could be effected, the management of the authority, and a lack of overall detail, resulted in the legislation not making it out of committee. However, there are plans are to reintroduce the bill in future legislative sessions and for SCAMA and ADWR staff to take a more active role to help address some of the concerns about the most recent bill. Although the arrangement of water flows, ownership, and potential terms of exchange is quite complex, some form of Ambos Nogales binational groundwater replenishment and management district has considerable potential to meet regional water resource management needs well into the future. The potential for a binational recharge district clearly acknowledges the hydrologic connectivity of ground and surface waters and the manner by which this connectivity is an important element in the dynamics of water uses on both sides of the border.

Paso del Norte

Regional water problems are closely linked to rapid population growth and high levels of poverty that have combined to create a situation where water distribution has not kept up with growth in water demand. One of the primary concerns is municipal water supply, which is where most of the growing need lies. As municipal and industrial demand has increased, groundwater basins are becoming contaminated or depleted such that serious shortages are expected in the near future. Estimates are that at El Paso's historic rates of withdrawal, potable water in the Hueco Bolson will be exhausted by the year 2025; Ciudad Juárez is expected to experience a major deficit by 2004. Water providers have been forced to look for means to extend the limited reserves in the Bolson, use surface water, and seek alternative supplies.

Competition for Rio Grande water, therefore, has increased significantly as growing urban areas face serious shortages and look to the river for replacement and new supplies. Ciudad Juárez and Las Cruces are still dependent on groundwater; El Paso is using the Rio Grande to meet demand during the irrigation season. Ciudad Juárez is currently investigating use of surface water for municipal needs.

Rising environmental concerns have also focused a need for water to be allocated for instream flows. Surface water allocation to agriculture has created friction over water distribution between use sectors. Although increased competition, to this point, has not resulted in an alteration of the allocation framework, small-scale transfers of water from agriculture to municipal use have been achieved through the leasing of water rights. Finally, because of asymmetry in growth and allocation, Mexican urban areas are experiencing pressure on water resources at a faster rate than U.S. communities. Under the current allocation structures, however, the potential for using agriculture waters to address municipal-industrial concerns is lowest in the Mexican portion of the Paso del Norte.

The past several decades have seen several cross-jurisdictional planning endeavors that have included the following:

1. The New Mexico-Texas Water Commission arose in 1991 out of the settlement of a lawsuit in which El Paso sued for the right to drill wells in New Mexico and pump that water to El Paso to meet municipal needs. The commission was established to look at methods to plan for surface water use between the parties. It successfully proposed the El Paso-Las Cruces Sustainable Water Project, which is a series of canal improvements, surface water treatment plants, distribution systems, and aquifer storage and recovery infrastructure. Although the clearly defined structure set up by the settlement agreement makes it difficult for other parties to join and for alternative concepts of water allocation, management, and planning to emerge, the Paso del Norte Watershed council was formed as a means to provide input on mitigation and other environmental issues associated with the Sustainable Water Project. The environmental impact process also has brought public input into the project. Mexico is still not a party to the commission, but commission members are seeking ways to incorporate Mexico into the dialogue.
2. The Paso del Norte Water Task Force (PdNWTF) attempts to promote the sharing of information and understanding among participants in order to encourage coordination in individual planning and management efforts. The PdNWTF was convened by the IBWC in 1999 and was initiated by the Houston Advanced Research Center with support from the Hewlett Foundation. The members of the PdNWTF are

binational stakeholders that have municipal, irrigation, and private water interests. An academic-scientific Support Team assists the Task Force. It has had initial success in a series of dialogues where members gained an in-depth understanding of other member's operations and concerns. At present, the PdNWTF Support Team has proposed a series of projects that will attempt to provide tangible results to address specific regional water concerns.

3. The Transboundary Aquifers and Binational Groundwater Database collaborative binational study included both sections of the IBWC, Junta Municipal de Agua y Saneamiento (JMAS), the U.S. Environmental Protection Agency (EPA), Texas Water Development Board, and the New Mexico Water Resources Research Institute. It was a multi-year, multi-agency effort that collected data on the groundwater hydrology, historic water levels, pumping trends, water quality, and current and future extration estimates. The report was published in 1997 and provided data and GIS-based maps for dissemination to all parties and the public. It did not, however, make a detailed analysis of the findings nor recommendations as to future groundwater management options. The official, State Department-level of this project made both the effort and the report important to collaborative regional efforts.

Análisis Comparativo de Estrategias de la Gestión de Aguas Fronterizas: Estudio de Casos en la Frontera México-Estados Unidos

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Resumen

En cualquier circunstancia el manejo de recursos acuíferos es una tarea difícil. Cuando múltiples jurisdicciones están involucradas, como en el caso de aguas que fluyen a través de fronteras, estas complejidades se incrementan dramáticamente. Las cuencas acuíferas han venido a ser los marcos idóneos para integrar los aspectos sociales ecológicos y económicos del manejo de recursos acuíferos. El rápido crecimiento de la población en la frontera México-E.U. con el consiguiente incremento en la demanda de recursos acuíferos ya de por sí escasos, requiere que los dos países optimicen el uso de éstos. En muchas regiones la frontera política divide las cuencas de drenaje. Para resolver esta problemática es esencial que las dos naciones coordinen sus esfuerzos hacia la solución de estos problemas dentro del contexto de estas cuencas binacionales.

En este texto examinamos las maneras en que se esta llevando a cabo la planeación en tres partes de la frontera: Ambos Nogales, Tijuana-San Diego, y El Paso-Ciudad Juárez. Para cada uno consideraremos: abastecimiento y demanda de agua, desafíos en aguas regionales, y esfuerzos innovadores binacionales.

San Diego-Tijuana

La región San Diego-Tijuana es única en el contexto fronterizo de diferentes maneras. Aunque ambas ciudades sostienen niveles relativamente altos de desarrollo dentro de sus contextos nacionales, las asimetrías económicas son bastante grandes y tienen implicaciones importantes en la capacidad financiera de respuesta a las demandas de abasto de agua. Ambas ciudades dependen de agua importada. En

el caso de San Diego importaciones del Río Colorado y del norte de California representan el 90% de los requerimientos anuales. En contraste, Tijuana parece tener menos opciones para atender las demandas presentes y futuras. El Río Colorado es la única fuente segura real para el abasto de la ciudad y representa el 95% del abasto anual de agua.

La reutilización del agua es parte esencial del futuro del agua en esta región. El *San Diego County Water Authority* está preparando un plan maestro para el condado que analiza una variedad de fuentes alternas de agua como desalinización de agua marina, recarga de mantos acuíferos, agua adicional del Río Colorado por medio de convenios binacionales y tratamiento de aguas residuales.

Una característica relevante al abasto regional de agua es el *Tijuana River Watershed (*Cuenca del Río Tijuana). Las implicaciones del carácter transfronterizo de esta son numerosas y poseen retos únicos en términos de planeación y coordinación binacional. Como resultado del drenaje natural de la cuenca del Río Tijuana, las aguas residuales fluyen de México al estuario de este río y la zona de *surf* de la región de la costa sur ha sido un problema por varios años. En 1997 se completó la planta binacional de aguas residuales para proveer tratamiento primario avanzado de las aguas residuales de Tijuana. A pesar de mejoras en el tratamiento de aguas residuales mexicanas, la contaminación generada por el drenaje transfronterizo sigue siendo un problema en el estuario y playas adyacentes.

Durante la década pasada un número importante de esfuerzos binacionales han sido llevados a cabo por universidades, agencias gubernamentales y organizaciones privadas de la región. Algunos ejemplos más notorios son los siguientes:

1. Programa de la cuenca del Río Tijuana comenzó con el desarrollo de un sistema de información geográfica (GIS, por sus siglas en inglés) de la cuenca en 1994 y ha hecho posible la ejecución de más de una docena de proyectos, la mayoría binacionales y enfocados en problemas en la calidad y cantidad de agua. Entre ellos están: Estudio de vulnerabilidad del Goat Canyon/Cañón de los Laureles, el proyecto del *Bight of the Californias*, y el estudio del corredor del Río Alamar.
2. En 1996, la asociación de gobiernos del San Diego (SANDAG, por sus siglas en inglés) formó el comité de oportunidades regionales binacionales (COBRO, por sus siglas en inglés) para desarrollar una política binacional y un plan de acción para enfrentar ciertos problemas incluyendo los del agua en la región San Diego-Tijuana. A través de COBRO y del mecanismo fronterizo enlace (BLM, por sus siglas en inglés), un consejo del agua fronteriza (BWC, por sus siglas en inglés) fue establecido en 1997. Representantes de la autoridad del agua en el condado del San Diego (CWA, por sus siglas en inglés) y la Comisión Estatal de Servicios Públicos de Tijuana (CESPT) son los co-gerentes del consejo. El esfuerzo mayor del BWC ha sido a estimular la exploración de las opciones para el transporte del agua de los valles Mexicali e Imperial a San Diego y Tijuana. Para facilitar los enfoques a través de la frontera en SANDAG, se creó una posición del director de planeación y coordinación y un comité de políticas fronterizas (BPC, por sus siglas en inglés). Con esta organización nueva, COBRO mandará recomendaciones políticas con respecto a asuntos binacionales al comité fronterizo lo cual se puede elevaral consejo.
3. Con el objetivo de asegurar el abastecimiento de agua adecuado para la región San Diego-Tijuana, el estado de California y el SDCWA han apoyado un estudio regional de la factibilidad del transporte del Río Colorado para explorar rutas potenciales del Río Colorado que sería compartido entre SDCWA y agencias estatales de California. El estudio de las opciones de alineación está dirigido por el comité técnico integrado por siete agencias estadounidenses y mexicanas. El estudio de opciones a través de la frontera está basado en el reconocimiento que un medio de transporte sería más económico con varias agencias involucradas. Este estudio conjunto es un ejemplo excelente de la efectividad de agencias de Estados Unidos y México y como pueden colaborar para determinar la manera más efectiva de cumplir con las necesidades del agua en la región.

Ambos Nogales

Los datos preliminares del censo 2000 indican que la población actual de ambos Nogales excede 200,000. Los aumentos en la población generan aun más necesidad del agua en los sectores municipales e industriales y un rango de asuntos relacionados de la calidad del agua. Asuntos relacionados al manejo de los recursos del agua en ambos Nogales incluyen una provisión de abastecimiento de agua a los sectores de la sociedad con necesidades opuestas, una provisión de la infraestructura y "plomería" para llevar el agua a los sectores de Nogales, Sonora, una provisión de la colección y tratamiento de aguas residuales y el manejo de las interacciones de aguas subterráneas y superficiales.

El agua subterránea es la fuente mayor de agua en la región. Los pozos a ambos lados de la cuenca afectan la disponibilidad de aguas subterráneas y el flujo de aguas superficiales hacia el río. El aumento en la extracción de agua subterránea disminuye la disponibilidad para el uso agrícola del agua de la cuenca y los usos urbanos también influyen negativamente en el flujo de aguas superficiales hacia el río y es una causa de alarma para la sustentabilidad futura del uso del agua subterránea. Adicionalmente, la provisión de agua potable es una necesidad generalizada e inmediata en Nogales, Sonora, y esto posee desafíos especiales para la planeación de los recursos acuáticos en la región.

Actualmente aproximadamente 10 millones de galones diario (MGD) generados en Nogales, Sonora se divierten a la planta internacional de tratamiento del agua residual en Nogales en Estados Unidos. La descarga del efluente [o agua residual] tratado de la planta tiene un impacto mayor en la dinámica del agua superficial y subterránea del río. La descarga regular del efluente es la fuente de recarga más grande en la región. Cabe destacar que mientras el agua residual está en México esta agua pertenece a México. Como agua residual, le falta valor. Una vez tratada, sin embargo, esta agua tiene valor como agua reciclada para usos de mucha variabilidad. En cuanto cruza la frontera y entra en la planta en Estados Unidos, esta agua pertenece al IBWC o la ciudad de Nogales, Arizona. Después de que el efluente es tratado y descargado en el río, se vuelve un recurso del agua dentro del estado del Arizona.

Varios esfuerzos significativos están en proceso en la región para resolver los problemas regionales de abastecimiento de agua y para el manejo de aguas residuales. Estos incluyen:

1. El proceso de planeación de facilidades (FPP en inglés) que comenzó en la región de Ambos Nogales es parte de un esfuerzo que extiende el apoyo técnico a las agencias regionales de planeación de recursos acuíferos para la construcción y el manejo e infraestructura de aguas residuales. Dentro del proceso de facilidades, las secciones esta dounidenses y mexicanas del IBWC-CILA, Comisión de Agua Potable y Alcantarillado del Estado de Sonora (CoAPAES), el departamento de recursos acuáticos del estado de Arizona (ADWR), la ciudad de Nogales, Arizona, y el rangode con sultores del sector privado han cooperado en los últimos años en un esfuerzo infraestructural regional. Como resultado de la cooperación, se aprobó el aumento de la capacidad en la planta internacional de tratamiento de aguas residuales, procesos mejorados de tratamiento, y el reemplazo de instalaciones de descarga. También se construirán más plantas de tratamiento de aguas residuales y potabilizadoras en Sonora.
2. Se han desarrollado dos esfuerzos en conjunto en el área del manejo activo de Santa Cruz (SCAMA en inglés) que son relevantes a los asuntos en el manejo de recursos acuáticos en el río debajo de Ambos Nogales, los cuales son el consejo de usuarios del agua subterránea de SCAMA y el grupo de acuerdo de SCAMA. El consejo de usuarios del agua subterránea es un esfuerzo oficial del gobierno en que los particulares que utilicen los recursos subterráneos se reúnen regularmente con personal de SCAMA para discutir los usos del agua subterránea en la región y las maneras de manejar los recursos más eficazmente. Un esfuerzo menos formal es el grupo de acuerdo de SCAMA. Esta organización está constituida por propietarios particulares dentro de SCAMA, abogados que representan los derechos legales de los dueños de los derechos grandes en la región, y varios miembros del departamento de recursos acuáticos de Arizona. El objetivo del grupo es solucionar el adjudicamiento de los derechos acuáticos en SCAMA aparte del proceso legal que ha durado años.

3. Con el objeto de establecer regulaciones en el del manejo del agua de Santa Cruz se propuso una legislación en la Legislatura Regular 45 del Estado de Arizona. Asuntos acerca de la capacidad de la Autoridad para generar ingresos para proyectos de manera tal que afectaría el flujo hacia México, el manejo de la Autoridad, y la falta de detalles en general del plan, resultó en que la legislación no se aprobara. Hay planes de reintroducir la misma legislación en futuras sesiones, con personal del SCAMA y ADWR dirigiendo los asuntos problemáticos para aumentar las posibilidades de que se apruebe. Aunque el arreglo de los flujos del agua, posesión y términos potenciales de la transferencia del agua es bastante complejo, una forma *de "Ambos Nogales Binational Groundwater Replenishment and Management District*" tiene un potencial considerable para cumplir con las necesidades del manejo del agua en el futuro cercano. El potencial de un distrito de recarga binacional reconoce claramente la conectivi-dad hidráulica de aguas subterráneas y superficiales y la manera por cual esta conectividad es un elemento importante enla dinámica de los usos del agua a ambos lados de la frontera.

Paso del Norte

Problemas regionales del agua están relacionados con el crecimiento rápido de la población y con los niveles altos de pobreza que se han combinado para crear una situación en cual la distribución del agua no ha podido satisfacer las demandas crecientes de agua. Uno de los asuntos municipales primordiales es el abastecimiento de agua, el cual es donde se concentra la mayor necesidad de crecimiento. Mientras la demanda municipal e industrial aumenta, cuencas del agua subterránea se están contaminando o agotando; se esperan faltas mayores en el futuro cercano. De acuerdo con proyecciones basadas en velocidades históricas de extracción de agua, el agua potable en el Hueco Bolsón será agotada en 2025 y se espera que Juárez sufrirá una falta del agua por el año de 2004. Se han esforzado proveedores del agua en buscar una manera de extender sus reservas limitadas en el Bolsón, utilizar agua superficial y buscar abastecimientos alternativos.

La competencia por el agua del Río Bravo ha aumentado sensiblemente a la vez que regiones urbanas experimentan faltas graves del agua mientras buscan abastecimientos nuevos del agua. Ciudad Juárez y Las Cruces todavía dependen del agua subterránea. El Paso utiliza el agua del Río Bravo para cumplir con la demanda durante la época de irrigación. Juárez está investigando la utilización de agua superficial para usos municipales. El aumento de asuntos ambientales ha causado la necesidad del enfoque de almacenar agua para el regreso a los tributarios. La asignación de agua superficial para la agricultura ha creado fricciones en la distribución entre los sectores que la usan. Aunque haya un aumento de competencia, hasta ahora no ha resultado en la alteración del armazón de distribución, en menor escala transferencias del agua de uso agrícola a municipal se ha realizado mediante pagos de alquiler. Finalmente como no hay una simetría entre el crecimiento y distribución del agua, las regiones urbanas en México se ven más presionadas en la distribución de los recursos del agua que las comunidades en los Estados Unidos. Sin embargo, con la estructura de asignación actual, el potencial uso de aguas agrícolas para asuntos municipales-industriales es más baja en la parte mexicana del Paso del Norte.

Esfuerzos innovadores binacionales includa:

1. La comisión del agua Nuevo México-Texas se creó en 1991 con la resolución de un conflicto en el cual El Paso le demandó a Nuevo México el derecho de perforar pozos en y bombear agua hacia El Paso para uso municipal. La comisión fue establecida para investigar métodos de planeación cooperativa para uso entre los dos estados. Propuso con éxito el Proyecto del Agua Sustentable en El Paso-Las Cruces, lo cual incluye una serie de mejoramiento de canales, plantas del tratamiento de aguas superficiales, sistemas de distribución y abastecimiento de acuíferos e infraestructura de recuperación.
2. Paso del Norte grupo operativo del agua (PdNWTF, por sus siglas en inglés) se trata de promover el flujo libre de información y comprensión entre los participantes para estimular coordinación en los esfuerzos de planeación y manejo. El PdNWTF fue convocado por el IBWC en 1999 y fue iniciado por el Centro de Investigaciones Avanzadas con apoyo de la Fundación Hewlett. Los miembros del PdNWTF pertenecen a un grupo pequeño binacional que incluye gente con intereses

municipales, de irrigación y de aguas privadas. Un equipo de apoyo científico-académico ayuda el grupo de trabajo. Al principio tuvo éxito en una serie de diálogos en los cuales se informó a los miembros de las operaciones y asuntos de otros miembros. En la actualidad, el equipo de apoyo del PdNWTF ha propuesto una serie de proyectos que intentarán proveer resultados fijos para asuntos regionales específicos del agua.

3. Base de datos del agua subterránea y acuíferos binacionales esto es un estudio cooperativo que incluye ambos secciones del IBWC-CILA, La Junta Municipal de Agua y Saneamiento, La Agencia de Protección Ambiental de Estados Unidos, El Consejo de Administración del Desarrollo del Agua en Texas, y el Instituto de Investigaciones del Agua en Nuevo México. Fue un esfuerzo que duró varios años e involucró varias agencias en el cual recogieron datos hidráulicos de aguas subterráneas, niveles históricos del agua, tendencias de bombeo, calidad del agua y estimaciones de extracciones del presente y del futuro. El reporte fue publicado en 1997 y proveyó mapas basados en datos y sistemas de información geográfica para diseminar a los varios miembros y al público. Lo que el proyecto no cumplió, sin embargo, fue en hacer un análisis de los des cubrimientos ni de hacer recomendaciones de las opciones del agua subterránea del futuro.

Introduction

Overview of Transborder Water Management

The physical qualities, various uses, and geopolitical nature of water make management a difficult task. When multiple jurisdictions are involved—especially when water crosses international borders—management complexities increase exponentially. Accordingly, much of the focus in transboundary water management concerns the manner by which different management styles, use practices, and national policies that can fragment surface and groundwater systems can be addressed. Cooperative water management is viewed as crucial for the optimization of resources in these shared systems. In trans-

boundary basins where water supplies are stressed, tensions over quality and supply are often heightened and regional problems can become national issues (Ingram, Laney, and Gilliam 1995). Therefore, as pressures on supplies grow and as quality is degraded, there is an increased need to manage basins and aquifers cooperatively for sustainable use and relieving of regional tensions (Salman and Boisson de Chazournes 1998). As such, contemporary water management philosophy advocates watershed-based planning and management as a tool to optimize water for the benefit of both human and ecological systems (Heathcote 1998; U.S Environmental Protection Agency [EPA] 1993).

In this chapter, three different sub-regions in the U.S.-Mexican border region are examined from a watershed perspective, specifically asking questions concerning the manner by which institutions within each region interact to advance regional water resource management. Before posing research questions in these regions, there is a brief review of the history of international watershed management and the manner by which water resource management in the U.S.-Mexican borderlands has occurred. Also introduced are the details and strengths of a comparative study of regions, especially the examination of U.S.-Mexican border twin cities. The three case studies are then explored in detail.

Since the early 1990s, watersheds have been viewed as "the best framework for integrating social, ecological and economic aspects of water and water-related management issues" (National Research Council 1999). One of the prime strengths of a watershed approach is that it is a multidisciplinary concept that involves physical processes, policy issues, management practices, and community interaction. "Many factors are converging to cause citizens, scientists, resource managers, and government decision makers to look increasingly to watershed management as an approach for addressing a wide range of water related problems" (National Research Council 1999). These factors, which operate in varying degrees on both sides of the border, include:

- Decentralization of power from federal to state and local agencies in implementing water programs
- Increasing involvement of grassroots organizations and stakeholders in influencing watershed management practices

- Increasing awareness of the pressing need to address problems of water quality and quantity in the face of rapid urbanization
- Improvements in the science of watershed analysis
- Advancements in geospatial technologies such as geographic information systems (GIS) and remote sensing for data collection and spatial analysis

The rapid population growth in the U.S.-Mexican border region, with the concomitant increasing requirement of scarce water resources, demands that government agencies optimize the use of water. In its Fourth Report to the President and Congress of the United States, the Good Neighbor Environmental Board (GNEB) strongly recommends that the watershed become the unit of management for addressing water problems along the border (GNEB 2000). Unfortunately, the U.S.-Mexican political boundary does not coincide with the patterns of water flow resulting in drainage basins often being split into two international jurisdictions. In order to overcome this fragmentation, it is essential that the two nations coordinate their efforts to address water problems within the framework of those watersheds that lie astride the border. Doing so will lead to greater efficiencies in addressing water problems and thus benefit the economic development and environmental conditions in the border region.

History of International Watershed Management

Addressing shared water problems in a cooperative manner that recognizes the interaction of the physical and human aspects of a basin has been attempted in many other transborder watersheds. A large number of surface and groundwater basins are shared among two or more nations. The equitable management of these resources is an extremely difficult problem. A wealth of cases exist that can shed light on how international neighbors have worked to resolve issues over shared water resources.

Although an exhaustive review of international watershed management efforts and literature is clearly beyond the scope of this chapter, it is helpful to review briefly some of the more notable efforts that have been advanced within an international context.

Early work by White (1963) examined the spatial links that exist among and between water management technology, economic efficiency, and the social agency by which development is advanced within the Mekong Delta. Looking at international borders a bit closer to home, the work of the International Joint Commission (IJC) concerning U.S.-Canadian issues is worth exploring due to the insights it can provide in looking at issues along the U.S.-Mexican border to the south.

The 1909 Boundary Waters Treaty established IJC to assist the governments of the United States and Canada in addressing problems that arise over shared lake and river waters. At the time of the treaty's negotiation, the northern border waters of the United States were stressed by the disposal of waste products by the industrialized cities on the Great Lakes and other northern waterways. Canada, the United Kingdom, and the United States negotiated not from the common interest of preservation and protection of shared waters, but from different political and economic interests. Canada, because of its political and economic status, wanted parity with the United States and a treaty that would provide for a strong body to manage waters and settle disputes. The United States, on the other hand, wanted a much more flexible governing body and an agreement that left tributaries under the sovereignty of each country (Beach et al. 2000). The resulting treaty preserved the sovereignty of each nation over waters within its own territory. The treaty also attempted to establish an egalitarian status between the two nations by creating a joint commission with arbitration and investigation powers, and by requiring the approval of both countries of any actions that would hinder the natural flow of shared waters.

Much of the focus of the commission has been related to water quality issues. In 1972, the Great Lakes Water Quality Agreement (GLWQA) was established, and a comprehensive protocol on water quality was instituted in 1987. Both have increased the commission's powers. The protocol uses an ecosystem approach to water management, defines specific water quality parameters, and emphasizes the need for "lakewide" management plans to address pollution. An ecosystem approach integrates the physical and biological aspects of a water system with the social environment and advocates the integration of public participation within the decision-making

process, similar to a watershed approach (van Ast 2000). The GLWQA provides for this integration through Citizens Advisory Groups and other procedures that bring stakeholder input into the process.

Although the IJC has been criticized as being too weak to address sustainability, develop a true ecosystem approach, and sufficiently integrate public participation into the process, the model has been effectively providing a structure for cooperative management and dispute resolution. The IJC has been instrumental in adverting more than 130 disputes related to shared U.S.-Canadian waters (Beach et al. 2000). In fact, it has been so effective that the two governments expanded the commission's mandate in 1991 to include air quality issues between the two countries.

Another example of an integrated attempt to manage a transboundary watershed is the Mekong Committee. The Mekong Committee was formed in 1957 to help develop the irrigation and hydroelectric potential of what was, at that time, a largely natural river system. The Mekong flows through China, Myanmar, Thailand, Laos, Cambodia, and Vietnam. In this system, supply and the allocation of that supply are not the primary issues; it is the development of the system for riparians that is at stake.[1] Recognizing this, the United Nations set in motion a process that established the Committee for the Coordination of Investigations of the Lower Mekong, which included Thailand, Laos, Cambodia, and Vietnam. The committee's goal was the promotion and development of water resource projects in the basin. Each member country has equal representation, and committee members have the authority to speak for their respective nations.

International donors heavily fund the committee and its projects, and the United Nations has played a significant role in regional efforts. This has had both positive and negative impacts on the committee. Many concrete projects, such as hydrologic and meteorological monitoring stations, were constructed in the early years, as were extensive programs of data collection and mapping. These cooperative efforts continued despite regional conflicts and have been credited with helping ease political tensions among member countries (Elhance 1999; Beach et al. 2000). Large scale water management projects, however, have been difficult to implement because of the

inherent political and economic problems associated with this type of engineering undertaking. Additionally, the role riparians play in relation to donor nations has had an influence on the success of these projects (Elhance 1999). The manipulation of external funding and the top-down approach to the development of projects appears to have been detrimental to the commission's efforts. To address this, donors must allow more regional control and local input.

The success of the Mekong Committee, therefore, has not been in the construction of large development projects, since to date no projects have been built across the main stem of the river, although smaller projects have been built along tributaries. Its success lies in the continued capacity of member countries to work together in light of significant regional turmoil, and the ability to conduct scientific studies, share data, and work toward basin-wide cooperation. Additionally, the committee has been able to expand its role from pure project development to sustainability and environmental programs. This flexibility has also helped the Mekong Committee's success. In 1970, the committee created a 30-year plan for the development of the Mekong and in 1975 established a Joint Declaration of Principles, which set out the "reasonable and equitable use" of the basin. In 1995 the committee was reconstituted as the Mekong Commission.

Several insights that could be beneficial to the U.S.-Mexican border region can be drawn from these examples. Although differences exist in national interests, economic realities, and the levels of cooperation and public participation, the dynamics that are seen in other cross-border basins are also evident in this border region. These cases show that the ability to coordinate the collection of data, whether toward the remediation of pollution, development of river courses, or the management of limited supply, is helpful to all parties. Cooperation over scientific studies can, and often does, lead to greater capacity and willingness to continue joint efforts. Additionally, coordinated efforts have the potential to ease tensions related to water disputes and even other non-related matters. The ability of institutions to be flexible in their roles and grow appears to be integral to the success of these organizations. Therefore, integrative approaches that are responsive to public concerns and

address the physical and socio-economic aspects of basins with a local and a national character are necessary for effective transboundary management of water.

U.S.-Mexican Water Institutions and their Jurisdictions

The United States and Mexico base the management of their common water resources on an institutional structure whose origins go back to the signing of the Treaty of Guadalupe Hidalgo in 1848. For nearly 40 years, this treaty served as the only institutional framework to approach any potential conflicts over common boundaries and natural resources. The increasing importance of the boundary problems between the two countries, however, made necessary the eventual adoption of certain rules—including the Convention of 1889—and the creation of a binational body to monitor their observance. This organization, the International Boundary Commission (IBC), was created in 1889. The major events related to U.S.-Mexican water management are highlighted in Table 1.

During its early years of operation, IBC was engaged in boundary matters. In time, the increasing uses along the international rivers began to create conditions for potential conflicts to develop between their users on both sides of the border (Bustamante 1999). To solve this situation, the two governments signed the 1944 Treaty for Utilization of Waters of the Colorado and Tijuana Rivers and of the Rio Grande, which provided guidelines to distribute the waters of the Colorado, Rio Grande, and Tijuana rivers. The treaty brought also a major modification in the institutional structure behind IBC that extended its capabilities as the implementer of the new rights and obligations assumed by each government. Accordingly, the name of the commission changed to the International Boundary and Water Commission (IBWC). Its functional organization has changed very little since.

The last 20 years have witnessed important transformations in the binational institutions. Two main forces are behind this trend. First is the growing concern about the environmental deterioration of the border region in the face of the demographic growth experienced by its communities over the past 40 years. Second is the demand from

different regional and local actors that they be permitted to participate in the decision-making processes surrounding the natural resources and environmental problems in their jurisdictions.[2] The rigid structure of operation at IBWC had begun to show its limitations to handle the new needs[3] and it became clear a new institutional approach was in order. This began to take form with the 1983 signing of the binational Agreement for the Protection and Improvement of the Environment in the Border Area, known also as the La Paz Agreement. The accord included formal guidelines for the participation of a broad range of government levels in both countries through the design and implementation of transboundary environmental solutions by specific work groups. Important leading agencies at the federal level included the EPA, Secretaría de Desarrollo Urbano y Ecología (SEDUE), and Secretaría de Desarrollo Social (SEDESOL).

The first negotiations over the North American Free Trade Agreement (NAFTA) among Canada, the United States, and Mexico brought a growing concern for its potential environmental effects along the border. These pressures led to the release of the Integrated Border Environmental Plan (IBEP) in 1992 by the federal governments of the United States and Mexico. The plan aimed to strengthen enforcement of environmental laws and increase cooperative planning efforts. In the same year, GNEB was created to advise the president and Congress on environmental and infrastructure issues in the states bordering Mexico. This board has representatives from different governmental levels and private organizations. In spite of being practically unknown within federal circles, the board has submitted a number of recommendations to Border XXI groups and other border institutions, some of which have been implemented (Spalding 2000).

Table 1. Major Events in the Evolution of the U.S.-Mexican Water Management Institutions

Year	Event	Objectives
1848	Treaty of Guadalupe Hidalgo	Definition of the international boundary between the U.S. and Mexico
1889	Convention that created the International Boundary Commission (IBC)	Observance of the rules of the Boundary Treaties of 1848 and 1853, and the 1884 Convention in relation to the changes of course in the international rivers
1944	Treaty for "Utilization of Waters of the Colorado and Tijuana Rivers and of the Rio Grande" (IBWC)	Distribute the waters of the international rivers between the two countries and extend the functions of the commission for the application of the terms of the treaty
1983	Agreement for the Protection and Improvement of the Environment in the Border Area (La Paz Agreement)	Provide formal guidelines for the participation of a broad range of government levels in both countries, in the design and implementation of transboundary environmental solutions by specific work groups. Define the border region as the area lying 100 kilometers to the north and south of the international border line
1992	Release of the Integrated Environmental Plan for the U.S.-Mexico Border Area (IBEP)	Strengthen enforcement of environmental laws, increase cooperative planning, completion of expansion of wastewater treatment facilities, and development of a computer tracking system on the transboundary movement of hazardous wastes
1992	Creation of the Good Neighbor Environmental Board (GNEB)	Advise the President and Congress on environmental and infrastructure issues along the bordering states with Mexico
1993	Creation of the Border Environment Cooperation Commission (BECC) and the North American Development Bank (NADBank)	Assist communities on both sides of the border in coordinating and carrying out environmental infrastructure projects
1996	Release of the Border XXI program	Promote sustainable development in the border region by seeking a balance among social and economic factors and environmental protection in border communities and natural areas

Sources: Mumme; Spalding

The signing of NAFTA in 1993 closed another important chapter in the evolution of the U.S.-Mexican water management institutions. The passage of the trade agreement was accompanied by the creation of two institutions under principles similar to those of the IBEP: the Border Environment Cooperation Commission (BECC) and the North American Development Bank (NADBank). BECC was created to provide technical support to local and regional efforts to build infrastructure that improves U.S.-Mexican border environmental quality, and to certify projects for funding by the second of

the institutions to arise from the NAFTA debate, NADBank. NADBank was developed to be a completely binational and bilateral regional development bank that enjoys joint U.S. and Mexican representation and funding. NADBank's charge is to provide funding for projects certified by BECC and finance community adjustment and investment activities in response to the relocation of production and related functions as NAFTA is implemented. The North American Agreement on Environmental Cooperation (NAAEC) included the creation of the Commission for Environmental Cooperation (CEC), a group whose main objective is to enhance cooperation between the three countries to better conserve and improve the environment.

The last addition to the current institutional structure was the implementation of the Border XXI program in 1996. This program was a continuation of the IBEP and was considered by many to be more innovative and inclusive. It emphasized public involvement, decentralized environmental management through state and local capacity building, and a better level of communication among the different government levels and agencies involved (Spalding 2000). In the arena of border water resources, IBWC and its Mexican counterpart, Comisión Internacional de Límites y Aguas (CILA); the U.S. Department of the Interior (DOI); EPA; and Mexico's Secretaría de Medio Ambiente y Recursos Naturales (SEMARNAT) participated.

Border Twin Cities and Case Studies

Forces and events on both sides of the U.S.-Mexican border have fostered human activities that have had significant impacts on environmental quality here. The entire border region has undergone dramatic economic development in the post-World War II era as a result of the major structural changes that occurred in the region's economy. Those changes were due to large-scale investment by the United States in the military-industrial sector in support of efforts in World War II (Hundley et al. 1993). More recently, a major period of industrialization and attendant population growth has occurred in border twin cities[4] as a result of unilateral programs in Mexico and agreements between the United States and Mexico.

The Border Industrialization Program (BIP) and the Program of the Northern Border (in Spanish PRONAF) were established in the 1960s and 1970s by the federal government in Mexico to deal with the end of the Bracero[5], or guest worker, Program and to increase general levels of border economic development (Dillman 1970a, 1970b, and 1976; Hoffman 1983). The goals of these programs were to increase employment in northern Mexico, offset the termination of the Bracero Program, and make major investments in the infrastructure of Mexico's northern border states. These programs allowed for the development of maquiladora plants[6] (twin or maquila plants). Maquiladoras are assembly and manufacturing plants owned by foreign investors that employ Mexican labor to perform the assembly of finished goods (Hundley et al. 1993). The BIP was successful in attracting maquiladoras to the border region, and several border twin cities have seen dramatic increases in industrial growth as a result. The advent of NAFTA has increased these trends in urbanization and development.

As a result of the economic development and industrialization detailed above, the U.S.-Mexican border has experienced dramatic population growth in recent decades, and much of this growth has occurred in twin cities. The literature varies on how much of the total border population resides in these cities, but estimates are somewhere between 72% (EPA-SEDUE 1991) and 90% (Ham-Chande and Weeks 1992). With a vast majority of border population in these cities, most (but by no means all) of the problems and challenges associated with water resource management and resulting pollution occur in or near these urban centers.

Regional approaches to resource-quality issues and the conflicts involved are well documented in the geographic and resource management literature (Mitchell 1989 and 1990). They have also been advanced by the EPA in examining domestic and binational resource management issues (Gallant et al. 1989; EPA 1991 and 1993). Watershed approaches that offer the river basin or catchment as a spatial framework and context within which resource management issues may be addressed have been extremely useful in resolving water-based conflicts and advancing holistic management of basin-wide water resources (White 1963 and 1977; Downs 1991; Montgomery et al. 1995; Milich and Varady 1999).

Three different approaches to binational water resource planning have unfolded in three U.S.-Mexican border cities, specifically San Diego-Tijuana, Ambos Nogales, and El Paso-Ciudad Juárez. In the San Diego-Tijuana region, there are a range of innovative cross-border efforts that have been advanced by the U.S. and Mexican Consuls General representing this region, the San Diego Association of Governments (SANDAG), researchers working within regional universities, staff at BECC, and non-governmental stakeholders. Within the Ambos Nogales region, IBWC-CILA; EPA; the Sonora state water authority (CoAPAES in Spanish); the State of Arizona Department of Water Resources (ADWR); the City of Nogales, Arizona; and a range of private-sector consultants have cooperated over the last few years on a facilities planning process (FPP) that has advanced binational and regional efforts to develop water infrastructure. This chapter examines the interactions of these Ambos Nogales stakeholder groups in developing innovative mechanisms and models of cooperation. Lastly, the chapter describes a range of innovative efforts toward regional water resource management ongoing in the Paso del Norte region, which is comprised of Ciudad Juárez, Las Cruces, and El Paso. In the Paso del Norte region, these efforts include the interactions of the Paso del Norte Water Task Force, the New Mexico-Texas Water Commission, and other regional stakeholders to build a regional identity and advance opportunities to cooperate in water resource planning for the region. A range of management options in other regions are also examined in a manner consistent with important earlier work that has explored watershed approaches to contemporary water resource management challenges (Michel 2000; National Research Council 1999; and Wescoat 2000).

Specific questions of concern include: the manner by which these policy tools have developed, the range of issues that have been successfully addressed through these efforts, and the lessons that these water resource planning and management activities can offer along the U.S.-Mexican border. Of special interest are the key socio-cultural, political, and technical elements that have coalesced to allow these efforts to explore the particularly difficult water resource issues involved. What are the roles of different levels of government in these efforts? What are the roles of non-governmental organizations (NGOs) and members of the general public, and how can this public

participation be facilitated? How can the efforts advanced in the twin cities examined be modified and replicated across the border region?

The San Diego-Tijuana Region

The San Diego-Tijuana region[7] is unique in many ways within the border context. While the highest levels of economic activity and demographic growth on each side of the border are found here, the most dramatic contrasts are also present in terms of economic, social, and cultural differences. The bordering sections of California and Baja California belong to a zone distinguished by two main types of weather: one extreme, desert-like climate toward the Sea of Cortez, and a warm, semi-arid climate along the Pacific Ocean. The rainy season occurs during the winter months and is characterized by low levels of precipitation—less than 10 inches annually. These conditions define a pattern of permanent water scarcity and make area rivers dry for most of the year. The Colorado River is the only reliable source in the region.

A representative feature of the San Diego-Tijuana region is the comparative dynamics of the population trends along the border. As Table 2 shows, the 1940s marked the beginning of a key period in the growth of the area. After the demographic boom that accompanied the flourishing of the military industry during and after World War II, the San Diego area has grown moderately as a result of both domestic and international in-migration.[8] In comparison, as a result of the end of the Bracero Program, Tijuana experienced an influx of migrants who were attracted by the labor opportunities during the decades that followed. Currently, this city remains an attractive labor market in the face of higher unemployment levels in other regions of Mexico—a condition that continues to keep its growth rates among the highest in the country.

While both San Diego and Tijuana command comparatively high levels of development in their own national contexts, their economic asymmetries are quite large. This characteristic is clearly reflected in different aspects of transborder interactions, such as the consumer markets in the commerce and service sectors, and a significant segment of Tijuana's economically active population (EAP) working in San Diego. Such differences also have important implications for the

financial capacity of the U.S. and Mexican governments to meet resource needs and approach specific issues in the region that are of mutual concern (including environmental problems).

Despite the obvious differences that exist in the region, recent years have witnessed an increase in the number of transborder initiatives to address common problems. These efforts have originated primarily from concerned groups of different backgrounds and have evolved into initiatives involving, in many cases, governmental agencies on both sides of the border. An innovative initiative came from SANDAG in the creation of the Committee for Binational Regional Opportunities (COBRO) in 1996. This group is an internal advisory committee that explores SANDAG's role in binational U.S.-Mexican planning activities. A key characteristic of COBRO is its wide representation of different sectors on both sides of the border, including the participation of the Consuls General of the United States and Mexico (Brown and Mumme 2001). Related to COBRO are the Border Liaison Mechanism (BLM), a formal vehicle for binational cooperation, and the Border Water Council (BWC), which originated out of the need for transborder cooperation on regional water concerns.[9]

Table 2. Population Growth in Tijuana and San Diego, 1900–2000

Year	Tijuana	Annual Growth Rate (%) *	San Diego	Annual Growth Rate (%)
1900	242		18,000	
1930	11,000		210,000	
1940	22,000	10.0	289,000	3.8
1950	65,000	19.5	557,000	9.3
1960	166,000	15.5	1,033,000	8.5
1970	341,000	10.5	1,358,000	3.1
1980	462,000	3.5	1,862,000	3.7
1990	747,000	6.2	2,498,000	3.4
2000	1,125,200	5.1	2,896,900	1.6

* Each figure corresponds to the decade ending in the related year.
Source: Weeks

One characteristic of the San Diego-Tijuana region relevant in the previous context is the Tijuana River Watershed (TRW). The implications here are numerous, as the watershed poses challenging circumstances in terms of transboundary coordination and planning efforts. To date, initiatives like the BWC have proved to be potential mechanisms to handle the region's common problems using approaches compatible with the watershed concept. On the other hand, Mexico's present decentralizing policies in relation to water management emphasize the organization of watershed councils, or *consejos de cuenca* in Spanish, at the regional level to address specific problems in each watershed. The experience gathered from these projects provides strong support for the possibility of a Binational Council functioning in this region (Brown and Mumme 2001).

Water Supply and Demand

In different ways, the water supply systems that operate in Tijuana and San Diego exemplify the structural differences that exist between the United States and Mexico. One primary distinction is the different characteristics of the water management institution. In the United States, individuals may appropriate water and the corresponding rights acknowledged by law independent of the rights-allocation system in use,[10] whereas in Mexico, water is considered by law a property of the nation and the management of this resource is entirely state run.[11] Mexican federal law, however, does grant specific rights to municipalities to manage a number of public services, among them potable water and sewage systems.[12] Essentially, both San Diego and Tijuana are dependent on imported water from the Colorado River. San Diego also receives water from Northern California. In the San Diego area, water imports account for nearly 90% of the yearly supply (Table 3). The distribution of this water by use sector can be seen in Table 4. The San Diego County Water Authority (SDCWA),[13] a public agency serving the region as a wholesale supplier of water for the local agencies, is the regional water manager. Local supplies account for nearly 12% of the available water. Among these, surface water is the most important and comes mainly from the reservoirs in the area, some of which are connected to the pipeline network of the SDCWA.[14] The SDCWA is

composed of 23 member agencies that purchase water from the Southern California Metropolitan Water District (MWD) and are, in turn, responsible for potable water services in their jurisdictions. During the fiscal year ending in June 2001, the SDCWA served a population of nearly 2.8 million distributed over 920,000 acres. The city of San Diego is the largest recipient of water in the area, accounting for roughly 45% of the population serviced and 42% of the water supplied for municipal and industrial uses (San Diego County Water Authority 2001).

Although water reclamation represents a priority alternative to meet the needs of the municipal water districts in the area, on average less than 2% of the water available to the SDCWA comes from this source (San Diego County Water Authority 2001). This is due in large part to the high costs of water reclamation and the lack of a distribution infrastructure to convey the recycled water to potential users.

Table 3. San Diego Area Water Supply Sources, June 2001

Imported Sources-88%		
Colorado River	431,751.9af	73.0%
State Water Project	159,689.1af	27.0%
Total Imported MWD	591,441.0af	100%
Local Sources-12%		
Surface Water	51,384.6af	62.5%
Well Water	12,685.7af	15.4%
Rec cled Water	12,693.0af	15.4%
Desalinated Groundwater	5,484.3af	6.7%
Total Local Water	82,247.6af	100%

Source: San Diego County Water Authority

Table 4. Water Uses in the San Diego Area 2001

User Type	Amount	Proportion
Residential	353,756af	54.7%
Industrial/commercial	126,021af	19.5%
Agricultural	107,227af	16.6%
Other	59,383af	9.2%
Total	646,387af	100.0%

Source: San Diego County Water Authority

In comparison to San Diego, Tijuana's options to meet its present and future water needs appear to be much more restricted. The water imported from the Colorado River represents the only real and dependable possibility for the city.[15] Currently, this source provides approximately 95% of its yearly supply, with the rest coming from local sources.[16] The potable water and sewage services in Tijuana and Rosarito are the responsibility of the Comisión Estatal de Servicios Públicos de Tijuana (Commission of Public Services for Tijuana, in Spanish CESPT), a state agency that operates with an administrative board headed by the governor of Baja California and includes representatives of the public and private sectors. CESPT serves four water users in the cities of Tijuana and Rosarito: residential, industrial, commercial, and government. Table 5 shows the participation of each sector in total water consumption during 2001.

Table 5. Water Consumed by Sector in Tijuana and Rosarito, 2001*

Water Use	Consumption	Total (%)
Residential	49,305af	74.9
Industrial	6,900af	10.5
Commercial	6,596af	10.0
Government	2,992af	4.6
Total	65,793af	100.0

*Based on current water billed
Source: CESPT

The operation of CESPT requires coordination with two other agencies, the Comisión Estatal del Agua (State Water Commission, in Spanish CEA) and the Comisión de Servicios de Agua del Estado (State Commission of Water Services, in Spanish COSAE). The first is responsible for planning activities while the second operates as an intermediary in the purchase of water between the Comisión Nacional del Agua (National Water Commission, in Spanish CNA) and the State Commissions for Public Services throughout the state (Castro and Sánchez 2001). Water imported by Tijuana is part of an annual allotment of 162,000 acre-feet (af) from the Colorado River, assigned by CNA to meet the urban demands in the region.[17] Approximately half of this quantity is delivered through the Colorado River-Tijuana Aqueduct (in Spanish ARCT) to Tecate and Tijuana.

One of the problems faced by most local and state agencies in Mexico relates to their financial difficulties in coping with the growing demand for their services. For potable water and sewage services, this is reflected in the inability to serve the regional population, which is particularly critical in Tijuana due to the high in-migration rates. CESPT continues to search for more efficient ways of providing service. By December 2001, the proportions of population served with potable water and sewage in the city were approximately 88%[18] and 76% respectively. Currently, CESPT cannot rely on alternative sources, such as treated wastewater, to supplement needs. Reclaimed water is not a viable option due to the low level of wastewater treatment[19] and the lack of infrastructure for the distribution of this resource.

Unique Regional Challenges

The long-term solutions to meet the water demands in this region are a priority for the agencies in charge of its management. According to the available projections, the population of the region in 2020 will be 5.7 million, two-thirds of whom will be living in San Diego while the other third will be living in Tijuana (Weeks 1999). This is a 42% increase based on a projection of moderate rates of growth for both San Diego and Tijuana. This growth will generate a demand for water for which each side is preparing in different ways.

In San Diego, provisions are being negotiated through two agreements that would supply the region with up to 200,000af annually (San Diego County Water Authority 2001). The first is the Water Conservation and Transfer Agreement with the Authority of the Imperial Irrigation District (IID) for an initial term of 45 years beginning in 2002. The second is a "Water Exchange Agreement" between the SDCWA and the MWD, which would have allowed the transfer of the water from the IID to the SDCWA.[20] However, before a water transfer agreement like this could be finalized, a number of issues must be addressed. These issues include: the effects on water levels in the Salton Sea, the potential repercussions on air quality and fish and bird habitats, growth induction impacts in San Diego County resulting from additional water supplies, and the socio-economic influences in the Imperial Valley related to land fallowing.

In comparison to San Diego, the Tijuana area faces a much more restrictive situation in terms of its long-term water supply. Like other cities in the area, the water conveyed from the Colorado River in the Mexicali Valley forms the basis for the proposed alternatives to meet water demands over the next 15 years to 20 years. In this regard, a collaborative project between Mexico and the United States was initiated with the signing of Minute 301 of the IBWC in October 1999 to conduct a joint feasibility study for an aqueduct to transport water from the Colorado River to the San Diego-Tijuana region. The study was completed by the end of 2001, and upon evaluation of its results both governments will proceed accordingly.[21]

Water reuse is an essential part of the San Diego-Tijuana region's water future. SDCWA is in the process of preparing a Regional Facilities Master Plan that involves the analysis of a variety of alternative water sources, such as seawater desalination, groundwater recharge, the conveyance of additional water from the Colorado River, and the recycling of wastewater.[22] Between 2002 and 2020 water recycling to tertiary levels in the county is expected to increase from 8.6 million gallons per day (MGD) to 121.3MGD, thus indicating a much greater reliance on reclaimed water in the future than is currently the case. Major recycling facilities in the southern half of the county are the City of San Diego North City Water Reclamation Plant, the Otay Water District Water Pollution

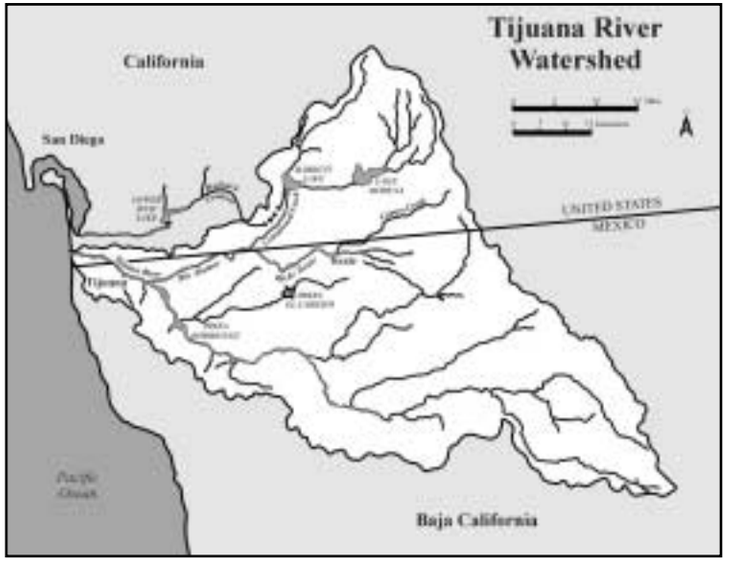
Control Facility, the Padre Dam Santee Basin Water Reclamation Facility, and the City of San Diego South Bay Water Reclamation Plant. These four facilities are expected to account for more than 50% of the tertiary treated water recycling capacity of San Diego County by 2020 (SDCWA 2002). Of special significance to the immediate border region is the South Bay Reclamation Plant, which is providing additional treatment capacity in the southern region of the City of San Diego, the Tijuana River Valley and the Otay Mesa area. This project lessens the southern part of the county's dependence on imported water supplies and will provide reclaimed water for markets in the Cities of San Diego, Imperial Beach, Chula Vista, and National City, and in the unincorporated areas of San Diego County.

As a result of natural drainage in the TRW (Figure 1), sewage flows from Mexico to the Tijuana River Estuary and the surf zone of the South Bay have been a problem for many years. In 1997, the International Wastewater Treatment Plant (IWTP) was completed to provide for advanced primary treatment of 25 million gallons of Tijuana sewage per day. The treated sewage is released through the South Bay Ocean Outfall, which was completed in 1999. The IWTP is intended to treat 50 million gallons of Tijuana sewage per day in conjunction with Tijuana's San Antonio de los Buenos treatment plant, which discharges treated sewage into the surf zone about four miles south of the border. Despite improvements in the treatment of Mexican sewage, pollution from cross-border sewage flows continues to be a problem in the Tijuana Estuary and adjacent beaches. One proposal to alleviate the situation is Bajagua, a controversial private wastewater treatment plant that would be built in Mexico and process between 50MGD and 75MGD of Tijuana's sewage. The water reclaimed through Bajagua would be available for industrial needs, public greenbelts, and groundwater recharge. Thus, it would help augment Tijuana's limited supplies from the TRW, the Colorado River, and the Guadalupe Valley. The controversy surrounding Bajagua relates largely to the privatization of wastewater, which continues to be a subject of intense debate.

Another interesting, but smaller-scale effort to reclaim water is EcoParque, a 15-acre project initiated in 1986 by El Colegio de la Frontera Norte (COLEF). The project is intended to represent a

model for the reuse of water in hillside urban areas. Given Tijuana's limited water supplies, topographic characteristics, location near the border, and its barren hillsides, there is a need to treat and reuse as much wastewater as possible to preserve precious water supplies, vegetate hillsides to reduce erosion and create green spaces, and reduce the flow of polluted waters into the United States. It remains to be seen if it is practical to extend the EcoParque model to other parts of Tijuana and the border region.

Figure 1. Hydrography of the Tijuana River Watershed



Source: Drafted by Carol Placchi, modified from IBWC and Pryde

Innovative Cross-border Efforts in the Region

Tijuana River Watershed Program

Universities and public agencies from both sides of the border have combined their efforts to help address environmental problems in the transborder TRW. The watershed covers 4,500 square kilometers—two-thirds of which is in Mexico—and has a wide range of

topography, climates, biological resources, land uses, and socio-political institutions (Wright et al. 1995). The TRW Program had its beginnings in 1994 when San Diego State University (SDSU) and COLEF signed a memorandum of understanding that laid out the guidelines for coordination between the two institutions in the development of a watershed GIS and its use for community outreach, education, and scientific research. Funding from the National Oceanic and Atmospheric Administration (NOAA), the Southwest Center for Environmental Research and Policy (SCERP), and other agencies has made possible the completion of more than a dozen projects, most of which have focused on water quality and quantity problems in the watershed.

Goat Canyon/Cañón de los Laureles Vulnerability Assessment

In 1998, the TRW was selected by the U.S. National Partnership for Reinventing Government and the U.S. Federal Geographic Data Committee as one of six pilot project areas in the United States to demonstrate the application of the National Spatial Data Infrastructure (NSDI) to solving community problems. The study area is Goat Canyon, or Cañón de los Laureles, a five square-mile canyon located just upstream from the Tijuana Estuary. Approximately 90% of the canyon is located in Mexico. Because of its physical and cultural characteristics, the canyon is a major source of the sediment that is rapidly encroaching on the estuary, which is a National Estuarine Research Reserve and one of the largest remaining functioning wetlands in Southern California. Like many other canyons in the area, Goat Canyon is subject to infrequent but intense precipitation events that lead to flash flooding and the loss of human lives, property, and natural habitats. The principal purpose of the project was to model the degree and geographic distribution of human vulnerability to flood hazards within the context of a binational, data-poor situation. Not unexpectedly, the sections of the canyon that were modeled as significant flood hazard areas were most likely to coincide with areas of low-income housing. This project demonstrates the difficulties of working in a transborder setting and what the paucity of human and physical data can overcome. This project relied on an effective binational data-sharing partnership struck among universities and federal and local agencies. In

addition, the project was assisted by technology transfer to some local partners in the private sector.

Flood Forecasting and Warning System for the Tijuana River Watershed
One of the outcomes of the TRW National Community Demonstration was a greater recognition of the fact that flooding is a serious threat to local communities. For this reason, some 13 institutions on both sides of the border have signed a declaration of intent to develop a flood forecasting system for the lower TRW. The participating agencies have agreed to:

- Participate in binational, interagency technical efforts to design a basin-wide flood monitoring system in support of the development of a flood forecasting model
- Seek opportunities to implement the monitoring program through binational, interagency partnerships
- Promote the development of a flood forecasting model and associated flood warning system for the TRW

The U.S. National Weather Service, the U.S. National Ocean Service, the County of San Diego Department of Public Works, and the City of Tijuana Protección Civil Estatal have led the way in moving the project along. In the first phase of the project, stream gages and precipitation recording stations were purchased and locations for the installation of this equipment were identified on the Cottonwood Creek, Alamar River, Campo Creek, and Tecate sections of the TRW. The equipment is scheduled for installation. The project will also involve an upgrading of the City of Tijuana's and County of San Diego's antennas to receive and transmit precipitation data to Protección Civil Estatal in the City of Tijuana and the Department of Flood Control in the County of San Diego.

Bight of the Californias Program
In 1995, the United States, Mexico, Canada, and more than 100 other nations adopted the Global Programme of Action (GPA) for the Protection of the Marine Environment from Land-Based Activities. The GPA encourages countries to develop or strengthen programs to address land-based sources of pollution in the marine environment. To help implement the GPA, CEC has established two

pilot programs, one in the Gulf of Maine and the other in the Bight of the Californias. The Bight is formed by an eastward indentation of the coast that extends from Cabo Colonet, Baja California, northward to Point Conception, California. Within the Bight, a sub-region centered on the U.S.-Mexican border and extending from Ensenada, Baja California, to Encinitas, California, has been selected as the project area. This subregion includes a regional population of more than 4 million in the urban areas of San Diego, Chula Vista, Tijuana, and Ensenada. Rapid population growth and intense economic development are having major impacts on the nearshore marine environment in this binational region. The overall goal of this project is to establish the information and methodological bases for protecting the nearshore marine environment in the Bight from land-based sources of pollution. Specific objectives of the project are to:

- Identify the types of pollutants entering the U.S.-Mexican border section of the Bight
- Inventory marine water quality monitoring activities in the study area
- Identify data gaps
- Develop a watershed-level GIS database
- Develop an integrated terrestrial point-source pollution GIS database

The project is being accomplished through a collaboration among San Diego State University, Universidad Autónoma de Baja California, and the Southern California Coastal Water Research Project with funding from NOAA and SCERP. Technical input is provided by a binational technical advisory team comprised of representatives from local, regional, state, federal, and international government agencies. These organizations are engaged in various ways with water quality matters and thus are also potential beneficiaries of the project.

San Diego Association of Governments and San Diego County Water Authority Work Toward a Border Water Council
In 1996, SANDAG formed COBRO to develop a binational policy framework and action plan for addressing a variety of problems in

the San Diego-Tijuana border region. For the past five years, COBRO has sponsored an annual conference on issues of major concern in the binational region. In recognition of the importance of water resources to the region, COBRO selected water as the topic of the first conference in 1997 (SANDAG 1997). Several recommendations came out of the conference, including suggestions to:

- Facilitate the exchange of information and technology on water-related issues
- Explore opportunities for binational participation in water transportation and storage projects
- Promote transborder water exchange and re-use
- Develop binational water conservation education and projects
- Develop plans to transfer water from one side of the border to the other in the event of an emergency
- Employ a watershed approach in addressing regional water problems

Under the auspices of the BLM, a Border Water Council (BWC) was established in 1997. Representatives of the SDCWA and CESPT are the co-chairs of the council. The BWC has moved toward the implementation of several of the recommendations of the 1997 workshop, but its major effort has been to encourage the exploration of options for the conveyance of water from the Mexicali and Imperial Valleys to San Diego and Tijuana. In recognition of the need to consider the county's bordering jurisdictions in matters of regional planning, the Board of Directors of SANDAG has made relations with its neighbors, especially Mexico, a high priority. To facilitate transborder approaches within SANDAG, a high-level position of Director of Binational Planning and Coordination and a Borders Policy Committee have been created. With this new organization, COBRO will send policy recommendations regarding binational matters to the Borders Committee, which then can elevate them to the full board (SANDAG 2002).

Regional Colorado River Conveyance Feasibility Study

Toward the goal of insuring adequate water supplies for the San Diego-Tijuana region, the State of California and the SDCWA provided funding for a study to explore potential routes for an aque-

duct from the Colorado River that could be shared by SDCWA and state agencies in California. The binational alignment options study, which is managed by a technical committee comprised of seven U.S. and Mexican agencies, is part of a larger regional facilities master planning effort being undertaken by SDCWA. The study of transborder options is based on the recognition that a conveyance facility may be more cost-effective if multiple agencies are involved and that SDCWA and Mexican agencies have a shared interest in evaluating the potential of a joint facility. Thus far, 10 binational alignment options have been identified in the study. This joint study is an excellent example of how agencies from the United States and Mexico can work together to determine the most effective way of meeting regional water needs. However, a number of issues will have to be resolved if the idea of a joint facility is to be pursued further, including:

- The use of the All-American Canal
- Security and reliability questions concerning the use of facilities outside each country's national territory
- Costs and methods of financing an international project
- The types of international agreements that will need to be put in place
- How to continue progress on the project with changes in administrations (Friehauf 2002)

Alamar River Corridor Study

San Diego State University, Arizona State University, and the City of Tijuana are examining alternatives for channelizing a portion of the Alamar River (Michel 2001). The study is being conducted as a part of the Borderlink Program coordinated by the Institute for Regional Studies of the Californias at San Diego State University. Borderlink is a highly successful program that involves university faculty and students from the United States and Mexico in collaborative projects on real world problems in the border region. The Alamar River is a segment of the TRW that extends from the U.S.-Mexican border downstream to the Tijuana River. The Alamar drainage, which includes Cottonwood Creek, Tecate Creek, and Campo Creek, provides approximately 50% of the flow of surface water in the TRW and is a major recharge area for the aquifer that underlies the lower

TRW basin. The principal finding of the project thus far is that the creation of a river park in the Alamar River corridor would provide a large number of benefits, including:

- Improved groundwater recharge to sustain or increase the supply of potable water for the City of Tijuana, which is rapidly out growing its supply of imported water
- Increased riparian habitats, which are home to a large number of threatened and endangered plant and animal species
- Expanded acreage given to open space and recreation in the City of Tijuana, which is well below international standards in the availability of green space per resident
- Improved water quality in the Lower Tijuana River Basin, an area characterized by ongoing problems with pollution in the groundwater aquifer, estuary, coastal beaches, and surf zone
- Restored natural hydrology of the lower Tijuana River basin to help reduce flooding, erosion, and sedimentation
- Reduced costs of providing flood control in an area subjected to serious flood events

This project demonstrates the value of integrating student education and applied research in addressing cross-border water resource problems.

Ambos Nogales Region and the Facilities Planning Process

The binational twin city of Ambos Nogales faces similar water resource management issues to those faced by San Diego-Tijuana and Paso del Norte regions. Preliminary population data from the 2000 census indicate that the current population in Ambos Nogales exceeds 200,000 (Instituto Nacional de Estadística, Geografía e Informática [INEGI] 2001). This number of people generates a growing need for water in the municipal and industrial sectors and creates a range of related water quality issues. Water resource management issues in Ambos Nogales include the provision of water supplies to sectors of society with competing needs; the provision of the needed infrastructure and "plumbing" to deliver water to major

sectors of Nogales, Sonora; the provision of adequate wastewater collection and treatment; proper management of groundwater and surface water interactions; and a range of water quality issues related to both groundwater and surface water resources. Figure 2, a map of the Upper Santa Cruz Basin within which Ambos Nogales lies, provides an overview of the spatial elements that exist in the Ambos Nogales region.

Unique Regional Challenges

Groundwater is the major source of water for the region, and wells in both the U.S. and Mexican portions of the basin affect groundwater availability and surface water flows in the river. Increasing urban groundwater extraction is impacting the long-standing agricultural use of groundwater in the basin and negatively impacting surface water flows in the river, which raises questions about sustainable use of groundwater for the future. Groundwater resources are frequently extracted at a much greater rate than that of groundwater recharge, making extensive extraction of groundwater, such as that found in the Ambos Nogales region, highly problematic.

In addition, the provision of drinking water is a particularly pervasive and immediate need in Nogales, Sonora, and this immediacy poses special challenges for regional approaches to water resource planning. The percentage of Nogales, Sonora, residents that have piped water or connections to sanitary sewers is estimated to be only 50% (Solís Garza 1999). Providing an enhanced delivery network, addressing major losses of water resources through leaks, and securing a raw water source with which to meet demand are three related and very important issues that face Nogales, Sonora. These needs have led to explorations of enhanced groundwater extraction in the areas upstream from the city near Mascarenas, Santa Barbara, and Parades (Barcenas 1999). As a first step to resolving these water supply issues, a major facilities planning process has been undertaken in the region. The effort is aimed at enhancing the wastewater collection and treatment facilities in the Ambos Nogales region and providing future supplies of potable water to Nogales, Sonora (Barcenas 1999; IBWC 1995).

Figure 2. Upper Santa Cruz Basin

Innovative Cross-border Efforts in the Region

The FPP that has been undertaken in the Ambos Nogales region is a binational planning effort that extends technical support to regional water resource planning agencies toward the goal of obtaining funds from EPA for the construction of needed wastewater management infrastructure (IBWC 1995). The FPP was formally established with the signing of Minute[23] 301 by IBWC and CILA. Within the FPP advanced under Minute 301, IBWC-CILA; CoAPAES; the ADWR; the City of Nogales, Arizona; and a range of private sector consultants have cooperated over the last several years on a regional water infrastructure effort. Both a technical working group and a policy group have developed various configurations of enhanced water resources infrastructure, and numerous options were explored (Barcenas 1999).

As a result of this process, an alternative was approved that provided for increased treatment capacity at the existing Nogales International Wastewater Treatment Plant (NIWTP), upgraded treatment processes, and replacement of outfall facilities (Camp Dresser & McKee 2000). Specifically, the treatment capacity at the international treatment plant will be increased from the present treatment capacity of 17.2MGD to 22MGD, an amount projected to meet the future demands of the sister cities. Wastewater treatment processes will be upgraded to increase nitrogen removal, thus allowing effluent treated in the plant to meet EPA and State of Arizona water quality regulations and also addressing water quality concerns advanced by members of the public downstream from the plant. Replacement of the outfall that brings sewage from the border to the plant will provide the additional transmission capacity needed to convey larger flows in the future and will also eliminate extraneous flows into the outfall due to infiltration of baseflow into the outfall (Camp Dresser & McKee 2000).

In addition, both wastewater treatment and potable water treatment facilities are to be built in Sonora. A small wastewater treatment plant (treating up to 5MGD) employing an advanced ponding system is to be built at Los Alisos in Nogales, Sonora, and a lift station will be built to convey wastewater to this new plant. Also, the existing wastewater collection network in Nogales, Sonora, will be

upgraded in an effort to reduce infiltration similar to that which poses problems with the outfall discussed above (EPA 2000). At the request of CoAPAES, a potable water component for Nogales, Sonora is being planned, which complicated the final design of the wastewater treatment plant and related funding issues. These complications were largely resolved in early 2001 and current plans are for approximately $8.5 million from the Border Environmental Infrastructure Fund (BEIF) to support the potable water component of the project (Sprouse 2001; Wachtel 2001).

The discharge of treated effluent from the IWTP also has a major impact on surface water and groundwater dynamics within the downstream reaches of the river from approximately Rio Rico to Amado (Figure 3). The regular discharge of this effluent is the largest source of groundwater recharge in the region; over time, this effluent has become the largest contribution to regional groundwater balances. One particularly important facet of the facilities planning negotiations has been the desire on the part of ADWR and downstream riparians to negotiate some form of guarantee that adequate amounts of Mexican wastewater will be diverted over the long run to insure viable levels of recharge to groundwater aquifers. This guarantee is of primary importance to the possible formation of a groundwater replenishment district, which will be discussed in greater detail (Barcenas 1999), yet this idea of a guarantee solely reflects the perspectives of downstream riparians and agency staff in Arizona and the United States.

What of the Mexican perspective? In Mexico, both water and wastewater are state resources controlled by the federal government; consequently, it is important to ensure a Mexican perspective is part of the discourse on wastewater management in the Ambos Nogales region. According to the Mexican Constitution and la Ley de Aguas Nacionales, untreated and treated wastewater is a state-owned resource managed and controlled at the federal level. Furthermore, under Resolution 11 of IBWC-CILA Minute 277, which facilitated construction of NIWTP, wastewater treated at the Arizona, is still owned by Mexico, and Mexico plant in Nogales, retains recapture rights to treated effluent.

Based on discussions with top-level water resource leaders in Mexico, the wastewater generated in Nogales, Sonora, and treated at

Figure 3. Santa Cruz Basins Subregion

the NIWTP in Nogales, Arizona, is clearly seen as a potential resource that could contribute to meeting water resource demands in Nogales, Sonora (Herrera 2002). CILA sees a need for an integrated regional water resource perspective that includes management of regional groundwater resources and the possible inclusion of treated effluent in some manner of a conjunctive use scenario (Herrera 2002). Mexican officials wish to retain control of the potential use of Mexican effluent, and this has been a considerable barrier to making much progress on negotiating a flow guarantee for Mexican effluent as part of discussions toward a regional groundwater replenishment district.

Two efforts have developed in conjunction with the Santa Cruz Active Management Area (SCAMA) staff that are of relevance to the water resource management issues in the reaches of the river below Ambos Nogales: the SCAMA Groundwater Users Advisory Council (GUAC) and the SCAMA Settlement Group.[24] GUAC is an official governmental effort whereby private citizens who are active users of groundwater resources regularly meet with SCAMA staff to discuss groundwater uses in the region and various means to manage these resources more effectively. Specific topics on which the council have focused include the status of water rights adjudication in the region, awards of ADWR grants to study groundwater resources, results of the Statewide Safe Yield Task Force, adjustment of pumping fees for groundwater users, and the status of a SCAMA surface water model (GUAC 1999). Of particular note is the extremely open manner by which these meetings are conducted. Not only are members of the council and SCAMA staff welcome to actively participate, interested members of the general public are also welcome to attend and contribute to the discussions. If openness and participation are deemed positive contributions to regional approaches to water resource management on the border, the efforts of this council provide a valuable lesson learned for future efforts in other regions along the border.

Related to GUAC is a less formal effort known as the SCAMA Settlement Group. This group is composed of private citizens who own water rights within SCAMA, attorneys representing the legal interests of large water rights holders in the region, and various staff members at ADWR. The goal of the Settlement Group is to work

toward resolution of water rights adjudication in SCAMA outside the ongoing legal process that has made little progress to date (Settlement Group 1999). Of special note is the extremely participatory manner by which the Settlement Group functions, a fact that is not surprising given the membership of the group and the open manner by which SCAMA staff conduct business.

An anecdote involving the activities of the Settlement Group demonstrates this openness and provides insight into how discussions concerning complex water resource management can be advanced. During late 1999 and early 2000, the group worked with ADWR staff to develop and implement a pilot project whereby water rights holders would be surveyed to gather data on land ownership and various facets of water rights. The first step in this project was the delineation of the study area, and ADWR staff presented a sophisticated, computer-generated map outlining what they thought was a reasonable area. Immediately, local water rights holders commented on several problems with this area, including areas with limited water uses that may not be worth the time and energy to survey, and other locations where an uninvited visit from ADWR staff could actually pose a risk to the staff involved. To the credit of ADWR staff, this local knowledge was actively welcomed into the debate. After more discussion, the study area was modified to take into account the hydrologic science that ADWR staff brought to the table, as well as the valuable local knowledge that ranchers and other water rights holders possessed. Given the political climate of rural Southern Arizona, considerable tensions exist among water rights holders and ADWR staff, and the cooperation evident in this meeting is a much needed ingredient in implementing this project. To date, all the surface and groundwater rights that exist in SCAMA have been documented, and this information has been provided to all water rights holders and claimants. Currently, ADWR staff are working to verify and qualify the water rights that have been asserted and also the amount of "wet water" that may actually be available for use in the SCAMA area. The goal of this work, which may be completed by 2003, is to reconcile the total water rights in the area with the amount of wet water, and then move toward some form of management strategy that would acknowledge the regional shortage of wet water relative to water rights in an equitable manner

(Barcenas 2002).

In addition to the water quantity issues SCAMA efforts are addressing, water quality of the treated effluent discharged by the NIWTP is also of importance. Monitoring of effluent quality and surface flows downstream from the plant has revealed elevated levels of ammonia and nitrates (Friends of the Santa Cruz River 1999). These levels raise water quality concerns that have been voiced to EPA staff involved in the upgrade of the plants (Valentine 1999). The IBWC, as the primary operator the NIWTP, has failed to meet National Pollution Discharge Elimination System Standards, and these water quality concerns have been a good part of the impetus for enhancements to the rigor of the treatment processes at the plant (Holub 1999).

A contributing factor to the establishment of the SCAMA in 1994 is its location directly on the U.S.-Mexican border. "…[T]he legislature recognized the international nature of water management issues facing the Upper Santa Cruz Basin … and the desire of the water-using community to participate in local water resource management and binational coordination efforts" (ADWR 1999). As noted above, one of the most difficult binational challenges facing SCAMA is how to reconcile the confluence of issues related to the treatment of binational wastewater in the Ambos Nogales region with the role of discharged treated effluent in regional water balances. This challenge is well-suited to regional approaches. Results of field work on this issue not only verify this proposition but also uncover an interesting and innovative means to handle the issues related to treating binational wastewater in Ambos Nogales.

Given the increasing rates of groundwater extraction occurring in the region and the daily generation of millions of gallons of treated effluent, what prospects exist for acknowledging the hydrologic connectivity of surface water and groundwater in the Ambos Nogales region? Various regional water resource experts have advanced the idea of a binational regional groundwater replenishment district as a means to reconcile the needs of various interest groups and water users across the border within a regional framework that acknowledges regional links, surface water and groundwater interactions, and the value of regional and local knowledge (Holub 1999; Barcenas 1999; GUAC 1999). Many variations on this theme have

been advanced, although the specific details of them are outside the scope of this chapter. However, a discussion of the basic concepts involved in this type of management regime is valuable to see how a regional approach may fit the relevant issues.

Presently, approximately 10MGD of wastewater generated in Nogales, Sonora, are diverted to NIWTP in the United States. At the plant, these flows and approximately 2.5MGD of wastewater from Nogales, Arizona, are treated and discharged into the Santa Cruz River. The cost to Mexico for treatment is approximately $300,000 per year, and this amount is paid by CILA. The NIWTP was built with U.S. federal money and has been managed and jointly owned by IBWC and the City of Nogales for many years.

As mentioned previously, the wastewater generated in Mexico is owned by the Mexican government. As wastewater, it lacks immediate value. However, once treated to various levels, this wastewater can have value as reclaimed water for a variety of uses. Once the wastewater crosses the border, enters the plant on the U.S. side, and is treated and discharged into the river, this treated effluent becomes an appropriable water resource within the State of Arizona (Barcenas 1999). Broad recognition exists in the region that the appropriable nature of this effluent poses a potential conflict with Mexico's right of recapture, as discussed above, and discussions to resolve this conflict have been ongoing for several years.

The aforementioned dynamic takes on more than academic importance when the impact of the treated effluent on downstream surface and groundwater balances is addressed. The treated effluent is the largest input of water supply into these water balances and has great importance to the riparian condition in downstream reaches and as a source of groundwater recharge to downstream aquifers. The reliability of the input of wastewater into this water balance is also of importance to IBWC-CILA, EPA, and BECC. All the plans for expanding wastewater management infrastructure in the Ambos Nogales region require that minimum inflows of effluent arrive at the plant to justify its build-out and ensure efficient and effective plant operation.

Implicit in this situation is the need, on behalf of Arizona riparians and ADWR, for some form of guaranteed minimum flows of wastewater to be generated by Mexico. The conditions by which this

guarantee are arranged form the pre-conditions for a binational groundwater replenishment and management district. One scenario advanced in the past is that some entity (perhaps the City of Nogales) assume the $300,000 per year cost of operation and maintenance that Mexico is paying and provide additional funds to buy or lease the rights to the wastewater involved, in exchange for a guarantee of certain minimum flows to the plant. A variation of this theme would see some U.S. entity provide treated potable water in exchange for the flow guarantee, perhaps at a 3:1 effluent to potable water credit rate (Barcenas 1999). This minimum flow guarantee would then be transferred into some variation of an assured water supply that the ADWR would accept as a valid source of supply for future management options. The actual discharged effluent would continue to enter the hydrologic system of this portion of the basin as a source of groundwater recharge, which could then be appropriated by some form of water right or leased water right by downstream users. These rights would be distributed via some form of market mechanism, and proceeds from the market transactions would fund the operation of the district and financial transfers to Mexico.

In order to create this type of a district and establish the Santa Cruz Water Management Authority, the State of Arizona Senate Bill 1410 was introduced (Arizona State Legislature 2002). ADWR and SCAMA staff questioned the ability of the authority to generate revenues for projects, the manner by which a flow guarantee with Mexico could be effected, and the overall management of the authority. These issues and a lack of overall detail prevented the legislation's being voted out of committee. Plans are to reintroduce the bill in future legislative sessions, with SCAMA and ADWR staff taking a more active role, which may help address some of the concerns that made the first bill problematic (Barcenas 2002).

Although this arrangement of water flows, ownership, and potential terms of exchange is quite complex, some form of an "Ambos Nogales Binational Groundwater Replenishment and Management District," has considerable potential to meet regional water resource management needs well into the future planning horizon. Such a district could also be viewed as a form of regional water resource management tool similar to watershed councils, or *consejos de cuencas*, which are advanced in Mexico's national water law by CNA (CNA 1992 and 1997). Implementing these tools would incorporate the value of local and regional knowledge into a spatial framework consistent with that of the Upper Santa Cruz Basin.

The above framework offers promise for innovation in binational water resource management, but it comes with several barriers. The principal barrier is the hesitance of the large federal and international agencies involved in water resource management to openly and actively engage the public and regional players in border water resource management (Barcenas 1999; dos Santos 1999; Holub 1999). The centralized manner by which IBWC-CILA and CNA have traditionally undertaken their responsibilities may pose a barrier to this type of regional cooperation. As noted in the 1944 Water Treaty, IBWC-CILA have the pre-eminent right and responsibility to direct binational water resource management and planning, and past experiences have shown a reluctance on the part of IBWC-CILA to surrender this political primacy. In addition, Mexico's water law established CNA as the Mexican agency with absolute authority for management of federal water resources (CNA 1992 and 1997). It is clear that these institutions must be at the table for a replenishment district to emerge, and to date, this participation and willingness to work with regional stakeholders has not been as evident as may be necessary for this to occur.

At the state and regional levels, issues of management and control are also potential barriers. Were a replenishment district to emerge, who would manage and control the district, ADWR headquarters in Phoenix, or the regional staff of the SCAMA? Historical management of the ADWR would argue for the former, while the degree of regional expertise and perspective needed to manage such a district would argue for the latter. This issue of management would need to be resolved for the needed support within the legislature and executive branches of government to materialize. Lastly, a lack of experience in managing traditional surface waters exists within the active management area (AMA) framework, which evolved primarily to manage groundwater resources.

How might these barriers be removed or lessened? At the federal level, participation of the Counsels General that serve the Ambos Nogales region through the BLM may be helpful in facilitating the

willingness of CILA and CNA to explore such a district. In addition, the recent tendency of IBWC-CILA to employ a more participatory and open management style would increase the likelihood that the proper links between IBWC-CILA leadership and regional stakeholders would emerge. Ambos Nogales is a smaller urban region than larger twin cities and it has a greater sense of community and a desire to cooperate regionally. This quality is also helpful in generating the needed intra-regional dimensions that a successful effort would require. Long-term communication and lobbying with key people at the state and national level will also increase the likelihood that these individuals will be willing to help the establishment of a replenishment district move forward (Holub 1999).

What insights can be drawn from the facilities planning process in Ambos Nogales that may be of use in other regions along the border? The potential for a binational recharge district clearly acknowledges the hydrologic connectivity of ground and surface waters. It also recognizes the importance of the connectivity in the dynamics of water uses on both sides of the border. These cross-border dynamics clearly exist in other border twin cities, and management efforts in other twin cities may benefit from actively and clearly acknowledging these dynamics. The successes of the SCAMA Groundwater Users Advisory Group and Settlement Group demonstrate the value of local and regional knowledge as well as the open exchange of information that facilitates public participation. This access and openness of operation can be considered a lesson learned that may benefit other efforts toward regional management of water resources along the border. IBWC-CILA and others involved in the facilities planning process made a sincere effort to involve open public participation in the later stages of their projects, but such an inclusion may have been of greater value if the public would have been more actively involved earlier in the process.

Paso del Norte Region

Regional Overview

The Paso del Norte region is defined by limited rainfall, scarce water resources, and its position at the junction of three states and an international boundary. Like many other twin city areas it is characterized by burgeoning growth, vast expanses of land, limited economic resources, and isolation from other population centers. The Paso del Norte region sits at the intersection of New Mexico, Texas, and Chihuahua, where the Rio Grande/Río Bravo shifts from a transboundary river to a boundary river. When defined by water issues, the Paso del Norte begins at Elephant Butte Dam in New Mexico and ends at the twin towns of Ft. Quitman, Texas, and Cajoncitos, Chihuahua. The region's geography is determined by a series of isolated mountain ranges—the Franklin Mountains in Texas, the Organ Mountains in New Mexico, and the Sierra de Juárez in Mexico—and a wide basin through which the Rio Grande flows. The area is semi-arid, receives an average 8.5 inches of rainfall annually, has approximately 64 inches of net annual evaporation, and is at the northernmost end of the Chihuahua Desert ecosystem. Regional elevation is approximately 4,000 feet and temperatures can range from 47°C (117°F) on summer days to below freezing on winter nights. The most dramatic temperature changes are found in the winter, where daytime and nighttime temperatures can shift as much as 4°C (40°F), causing atmospheric inversions that dramatically affect air quality.

The principal cities in the region are Las Cruces, New Mexico; El Paso, Texas; and Ciudad Juárez, Chihuahua, which had a combined official population of 2,073,100 in 2000, although other estimates are higher, as noted in Table 6. Although the combined population of the San Diego-Tijuana region is greater, the international urban area formed by El Paso-Ciudad Juárez is the largest community directly on the U.S.-Mexican border. That population is generally young, predominately Hispanic, and relatively poor. The region has experienced rapid population growth since the 1950s, and at current rates of growth—approximately 3% per year—the regional population will double by 2024. All of these factors impact how regional

institutions approach the challenge of increased demand and limited supply.

Table 6. Historic and Projected Population of El Paso and Doña Ana Counties and Ciudad Juárez

Year	El Paso County	Doña Ana County	Ciudad Juárez	Regional Total
1950	194,968	35,688	131,308	361,964
1960	314,070	55,509	276,995	646,574
1970	337,471	65,633	424,135	827,239
1980	479,899	94,051	567,365	1,141,315
1990	591,610	135,510	798,499	1,525,619
2000	745,000	174,700	1,521,500	2,441,200
2010	940,000	204,767	2,250,000	3,394,767

Sources: City of El Paso, Department of Planning, Research and Development; 1990 U.S. Census; 1990 Mexican Census; and Ciudad Juárez Planning Department

An international treaty and a state compact form the regulatory framework for this portion of the watershed. The Convention of 1906 between the United States and Mexico distributes the waters of the Rio Grande in the upper stretch. The Rio Grande Compact of 1924 then divides the waters in the upper stretch of the river not already allocated to Mexico between Colorado, New Mexico, and Texas. Under this framework, river allocations were based on a complicated formula that considered population, irrigated lands, and average annual flow at the time of the allocation, with some projections into the future. Surface waters are allocated primarily for irrigation use, and none are set aside in the legal framework for instream flows. The Mexican allocation from these waters is 60,000af annually, which is delivered at the American Diversion Dam in El Paso, Texas, and managed by the Valle de Juárez Distrito de Riego 009. In a full-water year, southern New Mexico is allocated 494,979af, which is managed by Elephant Butte Irrigation District (EBID), and 376,862af are allotted to El Paso County Water Improvement District #1 (EPWID#1) (Bureau of Reclamation 2001). When the river was apportioned, the number of irrigated acres and population was much less than at present, and recent

growth has shown that this allocation scheme does not reflect current needs. Although the entire stretch of the river has never been adjudicated, Brown and Ingram (1987) contend that the river is fully committed and most likely over-appropriated. Groundwater basins are also shared among states and the two countries. There is no treaty that regulates the use of aquifers between the countries.

Water is managed by a complex set of laws and institutions that include irrigation districts, state agencies, federal agencies, and international commissions, as detailed in Table 7. Many of these have overlapping jurisdictions. IBWC-CILA management and apportionment of border waters has historically represented a workable model of binational cooperation (House 1982). At the federal and state level in each country, water management is rooted in different legal traditions throughout the basin. In Mexico, water is the property of the federal government, while in the United States different state laws govern water. In New Mexico, water is owned by the state, and the right of prior appropriation conveys both surface and groundwater. In Texas, surface water is owned by the state, and groundwater is placed under common law that conveys it as a property right. At the federal level, surface water in Mexico is managed by CNA and in the United States by the Bureau of Reclamation (USBR). At the state level, it is managed by the Junta Central de Agua y Saneamiento, Chihuahua (JCAS), the New Mexico Office of the State Engineer (OSE), and the Texas Commission on Environmental Quality (TCEQ). At the local level it is managed by a number of utilities and irrigation districts.

Since the Paso del Norte region falls within the 100km zone designated by the environmental side agreements to NAFTA, planning for public water and wastewater infrastructure is influenced considerably by BECC purview. The certification process established by the BECC-NADBank system has the potential to influence the way water and wastewater projects in the border region are designed, funded, and implemented (Brown 1998), since projects seeking certification must address the sustainability of the project as it pertains to both physical and economic resources. Additionally, the certification process requires significant public input and transparency, which, historically, has not been common in the border region.

Table 7. Water Management Institutions

Agency Level	Name
International	Comisión Internacional de Límites y Aguas (CILA)
	International Boundary and Water Commission (IBWC)
Federal	Comisión Nacional de Agua (CNA)
	United States Bureau of Reclamation (BOR)
Tri-State	Rio Grande Compact Commission
State	New Mexico Office of the State Engineer (OSE)
	Texas Commission on Environmental Quality (TCEQ)
	Junta Central de Agua y Saneamiento, Chihuahua (JCAS)
Local	City of Las Cruces Water Resources Department
	El Paso Water Utilities (EPWU)
	Junta Municipal de Agua y Saneamiento, Cuidad Juárez (JMAS)
	Small Municipal Suppliers
	Elephant Butte Irrigation District (EBID)
	El Paso County Water Improvement District Number One (EPCWID)
	Valle de Juárez Distrito de Riego #009

Water Supply and Use

The Rio Grande and a number of aquifers supply water in the region. Table 8 provides specific information on water sources, use, and management institutions. The Rio Grande is the only renewable regional water source. All waters in this stretch originate in the United States and are the result of snowmelt from the Colorado Rocky Mountains, limited rainfall, and agricultural and municipal discharges into the river. Figure 4 provides a map of the basin. On this stem of the river two major reservoirs manage flow: Elephant Butte is a storage reservoir and Caballo is a regulating reservoir. Elephant Butte is approximately 125 miles north of El Paso and Caballo is about 25 miles south of Elephant Butte; both are operated by USBR. The average combined annual release over the life of the project has been 790,000af to United States irrigators. Rio Grande waters provide irrigation supply for approximately 178,000 acres of land in EBID and EPWID#1, 25,000 acres in the Juárez Valley, and 18,000 acres in Hudspeth County, which is managed by the Hudspeth County Reclamation District (HCRD). Hudspeth irrigation waters are composed primarily of drainage waters. The river is dry most years from Ft. Quitman-Cajoncitos until the Río Conchos enters the main stem near Big Bend National Park.

Table 8. Water Sources, Use, and Management Institution

Jurisdiction	Las Cruces, Doña Ana County, New Mexico		El Paso City & County, Texas		Ciudad Juárez, Chihuahua	
Use	Municipal-Industrial	Agricultural	Municipal-Industrial	Agricultural	Municipal-Industrial	Agricultural
Source	Groundwater	Surface water & Groundwater	Surface water & Groundwater	Surface water	Groundwater	Surface water & Groundwater
Amount	Las Cruces: 93% Mesilla Bolson	87% Rio Grande	44% Hueco Bolson	100% Rio Grande	100% Hueco Bolson	34% Rio Bravo 33% Hueco 33% wastewate return flow from M&I (2000)[2]
	7% Jornada del Muerto	13% Mesilla (2000) [1]	18% Mesilla Bolson			
			38% Rio Grande			
Annual Water Use	Las Cruces: 20,680af	545,435af (2000) [1]	41.6 billion gallons	264,127af (2000) [1]	150 million cubic meters	173,500 af (2000)[2]
	246gpc/d (2000)[1]		159gpc/d (2000) [2]		330 l/h/d (2000)[3]	
Management Institution	Water Resources Department	Elephant Butte Irrigation District	El Paso County Water Utilities	El Paso County Water Improvement District #1	Junta Municipal de Agua y Saneamiento	Valle de Juarez Distrito de Riego 009
Ownership	Surface water & Groundwater: State, NM State Engineers		Surface water: State, TCEQ Groundwater: Landowner		Groundwater: Nation – Landowner can drill subject	
					Surface water: Nation, CNA	

[1]Paso del Norte Water Task Force, [2]El Paso Water Utilities, [3]Luis Mario Gutierrez

Groundwater has provided the majority of the municipal and industrial supplies since the region was settled. The primary sources of groundwater are the Hueco and Mesilla Bolsons, and the Rio Grande Alluvium. These span the international border and are used for both municipal and agricultural purposes. For a full description of the structure, water quality, and available supply of these aquifers, see *Transboundary Aquifers of the El Paso/Ciudad Juárez/Las Cruces Region* (Texas Water Development Board and New Mexico Water Resources Research Institute 1997). Traditionally, municipal water was extracted from the bolsons—as was agricultural water during times of drought—while the river was maintained for agriculture since it is legally and historically allocated to the growing of crops. All three communities are reliant on these aquifers for the majority of municipal and industrial water. Until recently, groundwater was an inexpensive, dependable source of water. The Mesilla Bolson is

the principal source of groundwater for southern Doña Ana County, and a limited source for El Paso. It also has the potential to provide water for Ciudad Juárez; however, the exact amount and quality of that water is unknown. The Mesilla Bolson is a stream-related aquifer whose health is tied to the health of the Rio Grande. The extent to which regional development of the river will impact this basin still needs to be determined. The Hueco Bolson is the only current source of municipal water for Ciudad Juárez and a primary source for El Paso. It is a fossil aquifer that is being mined. The Rio Grande Alluvium is shallow, approximately 200 feet deep, and water from this alluvium is generally of poor quality (Lyndon B. Johnson School of Public Affairs 1999).

One of the primary regional water concerns is the municipal water supply. As municipal and industrial demand has increased, groundwater basins are becoming contaminated or depleted (Hetrick 1989; Sharp 1998). Due to increasing salinity and declining groundwater levels, serious shortages are expected in the near future. Estimates are that at El Paso's historic rates of withdrawal, potable water in the Hueco Bolson will be exhausted by the year 2025 (El Paso Water Utilities Public Service Board 2001). Pumping in the Ciudad Juárez portion of the Hueco Bolson, where there is less fresh water available overall, is almost double that of El Paso pumping. Ciudad Juárez is expected to experience a major deficit in the Hueco by 2004 (Gutierrez 2000). Water providers, therefore, have been forced to look for means to extend the limited reserves in the bolson, use surface water, and seek alternative supplies. Although Ciudad Juárez and Las Cruces are still dependent on groundwater, El Paso is using the Rio Grande to meet demand during the irrigation season. Ciudad Juárez is investigating the transfer of its 60,000af allotment of surface water from agricultural to municipal uses; however, these waters would be subject to seasonal availability and would require the alteration of the existing legal framework that allocates surface water to irrigators. Additionally, Ciudad Juárez is looking at use of the Mesilla Bolson to supplement municipal supplies through a project that is anticipated to cost $30 million and yield 25,567af annually (Gutierrez 2000).

Figure 4. Hydrography of the Rio Grande/Río Bravo Watershed

Source: Drafted by Carol Placchi, modified from U.S. State

Unique Regional Challenges

Finite water resources have combined with a rapidly expanding population to help define the regional water situation. Regional water problems are therefore closely linked to rapid population growth. Estimates are that the regional population will double in 21 years, with most of this growth in the urban areas of Ciudad Juárez. Growth has combined with high levels of poverty to create a situation where water distribution has not kept up with water demand. Under current use and allocation scenarios water demand is outstripping available supplies. The agriculture sector uses approximately 78% of the total water in the region while growing demand lies in the urban sector. Use among the urban sectors is also disproportionate, with Ciudad Juárez having the lowest per capita use at less than 100 gallons per capita per day (gpc/d) and Las Cruces having the highest at more than 240gpc/d. As well, the U.S. allocation is approximately 90% to 93% of available surface waters.

These allocation structures and growth patterns have impacted El Paso, Ciudad Juárez, and Las Cruces individually, and increased competition between sectors, communities, states, and nations. They have had an effect on how these communities relate to each other and surrounding areas. Communities surrounding El Paso fear that the city will look their way for additional groundwater as water supplies in the Hueco Bolson become harder and more expensive to access. This is a not entirely unfounded as El Paso's Public Service Board has purchased a 25,000-acre ranch approximately 150 miles south of the city as a contingent groundwater supply. They have done the same with several large tracts in New Mexico for their water rights. And, competition for Rio Grande water has increased significantly as growing urban areas face serious shortages of groundwater and look to the river for replacement and new supplies. Rising environmental concerns have also focused on a need for water to be allocated for instream flows. The treaties and the Rio Grande Compact did not provide water for instream flows or for the preservation of species. In 1994, the Rio Grande Silvery Minnow, whose habitat is in northern New Mexico, was declared an endangered species. This surface water allocation to agriculture has created friction over water distribution between use sectors (Bath 1986; Hetrick

1989; House 1982; Paule 1996). Although increased competition, to this point, has not resulted in an alteration of the allocation framework, small-scale transfers of water from agriculture to municipal use have been achieved through the leasing of water rights. Finally, because of asymmetry in growth and allocation, Mexican urban areas are experiencing pressure on water resources at a faster rate than U.S. communities; however, the potential for using agriculture waters to address municipal-industrial concerns is highest in the U.S. portion of the Paso del Norte.

Watershed-based planning and management would seem to be an optimal approach for the region since it provides a defined physical space and is thought to optimize the supply for human and ecosystem use (National Research Council 1999). Water resource planning in the region, however, is not held in any single authority, and no comprehensive plan exists for the area. Water planning is segmented by jurisdictions. All of the major jurisdictions currently have, or are in the process of generating, water plans, as noted in Table 9. Although the different planning mechanisms address similar aspects, such as population, land use, water supply, and water demand projections, how they deal with these issues varies. A review of the documents shows that population projections, land use, water use estimates, and even planning horizons are different for the various plans. Additionally, the assumptions and necessities inherent to irrigators and municipalities help to make many of these plans incompatible.

Innovative Cross-border Efforts

Several innovative efforts to address regional water concerns have arisen in the last two decades. The New Mexico-Texas Water Commission (NMTWC) is one such endeavor. The commission was formed in 1991 out of the agreement that settled a long, bitter, and expensive lawsuit between Texas and New Mexico over Texas' use of New Mexico groundwater. El Paso sued for the right to drill wells in the nearby Mesilla Bolson and pump that water over the New Mexico state line for municipal use. Out of this litigation came the commission, which was established to examine methods to plan cooperatively for surface water use between Texas and New Mexico. The parties agreed that instead of looking to Doña Ana County groundwater for

additional resources, El Paso would continue to broaden its options by looking to surface water allocations already made to Texas irrigators. Parties to the commission therefore work together to investigate the use of Rio Grande waters for municipalities. The commission has proposed the El Paso-Las Cruces Sustainable Water Project to achieve that goal. The project is a series of canal improvements, surface water treatment plants, distribution systems, and aquifer storage and recovery infrastructure. Environmental impacts have already been examined and the project sponsors, El Paso Water Utilities, and IBWC, are seeking the necessary permits.

NMTWC is unique in that it is a quasi-official cross-border water management effort. Its mission and the stakeholders involved, however, are clearly defined and structured by the settlement agreement, thus making it difficult for other parties and alternative concepts of water allocation, management, and planning to emerge. Until recently, the effort did not include environmental interests, but it changed because of continued pressure. As a result, the commission formed the Paso del Norte Watershed Council to provide input on mitigation and other environmental issues associated with the Sustainable Water Project. The environmental impact process also brought public input into the project as a requirement of an Environmental Impact Assessment.

Because of the history of the commission, Mexico is not included in either the commission or the subsequent Sustainable Water Project. Although there is recognition and discussion among members that effective planning cannot occur without Mexico at the table, at this time, NMTWC is still a New Mexico-Texas entity. Another point to be considered is that while the commission has been successful to date in project planning, it has not necessarily made relations between El Paso and Doña Ana County more relaxed, nor has it eliminated tensions between irrigators and utilities or lessened the regional tendency toward litigation. Part of the City of El Paso's long-term plan for contingency supplies involves the above-mentioned New Mexico tracts purchased for their water rights. Lawsuits are threatened as El Paso looks for ways to transfer water from those lands to Texas for municipal use.

Table 9. Paso del Norte Water Planning Efforts

Plan Name	Entity & Area Covered	Significant Aspects
Plan Maestro de Ciudad Ju rez	Junta Municipal de Agua y Saneamiento Ciudad Ju rez	Assessment of potable water services and supply, water reuse, transfer of agricultural waters to municipal uses Plan to 2020
Do a Ana County Regional Water Plan	New Mexico State University, EBID, Las Cruces Water Resources Department, Do a Ana County Do a Ana County	Water demand and use, surface and ground water supplies, no projections of future water sources Plan to 2035
Regional Water Plan — in progress	Lower Rio Grande Water Users Organization Portion of Sierra County & Do a Ana County	Water rights, surface and ground water aspects, water supply and demand, water quality and conservation issues Plan to 2040
Las Cruces Water and Wastewater System Master Plan	Las Cruces Water Resources Department Las Cruces	Municipal and irrigation water demand and supplies, continue to rely on groundwater for municipal uses Plan to 2015
Far West Texas Regional Water Plan	Far West Texas Planning Group, Texas Water Development Board 7 west Texas counties	Mandated under Texas Senate Bill 1, all regions have a plan, water supply and demand, no transfer of water rights, addresses drought of record conditions Plan to 2050
El Paso-Las Cruces Sustainable Water Project	New Mexico-Texas Water Commission El Paso & Las Cruces	Year round drinking supply through surface water treatment plants for municipal use, and aquifer storage and recovery systems
Tri-regional Planning Group	Junta Municipal de Agua y Saneamiento, Las Cruces Water Resources Department & NM regional Water Users, El Paso Water Utilities Ju rez, El Paso, Las Cruces	Surface water treatment plant for Mexico allocation and some additional waters for US

Source: Authors

Several other efforts to bring about regional water planning and management in the region have sprung from universities, private foundations, and NGOs. The concept of the university as an honest broker for regional dialogue is fairly well-established in the border

region and has been effective in achieving results in other areas. One of the first efforts in the Paso del Norte region was the University of Texas at El Paso's Binational Water Project (BWP), supported by the Ford Foundation. This project began in 1990 as an attempt to bring together water planners and policymakers from both sides of the border to share information, gain understanding, and establish a long-term dialogue. The BWP worked from the premise that community-based dialogue, local transborder networks, and data and information sharing were crucial to achieve regional planning and management of resources. The success of the BWP was its ability to provide an initial space for dialogue that would lead to the understanding of stakeholder concerns and needs, although very few concrete results arose from this endeavor.

Perhaps the most innovative and successful cross-border effort related to regional environmental issues is the Paso del Norte Air Quality Task Force (PdNAQTF), which was initially supported by the Environmental Defense Fund (now, Environmental Defense). The task force emerged in 1993 due to community concerns over unhealthy levels of PM_{10}, ozone, and carbon monoxide in the Paso del Norte region. The PdNAQTF is a "ground up" initiative that includes both governmental and non-governmental interests at all levels. The motivation behind this effort was the acknowledgment that air was shared in an "airshed" and thus could only be managed effectively if all parties worked together regardless of jurisdictional boundaries. The ultimate goal of the PdNAQTF is the development of an air quality district that would operate across boundaries to reduce regional pollution. Immediate goals, however, were the development and implementation of doable, applied projects that would have a direct impact on regional quality of life. In 1996, the Joint Advisory Committee on Air Quality Improvement for the El Paso-Ciudad Juárez-Doña Ana County Air Quality Management Basin was formed by the establishment of Appendix I to Annex V of the La Paz Agreement. The Joint Advisory Committee signifies federal-level recognition on the parts of the United States and Mexico as to the importance of joint management of air resources in the region, and paves the way for a regional air quality district. The Task Force continues to work toward the creation of that district.

The success of the PdNAQTF provides a model for other cross-

border environmental efforts. The PdNAQTF was successful in part because of a bottom-up approach that focused on community-level tangible results without losing sight of larger management goals. It is an inclusive binational group involving local, state, and federal agencies, as well as non-governmental health and environmental stakeholders. Additionally, it chose and implemented projects that had an impact on regional air quality and demonstrated, with the implementation and success of these projects, that jurisdictions could work together toward common goals. The PdNAQTF provided leadership and focus for regional efforts related to air quality, and it integrated governmental, non-governmental, academic, and regulatory concerns over air pollution on a level playing field.

However, the success of the PdNAQTF cannot necessarily be transferred to regional water issues. Attempts at cross-border water planning and management have been less favorable. Elemental differences exist between air and water both in the management and ownership of the resource, as well as in the resource itself. Air is not the finite resource that water is. Water, unlike air, has a well-defined historical structure of controls, management practices, and ownership patterns that are difficult to alter. Finally, there is a long history in the region of water conflict, primarily in the form of litigation. Nonetheless, innovative efforts currently are underway in the region that deserve recognition.

One such effort is the Paso del Norte Water Task Force (PdNWTF). Although many of the goals are similar to those put forth by the BWP, there are differences in approach. The PdNWTF attempts to promote sharing information and understanding among participants in order to avoid duplication among members, and to encourage coordination in individual planning and management efforts. The members of the PdNWTF are a small group of binational stakeholders that primarily includes municipal, irrigation, and private water interests, the assumption being that a small core group is necessary for meaningful results. An academic-scientific Support Team assists the task force.

The PdNWTF was convened by IBWC in 1999 and initiated by the Houston Advanced Research Center with support from the Hewlett Foundation. It had initial success in a series of dialogues where members visited each other's facilities to gain an in-depth

understanding of management and planning operations and concerns. The most important product of these visits and related efforts was the publication of a comprehensive report on regional water resource issues, *Water Planning in the Paso del Norte: Toward Regional Cooperation*. At present the PdNWTF Support Team has proposed a series of projects that attempt to provide tangible results to address specific regional water concerns. These include:

- An investigation of municipal-agricultural joint projects, with California as an example
- A regional water plan
- An assessment of regional water markets
- Expansion of a regional computerized seamless water resource map of the Paso del Norte region toward a GIS database that can be used by all parties

The implementation of these projects has the potential to further regional dialogue related to water. PdNWTF efforts, however, need to be expanded to include the public in this dialogue if it is to be meaningful in the long term.

Two areas where transborder collaboration has been most effective are the domain of research and NGO-based environmental and cultural efforts. A good example of cooperative research efforts is the Transboundary Aquifer Assessment Program, which is a collaborative regional study supported by IBWC-CILA. This project builds on 1997's *Transboundary Aquifers and Binational Groundwater Data Base Report—City of El Paso-Ciudad Juárez Area*. This report was the culmination of a multi-year, multi-agency effort that included IBWC-CILA, JCAS, EPA, Texas Water Development Board, and New Mexico Water Resources Research Institute. It collected data on groundwater hydrology, historic water levels, pumping trends, water quality, and current and future extraction estimates. It provided data and GIS-based maps for dissemination to all parties and the public. It did not, however, make a detailed analysis of the findings nor did it provide recommendations as to future groundwater management options. The official, State Department-level of this project made both the effort and the report important to collaborative regional efforts.

The Rio Grande/Río Bravo Basin Coalition is an NGO-based

environmental organization that grew out of university efforts in 1994 to bring together individuals and organizations from throughout the basin to share information and develop long-lasting networks. These coordinated efforts grew until the coalition was officially registered as a non-profit in 1996. The coalition currently has a board of directors, more than 50 NGO member organizations, and two co-directors who represent the United States, Mexico, and the Pueblo nations. It is committed to multi-cultural, multi-national efforts that unite the basin and promote sustainability and environmental health. It operates through the building of networks that operate at the local levels and across the watershed, the promotion of social and cultural diversity, and the creation of dialogues through a democratic process. This approach has worked well. The coalition currently has a paid staff, maintains an informative electronic listserv and website, and sponsors numerous events to raise environmental and cultural awareness about the basin and its inhabitants. The democratic, binational, basin-wide approach of the Rio Grande/Río Bravo Basin Coalition was difficult to mold initially, but has proven to be a successful model for dialogue between non-governmental entities.

The constraints to regional planning and management continue to be large. These include different legal systems that regulate water, historical use and ownership patterns, the litigious nature of water conflict between Texas and New Mexico, rural-urban and municipal-agricultural tensions, and rapid regional growth that requires both short-term actions and long-term decisions. However, the efforts outlined above show the potential for locally driven projects to build toward coordinated regional planning and management. These efforts provide several lessons.

Although the above efforts demonstrate that it is easier and more effective to cooperate on engineering and scientifically-based projects and studies, they also indicate that as the dialogue builds, larger and more sensitive technical concerns can be addressed. Often the collection of data provides a non-threatening avenue to cooperation concerning the very difficult issues surrounding regional water management. The sharing of information and building of formal and informal dialogues is an important step toward coordinated regional efforts. However, the decision on who participates, or more right-

ly stated, the exclusion of parties to that dialogue, is a concern. Many of the current efforts recognize, or are beginning to recognize, the need for regionally-based solutions that include all stakeholders. Often, however, the public and environmental voices continue to be excluded or are minor players in regional water discussions. Additionally, regional efforts are still highly fragmented around jurisdictions and are hampered by the existing legal structure that allocates water in the region. Although it is evident that litigation has not solved the problems in the region and that cooperative solutions save time and money in the long-term, litigation continues to have a large presence in the region.

Conclusions

Given the in-depth examinations of three twin cities that lie within three important border river basins, what general trends or lessons learned can be drawn from these case studies to provide insight in other regions on the border? These case studies have examined the utility of employing a watershed perspective to explore a complex array of water resource management challenges in border basins that include issues of water supply, wastewater treatment and management, flood control, and general water quality control and management. Watershed-based approaches and institutional organizations have provided valuable insight and acted as management frameworks that have been useful in all the basins employed. These include efforts like San Diego-Tijuana's Border Water Council, which has a fairly formal connection to existing governmental institutions like IBWC-CILA, SANDAG, and the San Diego County Water Authority. Conversely, less-formal efforts, including those in the Santa Cruz Active Management Area in Arizona, which are based on public input and participation, and the Paso del Norte Water Task Force and Paso del Norte Watershed Council, which also share similar structures and qualities, have been effective. In general, these types of watershed-based efforts have an important role to play in innovations toward improved water resource management along the U.S.-Mexican border.

What of more specific lessons that may have utility in other border regions? Looking at the federal levels of governments responsible for foreign relations on an international basis, several efforts are worth reviewing and exploring for their usefulness along the border. The Border Liaison Mechanism (BLM) that was so important in the formation of the Border Water Council in San Diego clearly has a role to play in bringing agency officials at all levels of government on both sides of the border together in a dialogue on water resource issues. One unanswered question that remains is: To what degree can this effort be applied in other regions?

BECC has also played an important role in fostering a greater level of public participation through its public participation mandate and by presenting a formal process through which this participation must be advanced to gain BECC certification. This process has also been partially responsible for a rather dramatic change in the manner by which IBWC-CILA conducts water resource planning and engineering works along the border. Both have worked harder to actively and openly include public input into their operations, and this is a welcome change from the past practices of these important agencies. Although BECC, IBWC, and CILA have received a fair amount of criticism that these efforts have not yet been enhanced, there is clearly a welcome change in how these agencies do business that is consistent with, if not openly supportive of, watershed-based initiatives along the border.

Examining the local and regional level of interaction along the border, it is clear an even wider array of innovations may be useful in a broader context. The San Diego-Tijuana region has seen numerous important research efforts advanced through partnerships between regional universities, local water and public works utilities, and state and government agencies, and these efforts highlight the role of partnerships across levels of governments and across the border. Perhaps one of the most successful outcomes in this region is the binational aqueduct planning process that came from the pioneering work of the Border Water Council. This effort also reinforces the importance of working across levels of government and across the border, and is an important and exciting development to follow. An unanswered research question to be examined in the future is: To what degree (and how) can the efforts of the Counsels General, the Border Water Council, an active association of governments such as SANDAG and regional water utilities be borrowed by

other regions to foster innovation on other cross-border water resource problems?

The Santa Cruz Active Management Area in Arizona also offers valuable lessons on how regionally grounded approaches that have active public participation and input can make progress on difficult water resource management challenges. Through this type of approach, stakeholders in the region have made progress on a water rights adjudication that saw considerable barriers over a long period of time in a traditional legal and litigation-based framework. Related to this is the potential development of some form of binational groundwater replenishment district that would take into account hydrologic connectivity of groundwater and surface water resources across the international border, and the complex manner by which wastewater and raw water supplies may need to be managed together. Future research should track these developments to determine how successful they may become and what lessons can be extracted and ported to other basins.

Looking to the Paso del Norte region, there are different configurations of institutions asking somewhat similar questions. Water supply challenges in this region involve conjunctive management of groundwater and surface waters, and a range of institutional innovations presently wrestle with the challenge of how to provide an adequate water supply to an actively growing region with dwindling groundwater resources and competing demands for finite, yet renewable, surface water resources. The model of a "task force" that brings regional stakeholders and experts together has been successful in the region. The Paso del Norte Air Quality Task Force has been successful in advancing a meaningful dialogue on air quality management issues, and the Paso del Norte Water Task Force has advanced similar discussions toward regional management of water resources. We have also seen innovations emerge from a protracted legal process in a manner similar to the situation in the Santa Cruz Active Management Area in Arizona. The New Mexico-Texas Water Commission brings together the large agricultural irrigation districts of the region with water utilities and university researchers for a discussion of regional water resource management, and the Paso del Norte Watershed Council specifically advances important dialogue on related environmental issues. Although not all these efforts

employ a strict watershed-based perspective, all benefit from explicitly regional approaches likely to be useful elsewhere.

The role of university-based research is an important theme in many efforts across the three regions. This investigation has illustrated the value of universities in participating in cooperative efforts across the border, and in some cases, university involvement is a key element in getting stakeholders to communicate across institutional and international borders. University-based research can also answer important applied scientific questions that, in turn, can help in the development of a regionally focused sustainability science approach, as advanced by Kates et al. (2001). Such a science-based perspective is connected to regional political agendas for development activities and is also connected to regional nature-society relationships—connections that are especially important in developing regions like the U.S.-Mexican borderlands (Kates et al. 2001). Related to this ability is the perception in many cases that universities can provide an unbiased perspective to complex problems that is useful in moving past the institutional and regional gridlock that often accompanies water resource challenges along the border.

These case studies have dealt with a wide range of water resource challenges in several regions of varying scales and configurations. Watershed-based efforts have clearly aided in helping answer many difficult questions, although many questions either remain unanswered or developed out of this initial inquiry. Even so, insights gained from this work have some small but important utility in future investigations of shared water resource management and other areas of collaboration along the U.S.-Mexican border.

Endnotes

[1] The term "riparian" refers to the banks of a river, stream, water way, or other body of water, as well as to plant and animal communities along such waters. Social scientists have also used the term to refer to human political jurisdictions that occupy the banks and drainage areas of these waters.

[2] In Mexico, important changes took place in the water institutions during this period. The first step was taken in the Federal Water Law of 1972, with the recognition of water's urban uses as the first priority over the traditionally favored agricultural uses.

The National Water Law (Ley de Aguas Nacionales) of 1992 reflected, in turn, important environmental and sustainability considerations and emphasized a more active participation of the private sector and the communities affected. The constitutional modifications of 1983 that supported the transfer of the management responsibilities behind the urban water services to the state and local governments around the country (Castro 2001) are also worth mentioning.

[3] IBWC has frequently been criticized for being too technical in its orientation and for its top-down structure, which does not allow any public participation in the commission's areas of jurisdiction (Mumme 1993; Spalding 1999).

[4] "Twin cities" are interrelated urban areas spatially contiguous to each other on both sides of the international border. "Boundary cities have become so functionally intertwined that their futures are inextricably bound, whether the two national governments are able or unable to devise formal procedures for addressing border related problems" (Ham-Chande and Weeks 1992).

[5] The Bracero Program was a guest worker program that formalized the flow of Mexican workers migrating north during World War II to fill the need for labor in the United States that resulted from large numbers of working-age American males entering the armed forces. The Bracero Program ended in the early 1960s, resulting in large numbers of Mexican workers being repatriated to Mexico.

[6] Maquiladora, or in-bond, plants are foreign-owned assembly plants that initially used lower-priced Mexican labor to assemble goods from imported components (Herzog 1990). Yet, NAFTA has allowed these plants to be full-scale production facilities (Koci-Pavlakovic 1994). In-bond refers to the lack of access to Mexico's domestic markets for the components involved (Dillman 1976). Maquiladora is a name reflecting the Spanish word *maquila*, the portion of flour retained by the miller as payment for grinding a client's grain (Herzog 1990).

[7] For analysis purposes, the San Diego-Tijuana region is usually defined as comprising San Diego County and the municipality of Tijuana. Its core is the urban conglomerate formed by the cities

of San Diego and Tijuana, together with a number of adjacent communities on the U.S. side of the border. In the case of water and environmental issues, the municipality of Rosarito is also considered (Ganster and Sánchez 1999).

[8] The 1990s witnessed dramatic changes in the growth of San Diego as an effect of the recession that hit the economy. This was due primarily to the disappearance of the defense industry in the area and the corresponding out-migration.

[9] Since its creation in 1998, BWC's activities have encompassed a wide range of objectives, among them, the enhancement of cross-border cooperation in delicate environmental issues through the use of a watershed approach.

[10] To assign water property rights, California uses the "reasonable and beneficial use" system, which is a combination of the appropriator's beneficial use of the water and the riparian landowner's reasonable use of the water (Dzurik 1990).

[11] The property rights of the resource fall entirely on the state. Individuals can only have access to temporary concessions.

[12] Article 115 of the Mexican Constitution bestows on state governments the ultimate decision to decentralize services to the municipalities. In the case of the potable water and sewage services, most state governments have kept the responsibility of the service at the local levels, pointing to the low-levels of operational efficiency shown by the municipal agencies.

[13] The Public Authority represents the usual and more extended form of governmental intervention for the management of public services in countries of Anglo Saxon origin. Its structure mixes elements of private enterprise nature, giving them the appearance of hybrid organizations (Mitchel 1992).

[14] The major seller of imported water for the SDCWA is the Southern California Metropolitan Water District (MWD), a Los Angeles-based regional agency that serves various counties in the state. Colorado River water is transported from Lake Havasu to a reservoir in Riverside County (Lake Matthews) via the 242-mile Colorado River Aqueduct. Water from Northern California is transported to the south from the delta of the Sacramento and San Joaquin Rivers via the 444-mile California Aqueduct. The water from both is blended at Lake Skinner and then sent to the

San Diego area by means of the two aqueduct systems operated by the SDCWA.

[15] Water from the Colorado reaches Tijuana through the Colorado River-Tijuana Aqueduct (in Spanish ARCT), a 118-mile pipeline connecting Irrigation District No. 14 in the Mexicali Valley with the El Florido treatment plant in the Tijuana area.

[16] These are usually a number of wells located in the Tijuana River and Alamar River beds within the urban zone. A third source, the Abelardo L. Rodríguez Dam located in the southeast part of the city, supplements the available supply only in periods of unusual heavy rain.

[17] Another 51,000af are assigned from the underground reservoirs in the state.

[18] Based on the number of connections for residential service in December 2001 (CESPT 2000-2001).

[19] The Tijuana area is served by two wastewater treatment facilities: the International Wastewater Treatment Plant on the U.S. side, and the San Antonio de los Buenos treatment plant operated by CESPT. In the first case, the treatment level of the plant has not been upgraded yet to the secondary level, as accorded by the two countries in IBWC-CILA Minute 283. The San Antonio plant has exceeded its capacity by about 12%, and its rehabilitation is pending (CNA 2000).

[20] This agreement with the MWD will permit the delivery of those 200,000af via the Colorado River Aqueduct.

[21] Currently there is already a proposal submitted by a consortium of private firms to construct a binational aqueduct, but so far there is no commitment on the part of either side to review or promote the project.

[22] Although the use of recycled wastewater in the San Diego area goes back to the 1960s, with the experience of the Padre Dam Municipal Water district, its consolidation on a larger scale has followed an uneven path. First, no regional coordination existed among the local water agencies until the SDCWA took the lead and developed the San Diego Area Water Reclamation Program in coordination with the area's agencies. A second obstacle faced by the proponents of reclaimed water was the initial opposition by

some agencies and water districts. This opposition was a reaction to negative public perceptions about the use of recycled water beyond the usual irrigation application (i.e. the toilet-to-tap con- cept).

[23] IBWC-CILA Minutes are formal agreements signed by senior staff of IBWC and CILA, who are also official representatives of the U.S. Department of State and Mexico's Secretaría de Relaciones Exteriores. These Minutes act as treaty mechanisms toward resolution of specific boundary and water resource problems along the border and carry the full weight of international law.

[24] Active Management Areas (AMA) were established under terms of the 1980 Arizona Groundwater Management Code as subregions within which groundwater resources were experiencing major overdraft. Specific management goals were developed for each AMA, with the overall goal being a 100-year assured water supply for areas relying heavily on groundwater resources (ADWR 1998 and 1999). The Santa Cruz Active Management Area is located adjacent to the U.S.-Mexican border, hence it is functionally linked to the Ambos Nogales region.

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VII

Evolving Political Institutions: A New Water Policy and its Impact on the Border Region

Daniel McCool

Abstract

All dams are temporary. Whether a dam is going to be decommissioned is not a question of if, but of when. Siltation, structural weaknesses, and changing social values will eventually combine to bring down the structures built in the dam-building era. Thus, a border region excessively dependent on dams is courting future disaster. As well, scarcity begets regulation. As water grows scarcer in the face of ever-increasing demands, government control over water will grow more pervasive and more restrictive. Individual freedom to use water will be dramatically curtailed.

That bleak assessment can be balanced against an alternative vision, presented here, called the River Commons. This is where river ecosystems—not just water—are managed primarily for the public good, not just for the economic gain of a few. Water use will focus on non-exclusive, non-consumptive uses. Such uses will serve the greatest number of people. Each individual will have the same potential access, which is determined by individual desires and values so long as that use does not appropriate the commons to the extent that it robs others of its value. The River Commons would be

governed by an open, participatory process that would stand in stark contrast to past traditions of closed, exclusionary politics.

Desarrollando Instituciones Políticas: Una Nueva Política y su Impacto en la Región Fronteriza

Daniel McCool

Resumen

Todas las presas son temporales. No es cuestión de que si una presa se va a cerrar o no, sino cuando. Sedimentación, debilidad estructural, y cambio de valores sociales se combinarán para destruir las estructuras hechas en la época de su construcción. Así que, una región fronteriza que depende excesivamente de presas tendrá desastre en el futuro.

La escasez produce regulación. Mientras la escasez de agua aumenta con el crecimiento de demanda, el control del agua del gobierno será más penetrante y restringido. La libertad de usar el agua será cortada dramáticamente. Así que, como una sociedad, hay que balancear el deseo de población infinita y crecimiento económico con nuestro deseo de libertad personal.

Esta valoración desolada se puede comparar con una visión alternativa que llamo River Commons. En lo cual el manejo de los ecosistemas de los ríos—no del agua solamente—está hecho para el bien público y no para el bien económico de unos pocos. El uso del agua se enfocará en los usos no exclusivos. Estos usos servirán un numero mayor de gente. Cada individuo tendrá el mismo potencial de acceso, determinado por los deseos y valores individuales por lo tanto que no se apropia de los comunitarios, robando el valor de los demás. River Commons será gobernado por un proceso transparente y participatorio que será muy distinto de las tradiciones políticas cerradas y exclusionarias.

Introduction

It is often said that water flows uphill to money, but that is not necessarily true. Water policy has often favored uses that are economically irrational, and the largest water consumers are not necessarily the wealthiest. Rather, politics determines who gets water and who pays for it, as evidenced by the highly institutionalized political system of distributing water and water development funding that has controlled western water policy for more than a century (Reisner 1986; Gottlieb 1988; Bates et. al 1993; McCool 1994). In that system there were very clear winners and losers. The winners included irrigators, hydropower producers, and special water districts; the losers were the environment, the taxpayers, and Native American Indian tribes. But the traditional politics of allocating water has collapsed: That "era has come to an end with much attention to [water] quality and ecosystems" (Rogers 2000). Economic pressures, changing demographics, issues of racial justice, and increasing emphasis on environmental protection—profound changes that are discussed in detail in the Western Water Policy Review Advisory Commission's 21 reports, available at http://www.den.doi.gov/wwprac—have combined to move the United States to the cusp of a new era in federal water policy.

This new era will have profound consequences for the U.S.-Mexican border region, especially with regard to the Colorado River and Rio Grande basins, the major river basins in the region. The U.S.-Mexican border is an arid region where decisions about the allocation of water have a direct impact on every aspect of life. The Colorado River and the Rio Grande are the lifelines of the communities along the border. Both rivers are highly developed with multiple dams and diversion structures. And both rivers are closely regulated by a complex panoply of treaties, compacts, court cases, statutes, and state and local laws. The politics of water in the southwest is Byzantine, complicated, and in the throes of fundamental change (Bates et al. 1993; World Commission on Dams 2000; Grossman 2002; McCool 2002). Anyone with a stake in these rivers needs to understand how these changes will affect them.

This chapter analyzes how new priorities are replacing traditional structural solutions to water problems. It describes the old net-

work of water interests—the iron triangle—and explains how changing political forces worked to undermine traditional federal water policy and replace it with a new agenda focused on water management, which, in turn, is being replaced by an ecosystem agenda focused on river restoration and dam removal. The chapter speculates about how this new federal water policy will affect the future of the border region.

The Dam Building Era

For 200 years the United States pursued a water policy exclusively focused on controlling rivers with dams, diversions, levees, and other human-made structures. The underlying belief was that more construction and development would solve all the nation's water problems. More than 75,000 dams, ranging from 700-foot behemoths to small weirs, have been constructed in the United States (Collier, Webb, and Schmidt 1996). By the 1970s, at the height of the dam-building era, the U.S. Army Corps of Engineers had constructed 19,000 miles of waterways, 500 harbors, 350 reservoirs, 9,000 miles of flood control structures, and 7,500 miles of "improved" channels. The U.S. Bureau of Reclamation had constructed irrigation works that serve 11 million acres, 50 powerplants, 345 diversion dams, 14,590 miles of canals, 990 miles of pipelines, 230 miles of tunnels, 35,160 miles of laterals, and 15,750 miles of drains (McCool 1994). The United States was not alone in its quest for countless dams. According to the World Commission on Dams, 45,000 large dams (defined as more than four stories high) have been built and half of all rivers have at least one large dam. Mexico has also seen considerable dam development (Barkin and King 1970).

The political alliance in the United States that drove the water development agencies for the first 200 years of their existence was a prime example of what political scientists and journalists call the "iron triangle." Iron triangles are alliances of convenience between congressional committees, government agencies, and interest groups that have common goals in public policy (Ferejohn 1974; Ripley and Franklin 1984; McCool 1998). For members of Congress, the goal is getting re-elected and collecting campaign donations. For government agencies, it is a desire to increase budgets and expand operations. For interest groups, the goal is to funnel public benefits to their members, be they funding, special privileges or rights, tax loopholes, or special services. When these three "corners" of the iron triangle work together, they can be more effective in meeting their goals.

But iron triangles can thrive only under certain circumstances. Two elements are essential. First, they need a political atmosphere of relatively low conflict, which, when it arises, is resolved by expanding the distribution of public benefits to include potential opponents. As long as this strategy is effective, conflict remains low and the iron triangle is unimpeded. The second element concerns the nature of the public policy that is the focus of the iron triangle's efforts. For this policy to be effective, the benefits must be concentrated among a specific set of beneficiaries—voters back home, supporters of special interests, and campaign contributors—but the costs must be widely distributed, and preferably hidden. That way, the people who receive the benefits of the iron triangle do not have to pay for it; this combination makes for strong alliances in politics (McCool 1998).

The ink was hardly dry on the U.S. Constitution when politicians realized that handing out local water projects, charged to the federal budget, was a great way to placate the voters and win the support of influential people. The U.S. Army Corps of Engineers, created in 1802, was one of the first federal agencies. As the nation expanded westward, the U.S. Bureau of Reclamation was created in 1902 to funnel federal water development money to that region. These agencies built water development projects with little or no regard for the environment because there was no political support for such actions within these very traditional iron triangles. As a consequence, the nation's waterways were subjected to significant environmental degradation. But when public values began to change in the 1960s and 1970s, the iron triangle was unprepared to respond adequately. The initial response was to resist change and treat environmentalists and other critics as implacable opponents (Palmer 1986; Gottlieb 1988; Andrews and Sansone 1983). But this was contrary to the true logic of iron triangles, which calls for placating opponents with an expansion of benefits. As a result, political conflict skyrocketed. The

costs of the dam-building era, both economic and environmental, went from hidden items in obscure budgets and reports to front-page news.

Inevitably this led to convulsive changes in the agencies and among supporters. The Corps and the Bureau were convinced, reluctantly, to expand gradually and include their former opponents in their network of benefits distribution. They have yet to abandon their old ways, but the future is clear, even to aging traditionalists—dams generate more controversy than electricity and powerful new political coalitions want water for cities, habitat, tourism, and recreation.

In a powerful act of symbolism, the Bureau of Reclamation was awarded Harvard University's "Innovations in American Government" award in 1995, noting that the scope of change at the agency was "unprecedented" and "went to the very heart of the organization." One bureau employee admitted that the agency had become "a New Deal agency in an e-mail age" and had needed the fundamental updating (Harvard Innovations 2002). The Corps also underwent a fundamental re-orientation. Without abandoning its traditional activities, it dramatically expanded its programs to include environmental protection. The agency's Chief of Engineers recently mandated a new set of "Environmental Operating Principles" to provide the Corps with "direction on how to better achieve its stewardship of air, water and land resources…." The first principle is a powerful statement about the Corps' new mission: "Strive to achieve environmental sustainability. An environment maintained in a healthy, diverse and sustainable condition is necessary to support life" (U.S. Army Corps of Engineers Operating Principles 2002). Twenty years ago the leaders of the Corps would have considered such a statement to be frivolous nonsense. Now it is their *raison d'etre*.

The Management Era

Today these agencies remain powerful and well-funded, but fundamentally changed. They have morphed from being solely water development agencies into water management agencies. In other words, their focus has shifted to include non-structural solutions

involving conservation, increased efficiency, as well as regulation and demand-control, rather than just pouring concrete to meet the needs of a narrow spectrum of the population. A brief look at their contemporary budgets reveals these new directions. Both the Corps and the Bureau of Reclamation requested appropriations for fiscal year 2001 to assist with the restoration of river systems. The Bureau requested $60 million for the California Bay-Delta Restoration Project and $38.4 million for the Central Valley Project Restoration Fund to restore fish and wildlife habitat. Typical of the Bureau's new direction is the CALFED program, which embodies both new missions and new decision-making processes. "The CALFED Bay-Delta program [is] a collaborative effort involving eighteen State and Federal agencies, and representatives of California's urban, agricultural, and environmental communities," according to the Budget of the United States for FY 2003.

The Corps' environmental programs accounted for 18.2% of its FY 2001 budget request, totaling $740 million. The projects included $91 million for Columbia River Fish Mitigation, $158 million to restore, preserve, and protect the Everglades and southern Florida, and $28 million for river restoration. The Columbia River basin project involves fish mitigation to increase fish population survival rates at the eight Corps dams on the Columbia and Snake Rivers. Perhaps the best known is the Corps' massive effort to restore the Kissimmee River, part of the Everglades and southern Florida restoration project (U.S. Army Corps of Engineers 2000). The total cost for the Kissimmee project is $518 million (U.S. Army Corps of Engineers 1999). The Corps is also responsible for administering some of the nation's most important environmental protection laws, including the Rivers and Harbors Act of 1899, the Clean Water Act of 1977, and the Marine Protection, Research, and Sanctuaries Act of 1972.

It is clear that these federal agencies have expanded their operations to include significant new environmental missions. However, they have not forsaken their traditional missions. There is still a strong engineering tradition in both agencies, with a predilection toward structural solutions. Their traditional political allies in the iron triangle still wield considerable influence in Washington. Thus, support for the environmental mission takes place within a context

that is not fully supportive of these new objectives. This has prevented the federal government from moving fully into the management era, and helps explain why the Corps and the Bureau were slow to respond to change. This dilatory response has, in effect, placed these agencies in a mindset that lags significantly behind the public, and will ensure that they are slow to adjust to new transitions and resistant to the next era of federal water policy, outlined below.

A Time of Transition

There is an old saying, "Land—they just don't make it like they used to." The same can be said for water and river ecosystems. As population and resource consumption continue to grow, these "commodities" will increasingly be in short supply, which in turn will dramatically enhance their perceived value. There is a basic rule in the politics of public resources: Scarcity begets regulation. This simple fact is driving the United States into another new era in water policy, characterized principally by river restoration and dam removal. This transition will be uneven and spasmodic. There will be variations among regions, presidential administrations, and social groups. But it is inevitable.

The population of the border region is growing at an unprecedented rate. Table 1 provides census data for the region for the last 20 years. Nearly 20 million more people are now living in the border states, an increase of nearly 50% in just two decades. On the Mexican side, millions of people have migrated to the border in search of jobs. Of course, there was no commensurate increase in river flows. There is no question that increasingly scarce supplies of water will severely constrain the use of that water. As a result, all water uses will become zero-sum—more water used for one activity will necessitate a commensurate reduction in water use for some other activity.

The zero-sum nature of water usage will pit user groups against each other. Those uses that are not economically justifiable or do not appeal to a broad spectrum of people will gradually lose political viability. This, in turn, will lead to a search for less-scarce resources to replace those in short supply.

This substitution will be accomplished through technological

advances and changes in the economy that increase efficiency and productivity. With regard to water, the uses most easily replaced will be irrigated agriculture, hydropower, and coastal urban water supply. Each of these will be discussed in detail.

Table 1. Total Population of States that Border Mexico

State	1980	1990	2000
Arizona	2,716,546	3,665,228	5,130,632
California	23,667,764	29,760,021	33,871,648
New Mexico	1,303,302	1,515,069	1,819,046
Texas	14,225,513	16,986,510	20,851,820

Source: U.S. Census 1990, 2000

Irrigated Agriculture

Irrigation in the American West expanded well beyond an economically rational level because of enormous subsidies. Farming operations that would lose millions of dollars annually if they paid all their business overhead (and environmental costs) could be made to look profitable with a powerful injection of public funds. As a result, more than 80% of water used in the American West goes to irrigation. The Bureau of Reclamation delivers water to more than 10 million acres in the West. By comparison, a total of 6.1 million hectares (about 15 million acres) of land are irrigated in Mexico, about half of which are publicly irrigated (Postel 2000).

In the United States there is complex system of subsidies that maintains this enormous irrigation empire. Western irrigators reap the benefits of four forms of subsidies. The oldest one is the interest subsidy, which was built into the original reclamation act, signed in 1902. Although most irrigation projects take more than 50 years to repay, the farmers pay no interest on their federal loans. In 1987 the Bureau of Reclamation calculated that the interest subsidy alone has averaged $114 million per year since 1903, and by the 1980s had risen to $500 million per year (U.S. House 1988). Richard Wahl explains what happened:

> ...various pieces of general reclamation legislation have lengthened the interest-free repayment period for irrigation, thereby increasing the value of the interest subsidy. The effect of the interest subsidy in the Reclamation Act of 1902 was to forgive about 14% of construction costs, but by 1939 this level had reached 50%. In addition, the gradual rise in nominal interest rates has greatly increased the value of the subsidy since 1960, reaching levels as high as 95%. (1989)

A second form of subsidy is the "ability to pay" provision in reclamation law. It would be unimaginable for a private bank to offer a loan and then instruct the borrower to pay back whatever amount the individual feels is possible, but that is exactly what the federal government does for the beneficiaries of federal reclamation projects. It should come as no surprise that the Bureau routinely rates the irrigators' ability to pay as extremely modest. For example, farmers slated to receive water from the Central Utah Project would receive water that costs the government between $12,000 and $24,000 per acre to deliver, but the farmer's ability to pay was set at $9.40 per acre (U.S. Senate 1988).

Wahl calculated the difference between what irrigators claimed was their ability to pay and what they actually were willing and able to pay for federally irrigated land on the open market: "The ratios ... show that the willingness to pay ranges from 1.5 to 51 times the repayment to the federal government" (1989).

A third form of subsidy in the reclamation program concerns below-market water pricing. Farmers usually pay only a small fraction of what their water would cost on the open market. An analysis by the General Accounting Office (GAO) discovered tremendous pricing subsidies on large reclamation projects. For example, at California's huge Central Valley project, water users pay between $2 and $17 per acre-foot (the amount of water it takes to flood an acre to a depth of one foot, or 326,000 gallons) for water that costs between $42 and $72 per acre-foot on the open market. Central Arizona Project water users pay $40 to $50 for water that is valued

at $250 (GAO 1991a). Farmers receiving Central Utah Project water were slated to pay less than $3 for the same water that sells for $250 a few miles away in Salt Lake County (U.S. Senate 1988). The Imperial Irrigation District in California also receives water at a rate far below the market price (Erie 1997).

A fourth subsidy is the double-subsidy, which describes the practice of irrigators who receive subsidies from the Bureau of Reclamation to grow surplus crops and also receive subsidies from the Department of Agriculture not to grow the same crops. Surplus crops are those that are over-produced. The Department of Agriculture pays out approximately $300 million annually to farmers who agree not to grow these crops. This maintains a high price for these crops and thus increases the profit margin for farmers. A 1991 report by the GAO found that 38% of the Bureau of Reclamation's water subsidies were used to grow subsidized surplus crops. The report calculated that annual irrigation subsidies totaled $2.2 billion, of which $830 million was used to grow surplus crops (GAO 1991a). Simply eliminating the subsidy for surplus crops would free up millions of acre-feet of water for other uses. Some of this water would go to urban uses and much of it could be used for river restoration.

A final form of subsidy goes right to the heart of the reclamation philosophy. The original goal of the program was to provide water to family farms. Project farmers were originally limited to 160 acres but this was increased to 960 acres in 1982. However, enforcement of the acreage limitation has been so lax that many corporate irrigators, masquerading as family farms, rely on subsidized reclamation water and thereby dramatically increase their profit margins. Investigations by the GAO in the early 1990s revealed wide-spread abuse of the acreage limitation by corporate irrigators. For example, the Boswell Company set up a dummy trust to make it appear that its 23,238-acre farm was merely a collection of small family farms (GAO 1989; GAO 1990: GAO 1991b).

Of course, not all irrigated agriculture would be abandoned if these subsidies were eliminated. Specialized crops with a high market value will remain in production but would be forced to operate efficiently and use less water. For example, water from the Bureau of Reclamation currently irrigates 60% of the nation's vegetables and

25% of its fruits and nuts (Keys 2002). These crops are in great market demand and will remain economically viable even if subsidies are eliminated. However, 23% of the lands watered by the Bureau produce hay, a low-value crop that requires large amounts of water. This hay represents only 7% of the nation's hay production (Bureau of Reclamation 1986). If water were priced on the open market, the water used to grow the hay would in many cases be worth more than the hay itself. Changing economic forces will eventually eliminate such wasteful and un-economic uses of water.

To a certain extent this has already begun to happen in Mexico. Government subsidies have been greatly reduced for the 3.3 million hectares of publicly irrigated land. This has forced farmers to adopt more efficient, and more economically rational, production methods (Postel 2000). The United States would do well to learn from Mexico's progress.

Hydropower

Hydropower produces 10% of the nation's power. The Bureau of Reclamation operates 58 hydropower dams in the western United States with a generating capacity of 14,741 megawatts (MW) (Keys 2002). The U.S. Army Corps of Engineers operates 75 hydropower dams with a generating capacity of 20,720MW (U.S. Army Corps of Engineers 2002). This power currently plays an essential role in the nation's supply of electricity. Hydropower does not produce air pollution and is relatively cheap to generate. But, it produces a host of environmental problems that reduce its desirability. Hydropower dams, and the reservoirs they create, have an inimical impact on native fish populations. Nowhere is this more evident than in the Columbia River basin, where a debate is raging over the impact dams have on anadromous fish runs, especially salmon. In the Colorado River Basin, dams have reduced the viability of native fish populations to such an extent that four of them are now on the endangered species list—the Colorado pike minnow, the humpback chub, the bony-tail chub, and the razorback sucker. In the Rio Grande Basin there are three species that are endangered—the silvery minnow, the Pecos bluntnose shiner, and the Colorado pike minnow.

Hydropower also consumes water through evaporation loss and seepage from reservoirs. In arid parts of the country this loss is significant. For example, Lake Powell loses on average 566,000 acre-feet (af) to evaporation and 276,000af to seepage. Evaporation losses at other major reservoirs in the Colorado River Basin are equally disturbing:

- Lake Mead loses 897,000af per year
- Fontenelle Reservoir loses 12,000af per year
- Flaming Gorge Reservoir loses 75,000af per year
- Navajo Reservoir loses 28,000af per year

The total losses from just these five reservoirs is nearly 2 million acre-feet—enough water for 8 million people, assuming a typical daily use rate of 225 gallons per capita (Utah State Water Plan 2002). The total loss from reservoir seepage and evaporation nationwide is staggering. However, federal agencies either do not know the total losses, or have hidden that data from the public. One can get an idea of the losses just by looking at the surface area of reservoirs—those built by the U.S. Army Corps of Engineers have a total surface area of 9,934,000 acres at full pool (comparable figures for the Bureau of Reclamation are not available). As the price of water escalates, these enormous losses will become less acceptable and at some point the water lost will be worth more than the hydropower produced.

Another cost of hydropower production concerns the impact these dams have on sediment deposition. Natural rivers deposit sediment loads in flood plains and deltas, keeping these areas ecologically viable. A dam stops sediment migration, and as a result, it builds up in the reservoir bed. Eventually, all reservoirs become clogged with sediment, not only rendering the dam useless but creating a significant environmental hazard. A stark example of this is the Matilija Dam on the Ventura River. This 200-foot high dam holds back a great reservoir of—not water—silt. Even massive Lake Powell will eventually become a giant mud pit; estimates on when that will happen vary from 200 years to 800 years, but nearly all observers agree that sediment will eventually render Glen Canyon Dam useless.

Managing dams for maximum power production also conflicts

with other uses. Water-borne recreation prefers a release regime that is fairly consistent over time, lasting all summer. But hydropower flow regimes are driven by the demand for electricity. They release sudden bursts of water during peak hours, and reduced flows during non-peak times. This can create conditions for recreational users that are at best a nuisance, at worst a danger to life. Hydropower also conflicts with the regime flow preferred by agriculture, which prefers minimal releases in spring and early summer and heavy releases in late summer when other sources are dry. However, power demands are fairly consistent throughout the summer. Hydropower also has negative impacts on downriver riparian areas. Perhaps the best example of this is the impact Glen Canyon Dam has had on the Colorado River corridor through the Grand Canyon. In 1992 Congress required the Bureau of Reclamation to develop an Environmental Impact Statement as part of an effort to reduce damage to the downstream river corridor.

It is inevitable that we will develop new sources of energy, possibly from hydrogen, cold fusion, and non-consumptive alternative sources such as wind and solar. The demand curve will also be influenced by technological advances in insulation, building materials, and window design. Much of the energy that is now wasted through inefficient applications will be captured and used by these new technologies. As these technologies become more affordable and widely available, and the price of water increases, the attractiveness of hydropower will decline.

Urban Water Use

Undoubtedly urban water use will continue to spiral upward. More so than hydropower and irrigation, this water use is not easily replaced. However, there are two aspects of urban water use that will play an increasingly important role in mitigating, if not reducing, future demands for municipal and industrial water. First, much urban water use in the western United States is wasteful, inefficient, or foolish. Las Vegas wasted an estimated 10.4 billion gallons of water last year (Wagner 2002). In Salt Lake City, half of all water use is for outdoor watering—in a city that gets nearly 14 inches of precipitation per year. In Albuquerque, New Mexico, 40% of the

city's water is used for turf grass. Nationwide, 60% of all residential water use is for outdoor watering (U.S. Water News October 2002). In addition, many city water systems are hopelessly out of date, inefficient, and fraught with leaks and breakdowns. The U.S. Environmental Protection Agency (EPA) estimates it will cost a staggering $150.9 billion to update the nation's water systems; the American Water Works Association made an even higher—$250 billion—estimate (U.S. Water News July 2002). As water becomes more scarce, there will be increasing pressure on municipalities to eliminate unnecessary water use and adopt strict water conservation measures (Vickers 2002). This process has already begun in some places and promises to accelerate (Pole 1995; Berk 2002). As one southern California water official put it, "Conservation is becoming a way of life" (Gastelum 1999). Some western cities already have water police, and in the future these enforcers of water conservation will become a common site in all cities.

Urban water use will also be affected by new desalination technologies, especially in cities along the west coast. Desalination is already in widespread use. In 2000 there were 5,000 desalting facilities throughout the world with a daily capacity of 6 billion gallons. In the United States there are 1,200 desalting plants in operation, producing more than 300 million gallons per day (American Membrane Technology Association [AMTA] 2002). Perhaps the best known is the Santa Barbara plant, built during the drought years of 1990-91. That plant has the capacity to produce 7,500af per year at an annualized cost of $1,500 per acre-foot. That price is comparable to the city's other water sources (Santa Barbara 2002). A large seawater desalting plant is under construction in Tampa Bay, and will have a daily capacity of 25 million gallons (AMTA 2000). San Diego County has three desalination plants under construction that will deliver 50 million gallons per day and Los Angeles is planning a similar plant (U.S. Water News Oct. 2002). Desalination is not limited to the coasts, as briny groundwater is also being desalinated in Texas and Florida. As new energy technologies become available, the cost of desalination will drop significantly—at the same time that the cost of other water sources will be rising precipitously.

Desalination is just one of the new technologies and management tools that cities can use to reduce water use. Other strategies include

using water transport bags (giant bladders that can move water along the coast) low-water plumbing facilities, storm-water retention, treating effluent, gray water systems (re-using household water for outdoor uses), dual water systems (potable water for indoor use, untreated water for outdoor use), xeriscaping (gardening with low-water plants), groundwater recharge, and progressive pricing structures. All of these methods have proven successful in reducing urban water use. Thus, while urban water demand will continue to escalate, it will be mitigated by new technologies and more efficient uses.

In sum, there are technological, economic, demographic, and management scenarios indicating that irrigation, hydropower, and some urban water uses will be reduced significantly in future years. The rate of this reduction will be driven by economic and political considerations and the advent of affordable technological innovation. In stark contrast to these traditional uses of water, there are other water uses that cannot be substituted or replaced and are experiencing a continued and rapid increase in demand. These uses relate to quality of life issues and include tourism and recreation, access to wilderness and wild rivers, and the aesthetic value of unspoiled water and watercourses. We can find new sources of power, we can learn how to desalinate seawater, we can introduce market efficiencies into irrigated agriculture. But we cannot create new rivers, dig new canyons, replace extinct species, or re-invent nature. Thus, it is inevitable that the social and economic value of these uses of rivers will increase as they become relatively more scarce. This will lead to yet another era of federal water policy: the era of river restoration and dam removal.

The Dam Removal Era

Recreation is big business in America. According to the U.S. Travel Data Center the American West is the most tourism-dependent section of the country. Three western states along the U.S.-Mexican border (Texas was not included in their sample) generated $68.9 million in tourist revenues last year. These millions of tourists do not come out west to see hayfields and hog farms, nor do they want to see mine wastes and clear cuts or visit dried-up streams (Rothman

1999). If they wanted flat-water recreation they could have stayed in the East or in Europe. The great draw of the West is its natural scenery, which is blessed by beautiful—but rare—watercourses.

The natural beauty of the West appeals especially to the growing trend in eco-tourism. A recent study found that between 40% and 60% of international travelers are eco-tourists—those who "travel to enjoy and appreciate nature"—with an estimated direct economic impact of $416 billion world-wide (Fillion et al. 1992).

Much of this tourism is water-related. Both the U.S. Army Corps of Engineers and the Bureau of Reclamation provide recreation, but most of it is flat-water recreation. The Corps has recreational facilities on 463 reservoirs, while the Bureau has 348 reservoirs, of which 300 have recreational sites. Clearly there is no shortage of reservoir-based recreation. The "commodity" that is in short supply is naturally flowing rivers, especially those with white-water sections, wilderness scenery, deep canyons, abundant fish and wildlife, and relatively clean water. These are precisely the resources that cannot be obtained through technological development or resource substitution.

As people move to the West in search of a better quality of life and tourists flock to the West in search of a better vacation, naturally flowing rivers and the steep-walled canyons they carve will increasingly be viewed as a priceless resource that must be protected and, in some cases, restored. We are currently on the leading edge of a new era in federal water policy that will meet that demand. It is already reflected in some major policy decisions but has not been adopted fully by the Corps, the Bureau, and tradition-bound politicians. Nevertheless, the dawn of this new era is clear. The removal of dams is just part of this new era—the most dramatic part. Removing dams will be one aspect of a larger policy of restoring riverine ecosystems. In addition to removing dams, this effort will include water pollution abatement, riparian restoration, protecting existing wildlife, re-introducing species (in some cases), and a comprehensive approach to planning based on the principles of multi-jurisdictional ecosystem management.

This new era is already under way (Grossman 2002; McCully 1996) as evidenced by:

- The removal of 480 dams in the United States, most of

them in the last 20 years, according to the non-profit organization American Rivers (2001a)
- Former Secretary of the Interior Bruce Babbitt's appearance at nine dam removal ceremonies and four dam sites that were candidates for removal
- A combination of stakeholders agreeing, after years of contention, to a plan to demolish the Elwha and Glines Canyon dams on the Olympic Peninsula of Washington
- The continuing long and bitter controversy over the removal of four dams on the lower Snake River (Larmer 1999; CQ Weekly Report 1999), dams that a new study by the Rand Corporation recommends be removed (Pernin 2002)
- The 200-foot high Matilija Dam on the Ventura River, probably the largest, being slated for removal

Glen Canyon Dam has also been the focus of a concerted political effort, although it is unlikely this effort will succeed in the near future. However, the fact that the debate is taken seriously indicates how much public attitudes have changed in recent years. The dam's supporters in Congress are sufficiently concerned that they routinely add a rider to water appropriations bills prohibiting the Bureau of Reclamation from expending any money for even studying the dam's removal.

In addition to efforts to remove dams, there are innumerable projects to restore aquatic habitats and river ecosystems. The Bureau of Reclamation and the U.S. Army Corps of Engineers now devote a considerable portion of their budgets to restoring damaged rivers. These restoration efforts literally range from coast to coast and border to border. In the border states, the Bureau is working on a Lower Colorado River Operations Program that funds restorative and protective measures required under the Endangered Species Act. Some $12.4 million was requested in fiscal year 2003. The Bureau is also working to restore the river channel through the Grand Canyon, including mimicking spring run-off with large dam releases (Sibley 2000; Newcom 2000-01).

Other river restoration efforts in the border region involve a coalition of public and private groups. On the Lower Rio Grande, the U.S. Fish and Wildlife Service, the Nature Conservancy, Texas

Parks and Wildlife, and the Audubon Society teamed up to create an acquisition program for the Lower Rio Grande, which buys land along the river to protect riverine habitat (Oko 2002). Smaller rivers in the region are also receiving attention. Arizona's Verde River, part of which is in the Wild and Scenic River system, will be protected by a new Forest Service management plan (American Rivers 2001b). Efforts are being made to restore and protect the Virgin River in southern Utah (Israelsen 2001; Grand Canyon Trust 2001). The San Pedro River, which rises in Mexico and flows through Arizona to the Gila River, is being restored (Hanson 2001). And even the much-abused Los Angeles River is making a comeback (Gumprecht 2000).

Riverine protection and restoration are also taking place on the Mexican side of the border. The Secretaría de Medio Ambiente y Recursos Naturales (SEMARNAT) is attempting to preserve 35 different areas, including six in the border region (Campoy 1999). The Río Alamar corridor in Tijuana is being turned into an urban park (Michel 2001) and the effort to restore the Colorado River Delta is just beginning—something former Interior Secretary Bruce Babbitt called "the single most important piece of unfinished business on the Colorado River" (Western Water 2000; Cohen and Henges-Jeck 2001). In 1993 the Mexican government created the Upper Gulf of California and Colorado River Delta Biosphere.

This fundamental shift in policy occurred as a result of several factors. The environmental movement sensitized the public to the value of rivers as critical components of the biosphere that provide water supply and habitat for fish and wildlife. As well, there has been a tremendous increase in water recreation; fly fishing, white-water rafting, and kayaking are now a major part of the travel/tourism industry. White water sports have become so popular that government agencies have instituted permit systems on most rivers to control the crowds. Perhaps the best-known whitewater experience is running the Colorado River through the Grand Canyon. Private rafters who want to run this river must put their name on a waiting list; the wait is now approximately 20 years. On the Salmon Middle Fork, another popular wild river, only one in 24 applicants is actually awarded a permit to run the river. This is symptomatic of the nation-wide problem of too many people crowding onto the few remaining natural rivers. The economic impact of

these white-water users is enormous. In Colorado, commercial white-water trips generate an estimated $125 million (Colorado River Outfitters Association 2001).

River running is just part of a larger movement to enjoy and recreate in and around natural rivers. A recent U.S. Forest Service survey found that 25 million Americans engaged in kayaking and rafting, 26 million engaged in backpacking, and 70 million said they visited a wilderness or primitive area (U.S. Department of Agriculture 2000). A survey of recreation on Bureau of Land Management (BLM) lands found that 22 million visitors engaged in ecotourism and 13 million engaged in water sports (BLM 1997). A 2001 survey by the U.S. Fish and Wildlife Service (USFWS) found that 82 million Americans engaged in wildlife-related recreation, primarily bird-watching, and spent a whopping $108 billion on those activities that year (USFWS 2002). Bird watching, which often takes place within a riverine or wetland ecosystem, is now a booming $25 billion a year activity (Clines 2001). All of these activities value water—not as a separate commodity, but as an integral part of a riverine landscape.

Another major factor pushing restoration is the Endangered Species Act, which requires the preservation of habitat for plants and animals listed as endangered. This act has forced government agencies to preserve critical riverine and wetland habitat and has fundamentally altered the management of both the Colorado and the Rio Grande rivers.

Restoring rivers and removing dams is an overtly political process and often provokes bitter controversy. But despite the resistance, dams have been removed in nearly every state of the union. The political impact of this new preservation approach will be enormous, but three facets of this political struggle are especially noteworthy.

First, discussions between the United States and Mexico regarding management of the Colorado River and the Rio Grande will become even more multi-faceted and complex. The International Boundary and Water Commission (IBWC) may well become the most important political body in the region as people on both sides of the border become desperate for more water—and more natural rivers.

River restoration and ecosystem preservation may actually work to the advantage of Mexico. Water to meet U.S. obligations under

the 1944 Water Treaty comes primarily from the Upper Basin of the Colorado River. Those in the Lower Basin use their share and more, thus any remaining flow must come from the Upper Basin. Due to concerns over endangered species and the political shifts described earlier, the Upper Basin missed the development-at-all-costs era that typified activity in the Lower Basin. As a result, the Upper Basin uses only about 4.2 million acre-feet of its river allocation of 7.5 million acre-feet, and probably will never divert its full allocation. If the Lower Basin ever succeeds in living within its Colorado River allocation, this water could end up in Mexico, especially if it is used to restore the Colorado River delta (Hunter 1999; McClurg 1999, 2001; Marston 2001).

Second, the politics of the new water era will be complicated by federally reserved water rights. In 1908 the U.S. Supreme Court in *Winters v. U.S.* ruled that Indian reservations have an implied water right that is sufficient to meet the purposes for which the reservation was created (207 U.S. 564). This right was expanded in 1963 in *Arizona v. California* (373 U.S. 546) to include all federal lands that have been withdrawn from the public domain. Thus, it is in direct conflict with Prior Appropriation, which is the prevailing water doctrine of the western states. The potential claims under this doctrine are practically limitless, given the large amount of land preserved for Indian reservations and other federal programs.

There are nearly 300 Indian reservations in the U.S. that total 52 million acres. In the past the federal government made little effort to reserve and divert water for Indian tribes. But this began to change in the 1960s when tribes began to assert their rights forcefully. By one account, tribes have potential claims in excess of 46 million acre-feet (Western Governors' Association 1984). In recent years the federal government has pursued a policy of negotiating settlements to Indian water claims rather than litigating them, and 17 settlements have been signed thus far reserving more than 2.8 million acre-feet of water for Indian use. Another two dozen potential settlements are currently under negotiation (McCool 2002).

Indian water rights have fundamentally changed some major western water projects in the border region. The Central Arizona Project has evolved from a cotton farmer pork-barrel to a device to help the federal government meet its legal obligations to Indian

tribes. One component of that project will deliver water to the Tohono O'odham Nation, which abuts the U.S.-Mexican border. The Animas-La Plata Project was originally designed to provide water for non-Indian hay farmers, but in its latest re-incarnation it is principally a holding tank for Ute water rights and now includes the Navajo Nation Municipal Pipeline. A major reason for lining the All-American Canal was to provide 16,000 acre-feet of water to the Mission tribes on the San Luis Rey to meet the requirements of their water settlement. The lining of the canal was approved in the "4.4 plan" developed by former Secretary of the Interior Babbitt (McClurg 2000).

Federally reserved water rights can also be claimed for withdrawn public lands. Consider that:

- BLM has 264 million surface acres (only BLM lands that have been specifically withdrawn from the public domain are capable of generating reserved water rights, including national monuments and wilderness areas; most BLM land remains in the public domain)
- The National Park Service has 83.6 million acres
- The U.S. Forest Service has 191 million acres
- USFWS has 93 million acres of refuges
- The Department of Defense has 18 million acres

These are precisely the lands (except the Department of Defense lands) that are now the focus of so much public recreational activity. The demand for water to maintain public watercourses, scenery, wildlife, and water-related recreation will pressure the federal government to protect these water sources and associated ecosystems.

A third complication will be water quality, especially salinity. The Colorado River carries 9 million tons of salt annually, and this salt accumulates with successive water withdrawals. In 1974 Congress responded to this problem by passing the Colorado River Basin Salinity Control Act, which sets limits and authorized the Bureau to take corrective action. There were two possible solutions to the salinity problem. One solution was to retire irrigated lands that were high in salt content; this would have been economical, long-lasting, and good for the environment. It also would have placed the burden of the solution on those who principally caused the problem.

Instead, the Bureau chose to build a de-salting plant just above the border near Yuma. This plant has been a conspicuous failure and is currently not in operation, although the Bureau has spent nearly $400 million on salinity reduction (McClurg 1997). The principal reason the United States has been able to meet its obligation to Mexico to deliver water at the accepted salinity level is that the Upper Basin's unused water is diluting the salt content of the Lower Basin. More diversions will greatly exacerbate the salinity problem. A related problem will be the increased salinity of the Salton Sea and the impact that has on fish and wildlife in that area.

In the Rio Grande basin, the problems are two-fold: siltation and pollution. The siltation is so great that the reservoir behind Elephant Butte Dam has lost 25% of its capacity. The U.S. Army Corps of Engineers built dams on tributaries just to trap silt (Bates et al. 1993). In the lower basin, agricultural run-off and pollution from maquiladoras and other urban sources has seriously degraded water quality. The river has become, in the words of one author, "a drainage ditch and a dumping ground for a growing border population" (Oko 2002). Increased up-stream diversions will only make these problems worse. In 2000, American Rivers placed the Rio Grande on its "most endangered" list.

Conclusion

We do not have a water crisis in the border region. We have a crisis of innovation, a lack of vision, and an unwillingness to face a future that will be radically different from the past. Relying upon existing models of resource use and distribution will not only fail to solve our water problems, it will create even greater problems. Then, we will have a water crisis. In the future, four basic factors should be considered.

First, the United States has become the most profligate society to ever inhabit the earth. Consumption of natural resources, especially water in the western United States, is way out of proportion to population. This makes western population growth even more ominous—it is not just the number of people, but their consumption level that threatens quality of life. In this there is a stark irony—quality of life is dependent on unprecedented consumption, but

efforts to sustain that level of consumption threaten to make such a lifestyle unsustainable eventually. A healthy dose of common sense now could avoid draconian measures later.

Second, it is important to remember that all dams are temporary. Decommissioning of a dam is not a question of if, but of when. Siltation, structural weaknesses, and changing social values will eventually combine to bring down the structures built in the dam-building era. Anti-dam sentiment and the new interests and values described above will make it nearly impossible to simply replace a failed dam with another. Thus, a border region excessively dependent on dams is courting future disaster.

Third, scarcity begets regulation. As water grows scarcer in the face of ever-increasing demands, government control over water will grow more pervasive and more restrictive. Individual freedom to use water will be dramatically curtailed. Thus, society needs to balance its desire for infinite population and economic growth against its desire for personal freedom. Do people really want to live in a society where access to water, especially in its natural state, is strictly rationed? Imagine the day when a permit is needed to wash a car, people are forbidden to water their lawns, and that dream fishing trip has to be planned ten years in advance to wait out the waiting list.

Fourth, that bleak assessment can be balanced against an alternative vision called the River Commons. This is where river ecosystems—not just water—are managed primarily for the public good, not just for the economic gain of a few. Water use will focus on non-exclusive, non-consumptive uses and thus will serve the greatest number of people. Each individual will have the same potential access to be determined by individual desires and values—so long as that use does not appropriate the commons to the extent that it robs others of its value. The River Commons would be governed by an open, participatory process that would stand in stark contrast to the traditional iron triangle. This idea correlates well with the concept of a "water ethic" proposed by others researchers (Bates et al. 1993). Rivers would be valued as a complex of public resources in a natural system, rather like thinking of forests as living ecosystems rather than merely a vertical lumber supply.

Given the economic, social, and political changes leading to the

era of river restoration and dam removal, river ecosystems will begin to play a fundamentally different role. They will become linear public parks with priority given to fish and wildlife habitat, recreation and tourism, open space and aesthetics, and riparian preservation. Remember that these are precisely the resources that cannot be replaced by technological substitution and do not possess the burden of economic irrationality that characterizes so much irrigated agriculture in the West. The River Commons makes sense socially, economically, and ecologically; gradually, it is beginning to make sense politically.

The enormous price paid for the singular drive to dam, divert, and destroy natural river systems has led to a re-evaluation of national policy. We have begun a new era in water policy that focuses on mitigating past damages and solving water problems through efficient management and water conservation, rather than building new dams. In effect, this new era of water policy will attempt to repair the damage done by the first era of water policy.

Thus far only the modest beginning of this new era has been seen, but changing political and economic realities guarantee that future water policy will give priority to dam removal and river restoration. For 200 years the nation abused its rivers; now begins the effort to bring them back to life.

Discussion Points

1. What political strategies and political coalitions will be most effective in the new era?

2. What will be the role of water marketing? (For an excellent analysis see Charles Howe, "Protecting Public Values in a Water Market Setting." *University of Denver Water Law Review* 3 [Spring 2000]: 357-372.)

3. How can local water agencies take advantage of these changes to enhance their water supplies?

4. Due to concerns about water quality, what will be the role of the EPA in managing the river?

5. Will the "Law of the River" be adjusted to meet new water demands? Specifically, will the Colorado River Compact be replaced or modified by a more contemporary approach to water allocation?

6. Will the Prior Appropriation doctrine be adjusted to accommodate in-stream flow needs?

7. Will the political movement to remove dams affect any structures in the border region? (See "Colorado River Report," report by the Sierra Club, February 2001. http://www.sierraclub.org/rcc/southwest/COreport.)

8. How will the new "4.4" agreement with California affect other water users in the Colorado River basin? Will the new limits on California's diversions be used for environmental purposes? (See H.R. 2764, the "Colorado River Quantification Settlement Facilitation Act." For an analysis see Ed Marston, "Quenching the Big Thirst." *High Country News* May 21,2001. For a more positive assessment see Bruce Babbitt, speech to the Colorado River Water Users Association, Dec. 17, 1999, at http: //www.doi.gov/news/archives/speeches&articles/nevada.htm.)

9. Will limits on groundwater mining affect the political equation?

10. Will efforts to achieve sustainability lead to more efficient and more responsive water institutions? For example, would the proposed basin-wide Colorado River commission improve management of the river? (See Sue McClurg, "Managing the Colorado River," *Western Water Magazine* November/December 1999.)

11. Will litigation continue to result in decisions that determine the basic allocation of water in the basin? (The most recent decision in the long-running *Arizona v. California* case was decided on June 19, 2000. See 530 U.S. 392 [2000].)

12. Will basin-wide water management—an approach endorsed by eight federal agencies that manage water—change the way the Colorado River is managed? (See "Clean Water Action Plan:

Proposed Unified Federal Water Policy for Ensuring A Watershed Approach to Federal Land and Resource Management." http://www.cleanwater.gov/ufp/proposal.html.)

13. Will globalization and increased cross-border economic activity change the way the United States and Mexico manage the major rivers in the region? (For context on a global look at water management and dams, see *Dams and Development: A New Framework for Decision-Making*, by The Report of the World Commission on Dams. London: Earthscan Publications. Nov. 2000. Also see "Water: A Special Edition Edited by Mikhail Gorbachev," *Civilization: The Magazine of the Library of Congress*. October/November 2000.)

14. To what extent will the Endangered Species Act and the U.S. Fish and Wildlife Service determine water allocations along the border? (See U.S. Department of the Interior news release titled "Landmark State-Federal Water Agreement Protects Endangered Fish and Water Users in New Mexico," June 29, 2001.)

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Index

1909 Boundary Waters Treaty, 298
1944 Mexican Water Treaty, 14, 53, 62-63, 65, 67, 69-71, 77, 108-109, 119, 122-123, 131, 137, 140-141, 155-156, 183, 207, 301, 332, 384

ability to pay, 373
agriculture, 10, 19, 20, 52, 59-60, 62, 97, 108, 112, 118, 122, 126, 127, 133, 135, 138-139, 177-178, 194-195, 209, 223, 225, 235, 239, 276, 286, 338, 341-342, 377
  drainage, 12, 19, 98, 116, 119,123, 135, 157
  irrigation, 98, 117, 119, 209, 272, 351
  water use, 9, 15, 70, 97, 107-108, 112, 117-118, 122, 124, 133, 176, 191, 209, 257, 260, 263, 268, 277, 283, 322, 352
Alamo Canal, 117, 118, 119
Albuquerque, New Mexico, 94, 212, 358, 377
All-American Canal (AAC), 98, 102, 109, 117-119, 121-122, 138, 144, 385
Ambos Nogales, 280, 283-285, 288, 291-293, 306, 321-322, 324-325, 327, 329, 330-333, 356
American Dam, 220
American Heritage River, 219, 220, 243
Antelope Valley Ranch, 214
aquicludes, 222
aquifer, 10, 12, 98, 100, 109, 118-122, 137-139, 141, 187, 191, 195, 201-202, 213, 232, 239, 249, 252-253, 262, 268-269, 273-278, 286, 320-321, 339, 343
  large-scale storage, 12, 249, 274
  serving El Paso and Ciudad Juárez, 191
architecture, 57, 61
Arizona Department of Water Resources (ADWR), 284-285, 292-293, 306, 324-325, 327-329, 330-332, 361-362
artificial drainage system, 116-117

Barrett Dam, 276
Bight of the Californias, 282, 289, 317, 318
binational allocation, 57
  aqueduct, 249, 267, 350, 355
  conveyance system, 281
  cooperation, 17, 52, 53, 57, 60, 68-69, 78, 88, 90-91, 99, 159-160, 308, 336
  desalination plant, 249, 267
  drought management, 67-68

water management, 13, 15, 60-61, 64, 65, 76
watershed planning, 280
water-supply crisis, 149
biodiversity, 16, 21, 86, 139, 252
Bismark Mine, 215
Border Environment Cooperation Commission (BECC), 19, 44, 53, 63, 68, 73-74, 76-78, 81, 83-85, 149, 161-165, 181-183, 233, 303-304, 306, 330, 336, 350
Border Environmental Infrastructure Fund (BEIF), 325
Border Health Commission (BHC), 74, 92
Border Industrialization Program (BIP), 305, 358
Border Liaison Mechanism (BLM), 17, 282, 308, 350
Border Water Council (BWC), 282, 289-290, 308-309, 318-319, 349-350
border water plan, 53
Border XXI Coordination Principles, 76, 83
Water Resources Group, 75
working groups, 73
Border XXI Program, 2, 14, 53, 63, 67-68, 70, 73-78, 81, 83, 88, 90, 94, 132, 302, 304, 361
Borders Policy Committee (BPC), 282, 289, 290, 319
Boulder Canyon Project, 137
Bracero Program, 305, 307, 353
Brundtland Report, 242
Bureau of Land Management (BLM), 282, 289-290, 308, 319, 332, 383, 385, 391

CALFED Bay-Delta program, 370
capacity of existing infrastruture, 248, 252
carriage losses, 207
Central Arizona Project (CAP), 158, 373, 384
Central Valley Project Restoration Fund, 370
Chamizal Settlement, 220
Ciudad Juárez, Chihuahua, 9-10, 31, 59, 69, 149, 153, 165, 166, 181, 186, 187-191, 194-199, 201-202, 205-206, 208, 213, 215, 220, 222, 225-227, 229-235, 237-241, 243-246, 285, 294, 306, 334-335, 338-339, 341, 357, 359
Clean Water Act, 158, 370, 389
cloud seeding, 58
Coachella Valley, California, 109, 118
CoAPAES, 284, 292, 306, 324, 325
Colorado Basin Salinity Control Act of 1974, 157
Colorado River, 4, 9, 14, 20-21, 27, 29, 31, 38, 45, 47, 57, 60, 62, 66, 71-72, 84, 86-88, 92-94, 96, 98-113, 116-122, 124, 129-145, 147-148, 152-153, 155-158, 165, 180-184, 203, 205, 209, 212, 216, 259-260, 268, 278, 281-282, 289-290, 301, 307, 309, 311-314, 320, 335, 337, 354-355, 363, 366, 375-377, 382-385, 389, 391-393

salinity problem, 99, 130, 157
Colorado River Basin Project Act of 1968, 158
Colorado River Compact of 1922, 131-132, 137, 156-157, 389, 393
Colorado River Delta, 4, 21, 29, 47, 71, 84, 93, 99, 107-109, 116-117, 119-121, 129-135, 137, 139-140, 142, 144, 145, 180, 354, 382, 384, 391
Colorado River Storage Project Act of 1956, 137, 158
Colorado River-Tijuana Aqueduct, 111, 312, 355
Comisión de Servicios de Agua del Estado (COSAE), 312
Comisión Estatal de Servicios Públicos de Mexicali (CESPM), 108, 114-115, 140
Comisión Estatal de Servicios Públicos de Tijuana (CESPT), 259-260, 263, 268, 274, 278, 282, 290, 311-312, 319, 355, 357
Comisión Estatal del Agua (CEA), 270, 271, 273, 312
Comisión Internacional de Límites y Aguas (CILA), 13-15, 21, 37-39, 47, 62, 77, 104, 119, 141, 154, 277, 284, 292, 295, 304, 324, 327, 330, 333, 350, 356-358
Comisión Nacional del Agua (CNA), 15, 39, 59, 97, 101-102, 109, 111, 113, 115, 123-124, 141, 143, 152, 154, 159, 166-169, 173-174, 177, 179, 184, 205, 208-209, 244, 277, 312, 332-333, 336, 355, 357
Commission for Environmental Cooperation (CEC), 67-68, 74, 81, 85, 93, 161, 185, 304, 317
Committee on Binational Regional Opportunities (COBRO), 17, 42, 282, 289-290, 308, 318-319, 361
competition, 1, 3, 15, 20, 22, 97, 135, 142, 186, 193, 286, 341-342
concessions, 208-209, 236, 354
Conejos Médanos, 202, 215
conflicts, 3, 147, 192-193, 299, 301, 305, 376, 377
Congressional Border Caucus, 161
consejos de cuencas, 17, 37, 42, 87, 123, 278, 309, 357
conservation, 13, 15, 20, 22, 57, 60, 62, 66, 68-69, 71, 78, 86, 134-135, 147, 149, 169-170, 172, 174-175, 177-180, 182, 210, 227, 229, 261, 370, 378
consumption of natural resources, 386
Convention of 1889, 155, 301
corporate irrigators, 374
crisis of innovation, 386
cross-jurisdictional, 77, 235, 286
Cuyahoga River, 132, 143

dams, 58, 66, 132, 155, 157, 165, 174, 191, 203, 364, 366, 367, 369-370, 375-376, 380, 381, 383, 386-389, 390
dam operations, 158
dam removal, 367, 371, 379,

381, 388
management era, 371
decentralization, 61, 76, 83, 90
deficit, 67, 148, 285, 339
Dell City, Texas, 214, 247
demographic growth, 4, 58, 105, 108, 111, 114, 124, 239, 242, 301, 307
desalinization, 58, 69, 171
development activities, 352
Director of Binational Planning and Coordination, 282, 319
dissolved minerals, 186, 216
distribution of effluent water quality, 265
Distrito de Riego 009, 166, 205, 208, 209, 216, 225
Doña Ana County, New Mexico, 194, 198, 220, 225, 240, 335, 338, 342, 343
double-subsidy, 374
Draft Environmental Impact Statement/Environmental Impact Report (DEIS/EIR), 99, 103, 129-130, 145
drought, 19, 20, 22, 53, 56, 62, 65-69, 88-90, 148, 155-156, 174, 192-193, 209-210, 226, 241, 253, 261, 338, 378
extraordinary, 65-68
long-term, 53, 62, 89, 260
management, 20, 67-69, 89
periodic, 68
prolonged, 65, 68-69, 209

ecological needs, 53, 57, 71
economy, 1, 2, 4, 15-17, 21, 23, 56-59, 64, 85-86, 91, 97, 99, 105, 107-108, 111, 113, 115, 118, 127, 129, 137, 139, 149-150, 156, 161, 164-165, 171-174, 178, 193, 197-198, 213, 219, 230, 231, 239, 241, 248, 251-252, 280-281, 296-298, 300, 304, 305, 307, 318, 334, 336, 354, 364, 369, 372, 375, 379-380, 382, 387-388, 390
economic development, 2, 5, 21, 105, 239, 297, 304, 305, 318
ecosystems, 14, 64, 71, 99, 129, 132, 135, 147-150, 158, 167, 170, 173-174, 186, 192, 236, 252, 366, 380, 383, 385, 387
efficiency, 10, 59, 115, 126, 164, 168, 170, 176, 178, 180, 242, 298, 354, 370, 372
effluent quality, 265, 329
El Paso County Water Improvement District No. 1 (EPCWID), 205, 208-209, 216, 221, 222, 225, 235, 237, 247
El Paso Water Utilities (EPWU), 166, 201-203, 205-206, 208-209, 213-216, 220-222, 225-226, 229-230, 232-233, 236-238, 240, 243-244, 339, 343, 358
El Paso, Texas, 9, 18, 31, 42, 52, 54, 60, 69, 92-93, 149, 153, 155, 165-167, 185-191, 193-196, 198-199, 201-202, 204-205, 208-215, 217-222, 225-227, 230-231, 233, 238, 240-241, 243-247, 280, 285-286, 288, 294, 306, 334-335, 337-339, 341-343, 345, 347, 358-359
Elephant Butte, 155, 165, 191, 203, 204, 205, 209-210,

212, 217, 219, 223, 334-335, 337, 386
Dam, 155, 165, 191, 203-204,209, 212, 219, 223, 334, 386
Irrigation District, 205, 212, 335
Reservoir, 209, 210, 212, 217,219
emergency storage reservoirs, 260
Endangered Species Act, 134, 158, 381, 383, 390
environmental degradation, 158-161, 163, 164, 174, 302, 308, 315, 368, 375
Environmental Impact Statement (EIS), 103, 130, 137-138, 144, 377
environmental protection, 61, 254, 259, 366, 369-370
equity, 21, 84, 164, 170, 242
eutrophic conditions, 98, 128
evaporation, 10, 20, 98, 110, 128, 148, 167, 203, 223, 334, 376

facilities planning process (FPP), 284, 292, 306, 322, 324, 333
Far West Texas Water Plan, 215, 240
Far West Texas Water Planning Group, 240
Federal Law of Environmental Protection, 159
fertility, 197, 198
flow, 1, 10, 86, 96, 99-100, 106, 109-111, 115-116, 119-120, 132-139, 141, 148, 155, 157, 165-166, 186, 191, 194-195, 203-206, 209-210, 212, 218-221, 232, 253, 261, 263, 265, 270-271, 273, 276, 297-298, 315, 320, 327, 331, 335, 337, 353, 377, 384, 389
average flow years, 210
excess, 19, 137, 138, 230, 275,384
flow meter, 115

gauging station, 119, 212, 219, 221
geography, 56, 139, 334
Gila Main Canal, 98, 117
Glen Canyon Dam, 131, 134, 158, 376-377, 381
Glen Canyon Environmental Studies Research Program, 158
Goat Canyon/Cañón de los Laureles, 282, 289, 316
governance, 61, 64, 78, 86
graduated rate structures, 228, 229, 230
Grand Canyon, 134, 158, 377, 381, 382
Grand Canyon Protection Act of 1992, 158
Great Lakes Water Quality Agreement (GLWQA), 298-299
groundwater, 1, 2, 4, 9-12, 14-15, 17, 19-21, 53, 58, 60, 65, 69-70, 72, 88-89, 91, 138, 141, 149, 169-171, 176, 180, 187, 191-192, 195-196, 198-199, 201-203, 206, 209-210, 212-217, 222-227, 232-234, 236, 239, 248, 252-253, 255, 259-262, 267-268, 272-274, 276-277, 281, 283-285,

287, 295, 297, 313-314, 321-322, 325, 327-332, 336, 338, 339, 341-342, 347, 351, 356, 378-379, 389
extraction, 187
importing, 187, 215
infusion, 58
production costs, 203
quality, 20, 70
recharge, 10, 17, 19, 21, 141, 255, 262, 267, 272, 276-277, 281, 283, 313-314, 321-322, 325, 330-331, 379
Groundwater Users Advisory Council (GUAC), 284, 327, 329, 361
Gulf of Mexico, 191, 204

habitats, 21, 47, 71, 313, 316, 321
aquatic habitats, 158, 381
Hoover Dam, 99, 131-132
Hueco Bolson, 187, 199, 201-202, 215, 233-234, 236, 245, 285, 339, 341
hydraulic network infrastructure
in the Mexicali Valley, 116
of the Imperial Irrigation District, 117
hydropower, 174, 366, 372, 375-377, 379

Imperial Dam (ID), 97, 117, 157, 335
Imperial Irrigation District (IID), 97, 101, 112, 117-119, 122, 128, 143, 168, 170, 313, 374
Imperial Valley, California, 19, 60, 97-98, 107, 112, 117-120, 122-123, 126-127, 129, 131, 139, 141, 143, 177, 282, 313, 319, 391
industrial, 59-60, 70, 108-109, 113, 126-127, 136, 139, 146-147, 150-151, 157, 160, 167, 169-171, 177, 183, 187, 189, 197, 201, 206, 208-209, 217, 223, 226, 235, 239, 257, 259, 261-262, 265, 271-275, 283, 285, 293, 305, 311, 314, 321, 338, 339, 377
development, 2, 15, 52, 53, 56-57, 61-64, 69-70, 74, 76-78, 81, 83-85, 87-88, 91, 105, 107-108, 114, 118, 131-132, 134, 139, 146, 157-159, 165, 194, 219, 221, 231, 235, 238-240, 242, 257, 281-282, 298-300, 304-305, 307, 316-317, 339, 345, 350-352, 366-369, 380
water use, 1, 10, 17-18,59-60, 69-70, 72, 84-85, 91, 97, 113-114, 126-127, 147-149, 167, 171-175, 186-188, 192, 209, 216, 223-226, 228, 230-231, 239, 241-242, 253, 263, 272, 285, 311, 328-329, 333, 342, 371-372, 373, 375, 377-379, 389
industrialization, 59, 107, 197, 304-305
Institutional Development Cooperation Program, 162
Instituto Municipal de Planeación (IMPLAN), 274
Integrated Border Environmental Plan (IBEP), 132, 302-304

interdependence, 96, 105, 138-139, 241
Interim Surplus Water Criteria, 136
International Boundary and Water Commission (IBWC), 13-15, 18, 21, 37-39, 43, 47, 62, 66-67, 69-71, 77-78, 81, 89, 92, 99, 109, 139, 141, 144, 149, 156, 166, 181-184, 207, 221, 244, 270, 275, 277, 283-284, 286-287, 291-292, 294-295, 301-302, 304, 313, 322, 324, 326, 329-330, 343, 346, 350, 353-354, 356, 359, 360, 383
International Boundary Commission, 154, 301
International Dam, 220
International Joint Commission (IJC), 2, 19, 25, 298, 299
international treaties, 187, 195
International Waste Water Treatment Plant (IWWTP), 254, 257, 264-265, 269-271, 273, 275-277, 281, 314, 325
interstate compacts, 166, 187, 195
iron triangle, 367-368, 370, 387
irrigation, 10-13, 15, 20-21, 78, 82, 97-99, 109, 116-118, 120-126, 131, 138, 141, 149, 155, 164-168, 170-178, 180, 183, 186, 191, 194-195, 203, 205-209, 212, 216-217, 219-220, 223-226, 228-230, 236-237, 257, 261-262, 271-273, 285, 287, 299, 335-337, 339, 346, 356, 367, 372-374, 377, 379
canals, 205, 216, 220
irrigated agriculture, 59-60, 147, 155-157, 167, 221, 225, 372, 374, 379, 388
Irrigation Modules, 123

Japan Bank for International Cooperation, 270
jointly owned and operated groundwater recharge and extraction system, 249
jointly owned and operated water infrastructure, 249
Junta Central de Agua y Saneamiento, Chihuahua (JCAS), 336, 347
Junta Municipal de Agua y Saneamiento (JMAS), 166, 201-203, 206, 208-209, 213-216, 226, 228-235, 237-238, 244, 287, 295
jurisdictions, 8, 52-53, 61, 63-64, 75, 78, 86, 91, 165, 192, 198, 224, 236, 241, 264, 280, 295, 297, 310, 319, 336, 342, 345, 346, 349, 352

La Paz Agreement, 21, 63, 72, 75-76, 90, 91, 132, 159-160, 302, 345
land use, 248, 252, 254-255, 257, 263-264, 269, 272, 316
Las Cruces-El Paso Sustainable Water Project, 240, 243
Law for Environmental Pollution Prevention and Control, 158
Law of the River, 99, 136, 389
Ley General del Equilibrio Ecológico y la Protección al Ambiente (LGEEPA), 159

Ley Nacional del Agua, 97, 123, 325
Lobatos, Colorado, 212
Long Range Operating Criteria (LROC), 137
Lower Colorado River Operations Program, 381
lower Rio Grande valley, 55
Lower Rio Grande Water Users Association, 240

managed release of water, 219
management, 1, 10, 12, 17, 53, 56-57, 60-62, 64-65, 67, 69-70, 73-78, 82-83, 86-91, 97, 100, 123, 159-160, 162, 164, 166-167, 181-182, 187-188, 194, 216, 227, 229, 232, 238, 241, 252, 262, 268, 280, 283-287, 295-301, 304-306, 309, 312, 321-322, 324-325, 327-328, 330-333, 336-337, 342-349, 351-354, 356, 371, 378-380, 382-383, 388-389
  of water resources, 10, 53, 61, 76, 78, 166-167, 252, 280, 283, 322, 333, 351
  supply-side, 188
  system, 62
maquiladoras, 56, 156, 197, 238, 273, 305, 386
market, 21, 64, 71, 83-86, 126, 164, 167, 170-171, 173-180, 182, 235-236, 265, 271, 307, 331, 373-375, 379
mechanisms, 21, 170-171, 174-176, 180, 182
  solutions, 84-85
Mekong Committee, 299-300
Mesilla Bolson, 187, 202, 232-233, 338-339, 342
Mexicali Valley, 96-98, 100, 107-109, 116-124, 126-127, 133, 138, 260, 313, 355
Mexican Water Treaty of 1906, 155, 204
migration, 23, 187, 197-198, 238, 307, 312, 354, 376
Mimbres Bolson, 57
Morelos Dam, 97, 109, 116, 119, 141
municipal and industrial water use, 59-60, 112, 147, 192, 194, 208-210, 212, 215, 217, 225-227, 235, 239, 310
Municipal Water District, 168

national environmental plan, 64
National Environmental Policy Act (NEPA), 132, 158
National Spatial Data Infrastructure (NSDI), 316
natural user, 100, 132-133
New Mexico Water Resources Research Institute (WRRI), 199, 244, 246, 287, 338, 347, 359
New Mexico-Texas Water Commission, 18, 240, 286, 342, 351
Nogales International Wastewater Treatment Plant (NIWTP), 283-284, 324-325, 327, 329-330, 357, 362
North American Agreement on Environmental Cooperation (NAAEC), 63, 183, 304
North American Development Bank (NADBank), 13, 53, 63, 68, 73-74, 76, 81, 83, 85, 149, 161-165, 171, 179, 181-183, 303, 304
North American Free Trade Agreement (NAFTA), 63, 72-73, 93, 160-61, 183, 197, 273, 302-305, 336, 353, 361
North American Transboundary Environmental Impact Assessment (TEIA), 16, 40-41, 81, 83

Organization for Economic Cooperation and Development (OECD), 85

Paso del Norte, 13, 18, 36, 43, 59-60, 70, 93, 149, 153, 166, 176, 181, 185-186, 191-196, 198-199, 203-205, 208-209, 212, 220, 222-225, 227-228, 231-232, 235-236, 238-246, 285-286, 293-294, 306, 321, 334, 336, 342-347, 349, 351, 359
  Air Quality Task Force (PdNAQTF), 345-346, 351
  Water Task Force (PdNWTF), 18, 59-60, 93, 166, 181, 185, 203, 224-226, 241, 244-245, 286-287, 294-295, 306, 346, 347, 349, 351
  Watershed Council, 70, 241, 343, 351
permeate, 213
Phoenix, Arizona, 112, 169, 332, 358, 361, 362
Point Loma wastewater treatment plant, 265
politics, 57, 62, 64-66, 71, 74, 76, 81, 86, 136, 138-139, 147-148, 150, 159-160, 163, 164, 170, 173-174, 178, 187, 192, 208, 228, 237, 248, 251-252, 263-264, 268, 277, 280, 297-300, 306, 328, 332, 352, 365-371, 379, 381, 383-384, 387-389
pollution, 15, 21, 63, 70, 72, 135, 146, 157, 160, 163, 270, 281, 298, 300, 305, 314, 317, 318, 321, 345-346, 375, 380, 386
  prevention, 86
population, 93, 145-146, 187, 194, 196, 198, 238, 245-247, 255, 279, 283, 308, 335, 372, 394
  growth, 60, 195, 251
  of the native species, 133
projections, 59, 198, 342
potable water, 73, 163, 248, 251, 253-254, 272, 284, 285, 309-312, 321-322, 324-325, 331, 339, 354, 379
  infrastructure, 253
primary treatment, 216, 270, 281, 314
prior appropriation, 147, 172-173, 194, 212, 222, 336
privatization, 61, 314
Programa de Medio Ambiente, 64, 93
Programa Nacional de Fortalecimento da Agricultura Familiar/Program of the Northern Border (PRONAF), 305
Project Development Assistance Program (PDAP), 162
public parks, 388
public participation, 18, 74, 76, 83, 87, 162-163, 182, 298-

300, 333, 350-351, 353
Pueblo Indians, 193-194

quality of life, 4, 10, 71, 163, 178, 241-242, 248, 251, 259, 268, 278, 345, 379-380, 386

rainfall, 55, 58, 156, 171, 248, 253, 259-260, 334, 337
rationing, 65
recharge, 12, 14, 98, 109, 118-122, 137-138, 149, 180, 187, 191, 199, 201, 222, 236, 239, 243, 249, 253, 260, 273-277, 285, 320, 325, 333
reclaimed water, 11-12, 19, 215, 275, 283, 313-314, 330, 355
Reclamation Act of 1902, 155, 174, 178, 373
reclamation era, 58
recreation, 183, 321, 369, 377, 379-380, 382, 383, 385, 388
recycled water, 12, 248-249, 253, 255, 257, 260-262, 264, 269-277, 310, 356
  injecting into underground aquifers, 253
  transfers, 249, 267
  uses, 272, 273
Region 1 National Advisory Council for Sustainable Development, 77
regional cooperation, 332
  water resource management, 242, 285, 296, 306, 331, 351
Regional Colorado River Conveyance Feasibility Study, 282, 319
Regional Facilities Master Plan, 281, 313
regulation, 70, 84-85, 105, 123, 134, 135, 172, 176, 364, 370-371, 387
remote imports, 60
replenishable, 187, 191-192, 203, 239
reservoirs, 4, 149, 165, 170, 206, 209-210, 212, 220, 223, 260, 309, 337, 355, 367, 375-376, 380
restoration, 11, 17, 99, 128-130, 134, 145, 249, 260, 274-276, 370, 380-383
reuse, 10, 12, 22, 171, 188, 215-216, 221, 224, 232, 236, 242, 249, 252-253, 262, 269, 272-275, 281, 313, 315
right of capture, 222
Río Alamar, 249, 251, 274-277, 289, 382
  Alamar River Corridor Study, 320
Rio Bosque Wetlands Park, 221, 247
Río Bravo Coalition, 78
Río Conchos, 65, 148, 152, 155, 156, 165-166, 173, 208, 221, 337
Rio Grande Alliance, 78
Rio Grande Canalization Project, 220
Rio Grande Compact of 1924, 166, 205, 212, 335, 341
Rio Grande Rectification Project, 220
Rio Grande/Río Bravo, 4, 9-10, 18, 21, 27, 43, 46, 57, 60, 62, 64-67, 78, 86-89, 92, 94, 147-148, 152, 155-156, 165-167, 181-185, 190-191, 193, 195-196, 198, 203-206, 208-210, 212-217, 219-222, 224-227, 232, 236, 241, 243, 244-247, 285, 301, 334-335, 337-341, 343, 347-348, 357, 359, 366, 375, 381-383, 386, 393
Rio Grande-Río Bravo Basin Coalition, 347-348
River Commons, 364-365, 387-388
river ecosystems, 364, 371, 381, 387-388
river protection, 16, 134, 158-159, 172, 176, 219, 298, 382
river restoration, 274, 367, 370-371, 374, 379, 381, 388

salinity, 20, 72, 98-99, 108, 116, 121-123, 126, 128-131, 133, 135, 137-140, 157-158, 203, 210, 213, 216-218, 262, 268, 276, 339, 385-386
Salton Sea, 19, 98, 99, 102, 104, 118, 120, 123, 128-130, 134, 139, 142-143, 145, 313, 386, 393
San Antonio de los Buenos Water Treatment Plant, 270-271, 273
San Diego Association of Governments (SANDAG), 17, 42, 282, 289-290, 306, 308, 318-319, 349-350, 361
San Diego County Water Authority (SDCWA), 112, 262, 281-282, 289-290, 309-311, 313-314, 318-320, 349, 354-355, 358, 361
San Diego-Tijuana, 12, 248-261, 263-264, 267-269, 277, 279-282, 288, 290, 306-307, 309, 313, 319, 321, 334, 349-350, 353, 358, 361-362
San Luis Rio Colorado Valley, 69
San Luis Valley of Colorado, 195, 212
San Pedro River, 57, 71, 78, 161, 185, 382, 392
Santa Clara Sludge, 99, 139, 141
Santa Cruz Active Management Area (SCAMA), 284-285, 292-293, 327-329, 331-333, 349, 351, 356, 361-362
Settlement Group, 284, 327, 361
Santa Cruz Basin, 322-323, 326, 329, 332
Santa Cruz Water Management Authority, 284, 331
Santa Cruz, Arizona, 57, 78, 284, 292-293, 322-323, 326-327, 329-332, 349, 351, 356, 358, 361-362
Secretaría de Desarrollo Social (SEDESOL), 93, 302
Secretaría de Medio Ambiente y Recursos Naturales (SEMARNAT), 73, 93, 304, 382
sediment deposition, 376
seepage, 20, 138, 167-168, 376
sewage, 63, 159-160, 236, 263, 281, 309, 311-312, 314, 324, 354
shortage, 113, 148, 165, 193, 246, 272, 328, 380
Sierra County, 219
siltation, 386
Sonoran state water authority, 284, 306

South Bay Water Reclamation Plant (SBWRP), 257, 264-265, 269-270, 273, 275-277, 314
sovereignty, 90, 242, 298
storage projects, 17, 58, 319
strategic planning, 8, 53, 65, 67, 75, 77-78, 81, 113
stream restoration, 253, 261, 268, 278
subsidies, 15, 18, 21, 59, 114, 174, 178, 372-375
sustainability, 10, 18, 23, 56-58, 63, 65, 81, 89, 115, 130, 132, 268, 299-300, 336, 348, 352-353, 369, 389
sustainable development, 1, 52-53, 56-57, 61-64, 68, 70, 72-78, 81-85, 88-89, 91, 99, 132, 135, 163, 193, 242
sustainable management, 67, 69
Systems of allocation of water resources, 191

tariff, 114
Tecate, Baja California, 97, 101, 108, 111, 140, 279, 312, 317, 320
technology, 10, 17, 66, 122, 150, 170, 182, 195, 242, 261, 298, 317, 319
Territorial Waters Act, 159
Texas Center for Policy Studies, 167
Texas Commission on Environmental Quality (TCEQ), 166, 231, 336
Texas Water Development Board, 166, 177, 181, 198-199, 215, 244, 246, 287, 338, 347, 359
Tijuana River, 4, 94, 155, 183, 257, 263-264, 268, 270, 276, 278, 281-282, 289, 301, 309, 314, 315, 317, 320-321, 356, 363
Tijuana River Watershed, 281-282, 289, 309, 315, 317, 356, 363
Tijuana River Watershed Program, 282, 315
Tijuana, Baja California, 4, 27, 57, 62, 78, 94, 97, 101, 108, 111, 113-114, 140, 144, 155, 160, 183, 249, 253, 254, 255, 257, 260-261, 263-265, 268, 270-279, 281-282, 289-290, 301, 307-309, 311-321, 353-357, 360, 363, 382, 393
total dissolved solids (TDS), 109, 141, 199, 203, 206, 212-213, 216-217, 220
tourism, 369, 379-380, 382, 388
transboundary, 12-14, 16-17, 63, 70, 72, 75, 77, 85, 90, 100, 138, 146, 160, 249, 252, 260-261, 263-267, 274, 277-278, 295, 299, 301-302, 309, 334
sharing of water resources, 249, 252
water basins, 75
water management, 252, 295
water sharing (see also Water Without Borders), 249, 252, 260-261, 265, 274, 277
water transfers, 249, 267
Transboundary Environmental Impact Assessment, 16, 81
treatment, 8, 10, 12, 17, 19, 72, 112, 114, 162-163, 205-206, 208, 213, 215-216, 220-221, 223, 236-237, 242, 253-254, 257, 262-265, 270-271, 275-277, 281, 283, 284, 286, 314, 322, 324-325, 329-330, 343, 349, 355
tertiary water treatment, 215
tertiary-treated effluent, 275
Treaty of Guadalupe Hidalgo in 1848, 301
tribal nations, 72, 147, 193, 194, 366, 384
water rights, 384
tri-party contracts, 216
Tri-Region Water Planning, 240
Tucson, Arizona, 112, 169, 357, 359, 361, 392, 393
Tularosa Basin, 199

U.S. Army Corps of Engineers, 62, 243, 367-370, 375-376, 380-381, 386, 394
U.S. Bureau of Reclamation (USBR), 104, 113, 130, 136, 140, 142-145, 203, 208-210, 216, 219, 222, 225, 246-247, 335-337, 357, 367-370, 372, 374-377, 380-381, 391, 393, 395
U.S. Department of Agriculture (USDA), 374, 383, 395
U.S. Department of the Interior (USDI), 62, 99, 120, 129-130, 133, 136-137, 145, 304, 390
U.S. Endangered Species Act, 147, 169
U.S. Environmental Protection Agency (EPA), 72-73, 76-77, 83, 87-88, 92, 94, 132-133, 162, 164, 244, 246, 287, 296, 302, 304-306, 324-325, 329-330, 347, 358-359, 362, 378, 388
U.S. Fish and Wildlife Service, 381, 383, 390, 394
U.S. Forest Service (USFS), 383, 385
U.S. Good Neighbor Environmental Board (GNEB), 70, 72, 76-78, 86, 88, 92, 297, 302
ultraviolet light irradiation, 263
United Nations Conference on Environment and Development, 56
unplanned diversions, 167
Upper and Lower Colorado River Basin States Water Compact, 136
Upper Gulf of California, 99, 134-135, 142, 382
urban development and ecology ministry, 12, 64, 69, 191, 249
urbanization, 146, 272, 297, 305
Utility Management Institute, 162

wastewater, 8, 10, 11, 17, 19, 22, 72-73, 108, 110, 112, 114, 128-129, 131, 160, 163, 169, 201, 209, 215-216, 220-221, 225, 231-232, 236-237, 242, 248, 252-254, 257, 262-265, 271, 273, 276, 281, 283-284, 312-315, 322, 324-325, 329-331, 336, 349, 351, 355

discharges, 216
network for collection, 253
reuse, 215
water
allocation, 10, 16, 62, 72, 112, 141, 147-148, 150, 155, 163, 166, 177, 182, 187,194-195, 198, 204, 206, 209-210, 225, 241, 286, 299, 335-336, 341-343, 366, 384, 389
availability, 10, 16, 58, 67, 105, 107, 114, 124, 157
conservation, 19-20, 58-59, 66-68, 108, 111-112, 114, 147, 168-171, 174, 188, 209-210, 227-229, 232, 257, 319, 378, 388
constrained access to, 187, 198, 225
consumption, 52, 59-60, 64, 97, 107, 111-114, 141, 142, 169, 176, 188, 223, 227, 229-232, 243, 257, 311, 371, 386-387
cost, 12, 15, 21, 22, 59, 85, 126-127, 147, 158, 163, 167-168, 171, 175, 179, 203, 206, 208, 213, 223, 227-228, 233, 242, 254-255, 257, 260-265, 269, 273, 276-278, 330-331, 339, 370, 373, 376, 378
crisis, 89, 386
deficit, 57, 64, 65
delivery service, 115, 118
demand, 1, 2, 3, 9-10, 23, 52, 58-59, 65, 66, 81-82, 107-109, 111, 113, 115, 124, 127, 131, 137, 139-140, 146, 156, 171, 173, 175, 186-188, 201, 206, 223-227, 229, 232-233, 235, 243, 255, 257, 260-261, 271, 273, 280, 285, 301, 312, 322, 335, 339, 341, 342, 375, 377, 379-380, 385
distribution of resources, 192
drinking, 73, 148, 163, 191-192, 195, 201, 203, 205-206, 208, 215, 236-237, 242, 283, 322
drinking standards, 192, 206, 236
found, 261
importing, 58, 195, 262, 281, 309, 314, 321, 354
infrastructure, 15, 63, 73, 76, 81, 84-85, 122, 248, 252-254, 257, 260, 262, 264, 284, 306, 324
laws, 187, 198, 222
management, 10, 13, 16, 20, 53, 60-63, 66, 68-69, 75, 77-78, 81, 83, 85-87, 89, 91, 146, 158-159, 161, 165-166, 179, 181-182, 234, 240-241, 252, 280, 295-296, 298-299, 301, 303, 309, 329, 336, 343, 348, 367, 369, 389-390
over-allocation, 71, 139
policy, 1, 22, 61, 63, 75, 150, 170, 178, 366, 367, 371, 379-380, 388
purchases, 112
quality, 17, 19, 21, 53, 65, 69, 72-74, 76-77, 88, 121, 163, 186, 192, 202, 216, 220, 233, 252-253, 265, 268-269, 274-275, 277, 282-283, 287, 297-298, 316, 318, 321-322, 324, 329, 338, 347, 349, 385-386, 388
rates, 115, 208, 229, 244
resources, 3, 4, 8, 10, 14, 16, 17, 21-23, 52-53, 56-60, 62, 64-65, 68-69, 71-72, 75-76, 78, 81, 83-84, 88-89, 91, 98, 109, 111, 117-118, 137, 141, 146, 149, 155-157, 165-166, 170-172, 175, 179, 181, 183, 186, 191-193, 195, 198, 201-205, 207-209, 212, 215-216, 221, 224, 227-228, 232-236, 240-243, 251-252, 257, 261, 263, 268, 273-274, 280-281, 283-286, 296-297, 299-301, 304-306, 309, 311, 313, 319, 321-322, 324, 327-332, 334-335, 337-339, 341-342, 349, 351, 355-356, 371, 372, 375, 380, 382, 387
rights, 16, 58, 61, 72, 106, 112, 116, 123-124, 126, 147, 155, 158-159, 166, 168, 172-177, 179, 187, 192, 194, 208-209, 214, 225, 235, 241, 259, 284, 286, 327-328, 341-343, 351, 366, 384, 385, 389
scarcity, 3, 13, 15, 22-23, 55, 64-66, 84-85, 89, 192, 227, 307, 364, 387
shared, 75, 260, 269, 297-298, 352
sources, 19, 149, 179, 235, 244, 248, 252-253, 263, 268, 281, 313, 337, 378, 385
supplies crossing the border, 252
supply problems, 69, 186, 198, 232, 239-240, 248, 251, 283, 351
surface, 2, 4, 9-10, 13-14, 128, 133, 146, 156, 169, 171, 186-187, 192, 195, 198, 201, 204-206, 208-209, 212, 216-217, 220, 222, 224-225, 227, 232, 236-237, 239, 248-249, 252-253, 269, 274, 283, 285-286, 309, 320, 322, 325, 327, 329, 332-333, 336, 339, 341-343, 351
surplus, 100, 117, 119, 135-137
sustainable use, 57
trading, 257
use, 1, 10, 17-18, 20, 59-60, 69-70, 72, 84-85, 89, 91, 97, 113-114, 126-127, 147-149, 167, 171-175, 186-188, 192, 209, 216, 223-226, 228, 230-231, 239, 241-242, 253, 263, 272, 285, 311, 328-329, 333, 342, 371-373, 375, 377-379, 389
valuation, 59
Water Without Borders, 75, 248, 260, 269, 297-298, 352
watershed, 1, 67-68, 72, 77-78, 81, 85, 87-88, 91, 305, 349, 366
watersheds, 4, 13-14, 17, 53, 56, 71-72, 77-78, 82, 83, 85-

88, 90-91, 98, 195, 252, 260, 268, 274, 276-277,280-282, 296-297, 299, 306, 309, 315-316, 319, 331, 335, 348-349, 354
approach, 17, 77, 85-87, 252, 274, 277, 296, 299, 306, 319, 354
as a planning region, 252
councils, 13, 17, 81, 87-88, 91, 331
history of international watershed management, 296
management, 53, 86-88, 90-91, 296-297
wells, 14, 98, 109, 121-122, 131, 138, 140, 187, 201-203, 206, 268, 273-274, 286, 322, 342, 355
Wellton-Mohawk Irrigation District, 98-99, 103, 117, 130-131, 157
Western Water Policy Review Advisory Commission, 87, 94, 178, 185, 366
Wild Horse Valley Ranch, 214