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Challenges and Opportunities for Water of the Rio Grande

M. Edward Rister, Allen W. Sturdivant, Ronald D. Lacewell, and Ari M. Michelsen

The Rio Grande has headwaters in Colorado, flows through New Mexico, and serves as the United States.–Mexico border in Texas, emptying into the Gulf of Mexico. Snow melt in Colorado and northern New Mexico constitutes the water river supply for New Mexico and the El Paso region, whereas summer monsoonal flow from the Rio Conchos in Mexico and tributaries, including the Pecos River, provides the Rio Grande flow for southern Texas. The region is mostly semiarid with frequent long-term drought periods but is also characterized by a substantial irrigated agriculture sector and a rapidly growing population. International treaties and interstate compacts provide the rules for allocation of Rio Grande waters between the United States and Mexico and among Colorado, New Mexico, and Texas. Water rights in Texas have been adjudicated, but the adjudication process was based on a wet period; hence, contemporary Rio Grande water rights are overallocated. Issues related to the waters of the Rio Grande include: frequent drought, increased municipal demand caused by a rapidly increasing population, supply variability, underdeliveries from Mexico, increasing salinity, inefficient delivery systems, health issues of the population, no economic/financial incentives for farmers to conserve, and water is not typically priced for efficiency. Stakeholders are interested in identifying solutions to limited water supplies while there is increasing demand. There are several activities in place addressing Rio Grande-related water needs, including enhancing delivery distribution efficiency of raw water, conversion of rights from agriculture to urban, improving both agricultural irrigation field distribution and urban use efficiency, developments in desalination, and litigation. None of the solutions are easy or inexpensive, but there are encouraging cooperative attitudes between stakeholders.

Key Words: agriculture, agricultural economics, conservation, irrigation, natural resources, renewable resources, resources, water

JEL Classifications: Q5, Q15, Q20, Q25, Q28

Along its 1885 miles, the Rio Grande serves as a water catchment and conveyance channel for its namesake basin, facilitates in-stream reservoir storage for eight million acre-feet (af) of water in the Caballo and Elephant Butte reservoirs in New Mexico and Amistad and Falcon International Reservoirs in Texas, and serves as the United States–Mexico border in Texas (Lurry,

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Reutter, and Wells, 1998; Texas Water Development Board, 2007). Between its headwaters in Colorado and its terminus into the Gulf of Mexico, the Rio Grande includes 336,000 square miles of territory, which form the Rio Grande Basin. The basin collects flow from Colorado, New Mexico, Texas, and Mexico (Figure 1). States within the basin in Mexico are Chihuahua, Coahila, Nuevo Leon, and Tamauilpas. Territory within the Basin is mostly arid or semiarid and is home to some ten million people (Lurry, Reutter, and Wells, 1998) with 2.7 million Texans residing in the 31 Texas counties in the basin (Texas Department of State Health Service, 2010).

Flow characteristics effectively make the Rio Grande act as two independent rivers. The upper stretch uses melted snow for flow from Colorado, through New Mexico, and to an area below the Fort Quitman, Texas area. As a result of strict reservoir management and the consumptive use along this area, the river is often allowed to stop flowing at this point. Inflow from the Pecos and Rio Conchos tributaries provide most of the flow of the Lower Rio Grande and facilitate storage reserves for the Lower Rio Grande reservoirs (Lacewell et al., 2010).

Governance and Regulation

With its unique geography and hydrology, the surface water within the Rio Grande Basin is uniquely apportioned by a series of both international treaties and interstate compacts. Subsequently is a brief overview.

Governance between the United States and Mexico

- **The Convention of 1906—**The *Equitable Distribution of the Waters of the Rio Grande* stipulates the United States shall deliver 60,000 af annually to Mexico, and in return, Mexico will waive any claim to Rio Grande waters between the present Mexican Canal and Fort Quitman, Texas.
- **The Water Treaty of 1944—**The *Utilization of Waters of the Colorado and Tijuana Rivers and of the Rio Grande* guarantees from the United States to Mexico 1.5 million af from the Colorado. Furthermore, Mexico owes the United States an annual average amount of 350,000 af from the Rio Grande (averaged over cycles of five consecutive years).

Governance among Colorado, New Mexico, and Texas

- **The Rio Grande Compact of 1938—**The *Rio Grande Compact* apportions water among the three states from its headwaters in southern Colorado to Fort Quitman, Texas.

Governance between New Mexico and Texas

- **The Pecos River Compact of 1948—**The *Pecos River Compact* apportions the water of the Pecos and facilitates the construction of works for saving water, making more efficient use of water and protecting life and property from floods.

Current Use, Value of Agricultural Production, and Changes

Considering the region's predominant agricultural use of surface water and supply/demand impacts from dynamic weather events (e.g., snowpack, tropical storms, etc.), fluctuating diversions from the Rio Grande are normal and expected. From 1989 to 2009, diversions below the Amistad Dam ranged from a low of 797,294 af to a high of 1,826,603 af with an average annual diversion of 1,172,631 af (Yarrito, 2010) (Figure 2).[1]

Increasing municipal water demand, stimulated by rapid population growth, is a key aspect of Rio Grande water issues. County population estimates for 2009 are suggestive of the regional average increase surpassing 24% during 2000–2009 in contrast to the comparable national

[1] In this article, segments of the Rio Grande are considered as being the: *Upper*—from its Colorado headwaters to Elephant Butte Dam; *Middle*—from Elephant Butte Dam to Amistad Dam; and *Lower*—from Amistad Dam to the Gulf of Mexico. Furthermore, the Rio Grande which falls within Texas' boundaries is oftentimes referred to as the: *Upper*—Fort Quitman, Texas to Amistad Dam; *Middle*—Amistad Dam to Falcon Dam; and *Lower*—Falcon Dam to the Gulf of Mexico (Hinojosa).

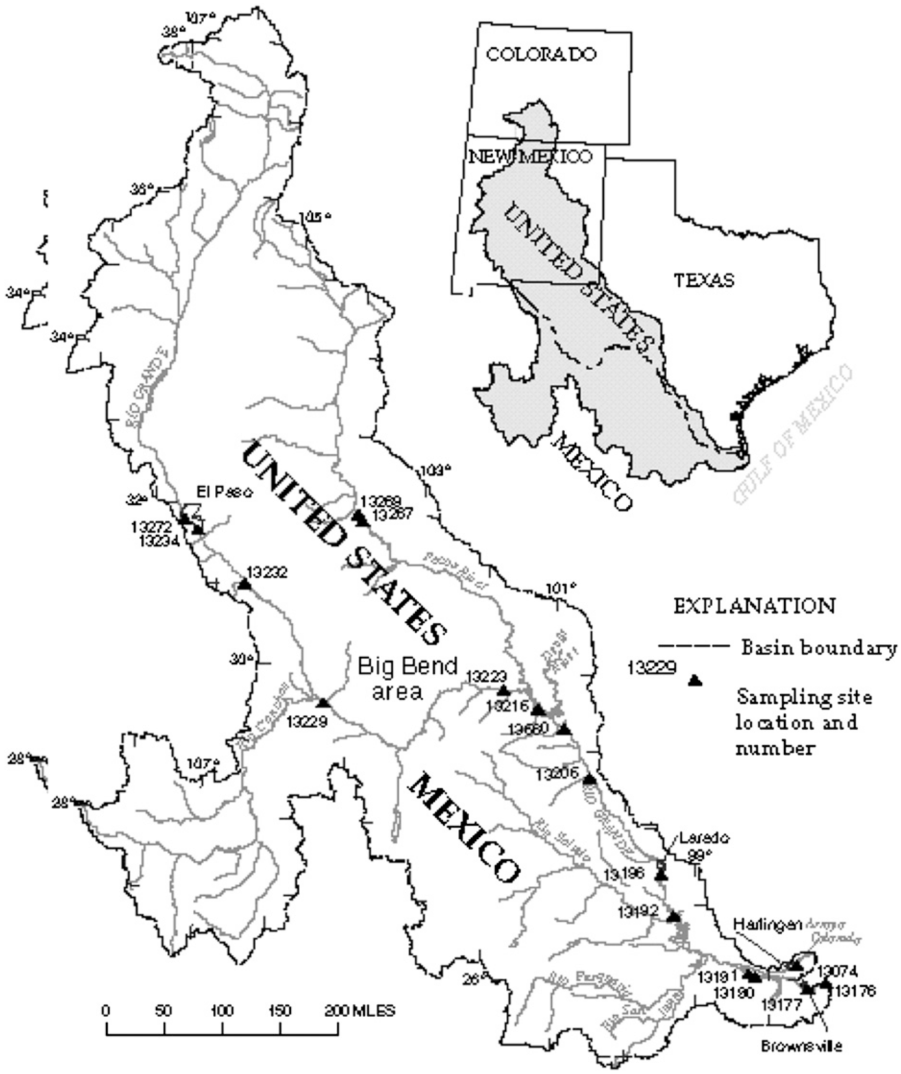

Figure 1. Illustration of the Rio Grande Basin. Source: U.S. Geological Survey, 2010a

average increase of 9.7% (U.S. Census Bureau, 2010).

Even with rapid population growth and conversion from an agrarian economy to a manufacturing and service-based economy, the vast majority (87%) of surface water rights in the Rio Grande Basin are for *Irrigation* (vs. *Municipal and Mining*) use (Texas Water Development Board, 2007). Many of the water delivery systems carrying water away from the Rio Grande originated in association with irrigation deliveries (Stubbs et al., 2003).

Diversions using these *Irrigation* rights facilitate an abundant part of the economy along the Rio Grande. Figure 3 is a depiction of cash sales for the major U.S. agricultural-producing areas and enterprises along the Rio Grande.

Major Water Issues, Opportunities, and Successes

Even with its record of successful regulation and mature infrastructure and diversion operations, water conveyed through the Rio Grande

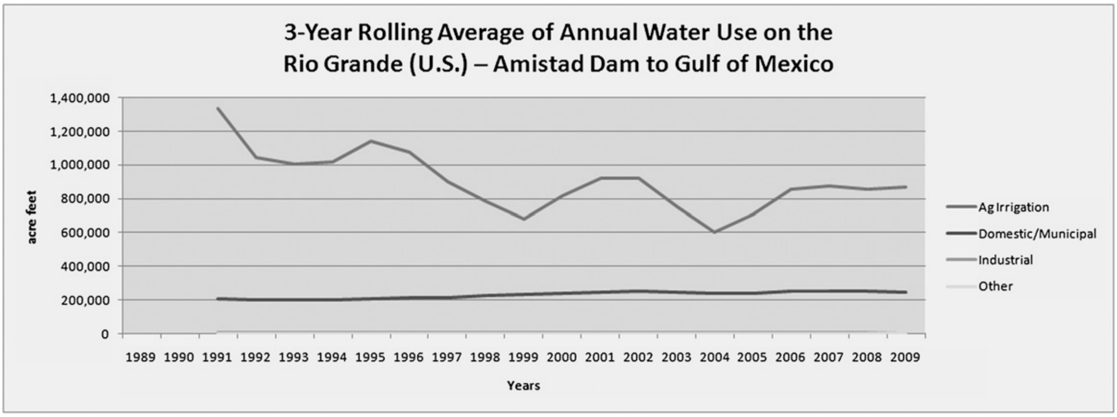

Figure 2. Three-Year Rolling Average of Historical Annual U.S. Diversions, by Type, from the Lower Rio Grande, 1991–2009 (Source: Yarrito, 2010)

continues to exhibit significant, and sometimes very contentious, issues. Some of them—also known as *problems* or *challenges*—are perennial issues, whereas others are relatively new to the region's water concerns. For the purposes here, the major issues are categorized into *ownership*, *quantity*, *quality*, and *environmental*.

Water Ownership: Treaties, Compacts, and Rights

Often topping the list for *issues* dealing with natural resources is that of ownership. Heretofore, there have been some lengthy and costly battles, both legal and political, waged about the Rio Grande's waters (and/or its tributaries). Even with long-ago settlement of certain lawsuits and specific treaties, some contemporary allocation disagreements have arisen.

Shortfalls in Deliveries by Mexico

Per the Water Treaty of 1944, the United States provides Mexico with 1.5 million af annually from the Colorado River, whereas Mexico provides the United States with an average of 350,000 af from the Rio Grande. On October 2, 2002, Mexico officially defaulted, owing the

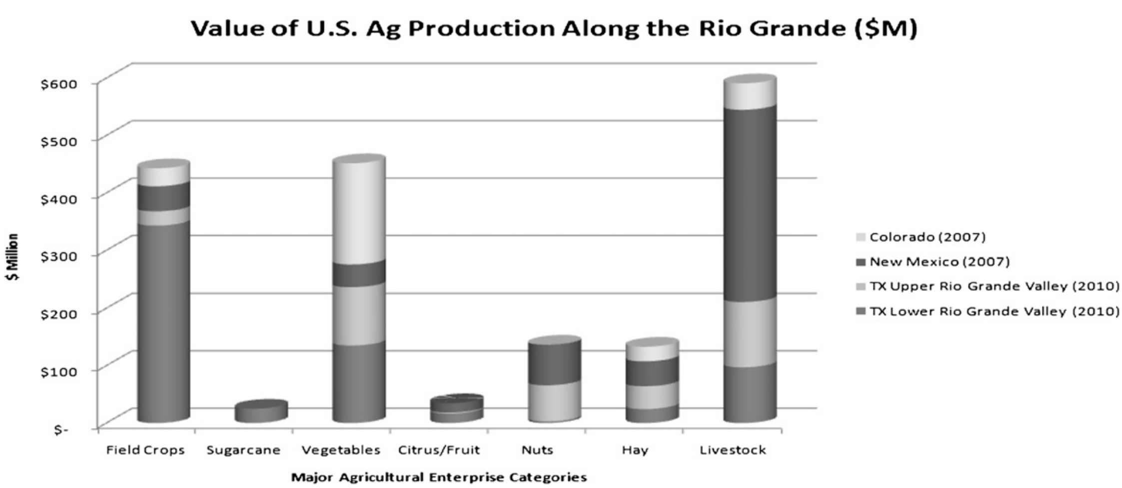

Figure 3. Estimated Value (farm-gate cash receipts) for Select U.S. Areas and Agricultural Enterprises Along the Rio Grande (Sources: Burke and Anderson, 2010; and USDA-NASS, 2010)

United States more than 1.5 million af (Taylor, 2002). Attempts by U.S. farmers to file with the government of Mexico to compensate for their losses were ineffective. Eventually, Mexico repaid its debt (in September 2005), which had accumulated during 1992–2002 (Spencer, 2005) as a result of monsoon rains causing reservoir spillage. From the perspectives of U.S. stakeholders, no new actions have been taken to date that will prevent another default by Mexico.

Rio Grande Project Water Right Ownership and Allocation

When authorized in 1905, the Rio Grande Project allocated all of the area's water to the Elephant Butte Irrigation District and the El Paso County Water Improvement District No. 1. The then small city of El Paso decided it did not need Rio Grande water. With its population growth from less than 10,000 in 1900 to 700,000 in 2010, the environment changed. After substantial litigation, many issues were resolved with the signing of a Rio Grande Project Operations Agreement. Key to the agreement were aspects that provided incentives to conserve and improve water management (e.g., paying for lining of irrigation district canals for delivery of conserved water and supplying 1 af of Rio Grande water for 2 af of treated EPWU waste water).

Ownership Disagreements below the Falcon Reservoir

The Water Rights Adjudication Act of 1967 created an administrative and judicial system for dealing with water rights, but it did not "settle" the issue. It was a lengthy lawsuit and cost an estimated $10 million (based on 1950–1960 dollars) in court costs and attorney fees and involved approximately 3000 claimants (Jarvis, 2010). The often-referred-to *Valley Water Suit* (i.e., *State of Texas v. Hidalgo County Water Control & Improvement District No.* 18) set legal precedent for water rights downstream of Falcon Reservoir. Key aspects of the legislation include establishment of 1) several categories of rights, with *Domestic*, *Municipal*, and *Industrial* having higher priority; and 2) Class A and Class B *Irrigation* rights. Furthermore, the af of rights adjudicated exceeded sustainable af of diversions. Thus, an ability for *Irrigation* rights to be purchased and converted to *Municipal* rights was also established. Over time, the number of total af of rights will be reduced, thereby correcting the previously overappropriated system (Stubbs et al., 2003).

Disincentive for Agricultural Irrigation Conservation

Another ownership issue is that the majority of water rights adjudicated in the *Valley Water Suit* were distributed to irrigation districts rather than to individual farmers. This translates into there being no direct economic (or pricing) incentives for producers to conserve water with individual irrigation applications. An encouraging evolution shows irrigation districts adopting meters at field outlets and beginning to charge for water deliveries on a per-unit basis. This provides incentives to reduce water use but still fails to reward conservation by individual farmers because they have no explicit rights to the associated saved water.

Exemplifying successful multinational cooperative efforts in the Rio Grande region is the establishment of the binational Paso del Norte Water Task Force. This group exchanges information and develops solutions to water resource issues. Another collaborative program is the United States–Mexico Transboundary Aquifer Assessment Program, which develops information on the extent, use, quality, and recharge of selected shared United States–Mexico aquifers.

Water Quantity—Conservation and Supply Planning

Closely akin to the ownership/allocation concerns discussed previously is the issue of drought. As depicted in Figure 4, droughts occur frequently and can intensify any allocation-related disagreements between stakeholders of the basin. A closer inspection of the data (for the Texas Lower Rio Grande Valley) reveals that none of the "recent" drought periods have been as severe as the 1950s drought of record but

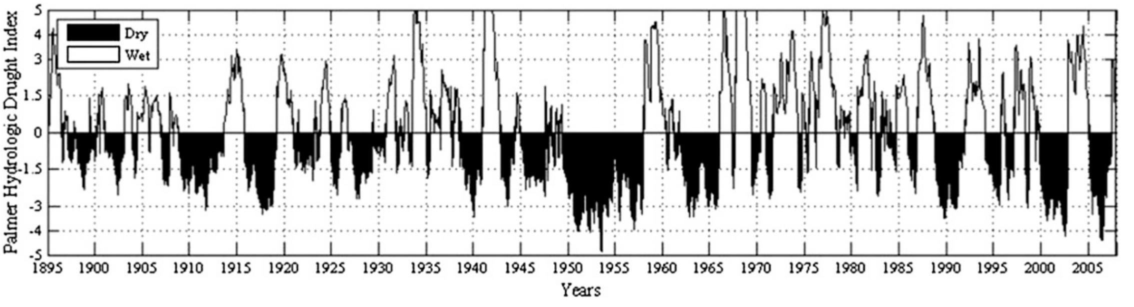

Figure 4. The Palmer Hydrologic Drought Index for the Texas Lower Rio Grande Valley (i.e., Hidalgo and Cameron Counties) (Sources: Leidner et al., 2011)

that drought conditions have persisted for the region for 60% of the time between 1990–2007 (Leidner et al., 2011).

A tangible response to the drought and supply issues (and other issues) has been coordinated and comprehensive water-resource planning at the state level by the Texas Water Development Board. A key purpose for the state's planning is for consistent analyses and preparation for the state's future water resources in all parts of the state.

Regional Planning

In June 1997, Senate Bill 1 (SB 1) was enacted by the 75th Texas Legislature. This comprehensive water legislation was an outgrowth of increased awareness of the vulnerability of Texas to drought and to the limits of existing water supplies to meet increasing demands as the population grows. This planning activity divided Texas into 16 regions with a comprehensive planning activity for each, including the responsibility to coordinate with neighboring regions and states. Counties in south Texas along the Rio Grande are represented by Region M, whereas far west Texas (El Paso region) is represented by Region E. This planning process is a dynamic activity with the plan updated every five years.

Supply-Enhancing Alternatives

To mitigate supply risks (e.g., drought, population), each water-planning region in Texas has identified supply-enhancing alternatives for its area. With the identification comes recognition that each alternative provides benefits and requires money; so from an economic perspective, the question becomes, *"Which is/are the most cost-effective way/ways to add H_2O to the regional supply?"*

Infrastructure Rehabilitation Projects

To answer this question for the middle and lower Rio Grande, a successful collaborative effort involving irrigation districts, North American Development Bank, the U.S. Bureau of Reclamation, the Texas Water Development Board, Texas AgriLife Research, and Texas AgriLife Extension Service began in 2002. The 24 water and energy-conserving projects analyzed annually save an estimated 58,250 af of raw irrigation water at an "annualized" cost of \$12/af to \$427/af (Lacewell et al., 2010). The average annualized costs also vary according to project type (Table 1).

Desalination

Desalination has become more interesting because it has become economically competitive with conventionally treated surface water (Boyer et al., 2010). Adoption, location, and dependance on this technology vary. It is being adopted by communities of all sizes and can provide the sole source of potable water for an area or it can be used to provide supplemental water. Some of the reverse-osmosis desalination facilities recently constructed within the Rio Grande Basin includes those identified in Table 2. These

Table 1. Annualized Costs of Saving Raw Water through Infrastructure-Rehabilitation Projects in the Texas Lower Rio Grande Basin, 2008

Rehabilitative Project Type	$/ac-ft
Meters and telemetry	$83
Lining (protected and non)	$35
Pipeline (multisize)	$56
58,250 acre-foot/year aggregate (overall)	$45

Source: Rister et al. (2008).

costs are comparable to the $772/af calculated for the McAllen Northwest conventional surface-water treatment facility (Rogers et al., 2010).

Agricultural Conservation—Middle Rio Grande Basin

In a water conservation study, Michelsen et al. (2009a) evaluated the applicability of select agriculture best management practices (BMPs) in the far west Texas region. The study determined the quantities of water which could be saved by the BMPs and their respective costs (Table 3) in times of drought and full allocation.

Agricultural Conservation—Lower Rio Grande Basin

Extended periods of drought (Figure 4) resulting in reduced supplies in the Amistad and Falcon International Reservoirs, increased competition among water users, and an inherent desire to improve the reliability of supplies and the overall water situation underpin efforts for conserving water in the area. The first irrigation networks (canals and laterals) were built in the area beginning in 1895 (Stubbs et al., 2003) with water applied in the field using the furrow (or surface) irrigation technique. Since then, the adoption of newer, more efficient technologies has diversified the in-field water application methods used (Table 4). Although there is little apparent incentive for a farmer to conserve water, adoption of advanced technologies has implications for labor savings and convenience.

Pricing for Improved Efficiency

Although improvements to in-field water efficiency have been made with subsurface irrigation techniques and materials, impediments to maximum efficiency exist (95% of in-field application is by a flood irrigation technique). That is, financial incentives for agriculture producers to conserve water are absent as a result of the region's legal structure of water-right ownership (irrigation districts own/control most of the water rights) and the fact that irrigation districts prefer *economies of size* with regard to deliveries. Thus, their delivery rate charges are based on delivery volume (by the ID) rather than by volumetric use/pricing by producers. With appropriate incentives established through volumetric pricing, agricultural producers' adoption of conserving technologies in the region could perhaps increase.

Water Quality

Water quality issues throughout the Rio Grande portion that serves as the border between the United States and Mexico are dominated by salinity, nutrients, pharmaceuticals, and fecal coliform bacteria (Flores, 2001). Several brief overviews of related issues are capsulated subsequently.

Table 2. Data for Select Desalination Facilities in the Rio Grande Basin, 2010

Facility Name	Million Gallons per Day	City, State	Population	$/af/year
Kay Bailey Hutchison	27.5	El Paso, TX	773,125	N.A.
Southmost	7.5	Brownsville, TX	143,411	$770
La Sara	1.13	La Sara, TX	1,024	$745

Sources: Boyer et al. (2010).
af, acre-foot.

Table 3. Potential Annual Water Savings and Range in $/af Cost for Far West Texas, by Best Management Practice, for Drought and Full Supply[a]

BMP Strategy	Acre-Feet of Potential H_2O Savings		Range in BMP Cost ($/af)
	Drought	Full	
Scheduling[a]	5,275	17,524	24–55
Lining Canals	25,000	50,000	161–405
Tailwater Reuse	2,312	9,412	104–529
Total	32,587	76,936	

Source: Michelsen et al. (2009a).
[a] Estimates are for three irrigation districts: EPCWID1, HCCRD1, and HCUWCD1.
af, acre-foot; BMP, Best Management Practice.

Salinity could be considered the most prevalent water quality issue along the Rio Grande as 87% of the region's surface water rights are *Ag Irrigation* (Texas Water Development Board, 2007). Of the key impediments to improved quality, agriculture is the largest user of water and salts impacting agriculture are the most voluminous. However, salts impact both potable and agriculture irrigation water supplies with the primary impact of increasing salinity being on downstream users. That is, "*. . . the water is of good quality in the upper parts of the basin, but the quality decreases as the water moves downstream*." This is exemplified in Figure 5. The degradation in quality is generally associated with significant agriculture return flow, natural saline springs, and evaporation during the summer months (U.S. Geological Survey, 2010b).

Table 4. Predominant Irrigation Methods in the Lower Rio Grande Basin, 2007

Predominant Irrigation Methods in the Lower Rio Grande Basin	
Surface (flood) Irrigation	Percent[a]
Poly-pipe	52.2
Earthen ditches	32.8
Gated pipe with flood valve	9.9
Subsurface Irrigation	
Drip	3.4
Sprinkler (center pivot, microjet)	1.6
Total	100.0

Source: Enciso and Périès (2007).
[a] Percentage of an approximate 400,000 acres of irrigated farmland in 27 irrigation districts.

Damages associated with the high salts depicted in Figure 5 have been quantified in a recent economic study, which quantified salinity damages from agricultural and urban use of Rio Grande water in the specified area (Michelsen et al., 2009b). The reported economic damages are summarized in Table 5.

Additionally, there are potential economic damages from high-saline water for the Lower Rio Grande as documented in Lacewell et al. (2007) on the expected economic benefits of the El Morillo Drain. This study reports an estimated 300,000 tons of salt is prevented from entering the Rio Grande each year by infrastructure, which drains vast agriculture acreage in Mexico (referred to as *El Morillo Drain*). If the drain fails, the region would suffer damages because cities using Rio Grande water would exceed standards established under the Clean Drinking Water Act and agriculture would realize reduced yields and/or quality. Table 6 summarizes the estimated range in potential damages (also known as "benefits" of the infrastructure).

Excess *nutrient runoff* has become an ever-increasing water-quality issue along the Arroyo Colorado watershed in south Texas. This 450,000-acre subwatershed of the Nueces-Rio Grande Coastal Basin is largely supplied by agricultural runoff and is used as a conduit for wastewater, recreational uses, and is important for many marine species (Arroyo Colorado Watershed Partnership, 2010). An ongoing effort to address water quality in the Arroyo Colorado is the Rio Grande Valley Nutrient Management Education Program conducted by the Texas AgriLife Extension Service and Texas AgriLife Research. To date, the

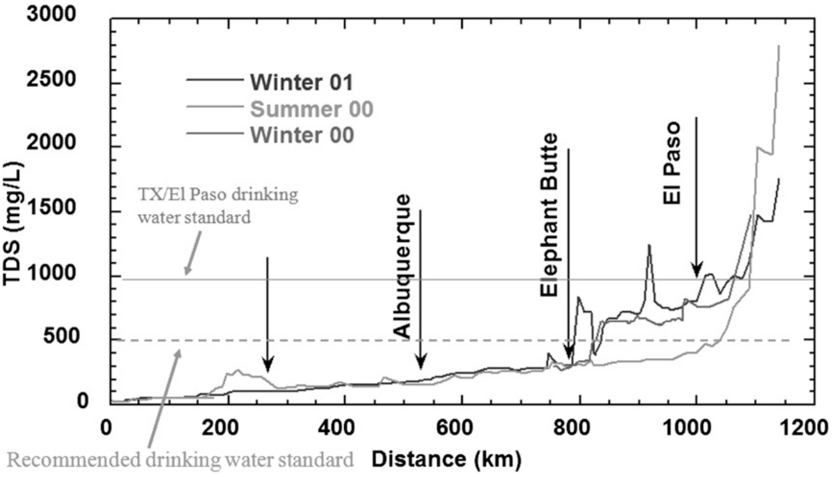

Figure 5. Total Dissolved Solids (i.e., salts) along the Rio Grande, 2000–2001 (Source: Phillips and Michelsen, 2011)

program has analyzed more than 3,200 soil samples for 135,000 acres and educated 1,400 farmers. Cumulative impacts include reduced nitrogen and phosphate applications of 3.6 million and 3.9 million pounds, respectively. These activities translate into cost savings of up to $26.55 per acre and total economic benefits to producers (since the program's inception in 2001) of $2.5 million (Smith, 2010).

Pharmaceuticals in drinking water is an issue receiving significant scientific attention, including along the Rio Grande. Obviously, having biologically active compounds in surface and/or potable waters is a concern to both human and aquatic health.

Fecal coliform contamination is the result of untreated and poorly treated discharges through inadequate wastewater treatment facilities, mainly in Mexican cities. However, adding to the issue are malfunctioning septic systems and/or pet animal wastes not properly managed along the Rio Grande and its tributaries.

Industrial inflows have been reported below population centers, mostly near the maquiladora industrial parks (HARC). It is reported that toxic chemicals are making their way to the Rio Grande from warehouses built along the banks of creeks that feed the river (TX Peer, 2008). Fish tissues have been found to contain arsenic, mercury, chlordane, and other chemicals at numerous points along the river.

Waterborne diseases are a concern with the rapid population growth in certain communities along the Rio Grande, which were developed with little to no consideration for proper infrastructure to assure safe water. With waterborne contamination of household water, there is an increased incidence of diseases for this population, causing losses of days from work, suffering illness, reduced productivity, costs for treatment, and potentially contaminating a broader sector of the population.

A further example of water quality and ecosystem adjustments along the Rio Grande is observed in the "Forgotten River" (Teasley, McKinney, and Patiño-Gomez, 2010), which extends downstream from El Paso, Texas, to the confluence of the Rio Conchos near Presidio,

Table 5. Economic Damages from Salt in the El Paso-Hudspeth County, Texas, Region, 2009

Type of Use	Impact per Year ($ millions)	Percent
Agriculture	2.4	24
Residential	4.3	42
Landscape	1.2	12
Commercial	1.8	17
Industrial	0.3	3
Treatment Plants	0.1	1
Total	10.2	100

Source: Michelsen et al. (2009b).

Table 6. Potential Economic Damages Associated with Failure of El Morillo Drain (i.e., benefits without failure) Along the Texas Lower Rio Grande, 2007

	Range ($ million)	
Benefits	Lower	Upper
Residential and municipal	20.1	31.6
Agriculture	20.5	76.9
Total	40.6	108.5

Source: Lacewell et al. (2007).

Texas. Where plants, animals, and fish were plentiful, the Forgotten River has dwindled to a trickle of salty water bordered by acres of water-thirsty invasive salt cedar. In April 2003, the Forgotten River dried up through Big Bend National Park's Mariscal Canyon, halting recreational rafting and stranding fish and aquatic species (Lacewell et al., 2010).

Environmental—Invasive Plant Species

Large dense stands of nonnative giant reed (*Arundo donax*) and salt cedar (*Tamarix* spp.) infest the banks and flood plains along much of the Rio Grande. The USDA-ARS estimates the Arundo-infested acres on both the United States and Mexico sides of the river from Lajitas to Del Rio at 5,055 ac (2,046 ha) with most of the infestation being between Del Rio and Big Bend (Yang, Everitt, and Goolsby, 2010). Tamarix infestations are even more extensive. In 2007, it was estimated that 39% (15,281 ac) of the riparian corridor between Fort Quitman and Presidio was dominated by Tamarix. Extensive stands of Tamarix are also present along the Rio Grande in Big Bend National Park, where an estimated 15,000 ac occur (National Park Service, 2007).

With Arundo and Tamarix growing to heights of 8 m (26 ft) and 18 m (56 ft), respectively, these dense stands of invasives impact border security by blocking the U.S. Border Patrol's infrared sensors from detecting movement of illegal immigrants (Seawright et al., 2009). Additionally, this invasive vegetation is linked to sediment accumulation, channel constriction, and increased flooding frequency.

Recently, Seawright et al. reported on the economics associated with a USDA-ARS project, which incorporates a biological control agent (also known as beneficial insect) to slow and reduce Arundo infestation. From this, there would be a net water savings by reducing the invasive and replacing it with native vegetation. Applying economic benefits of the "saved" water to agricultural water resulted in robust economic results, which include:

- the baseline benefit–cost ratio indicated $4.38 of benefits for every dollar of public investment, and
- the cost of water saved is $44.08 per af (a value comparable to other projects designed to increase water supply for the region (Rister et al., 2008)).

Concluding Comments

The Rio Grande is largely responsible for the prosperous urban and agricultural sectors that comprise the Rio Grande Basin. A rapidly increasing population is contributing to growing pains associated with increasing demands for potable water, either from the Rio Grande or from limited groundwater around El Paso or from what was once a relatively more expensive source, brackish groundwater desalination in south Texas. A history of legislation and litigation facilitate a functioning water market, albeit with some imperfections associated with manmade institutions and uncertainties stemming from dynamic climate events. Water ownership, water quantity and quality, environmental issues, and economic institutions are at the forefront of concerns and future opportunities for enhancing the value of Rio Grande water. There are several activities in place addressing the water needs. None of the solutions are easy or inexpensive, but there are encouraging cooperative attitudes among stakeholders.

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