Lower Rio Grande Basin Study

Under the Authority of the SECURE Water Act (Public Law 111-11)
Great Plains Region, Oklahoma-Texas Area Office

U.S.Department of the Interior
Bureau of Reclamation
Denver, Colorado

Rio Grande Regional Water Authority

December 2013

Mission Statements

The U.S. Department of the Interior protects America's natural resources and heritage, honors our cultures and tribal communities, and supplies the energy to power our future.

The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

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Acronyms

2010 Region M Plan	*Rio Grande Regional Water Plan*, dated October 1, 2010
ac-ft/yr	acre-feet per year
Basin Study	Lower Rio Grande Basin Study
BCSD	Bias Corrected Spatially Downscaled Surface
BGD	brackish groundwater desalination
BPUB	Brownsville Public Utilities Board
CMIP-3	Climate Model Inter-comparison Project Phase 3
DFC	desired future condition
DMI	domestic-municipal-industrial
EPA	United States Environmental Protection Agency
ERHWSC	East Rio Hondo Water Supply Corporation
ET_0	reference evapotranspiration
GAM	Groundwater Availability Model
GCM	global climate model
GHG	greenhouse gas
GMA	Groundwater Management Area
GNEB	Good Neighbor Environmental Board
GWA	Groundwater Management Area
HUD	Housing and Urban Development
IBWC	International Boundary and Water Commission
Interior	U.S. Department of the Interior
ITC	Irrigation Technology Center
M&I	municipal and industrial
mg/L	milligrams per liter
MGD	million gallons per day
NAFTA	North American Free Trade Agreement
NAWSC	North Alamo Water Supply Corporation
P&Gs	*Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies*
P.L.	Public Law
PC	percentage change

PM	Penman-Monteith
psi	pounds per square inch
QA/QC	quality assurance/quality control
Reclamation	Bureau of Reclamation
RGRWA	Rio Grande Regional Water Authority
RO	reverse osmosis
ROI	return on investment
ROW	right-of-way
SB1	Senate Bill 1
SECURE	Science and Engineering to Comprehensively Understand and Responsibly Enhance
SRWA	Southmost Regional Water Authority
State Water Plan 2012	Statewide plan entitled *Water for Texas – 2012*
TCEQ	Texas Commission on Environmental Quality
TDS	total dissolved solids
Treaty	*Treaty of 1944 Utilization of Waters of the Colorado and Tijuana Rivers and of the Rio Grande*
TWDB	Texas Water Development Board
UCM	Unified Costing Model
USDA	U.S. Department of Agriculture
USGS	U.S. Geological Survey
VIC	Variable Infiltration Capacity Hydrology Model
WAM	Water Availability Model
WaterSMART	Sustain and Manage America's Resources for Tomorrow
WMS	water management strategy
WRAP	Water Rights Analysis Package
WSC	water supply corporation
WUG	water user group
WWCRA	West Wide Climate Risk Assessment

Symbols

°F	degrees Fahrenheit
%	percent
§	section

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SUMMARY

I. Background

The Lower Rio Grande Basin Study (Basin Study) proposal was selected for fiscal year 2011 funding in July 2011. The Bureau of Reclamation (Reclamation) and the Rio Grande Regional Water Authority (RGRWA) with its 53 member entities, in collaboration with other Texas water and environmental agencies, and the International Boundary and Water Commission (IBWC) conducted the cost-shared Basin Study to evaluate the impacts of climate variability and change on water supply imbalances within an eight-county region (State of Texas water planning Region M) along the U.S./Mexico border in south Texas. The study was conducted under the authority of Public Law (P.L.) 111-11, Subtitle F.

Water supplies in the area are primarily from the Rio Grande, with much of the drainage located in Mexico and regulated by releases from Falcon and Amistad Reservoirs (figure S-1), which are managed by the IBWC, in compliance with the *Treaty of 1944 Utilization of Waters of the Colorado and Tijuana Rivers and of the Rio Grande* (Treaty). Much of the water deliveries in the study area are made through a network of canals that are managed by 27 different irrigation districts. The supply issues facing the Lower Rio Grande Basin in both the United States and Mexico are extremely complex, ranging from a multinational to local scale.

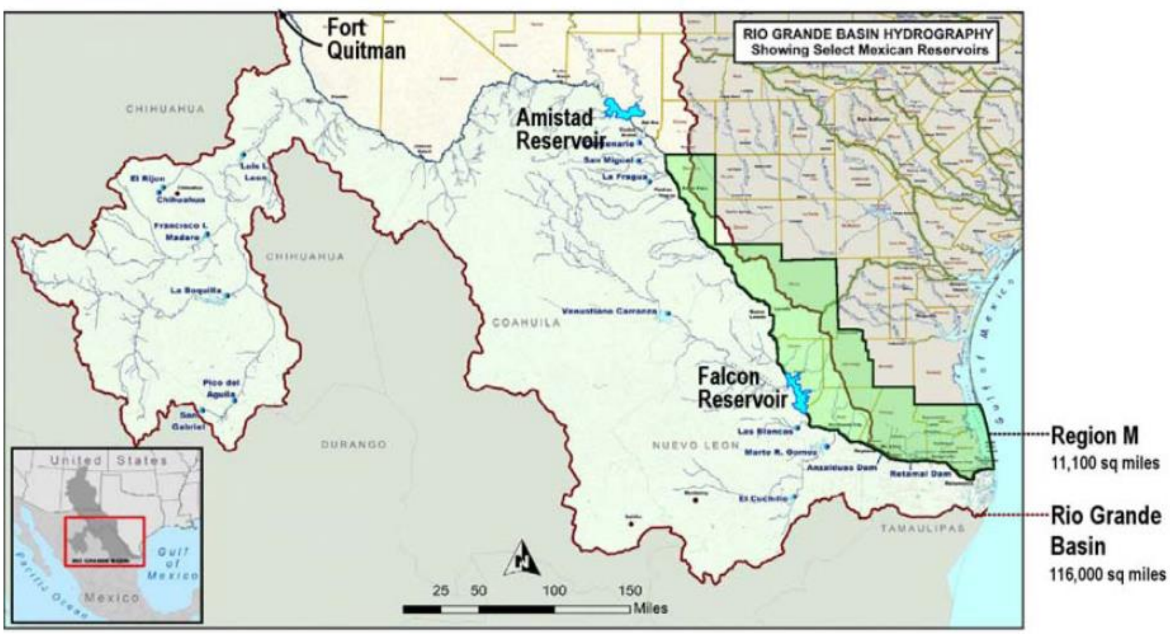

Figure S-1: Project study area.

Under the authority of the SECURE Water Act (Public Law [P.L.] 111-11), the U.S. Department of the Interior (Interior) established WaterSMART (Sustain and Manage America's Resources for Tomorrow) in February 2010 to facilitate the work of Interior's bureaus in pursuing a sustainable water supply for the Nation. The program focuses on improving water conservation and sustainability and helping water resource managers make sound decisions about water use. It identifies strategies to ensure that this and future generations will have sufficient supplies of clean water for drinking, economic activities, recreation, and ecosystem health. The program also identifies adaptive measures to address climate change and its impact on future water demands. The four required elements of a Basin Study are:

1. Projections of water supply and demand within the basin, including an assessment of risks to the water supply relating to climate change as defined in section 9503(b)(2) of the SECURE Water Act.

   The study finds that climate change is likely to result in increased temperatures, decreased precipitation, and increased evapotranspiration in the study area (chapter 2).

2. Analysis of how existing water and power infrastructure and operations will perform in the face of changing water realities, such as population increases and climate change, as well as other impacts identified within section 9503(b)(3) of the SECURE Water Act as appropriate.

   The study finds that in addition to the 592,084 acre-feet per year (ac-ft/yr) of supply shortfall (demand minus supply) predicted by the existing regional planning process by 2060, an additional 86,438 ac-ft/yr will be needed due to climate change. This will greatly reduce the reliability of deliveries to all users dependent on deliveries of Rio Grande water via irrigation systems (chapter 2).

3. Development of appropriate adaptation and mitigation strategies to meet future water demands.

   The study developed a planning objective that would reduce dependency on the Rio Grande in the part of the study area most susceptible to water supply imbalances and would meet the additional shortfall projected (chapter 3).

4. A tradeoff analysis of the strategies identified and findings and recommendations as appropriate. This includes an analysis of all proposed alternatives in terms of their relative cost, environmental impact, risk (probability of not accomplishing the desired/expected outcome), stakeholder response, or other attributes common to the alternatives.

The study examined the existing water management strategies proposed by the regional planning process against the planning objective and selected four for further study (seawater desalination, brackish groundwater desalination [BGD], reuse, and fresh groundwater development) while emphasizing the continuing need for conservation and the need for a portfolio approach to include all approved elements of the regional planning process (chapter 3). The four strategies are examined further in chapter 4. Brackish groundwater desalination was recommended as being most suitable for preliminary engineering and affordability analysis. This strategy was further developed to recommend three generalized locations for future desalination plants, which were then analyzed using the Texas Water Development Board's (TWDB) Unified Costing Model (chapter 5), and an affordability analysis was conducted (chapter 6).

The study cost $412,798 (52 percent (%) RGWRA; 48% Federal cost share) and was completed in 24 months.

II. Findings

A. Water Supplies and Demands

The magnitude and frequency of water supply shortages within the study area are severe, even before projecting the effects of climate change. Based on an analysis of the currently adapted Region M Plan, which is incorporated in the State Water Plan,[1] the population in the eight-county region is expected to grow from 1.7 million in 2010 to 4.0 million in 2060, resulting in the need for an additional 592,000 ac-ft/yr, or about 35%, of the total water demand. The State Water Plan identified strategies to meet those needs. This study determined that climate change may likely increase the shortage by an additional 86,438 ac-ft/yr, and this was the focus of this Basin Study.

B. Planning Objective

The study's planning objective was developed to address the 86,438 ac-ft/yr shortfall in consideration of the following requirements and constraints:

- Reduce dependency on the Rio Grande
- Preserve existing water rights

[1] Texas Water Development Board. 2012 Water for Texas State Water Plan. January 2012.

- Preserve downstream flows for irrigation/push water and environmental needs
- Contain actions that are within the reasonable control of study sponsors
- Concentrate on Cameron, Willacy, and Hidalgo County needs

Alleviate projected water supply imbalances in the study area by developing one or more alternatives in Cameron, Willacy, and Hidalgo Counties that will (1) provide a minimum of 86,438 acre-feet of water year round by 2060; (2) protect existing water rights; (3) be compatible with regulations, policies, and environmental law; and (4) be implementable within the reasonable control of study sponsors.

C. Alternatives/Adaptive Strategies

An appraisal-level plan formulation and evaluation process was conducted that divided the study area into four major groups based on proximity and existing interconnecting pipelines and transfer agreements. Each group was evaluated based on vulnerability to drought (towns that have been in danger of losing access to water within 6 months according to the Texas Commission on Environmental Quality's 180-day drought watch list)[2] and projected average annual shortages as shown in the 2012 State Water Plan. The distribution of demands among the groups was used to distribute proposed supplies.

The analyses showed that an alternative comprised of three distinct regional BGD systems would best meet the planning objective.

- The Group 1 system, shown on figure S-2, would serve 10 communities by constructing two BGD facilities at 31.4 million gallons per day (MGD) each and associated transmission pipelines and pumps. The 70,400 ac-ft/yr project is estimated to cost $308,046,000 (2012).
- The Group 2 system is shown on figure S-3 and would serve 10 communities. It would include one BGD facility at 9.2 MGD and associated transmission pipelines and pumps. The cost is estimated at $86,477,000 (2012) and would provide 10,300 ac-ft/yr.
- The Group 3 system is shown on figure S-4 and would serve eight communities. It would provide 12,300 ac-ft/yr and include an 11.8-MGD BGD facility and associated transmission pipelines and pumps. The cost is estimated at $99,551,000 (2012).

[2] http://www.tceq.texas.gov/drinkingwater/trot/droughtw.html

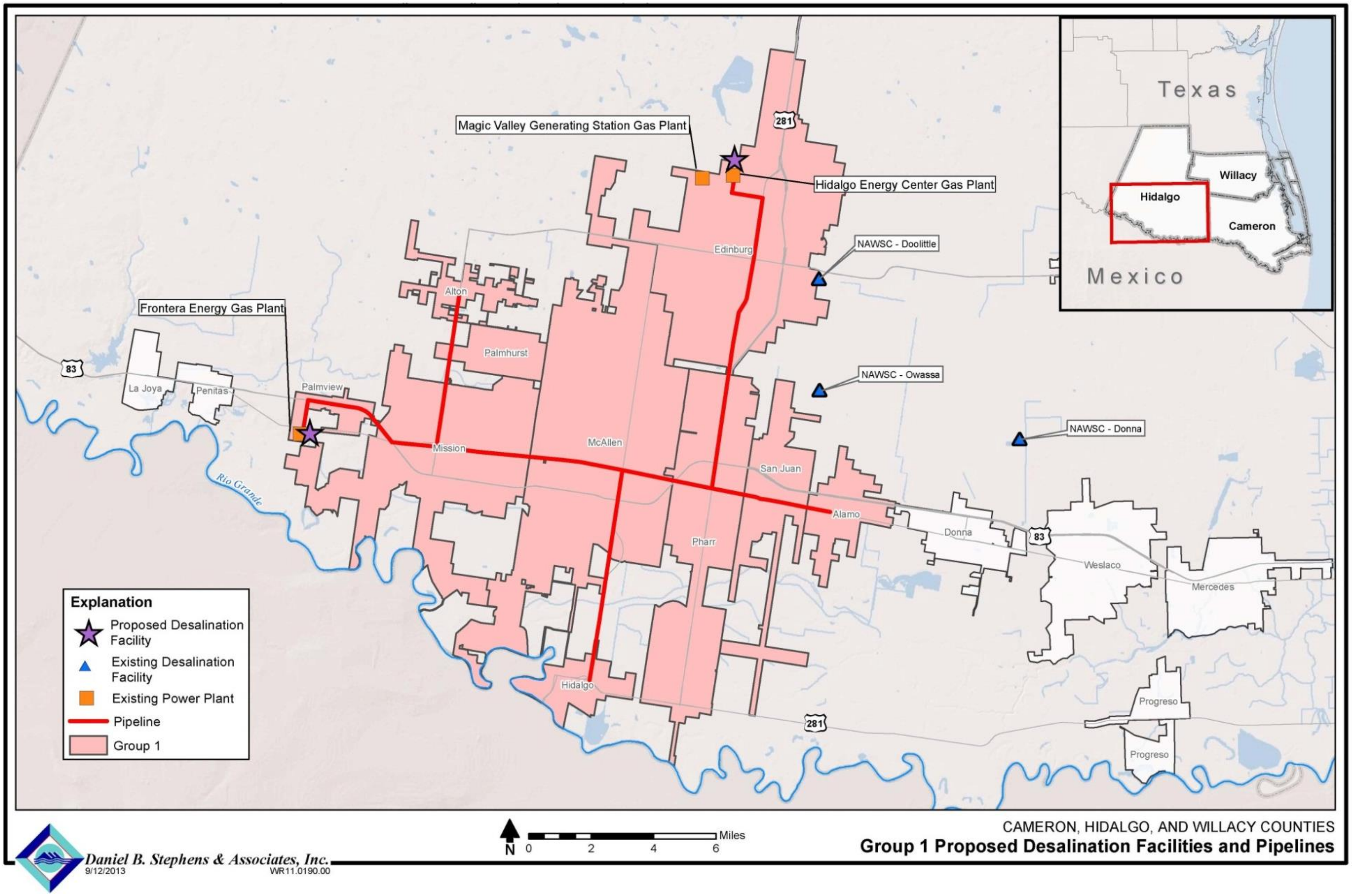

Figure S-2: Group 1 facilities.

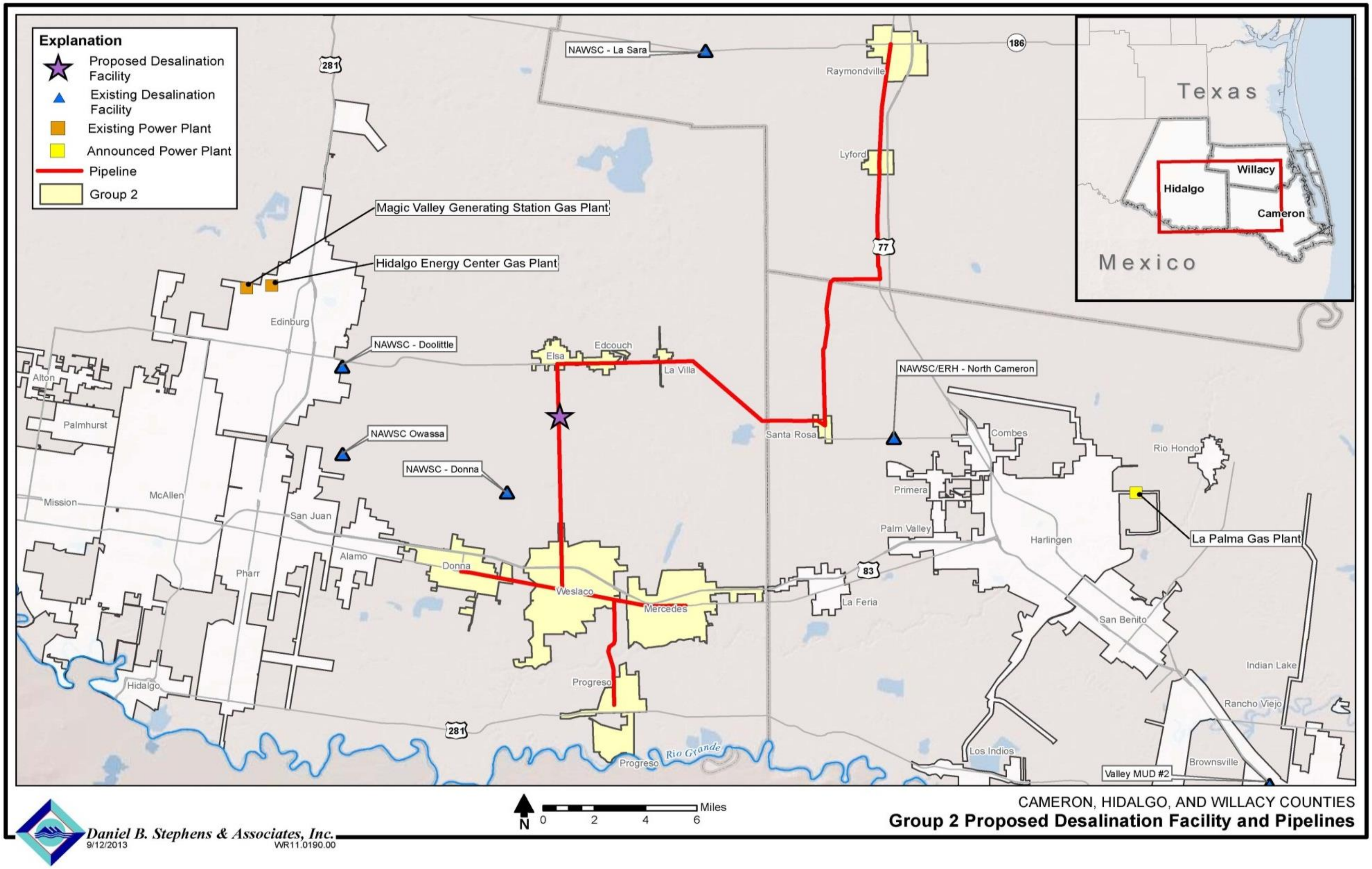

Figure S-3: Group 2 facilities.

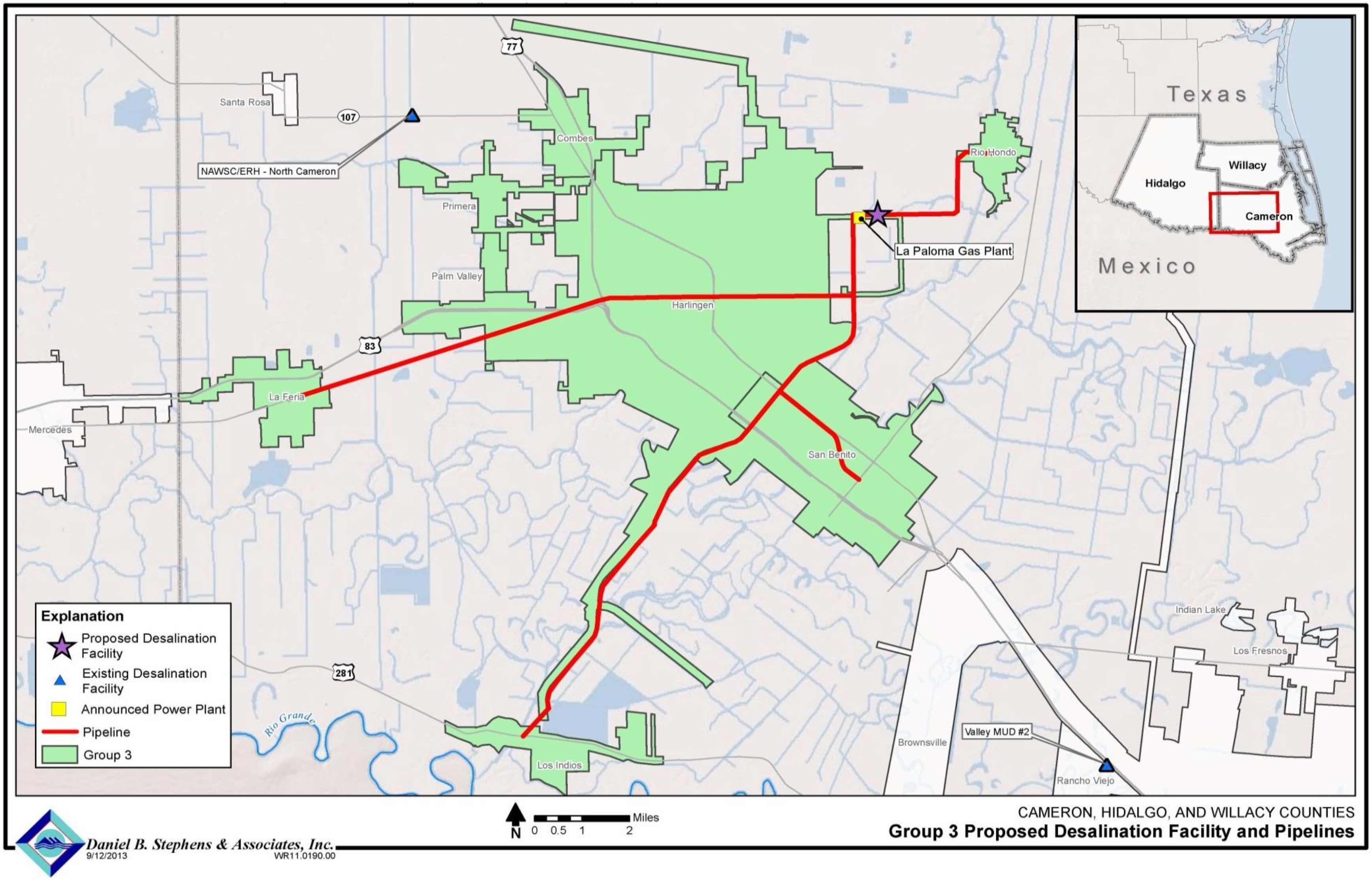

Figure S-4: Group 3 facilities.

- Group 4 includes Brownsville and shows the greatest projected shortage in 2060. However, since the Southmost Regional Water Authority (SRWA) Desalination Plant is operating at full capacity and currently undergoing expansion, the communities that are served by this facility (and therefore the group) are not included in this BGD alternative. It is recommended that an expansion of the SRWA facilities be considered as a component in any regional water supply plan.

A summary of the BGD alternative based on the P&Gs[3] of effectiveness, acceptability, completeness, and efficiency is as follows:

EFFECTIVENESS	Effectiveness is the extent an alternative plan alleviates the problems. Distributed brackish desalination systems could feasibly provide the target production volume to municipal groups.
ACCEPTABILITY	Acceptability is the workability and viability of the alternative with respect to acceptance by State/local/public entities and compatibility with laws and regulations. Brine disposal may be challenging depending on the particular location, but regional precedent is set for surface water discharge.
COMPLETENESS	Completeness is the extent an alternative provides and accounts for all necessary investments or other actions.
EFFICIENCY	Efficiency is the extent to which an alternative is the most cost-effective solution. The distributed facilities appear to be most efficient in operational costs.

D. Next Steps and Future Considerations

Brackish groundwater desalination facilities have been identified at an appraisal level of detail to meet the planning objective. There may be opportunities for Reclamation to assist the local entities with additional analyses through cost-shared WaterSMART Title XVI feasibility studies (P.L. 102-575) or SECURE feasibility studies (P.L. 111-11).

Non-Federal funding may be available through the following programs administered by the TWDB (described more fully in chapter 6):

- Drinking Water State Revolving Fund
- Rural Water Assistance Fund
- State Participation Program
- Water Infrastructure Fund

[3] U.S. Water Resources Council. *Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies*. Government Printing Office, Washington, DC. 1983.

- Economically Distressed Areas Program
- Regional Water Supply and Wastewater Facilities Planning Program

E. Consequences of Taking No Action

The impacts of not addressing the staggering water supply and demand imbalances, both current and future, in the Lower Rio Grande River Basin are severe. The study area is home to 27 irrigation districts and a multimillion dollar crop and citrus industry that drives both the local and national economy. The annual value of crops and citrus grown in the study area is estimated at $50 million and $200 million, respectively. Texas is the third largest citrus producer and fourth largest sugarcane producer in the United States, most of which is grown in the study area. Other prominent crops include cotton, sorghum, and corn. Irrigation water rights in the study area are junior to municipal and industrial rights (M&I), and as such are subject to proration during supply shortages, which can have devastating impacts on agricultural uses and the local economy when shortages occur. For instance, the 2009 drought resulted in interrupted water diversions for some irrigation districts with junior water rights, which resulted in a 49% loss of acreage and $19 million in losses for farmers in parts of the study area.[4]

Droughts can result in potential curtailments to M&I users as well. As a result of severe drought conditions since 2011, several irrigation districts in the region announced this spring (2013) that agricultural deliveries were being curtailed, which also subsequently affected municipal supplies that depend on agricultural conveyance systems for water deliveries. Climate change will likely exacerbate this competition by making less water available for agricultural uses, thereby placing even more pressure on proposed reallocations from agricultural to M&I uses.

According to the Region M Plan, when agricultural shortages occur, costs to the local economy have been estimated to be about $135 million and a loss of 4,130 jobs annually. These adverse economic impacts would have environmental justice implications as well. The study area contains a disproportionate number of persons living below the poverty level when compared to the rest of Texas (35.7 versus 15.4%). In addition, the median household income in the area is $23,489, well below the State average of $39,927.

The consequences of water supply imbalances extend well beyond adverse impacts on the economy of the region. Imbalances are and will continue to have adverse impacts on the sensitive ecological communities that depend on the Rio Grande River and associated riparian habitat. The Lower Rio Grande Valley

[4] Santa Ana, R. "Drought losses top $19 million in Lower Rio Grande Valley," AgriLife NEWS, Texas A&M University. November 13, 2009.

National Wildlife Refuge and Wildlife Corridor, administered by the U.S. Fish and Wildlife Service and Texas Parks and Wildlife, respectively, cover 91,000 acres in the region, with plans to expand to 132,000 acres. The study area is located within a major confluence of two flyways for migratory birds and waterfowl and is home to the World Birding Center, which is a top worldwide destination for birdwatching. Furthermore, 69 rare, threatened, or endangered species are supported by these protected areas. All of these sensitive resources will be subject to increased stressors in the future as water supplies become more constrained by increased demand and climate change.

Solutions to the expected shortages in the study area must include the continued development of the range of strategies recommended by Region M and adapted by the State Water Plan, many of which would increase the efficiency of the use of Rio Grande supplies when implemented by the water user groups and government entities at all levels. Figure S-5 depicts the relative portions of future water strategies contained in the current Region M Plan for meeting all but 86,438 ac-ft/yr identified in this study.

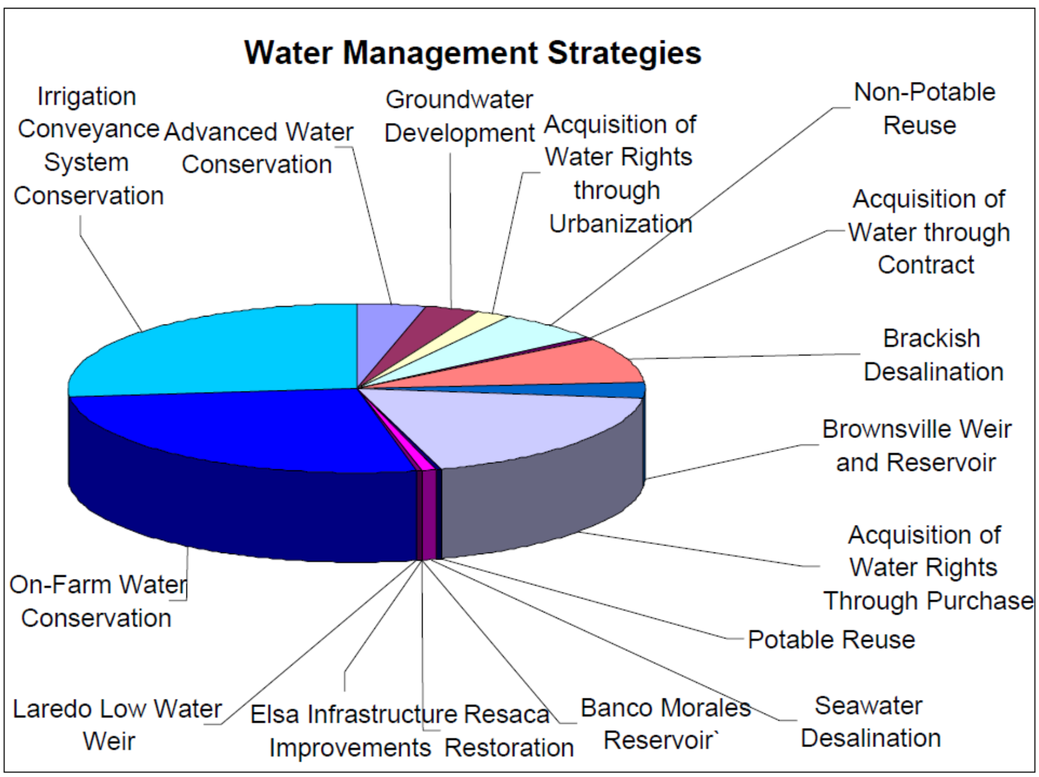

Figure S-5: Relative portions of future water supply strategies from the 2010 Region M Plan.

CHAPTER 1: PROBLEMS, NEEDS, AND OPPORTUNITIES

I. Introduction

A. Purpose of Study

The Bureau of Reclamation (Reclamation) and the Rio Grande Regional Water Authority (RGRWA) with its 53 member entities, in collaboration with the Texas Region M Planning Group, Texas Water Development Board (TWDB), Texas Commission on Environmental Quality (TCEQ), and International Boundary and Water Commission conducted the Lower Rio Grande Basin Study (Basin Study) to evaluate the impacts of climate variability and change on water supply imbalances, and to develop adaptation and mitigation strategies to address those imbalances, within an eight-county region along the U.S./Mexico border in south Texas (Cameron, Willacy, Hidalgo, Starr, Zapata, Jim Hogg, Webb, and Maverick Counties) (figure 1-1).

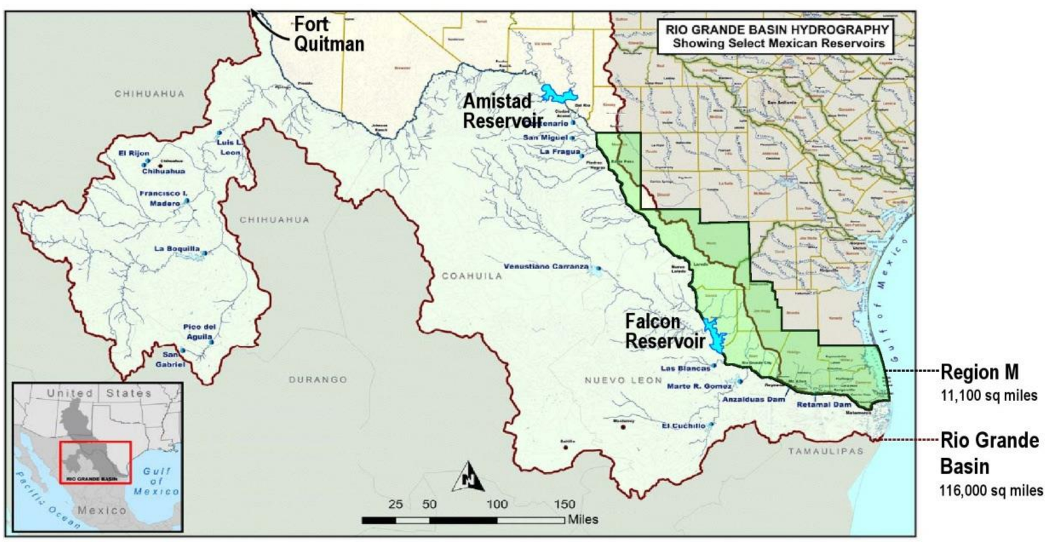

Figure 1-1: Project study area.
Source: Reclamation Project Fact Sheet, 2011.

Under the authority of the SECURE Water Act (Public Law [P.L.] 111-11), the U.S. Department of the Interior (Interior) established WaterSMART (Sustain and Manage America's Resources for Tomorrow) in February 2010 to facilitate the work of Interior's bureaus in pursuing a sustainable water supply for the Nation. The program focuses on improving water conservation and sustainability and helping water resource managers make sound decisions about water use. It identifies strategies to ensure that this and future generations will have sufficient supplies of clean water for drinking, economic activities, recreation, and ecosystem health. The program also identifies adaptive measures to address climate change and its impact on future water demands. This Basin Study, authorized under the SECURE Water Act, cost $412,798 (52 percent [%] RGWRA; 48% Federal cost share) and was completed within 24 months.

The supply issues facing the Lower Rio Grande River Basin are extremely complex, ranging from a multinational to local scale. First, because the study area is shared by both the United States and Mexico, numerous issues are presented both politically and technically. Flows within the Lower Rio Grande River are dependent upon reservoir operations and runoff emanating from both the United States and Mexico, which is complicated by issues relating to required reservoir releases pursuant to stipulations set forth in the Treaty.

The magnitude and frequency of water supply shortages within the study area are severe, even before projecting the effects of climate change. Based on analysis of currently adapted Regional and State Water Plans, while the population in the eight-county region is expected to grow from 1.7 million in 2010 to 4.0 million in 2060, the water supply shortage is expected to reach a staggering 592,084 ac-ft/yr by 2060, which would result in 35% of water demands being unmet. The study has determined that climate change may likely increase this shortage by an additional 86,438 ac-ft/yr.

As a result of severe drought conditions since 2011, several irrigation districts in the region announced this spring that agricultural deliveries were being curtailed, which also subsequently affected municipal supplies that depend on agricultural conveyance systems for water deliveries.

As a result of the climate-affected, long-range supply imbalances predicted by the study, alternative solutions have been evaluated, and the study is focused on investigating a regional BGD plan to meet planning objectives.

1. Local Planning Process

In 1997, the 75th Texas Legislature enacted Senate Bill 1 (SB 1), legislation that grew out of the drought of the early to mid-1990s and the increasing public awareness of rapidly growing water demands in the State. The issues and concerns addressed in SB 1 include State, regional, and local planning for water conservation, water supply and drought management, administration of State water rights programs, interbasin transfer policy, groundwater management and joint planning, water marketing, State financial assistance for water-related projects, and State programs for water data collection and dissemination. SB 1 radically altered the manner in which State Water Plans are prepared, establishing a “bottom up” approach based on Regional Water Plans that are prepared and adopted by appointed Regional Water Planning Groups representing 11 different stakeholder interests. The planning process is coordinated by the TWDB, which assembles the 16 Regional Water Plans into 1 comprehensive State Water Plan. Initially designated by TWDB as "Region M," the Rio Grande Regional Water Planning Area (or the Rio Grande Region) consists of the eight counties adjacent to or in proximity to the Lower Rio Grande: Cameron, Hidalgo, Jim Hogg, Maverick, Starr, Webb, Willacy, and Zapata. The planning group is tasked with developing a 50-year water supply plan in response to a repeat of the record drought. In the hydrologic models used for availability, this period occurred in the mid-1950s.

The current plan adopted by Region M is entitled *Rio Grande Regional Water Plan,* dated October 1, 2010 (2010 Region M Plan)[5]. The findings and information provided in the 2010 Region M Plan were incorporated into the current Statewide plan entitled *Water for Texas – 2012*[6] (State Water Plan 2012). There is an ongoing effort within Region M to produce a revised 2013 plan, but the data for that later plan has not yet been available for inclusion in this Basin Study. However, the development of this Basin Study has been presented at the Rio Grande Regional Water Planning Group at its meetings held every 2 months, and many of this study's findings, particularly regarding climate-affected future outcomes and planning alternatives, will be incorporated into the 2013 Region M Plan.

2. International Jurisdiction

The waters of the Lower Rio Grande are governed by the *Treaty of 1944 Utilization of Waters of the Colorado and Tijuana Rivers and of the Rio Grande* (Treaty) between the United States and Mexico. The Treaty distributed between the two countries the waters of the Rio Grande from Fort Quitman to the Gulf of Mexico (the upstream and downstream endpoints of the Rio Grande included in this Basin Study) and the waters of the Colorado River. Of the waters of the Rio Grande, the Treaty allocates to Mexico (1) all of the waters reaching the main channel of the Rio Grande from the San Juan and Alamo Rivers, including the return flows from the lands irrigated from those two rivers, (2) two-thirds of the flow in the main channel of the Rio Grande from the measured Conchos, San Diego, San Rodrigo, Escondido, and Salado Rivers and the Las Vacas Arroyo, subject to certain provisions, and (3) one-half of all other flows occurring in the main channel of the Rio Grande downstream from Fort Quitman. The Treaty allots to the United States (1) all of the waters reaching the main channel of the Rio Grande from the Pecos and Devils (United States) Rivers, Goodenough Spring, and Alamito, Terlingua, San Felipe, and Pinto Creeks; (2) one-third of the flow reaching the main channel of the river from the six named measured tributaries from Mexico (and provides that this one-third shall not be less, as an

[5] http://www.twdb.state.tx.us/wrpi/rwp/3rdRound/2011_RWP/RegionM/
[6] http://www.twdb.state.tx.us/wrpi/swp/swp.asp

average amount in cycles of 5 consecutive years, than 350,000 acre-feet annually); and (3) one-half of all other flows occurring in the main channel of the Rio Grande downstream from Fort Quitman.

Each section of the International Boundary and Water Commission (IBWC) gages the spring inflows from its side to the river downstream from the International Amistad Dam on the Rio Grande. The U.S. section operates 13 gaging stations for flood warning and operation of flood regulation storage in the International Amistad and Falcon Reservoirs on the Rio Grande. The U.S. section also operates and maintains 14 gaging stations on the main channel of the Rio Grande as well as 12 gaging stations on the measured tributaries in its country. In addition, the U.S. section operates several gaging stations on U.S. diversion and return flow channels. The Mexican section operates and maintains four gaging stations on the main channel of the Rio Grande, and eight gaging stations located on measured tributaries in Mexico, as well as gaging stations located on diversion and return flow channels in Mexico. The data provided by these gaging stations form the basis for joint accounting by the two sections of the waters belonging to each country. The national ownership of waters has been determined since 1953. The Water Accounting Division also oversees the operation of 10 gaging stations on the Lower Colorado River in association with deliveries of water to Mexico pursuant to the Treaty.

The Treaty further provided for the two governments to jointly construct, operate, and maintain on the main channel of the Rio Grande the dams required for the conservation, storage, and regulation of the greatest quantity of the annual flow of the river to enable each country to make optimum use of its allotted waters.

3. Social Characteristics

According to the Region M Plan, the population in the eight-county region is expected to grow from 1.7 million in 2010 to 4 million in 2060. This represents a growth rate of 2.8% per year, which is seven times faster than the State's average growth rate of 0.4% per year. The study area contains a disproportionate number of persons living below the poverty level when compared to the rest of Texas (35.7 versus 15.4%). In addition, the median household income in the area is $23,489, well below the State average of $39,927.

The impacts of not addressing the staggering water supply and demand imbalances, both current and future, in the Lower Rio Grande River Basin are severe. The study area is home to 27 irrigation districts and a multimillion dollar crop and citrus industry that drives both the local and national economy. According to the Region M Plan, the annual value of crops and citrus grown in the study area is estimated at $50 million and $200 million, respectively. Texas is the third largest citrus producer and fourth largest sugarcane producer in the United States, most of which is grown in the study area. Other prominent crops include cotton, sorghum, and corn.

Irrigation water rights in the study area are junior to municipal and industrial (M&I) rights and, as such, are subject to proration during supply shortages. This can have devastating impacts on agricultural uses and the local economy when shortages occur. For instance, the 2009 drought resulted in interrupted water diversions for some irrigation districts with junior water rights, which resulted in a 49% loss of acreage and $19 million in losses for farmers in parts of the study area[7]. In general, when agricultural shortages occur, costs to the local economy have been estimated to be about $135 million and a loss of 4,130 jobs annually.[8]

Due in part to its proximity to Mexico, the trade, services, and manufacturing sectors are becoming increasingly important to the region's economy. The trade and service sectors of the economy have been responsible for much of the economic growth in the Rio Grande Region over the past decade in terms of both revenue and employment. Growth in these sectors of the economy is largely attributable to the significant expansion of trade between the United States and Mexico under the North American Free Trade Agreement (NAFTA). Under NAFTA, the region is becoming increasingly important as a transportation hub for trade with Mexico.

Manufacturing is an important sector of the economy, primarily in the region's three U.S. Census Bureau-designated Metropolitan Statistical Areas of Brownsville-Harlingen-San Benito, McAllen-Edinburg-Mission, and Laredo. The most important factor in the expansion of the region's manufacturing sector has been the growth of the maquiladora industry in Mexico. At the end of the millennium, approximately 81% of the more than 2,000 maquila plants in Mexico were located in the six northern border States. The maquila industry was originally designed to take advantage of certain U.S. tariff code provisions that allowed U.S. firms to export unassembled products to Mexico for assembly. The assembled products were then imported in the United States. Duties were only paid on the value added during the assembly process rather than on the full value of the product. Even more favorable tariff conditions are now in place under NAFTA, and the maquiladora industry has been shifting toward full transformation of raw materials into finished products.

In Jim Hogg, Webb, Starr, and Zapata Counties, oil and gas production and trade are also important sources of income, averaging over $1 billion per year in taxable

[7] Santa Ana, R. 2009. "Drought losses top $19 million in Lower Rio Grande Valley," AgriLife NEWS, Texas A&M University. November 13, 2009.

[8] Robinson, J.R.C. et al. Water Policy 12 (2010) 114–128 Mitigating water shortages in a multiple risk environment.

value in the past decade. As will be described later in this study, oil development activities outside of the study area, but nearby, are beginning to show increased demand for water from within the study area.

The Texas Department of Tourism Web site illustrates that in 2008 the total destination spending for tourism for Cameron, Hidalgo, Willacy, Webb, and Starr Counties was over $2,000 million.[9] Tourism in Falcon State Park has a significant economic impact in Zapata and Starr Counties. In addition, water-related recreational activities such as boating, sport fishing, birdwatching, and commercial fishing in the lower Laguna Madre and adjacent waters also influence the regional economy.

The Lower Rio Grande Valley National Wildlife Refuge and Wildlife Corridor, administered by the U.S. Fish and Wildlife Service and Texas Parks and Wildlife, respectively, covers 91,000 acres in the region, with plans to expand to 132,000 acres. The study area is located within a major confluence of two flyways for migratory birds and waterfowl and is home to the World Birding Center, which is a top worldwide destination for birdwatching. According to the McAllen Chamber of Commerce, the economic impact by birdwatchers in the Rio Grande Valley is estimated to be approximately $125 million per year. Santa Ana National Wildlife Refuge attracts an estimated 99,000 birdwatchers per year, most of who have traveled from outside of the four-county area, and most from other States. These visitors inject $36 million into the local economy, with a total gross input of almost $89 million.

4. Environmental Characteristics

a. Climate

The climate of the Rio Grande Region ranges from a humid subtropical regime in the eastern portion of the region to a tropical and subtropical regime in the remaining portion of the region. Prevailing winds are southeasterly throughout the year, and the warm tropical air from the Gulf of Mexico produces hot and humid summers and relatively mild and dry winters. The July maximum temperature in the region ranges from about 96 degrees Fahrenheit (°F) to 98 °F. The January minimum temperature in the region ranges from about 40 °F to 49 °F. The number of frost-free days (growing season) varies from 320 days at the coast to 230 days in the northwestern portion of the region near Maverick County. The average annual net lake evaporation in the Rio Grande Region varies from 40 to 44 inches at the coast to approximately 60 to 64 inches at the central portion of the region near southern Webb County. Lake-surface evaporation rates are highest in the summer months.

The amount of rainfall varies across the Lower Rio Grande Region from an average of 28 inches at the coast to 18 inches in the northwestern portion of the

[9] http://travel.state.tx.us/TravelResearch.aspx

region. Most precipitation occurs during the spring from April through June and during the late summer and early fall, from August through October. Spring precipitation is the result of seasonal transition as inflowing warm, moist air from the Gulf of Mexico and the Pacific Ocean generates thunderstorms. The period from late summer to early fall is the hurricane season during which Atlantic and Gulf storms may move ashore along the Texas or Upper Mexican Gulf Coast. These storms can generate tremendous amounts of rainfall over a short period of time, causing extensive flooding due to the relatively flat nature of the region's terrain. It is these fall storms that provide a large portion of the surface water runoff captured in water supply reservoirs within the Rio Grande Basin.

### *b.	Water Resources*

### (1)	Surface Water

The Rio Grande Basin extends southward from the Continental Divide in southern Colorado through New Mexico and from Texas to the Gulf of Mexico. From El Paso, Texas, to the Gulf of Mexico, the Rio Grande forms the International Boundary between the United States and Mexico, a straight-line distance of 700 miles and a river mile distance of nearly 1,250 miles. Approximately 176,000 square miles of the 355,500 square miles in the entire Rio Grande Basin contribute to the Rio Grande (figure 1-2). The remainder of the basin consists of internal closed sub-basins.

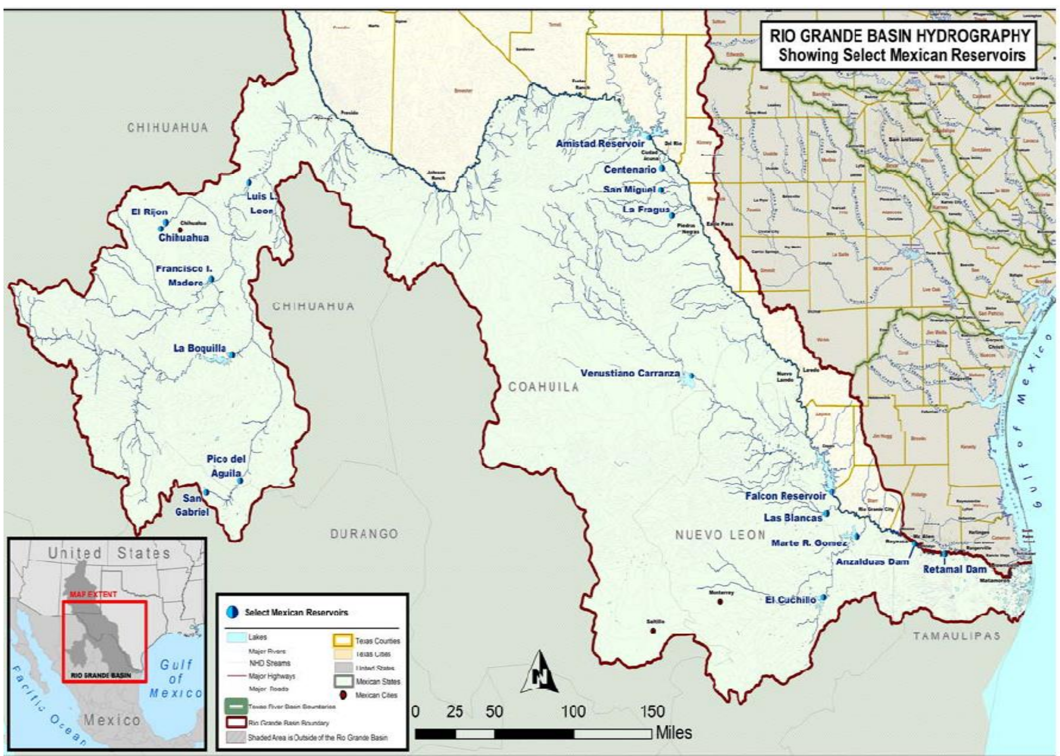

Figure 1-2: Rio Grande Basin with reservoirs.
Source: TWDB Region M Plan.

In Mexico, the Rio Conchos, Rio Salado, and the Rio San Juan are the largest tributaries of the Rio Grande. The Rio Conchos drains over 26,000 square miles and flows into the Rio Grande near the town of Presidio, Texas, about 350 river miles upstream of Amistad Reservoir. The Rio Salado has a drainage area of about 23,000 square miles and discharges directly into Falcon Reservoir on the Rio Grande. Falcon Reservoir is located between the cities of Laredo, Texas, and Rio Grande City, Texas, about 275 river miles upstream of the Gulf of Mexico. The Rio San Juan has a drainage area of approximately 13,000 square miles and enters the Rio Grande about 36 river miles below Falcon Dam near Rio Grande City, Texas. The Amistad-Falcon Reservoir System is designated as a special water resource by the TWDB (31 Texas Administrative Code 357.5(g)).

The Texas portion of the contributing watershed encompasses approximately 54,000 square miles. Approximately 8,100 square miles within the Texas portion of the basin are in closed sub-basins that do not contribute flows to the Rio Grande. The Pecos and Devils Rivers are the principal tributaries of the Rio Grande in Texas. Both of these rivers flow into Amistad Reservoir on the Rio Grande, which is located upstream of the city of Del Rio, Texas, about 600 river miles from the mouth of the Rio Grande. Once the river reaches Fort Quitman, Texas, downstream from El Paso, diversions to the United States and Mexico have essentially utilized all of the upstream surface waters. Therefore, for the purposes of water accounting and planning, the Rio Grande south of Fort Quitman is treated as a separate unit by the IBWC. Since waters upstream of Fort Quitman do not contribute to the Amistad and Falcon Reservoirs which serve the study area, the basin downstream from Fort Quitman comprises the hydrologic basin for this study.

Practically all of the surface water used in the Rio Grande Region is from the Rio Grande. Nearly all of the dependable surface water supply that is available to the Rio Grande Region is from the yield of the Amistad and Falcon International Reservoirs. These reservoirs are operated as a system by the IBWC for flood control and water supply purposes. These impoundments provide controlled storage for over 8 million acre-feet of water owned by the United States and Mexico, of which 2.25 million acre-feet are allocated for flood control purposes and 6.05 million acre-feet are reserved for sedimentation and conservation storage (water supply).

Some very limited supplies are available from tributaries of the Rio Grande in Maverick, Webb, Zapata, and Starr Counties: from the Arroyo Colorado, which flows through southern Hidalgo County and northern Cameron County to the Laguna Madre; from the pilot channels within the floodways that convey local runoff and floodwaters from the Rio Grande throughout the Lower Rio Grande Valley to the Laguna Madre; and from isolated lakes and oxbows (locally known as “resacas”) in Hidalgo and Cameron Counties. Under drought of record conditions, surface water supplies from sources other than the Rio Grande have very little flow and are of little significance.

Existing springs within the Rio Grande Basin of the Region M Planning Area (primarily Maverick, Webb, Zapata, Jim Hogg, and Starr Counties) are not numerous and are small in terms of their discharge quantities. There are no major springs that are extensively relied upon for water supply purposes. Many of the small springs do provide water for livestock and wildlife when they are flowing. Typically, the flow rate of the existing springs is less than 20 gallons per minute, with most springs in the region flowing at a rate of only a few gallons per minute.

(2) Groundwater

The major aquifers within the region include the Gulf Coast aquifer, which underlies the entire coastal region of Texas, and the Carrizo aquifer that exists in a broad band that sweeps across the State beginning at the Rio Grande north of Laredo and continuing northeast to Louisiana (figure 1-3). In general, groundwater from the various aquifers in the region has total dissolved solids (TDS) concentrations exceeding 1,000 milligrams per liter (mg/L) (slightly saline) and often exceeds 3,000 mg/L (moderately saline). The salinity hazard for groundwater ranges from high to very high. Given the recent droughts and competition for surface water supplies, developing and desalinating groundwater in the study area are increasingly of interest.

c. Plants and Wildlife

Located within the Matamoran District of the Tamaulipan Biotic Province, the Lower Rio Grande Valley is the northern boundary of much of the semitropical biota of Mexico. A number of plant and animal species from the more xeric and mesic areas to the west and northeast, respectively, converge in the Lower Rio Grande area.

The predominant vegetation type in this area is thorny brush, but there is an overlap with the vegetative communities of the Chihuahuan Desert to the west, the Balconian Province to the north (Texas Hill Country), and the tropical plant communities of Mexico to the south. The result is unique and varied flora and fauna. Xeric plants such as mesquite (*Prosopis glandulosa*), leatherstem (*Jatropha dioica*), lotebrush (*Ziziphus obtusifolia*), and brasil (*Condalia hookeri*) are found in this area. Sugar hackberry (*Celtis laevigata*) and Texas persimmon (*Diospyra texana*) more prevalent to the north, are also located in the Lower Rio Grande Valley. Other common species such as lantana (*Lantana horrida*), Mexican olive (*Cordia boisierri*), and Texas ebony (*Pithecellobium ebano*) are typically more tropical in location. Montezuma bald cypress (*Taxodium mucronatum*), Gregg wild buckwheat (*Eriogonum greggi*), Texas ebony, and anacahuita (Mexican olive) have their northernmost extension in the Lower Rio Grande Valley. More than 90% of total riparian vegetation and 95% of Tamaulipan thornscrub have been cleared since the 1900s.

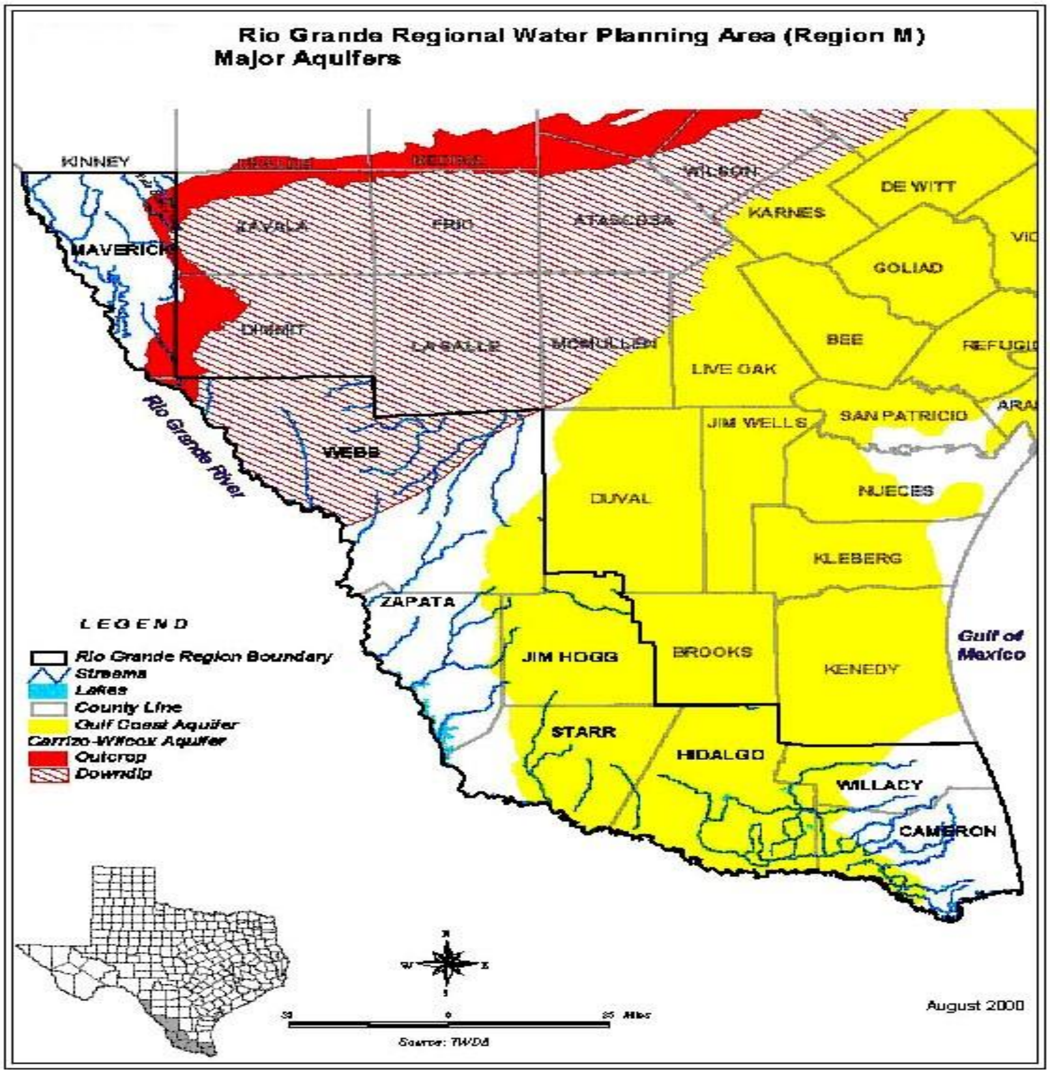

Figure 1-3: Major aquifers in the study area.
Source: TWDB Region M Plan.

Sixty-nine rare, threatened, or endangered species are supported by the Lower Rio Grande Valley National Wildlife Refuge and Wildlife Corridor. All of these sensitive resources will be subject to increased stressors in the future as water supplies become more constrained by increased demand and climate change.

d. Archeological Resources

A good chronology of the prehistoric occupation of the lower Rio Grande Delta is not available. There has been a significant amount of archeological work done in the south tip of Texas, but most of it is derived from surface surveys, and not the careful excavation of buried sites, which would provide clear definitions and a precise dating sequence. It is clear that the area has been occupied at least periodically for the last 13,000 years. The earliest period of documented occupation is the Paleo-Indian Period, which was at the end of the last ice age, when many large animals such as mammoths, extinct forms of bison, horse, and camels were common in North America. However, only sparse evidence from this period has been reported in this part of south Texas. In the following Archaic Period, investigations around Falcon Reservoir, just to the west of this area, have led some researchers to propose the "Falcon Focus."[10] The "Aransas Focus" also has been described in the central coastal region for this period.

In the still more recent Late Prehistoric Period, two cultural units have been proposed for the Rio Grande Delta region: the Brownsville and Barril Complexes, which were described by MacNeish.[11] It has also been suggested that the "Rockport Focus," which was described for the Coastal Bend region near Corpus Christi, may have exploited the coastal margin as far south as Willacy County. To the west, the poorly defined "Mier Focus" is also present in this Late Prehistoric timeframe.[12] The Panuco and Catan Complexes have been described to the south in Mexico.

By the time of first European contact, Native Americans in south Texas and northern Mexico included two distinct groups: the inland bands, known as the Coahuiltecans, and the coastal bands known as the Karankawas.[13] The area was also occasionally visited by the Lipan Apache in the late-prehistoric and early historic periods. Archeological sites are occasionally exposed by erosion or construction; however, they are more commonly identified by surface surveys, which record scatters of surface materials such as shell, stone flakes, fire-cracked rock, and occasionally stone tools or ceramic fragments. Once these sites are identified, they are evaluated by test excavation of areas where surface materials are recorded. Prospecting of some highly likely areas for occupation, such as the low levees adjacent to resacas and abandoned river channels, is also a possibility.

e. Historical Resources

The history of the Lower Rio Grande Valley is strongly connected to the development of water resources. Since the formulation of the planning objective for this study concentrates on the water issues of Cameron, Hidlago, and Willacy

[10] Suhm, D.A., E.B. Jelks, and A.D. Krieger. An Introductory Handbook of Texas Archeology, Bulletin of the Texas Archeological Society 25. 1954.

[11] MacNeish, Richard S. A preliminary report on coastal Tamaulipas, Mexico, American Antiquity. July 1947.

[12] Suhm, D.A., E.B. Jelks, and A.D. Krieger. An Introductory Handbook of Texas Archeology, Bulletin of the Texas Archeological Society 25. 1954.

[13] Newcomb, W.W. The Indians of Texas: From prehistoric to Modern Times Texas History Paperbacks. 1969.

Counties in the Lower Valley, historical context is best captured with excerpts from the Texas Department of Transportation's *A Field Guide to Irrigation in the Lower Rio Grande Valley*.[14]

The Spanish began settling the Lower Rio Grande Valley in the 18th century. Spanish settlers engaged primarily in livestock production. José de Escandón colonized the area known today as Hidalgo County in 1749, dividing the area along the river into 80 *porciones* (approximately a league or 4,428 acres), with larger grants to allow river frontage for each settler. As a result, these long lots measured approximately 9/13 of a mile in width and approximately 11 to 16 miles in length away from the river. In contrast, the land in Cameron County was issued in several large grants. Only three Spanish and Mexican grants were made in the area covered today by Willacy County.

Following the Texas War for Independence, the area south of the Nueces River became disputed territory with Mexico. The formation of Cameron County from San Patricio County occurred after the Mexican War (1846–1848) in which Mexico finally accepted the Rio Grande River as it border with the signing of the Treaty of Guadalupe-Hidalgo (1848). This Treaty established the boundary between Texas and Mexico at the middle of the deepest channel of the river from El Paso to the Gulf. It also allowed those Mexican citizens living on the Texas side to retain ownership of their lands. At that time, Cameron County encompassed almost all of south Texas, some 3,308 square miles, including parts of Hidalgo, Willacy, Kenedy, and Brooks Counties. Hidalgo County was subsequently established in 1852.

Throughout the early settlement period of the Lower Rio Grande Valley, cattle production dominated the economy of the semiarid region in the 18th and 19th centuries. Early attempts to irrigate the fertile lands of the delta were not commercially successful until a number of developments occurred, including: (1) a dependable form of transportation to markets through a rail line, (2) an efficient means of pumping water over the high banks of the river with centrifugal pumps, (3) an influx of capital from investors for the development of irrigation systems, (4) the arrival of farmers to purchase the irrigated farm lands, and (5) a supply of cheap farm labor. Once achieved, an agricultural boom occurred in the valley after 1904 with an explosion in the number of private land and irrigation companies investing in the area.

The Lower Rio Grande Valley experienced a period of expansion until the post-World War I years at which time undercapitalized developers could not withstand the economic impacts of the Mexican Revolution, drought and flood, and the post-war agricultural depression. Subsequently, the valley witnessed the transfer of control of irrigation from private companies to publicly owned irrigation

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[14] Environmental Affairs Division, Work Authorization 576-15-SH002, Knight & Associates. 2009.

districts. The rise of the citrus industry during the 1920s produced a second land boom, resulting in the creation of a number of new developer-initiated irrigation districts for the construction of new irrigation systems that increased the number of irrigated acres in the valley.

Unfortunately, many of these new irrigation districts were created on the eve of the Depression, and the numbers of irrigated acreage steeply declined during the following years. A third agricultural boom began in 1942 at which time the lands within the existing irrigation districts were fully developed. The drought and devastating freezes of the early 1950s, coupled with the increasing demand for limited water resources by a growing agribusiness and urbanization of the valley, transformed the way water was allocated and distributed to the irrigation districts as well as to the physical appearance of the irrigation systems themselves by the 1960s. The agricultural development of the Lower Rio Grande Valley represented the most successful and the largest concentration of irrigated land in Texas until the development of the Panhandle and High Plains after World War II.

Today, the irrigation districts, which are at least 50 years old, are eligible to be listed or are listed in the National Register of Historic Places. The Reclamation cost-shared activities in renovating the irrigation systems under the Lower Rio Grande Water Conservation and Improvement Act of 2002, as amended (P.L. 107-351), and the SECURE Water Act of 2009 (P.L. 111-11) continue to be examined for their effects on these historic properties and have for the most part been determined to have no adverse effect. In some cases, additional documentation or mitigation has been required prior to the activities going forward.

5. Present Water and Related Land Development

There are many ongoing Reclamation activities in the study area. The Lower Rio Grande Water Conservation and Improvement Act of 2002, as amended (P.L. 107-351), provided Reclamation with the authority to fund 50% of the costs, up to $55 million, to plan, design, and construct water conservation improvements on 19 irrigation districts within the study area. Twelve of the 19 projects executed cost-share agreements – 9 are complete and under operation, and 2 are under construction. The remaining seven districts elected to postpone construction until additional funding becomes available for the program. New legislation (H.R. 550) has been introduced into the 112th Congress to authorize an additional 19 projects with a $42 million Federal cost share.

Reclamation also provides financial assistance to several irrigation districts and municipalities within the study area through the WaterSMART Program – a total of 13 grants have been awarded ($3.5 million Federal funding), totaling about $11 million in projects when combined with non-Federal partners' cost share. The amount of Federal funds flowing into the study area over the last decade is a testament to the urgent need that currently exists in this region to better manage and conserve water. One of the benefits of conducting a study on this region is that it includes a comprehensive evaluation of regional water supply options to meet the needs of entities that otherwise would continue to pursue “piecemeal” solutions to their individual water needs. This is not to detract from the value of implementing water conservation and improving water delivery efficiencies, but more needs to be done if the region hopes to address the projected supply deficits in the study area.

An urgent need exists to reduce dependence on the Rio Grande River and address a current and projected water supply deficit within the study area, which is one of the fastest growing and most economically depressed areas in the United States.

6. Public Involvement

Public involvement was actively sought and achieved throughout the study, primarily through Study Partner and stakeholder representation at bimonthly public meetings of the RGRWA Board of Directors. The RGRWA board consists of 18 members representing irrigation districts, the public, municipalities, water supply corporations (WSCs), and counties. Meeting agendas always included a presentation on Basin Study progress, and consensus was obtained following discussion and a formal vote on major study actions, including acceptance of the climate change-affected future conditions projections, formulation of the planning objective, evaluation of alternatives, and recommended alternative analysis. Stakeholders were specifically reminded by Reclamation at meetings that they are expected to represent all of their relevant member interests. Communications were also held on a case-by-case basis as needed to solicit input, expertise, and data. In addition, meetings of the RGRWA board also included representatives from the following:

- Texas Water Development Board
- Region M Planning Group
- Texas Commission on Environmental Quality, Office of Rio Grande Watermaster
- Texas Parks and Wildlife Department
- International Boundary Water Commission
- United States Department of Agriculture (USDA) Cooperative Extension Service
- U.S. Geological Survey (USGS)

In addition, RGRWA's consulting team, which performed the technical analyses for the study, also regularly attended the biweekly Region M Planning Group public meetings to stay abreast of water planning issues in the study area. Some member companies of the Basin Study consulting team were also subcontractors to the team contracted by the Region M Planning Group to perform the required 5-year update of the Region M Plan, which facilitated communication and coordination with the Basin Study. For example, proposed criteria emerging from the Basin Study for the location of the preferred alternative BGD plants were circulated in a Region M Plan survey on water supply strategies.

Also, Reclamation was invited to speak and conducted presentations on the study at two different meetings that involved both governmental and public attendees, which included:

- U.S. Army Corps of Engineers Conference on the Lower Rio Grande, October 2010
- IBWC Citizens' Forum , October 2012

Public involvement was also achieved through the Internet, where a link on the RGRWA Web site was be maintained to provide up-to-date information on the Basin Study.[15] The following was provided on the Web link:

- Summary and background information
- A link to the original proposal for funding
- A link to the final Plan of Study
- Updates/news releases on completed milestones
- Points of contact

The final report will also be posted on the Web site, and press releases will solicit public comment by providing a link to the document on the RGRWA Web site.

### *a.	Quality Assurance/Quality Control and Technical Sufficiency*

The Quality Assurance/Quality Control (QA/QC) Team provided policy guidance, independent oversight, and peer review over technical aspects of the study. In-progress reviews were conducted by Reclamation project team members through telephone and email communications no less frequently than every 2 weeks and 1 week in advance of each deliverable. Reclamation's team

[15] http://www.rgrwa.org/projects/lower-rio-grande-basin-study/

members had the added responsibility of ensuring that the study adhered to Reclamation policy; directives and standards; guidelines with respect to planning, engineering design, and cost estimating; hydrology; economics; environmental impacts; and any other technical aspects of the study.

(1) Quality Assurance

The application of the data for this Basin Study in modeling future supply conditions was conducted by experienced hydrologist Dr. Subhrendu Gangopadhyay, PhD, P.E., of Reclamation's Water Resources Planning and Operations Support Group. Quality assurance of Dr. Gangopadhyay's work was performed by Delbert M. Smith, Manager of Reclamation's Water Resources Planning and Operations Support Group. The QA/QC Team included individuals from various technical and nontechnical disciplines. Members included, but were not limited to:

- Rio Grande Regional Water Authority
    - Marcie Oviedo, Director of Planning for the Lower Rio Grande Valley Development Council
    - RGRWA Basin Study Technical Team, headed by Brian E. Macmanus, P.E., of East Rio Hondo Water Supply Corporation (ERHWSC)
- Reclamation
    - Kip Gjerde, Regional Planning Officer
    - Del Smith , Manager of Reclamation's Water Resources Planning and Operations Support Group
    - Jeff Gerber, Environmental Protection Specialist
    - Bob Jurenka, Plant Structures Engineer
    - Andrew Tiffenbach, Mechanical Engineer
    - Katharine Dahm, Civil Engineer
    - Collins Balcombe, Supervisory Program Coordinator
    - Steve Piper, Economist

(2) Quality Control

Data used in climate and hydrology modeling have previously been subjected to and satisfied Reclamation's Peer Review of Scientific Information and Assessments Directives and Standards during development of the West-Wide Climate Risk Assessments: Bias Corrected Spatially Downscaled Surface (BCSD) Water Projections, which utilized the BCSD climate projections and Variable Infiltration Capacity Hydrology Model (VIC).

QA/QC of preliminary cost estimates for the proposed project infrastructure developed using the TWDB's Unified Costing Model (UCM) was performed by Dr. Katharine Dahm, PhD, and Andrew Tiffenbach of Reclamation's Water Treatment Group. Reviewers evaluated the use of the UCM on the phased build-out approach developed by the contractor. Affordability calculations and discussions were reviewed by Dr. Steve Piper, PhD, of Reclamation's Economics and Resource Planning Team.

Quality assurance included the verification of proper methodology for use of a modified UCM developed to represent the complex well field, pipeline, pumping, land acquisition, and phased treatment plant build-out of the three grouped study areas. Modifications to the UCM were evaluated and developed collaboratively with reviewers to ensure that UCM assumptions and accuracy were correctly applied. The verification of cost estimates included detailed tracking of calculations through final costing to ensure the incremental phased costs were represented appropriately based on the contractor's framework. Capital and annual cost calculations were verified for each group and phase of the UCMs prepared by the contractor.

Quality control included rigorous checking of UCM inputs, such as conveyance distances, delivery volumes, pipeline elevations, well field drawdown, groundwater well development, source water quality, treatment plant efficiency, land cost, and operation and maintenance (O&M) criteria, specifically power and pumping requirements, to properly calculate preliminary cost information. Copies of the UCM were exchanged among reviewers and the contractor until all input assumptions were verified. Due to the preliminary nature of the estimates, reviewers provided a memorandum to Reclamation project leads assessing the technical sufficiency of the preliminary engineering analysis and outlining suggested areas of additional investigation in the next phase of this project (appendix A).

CHAPTER 2: REGIONAL DEMANDS AND SUPPLIES AND FUTURE SYSTEM RELIABILITY

I. Introduction

A. Chapter Organization

This chapter's overall methodology and order of presentation is patterned after Reclamation's Basin Study framework as follows:

- **Hydrologic Projections of Water Supply and Demand:** Consistent with the current Region M Water Plan, this report discusses the surface and groundwater availability methods used in the current water supply planning process and associated water demands for the period 2010–2060 in the study area. As surface water and groundwater are administratively regulated separately in Texas and there is little surface water/groundwater interaction in this region, surface water and groundwater and resources can be addressed separately in this report.

- **Analysis of How Existing Water and Power Infrastructure Will Perform in the Face of Changing Water Realities:** Climate variability modeling procedures and results are discussed, followed by their application to ascertain the future supply reliabilities.

II. 2010–2060 Water Supply and Demand

A. Surface Water Supply Availability Methodology (WAM/WRAP)

Presented in the following sections are the specific steps and procedures that have been undertaken to determine the estimated quantities of surface water and groundwater that are considered to be available from currently existing sources (State Water Plan 2012) for meeting future water demands in the eight counties of the Lower Rio Grande Basin in Texas.

The current operating rules of the TCEQ for the Rio Grande in the study area provide a reserve of 225,000 acre-feet of storage in Amistad and Falcon Reservoirs for domestic, municipal, and industrial uses, which is referred to as the domestic-municipal-industrial pool ("DMI pool"),[16] and an operating reserve that fluctuates between 380,000 and 150,000 acre-feet depending on the amount of water in conservation storage in the reservoirs.[17] The stated purpose of the operating reserve in the TCEQ rules is to provide for (1) loss of water by seepage, evaporation, and conveyance, (2) emergency requirements, and (3) adjustments of amounts in storage as may be necessary by finalization of IBWC provisional U.S.-Mexico water ownership computations.

The operating reserve is calculated monthly by multiplying the percentage of total U.S. conservation storage in the Amistad-Falcon Reservoir System by the maximum operating reserve of 380,000 acre-feet. The calculated reserve cannot be less than 275,000 acre-feet unless there is insufficient water stored in the reservoirs, in which case the balance of the water in storage, after allocations for the DMI pool and irrigation account balances, is assigned to the operating reserve. Under no circumstances can the operating reserve be less than 75,000 acre-feet, unless in emergency situations or as determined by the TCEQ's administrator, entitled the Watermaster."

TWDB data from the 2012 State Water Plan and from the Lower Rio Grande Regional Water Plan of 2011[18] were used for present (2010) water supply data. The supply availabilities are based on model runs from the Texas Water Availability Model (WAM) and chapter 2, section II.B Groundwater Supply Availability Methodology as well as policy decisions set by the Rio Grande Regional Water Planning Group, Groundwater Management Area (GMA) 16, TCEQ, and the TWDB. A WAM is a computer simulation used to predict the amount of water that would be available in a river or stream under a specified set of conditions. State WAMs used in water rights administration and the regional water planning process for Texas were used to evaluate projected water availabilities. These models were used to provide a consistent picture of baseline availabilities as provided by the State Water Plan without climate-based impact due to any climate impacts as simulated by Reclamation. The surface WAM is based on the Water Rights Analysis Package (WRAP) code developed at Texas A&M University by Dr. Ralph Wurbs. This model is used by the TCEQ to determine surface water right availability under the State administrative surface water rights process. It is based on a prior appropriation, first-in-time-first-in-right appropriation system and is a point-node accounting model.

The period of record includes major floods and droughts, thereby representing an approximation of historical hydrologic variability. Importantly, the WAM includes data points in the Mexico portion of the basin as well as the U.S. portion.

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[16] Referred to as "DMI" because the reservoir design was to meet minimum storage requirements for domestic, manufacturing, and industrial demands during conditions reflecting the drought of record.

[17] Chapter 303: Operation of the Rio Grande," 30 Texas Administrative Code, Rules 303.21 and 303.22; October 26, 2006; Austin, Texas.

[18] TWDB. 2012 Water for Texas State Water Plan. January 2012.

The adopted 2012 Texas State Water Plan numbers were used, as these were the official, State-adopted demand and availability data for the study area. Present availabilities and demands as presented in this report are based on the year 2010. The naturalized flow data are a key input for the baseline WAM and the WRAP code for surface water availability estimates. Key inputs to the WAM are as follows:

- **Inflow and Accretion Data from Gages or Models**: Inflow data were used on both the surface and groundwater models. The WAM uses USGS gage-based flows to determine naturalized flows and distributed flow values at control points for inflows. The Groundwater Availability Model (GAM) derives inflows through a water balance approach based on pumpage, aquifer parameters, and precipitation inputs with effects on recharge. The GAM and WAM are administered by separate agencies, and the models are not interconnected.

- **Runoff from Precipitation, Topography, Temperature, etc.:** For present water supply conditions, runoff from precipitation, topography, temperature, and other factors were considered to be included through the use of the USGS gages and the naturalized flow inputs of the surface and groundwater models.

- **Snowpack Levels, Soil Moisture, and Other Physical Measurements:** For present (2010) water supply conditions, runoff from snowpack, soil moisture, and other physical measurements were considered to be included through the use of the USGS gages and the naturalized inputs of the surface and groundwater models.

- **Climate Factors and Impacts for Mexico:** Mexican data are reported to the IBWC and are included in the results presented in this report.

Stream gage data from the USGS were used to determine historical flows in the Rio Grande. The naturalized flow data were developed using these same historical flows measured by USGS gages to develop an estimate of flow without anthropological impacts. Naturalized flow is the amount of water in the stream that would be there if not for the influence of man’s activities. Naturalized streamflow cannot be directly measured, yet it is the baseline condition for water availability accounting. For most Texas river systems, the naturalized flows encompass at least a 50-year period of record that includes the drought of the 1950s.

Given the physical flows modeled in the WAM, the WRAP simulates management of the water resources of a river basin or multiple-basin region under a priority-based water allocation system. The model facilitates assessment of hydrologic and institutional water availability and reliability for specified water use requirements using a monthly time step. Basin-wide impacts of water resources development projects and management strategies are evaluated through programming within WRAP. The software package is generalized for application to any river/reservoir system, with input files being developed for the particular river basin of concern.

The TCEQ Rio Grande Watermaster administers the water allocations to municipal/domestic, industrial, agricultural, and other user storage accounts. Such allocations are based on the available water in storage in Falcon and Amistad Reservoirs, as reported by the IBWC on the last Saturday of each month, less dead storage. To determine the amount of water to be allocated to various accounts, the Watermaster makes the following computations at the beginning of each month:

1. From the amount of water in usable storage, 225,000 acre-feet are deducted to re-establish the reserve (i.e., the DMI pool, for domestic, municipal, and industrial uses; hence, these uses are given the highest priority).

2. From the remaining storage, the total end-of-month account balances for all Lower and Middle Rio Grande irrigation and mining allottees are deducted.

3. From the remaining storage, the operating reserve is deducted.

After the above computations are made, the remaining storage, if any, is allocated to the irrigation and mining accounts. The allotment for irrigation and mining uses is divided into the Class A and Class B water rights categories. Class A rights (allottees) receive 1.7 times as much water as that allotted to Class B rights. An irrigation allottee cannot accumulate in storage more than 1.41 times its annual authorized diversion right, and if an allottee does not use water for 2 consecutive years, its account is reduced to zero. If there is not sufficient water in storage to fully restore the operating reserve in step No. 3 above, the TCEQ rules authorize the Watermaster to make negative allocations of water from the irrigation and mining accounts in sufficient amounts to provide the minimum 75,000 acre-feet of operating reserve capacity.

For the surface water supplies reported in this study, WAM Run 3 was used for the Lower Rio Grande Basin in Texas and the control points discussed later in this report for the years 2010–2060. Run 3, representing the **full authorization** simulation, in which all water rights use their maximum authorized amounts with no return flows, is used to evaluate applications for perpetual water rights and amendments. This includes the naturalized modification of historical flow for both the United States and Mexico. The water rights within Mexico are represented as reflections of the historical flow (i.e., historical flows are evidence of the exercise of water rights against natural flows).

The results from these State Water Plan models and regional planning decisions are shown in table 2-1.

Table 2-1: Projected firm annual yields of the Amistad-Falcon Reservoir System for the United States and Mexico by decade

Year	Projected firm annual yield (ac-ft/yr)		
	United States	**Mexico**	**Total**
2010	1,011,976	888,200	1,955,510
2020	1,004,976	879,700	1,936,419
2030	998,476	869,200	1,918,165
2040	991,976	858,700	1,900,327
2050	985,476	846,700	1,881,292
2060	979,476	835,700	1,860,687

Source: 2011 Rio Grande Regional Water Plan.

Results from the firm annual yield analyses of the Amistad-Falcon Reservoir System completed for the 2011 Rio Grande Regional Water Plan are presented in table 2-1. Values of the firm annual yield are listed for both the United States and Mexico by decade for the period 2010–2060. As expected, the firm yield of the system for both countries gradually decreases in the future as sedimentation of the reservoirs is projected to occur over time and reduce the reservoirs' storage capacity. The U.S. share of the firm annual yield of the reservoir system decreases from 1,011,976 acre-feet per year (ac-ft/yr) in the year 2010 to 979,200 ac-ft/yr in the year 2060, a reduction of about 6%. The Amistad-Falcon Reservoir System firm yield analysis is then broken down by water use type in table 2-2 per decade. Figure 2-1 also shows the firm yield of Amistad-Falcon and their respective use. Again, these yield values represent the maximum amount of water that can be withdrawn from the reservoirs on a continual basis by the United States should conditions similar to the drought of record recur.

Table 2-2: Current supplies from Amistad-Falcon Reservoir System

	Firm yield (ac-ft/yr)					
	2010	**2020**	**2030**	**2040**	**2050**	**2060**
Nonirrigation	303,353	303,925	304,528	304,965	304,978	305,067
Irrigation	701,262	694,273	687,785	681,297	674,807	668,818
Unallocated	7,361	6,778	6,163	5,714	5,691	5,591

Source: 2011 Rio Grande Regional Water Plan.

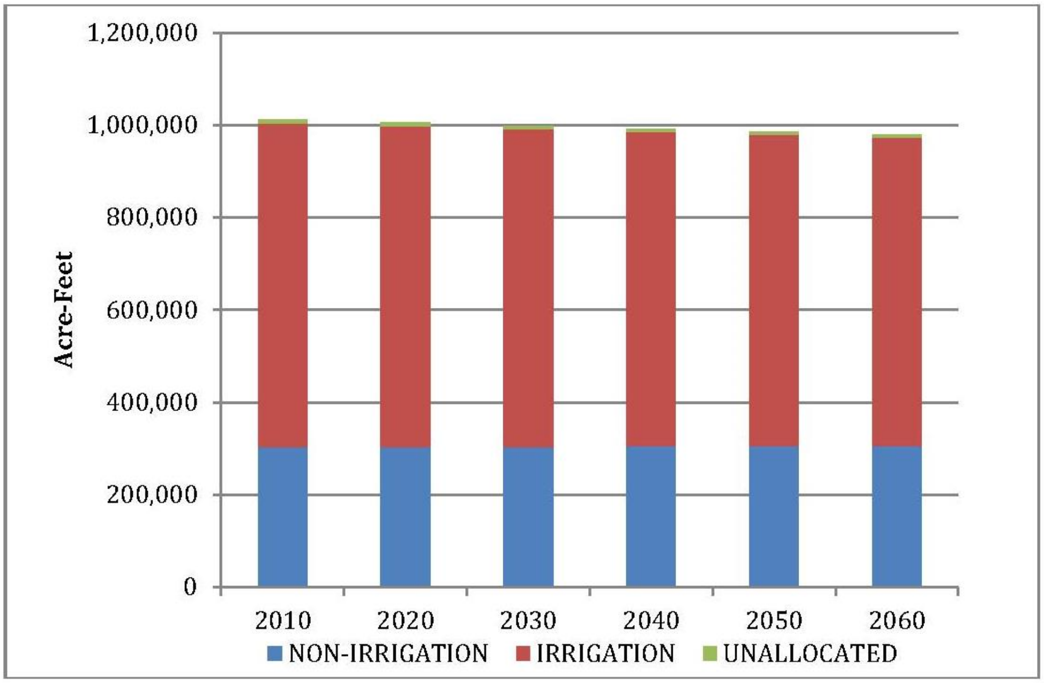

Figure 2-1: Current supplies of Amistad-Falcon Reservoir System (firm yield).
Source: 2011 Rio Grande Regional Water Plan.

B. Groundwater Supply Availability Methodology

The GAM is based on a finite-difference MODFLOW™ model that is administered by TWDB to determine groundwater availabilities based on desired future conditions (DFCs) for Texas aquifers. DFCs are determined through a joint planning process among all local groundwater conservation districts with common jurisdiction over relevant aquifers within that GMA. The process looks at current and future groundwater demands to determine policy decisions for DFCs. These DFCs (e.g., drawdown) are then used as inputs to the GAM to determine a modeled available groundwater quantity to be distributed over the 2020–2060 projection time period. Although the groundwater aquifers are transboundary, there was no GAM or results for the Mexican portion of the study area.

Aquifer systems are complex due to flows into and out of the aquifer, the interaction between surface water and groundwater, and the uncertainty of aquifer properties. Because of this complexity, computer models are excellent tools for assessing the effect of pumping and droughts on groundwater availability. Groundwater availability modeling is the process of developing and using computer programs to estimate future trends in the amount of water available in an aquifer and is based on hydrogeologic principles, actual aquifer measurements, and stakeholder guidance. A GAM includes comprehensive information on each aquifer, such as:

- Discharge (pumping or springs)
- Recharge (amount of water entering the aquifer)
- Geology
- Rivers, lakes, and springs
- Water levels
- Aquifer properties
- Pumping

Each model is calibrated to ensure that it can reasonably reproduce past water levels and groundwater flows. The interaction between groundwater and surface water in this area is limited due to geology and the lack of surface water streams outside the Rio Grande and related irrigation canals. The GAM incorporates a "river" package that serves as the sole source of direct groundwater/surface water interaction in the model; the interaction among groundwater and the streams/rivers included in the river package is driven by the water levels in the aquifer and in the river. The WAM incorporates a percentage loss factor between control points that approximates estimated stream loss/gain based on gage data. No other forms of percolation are considered by either model, and there is no direct interaction between the GAM and the WAM.

C. 2010–2060 Water Supplies

This section describes the surface and groundwater supplies available in 2010–2060 in the eight Lower Rio Grande counties as reported in the 2012 Texas State Water Plan. The availabilities in these reports are based on WAM and GAM results for surface water and groundwater supplies.

The development of estimates of the current water supplies that are available for meeting projected future water demands in the RGRWA planning area has been accomplished through two separate but interrelated processes: one for surface water and a separate method for groundwater. Both of these activities have been conducted in generally the same manner by examining the existing sources of water for the region with regard to the following:

- The maximum available supply under drought of record conditions

- Other supply restrictions, such as:

    - Firm yield/volume available in Falcon and Amistad Reservoirs

    - Current capacity of existing well fields

- Hydrologic properties of aquifers in the region
- The quality of existing supplies with regard to usability
- Current water rights
- Historical flows as representative of U.S./Mexico performance under the Treaty
- Permits and other regulatory restrictions
- The hydraulic capacity of existing conveyance infrastructure
- Current contracts and/or option agreements
- Regulated flows
- Obligations that a water user group (WUG) may have in terms of contracts or direct/indirect water sales to other WUGs

In some instances, one or more of these factors have determined the available supply for individual water users. Table 2-3 summarizes the 2010 water supplies available to the region. Table 2-4 is a summary of projected water supplies available over the planning horizon as determined by the Lower Rio Grande Planning Group and incorporated into the Texas State Water Plan.

Table 2-3: 2010 water supplies

	2010 supply (ac-ft/yr)
Surface water (TWDB)	1,015,958
Groundwater (GAM)	341,692
Total	**1,357,650**

Source: TWDB (WAM Run 3, GAM Results from Gulf Coast, Carrizo Wilcox, Yegua-Jackson, and other aquifers).

Table 2-4: Projected 2010–2060 water supplies

	Region M projected water supply (ac-ft/yr)					
	2010	**2020**	**2030**	**2040**	**2050**	**2060**
Groundwater	341,692	341,692	341,692	341,692	341,692	341,692
Surface water	1,015,958	1,008,958	1,002,458	995,958	989,458	989,458
Total	**1,357,650**	**1,350,650**	**1,344,150**	**1,337,650**	**1,331,150**	**1,331,150**

Source: TWDB State Water Plan 2012.

D. 2010–2060 Water Demands[19]

TWDB Rules Exhibit B-31 Texas Administrative Code Chapter 357 provides the following guidance for development of current and projected demand numbers:

- Population and water demand projections for 2010–2060 for the State, counties, cities, and county-other (including utility subcomponents) are reviewed through a process coordinated by the Executive Administrator of the TWDB with the planning groups, Texas Natural Resource Conservation Commission [now TCEQ], Texas Department of Agriculture, and the Texas Parks and Wildlife Department.

- New population projections are developed using the 2000 Census[20] and other pertinent sources. Projections are developed first at the county level; then, the projections will be allocated to municipal and county-other WUGs.

TWDB met regularly with representatives of the various parties involved to achieve consensus. The projections were extensively evaluated before reaching final draft stage. Then, after lengthy analysis of population and water demand projections, TWDB approved these estimated demands as shown in table 2-5

Table 2-5: 2010 water demand

Use	2010 demand (acre-feet)
Irrigation	1,163,634
Livestock	5,817
Manufacturing	7,509
Mining	4,186
Steam electric power	13,463
Municipal	288,323
Total	**1,482,932**

Source: TWDB State Water Plan 2012.

Population is the main factor in calculating total municipal water demand, including residential and commercial uses; these data were used to calculate each city's base per capita water use. Overall, municipal water demand projections are the product of three variables: (1) current and projected population, (2) per capita

[19] In this planning study for RGRWA, we do not examine Mexican demand growth. Mexican demand for water is assumed to be represented by the amount of releases to the Rio Grande as called upon by Treaty obligations.

[20] Projections based on the 2010 Census were not available from TWDB for use at this time.

water use, and (3) assumptions about the effects of certain water conservation measures. Therefore, future water savings resulting from installation of more water-efficient fixtures (according to the 1991 State Water-Efficient Plumbing Act) were also a consideration.

The population of the study area is projected to grow at an average rate of nearly 2% annually over the 50-year planning period, which suggests an increase from approximately 1.62 million residents in 2010 to over 3.93 million in 2060. Cameron and Hidalgo Counties lead with the highest total populations, while Webb County is forecasted to experience the greatest proportionate annual increase for the region.

The total annual water demand for the study area was projected to *increase* until 2010, *decrease* until 2030, and then steadily *increase* until 2060. This trend is attributable to diminishing irrigated acreage and rising urban populations, especially in the Rio Grande Valley, as land use changes from agriculture to urban uses.

Despite growing urbanization, irrigation districts control the overwhelming majority of rights to Rio Grande water as well as the system used to distribute that water to both farms and M&I users. There are 39 municipal water treatment plants that take raw water from the water distribution networks of 14 irrigation districts in Hidalgo and Cameron Counties in the Lower Rio Grande Valley. Built for sporadic and large irrigation flows, the system is inefficient for M&I deliveries, which require lower flows that are sustained over time. Control of water rights and the water distribution system can pit one State-sanctioned entity (e.g., a home rule city) against another (e.g., an irrigation district). Currently, there is no coordinated method for involving municipalities that may want to invest in or improve irrigation systems or for involving irrigation districts in planning for urban and economic growth.

Irrigation makes up nearly 80% of the total regional demand for water. A thorough analysis of irrigation water demand data is therefore critical. In Region M, irrigation demand is primarily based on the available supply from the Amistad-Falcon Reservoir System. During droughts, supply is limited, and allowable irrigation water is allocated accordingly, resulting in a perceived reduction in demand. Ultimately, the demand on any given irrigation district would be such that all land in the district that is included as flat-rate acreage would have the option to receive irrigation water. In turn, irrigation districts typically own enough irrigation water rights to serve irrigation water users within their boundaries should the water be available in the reservoir.

The region's annual demand for irrigation water is projected to decrease from 1,163,633 ac-ft/yr in 2010 to 981,749 ac-ft/yr in 2030 and then are projected to remain flat through 2060 (figure 2-2). This lower demand estimate arises primarily from the anticipated spreading urbanization, which is predicted to

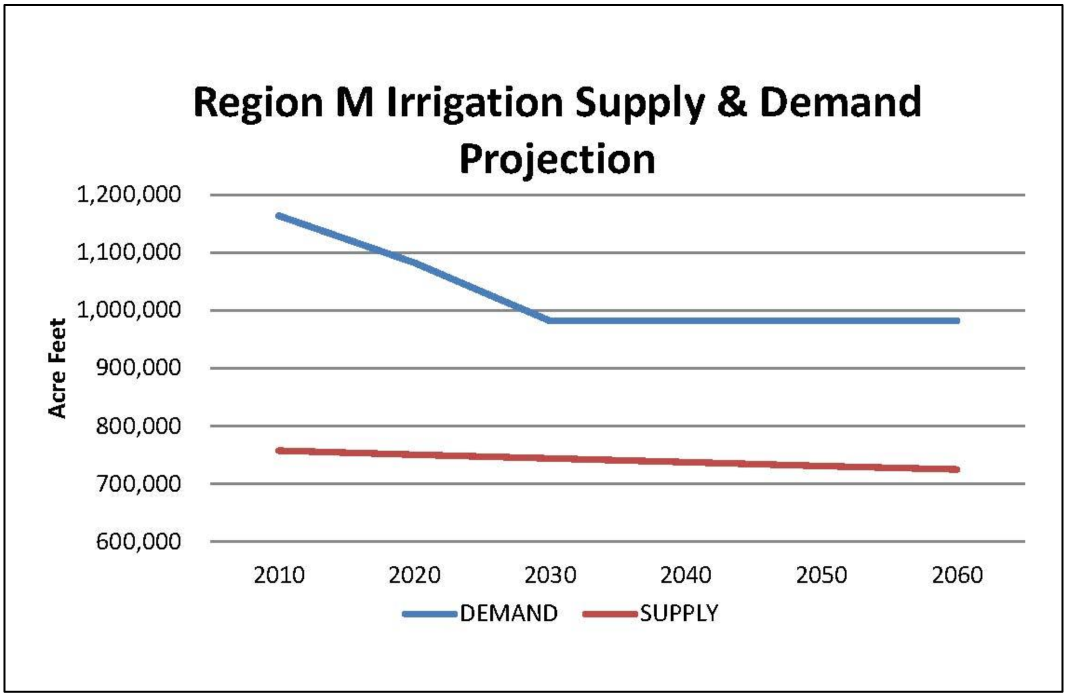

Figure 2-2: Projected irrigation demand and supply.
Source: TWDB State Water Plan 2012.

reduce irrigable acreage, primarily in Cameron and Hidalgo Counties, and other factors including costs, economics, and competition. Livestock demand is expected to decline from the already low levels of 2010 to an insignificant level by 2060. Conversion of the irrigation rights to municipal and domestic use also carries a reduction in the allocation amount according to water right class.

Consequently, total water demand for irrigation in the region is projected to fall over time from the current 78.5% of the overall water demand to 58.2% by 2060. The conversion from irrigation to municipal use is one of the key factors driving the decline described above. From 2010 to 2060, municipal water demands are projected to increase from the current 15.5% of the overall demand to 37.7 percent in 2060. Projected demands and supplies are illustrated on figure 2-3.

Another issue related to irrigation demand is the amount of "push water" needed to enable delivery of water from the river, through the irrigation system of canals and/or pipes, to its final destination of either agricultural or M&I delivery points. One of the concerns regarding the availability of water in the study area pertains to the delivery of water to municipal users during severe drought periods, when irrigation water use may be curtailed or completely eliminated as the total supply of U.S. water stored in Amistad and Falcon Reservoirs falls to low levels. Under the current Rio Grande operating rules, the available supply of water in the reservoirs for irrigation use is gradually depleted as irrigation diversions are made during periods when the inflows to the reservoirs are low. During extended

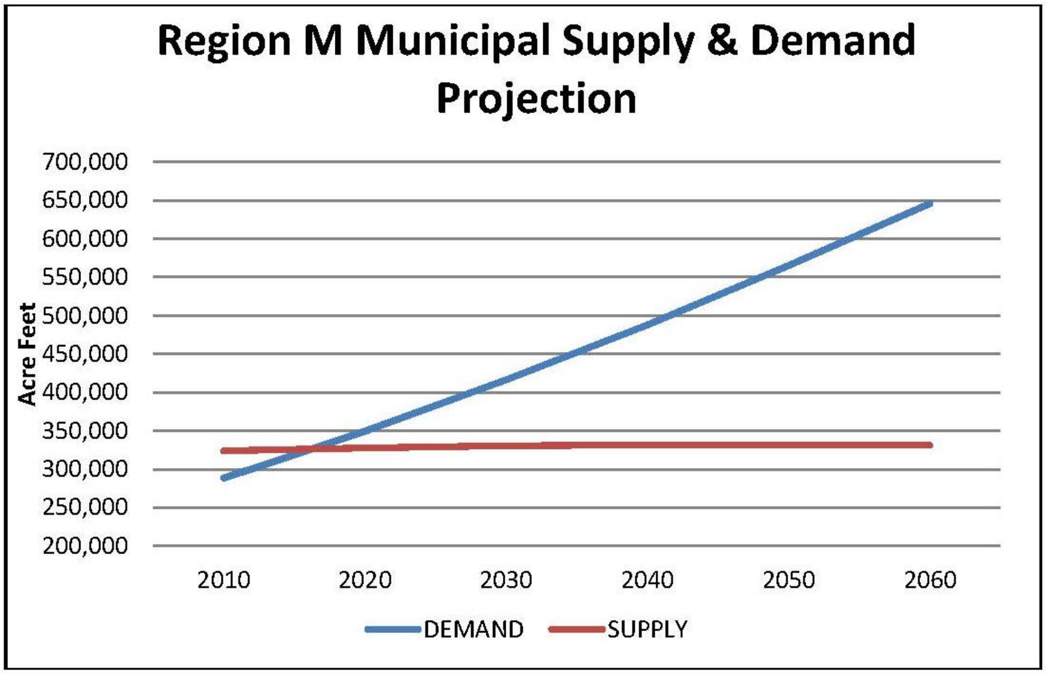

Figure 2-3: Projected municipal demand and supply.
Source: TWDB State Water Plan 2012.

periods of continued irrigation use and low reservoir inflows, the available quantity of irrigation water stored in the reservoirs can be reduced to zero.

Should such conditions occur, as they have in 2013, no releases of irrigation water would be made from Falcon Reservoir. This would mean that deliveries of municipal water from the reservoir to entities in the Lower Rio Grande Valley would have to be made without the normal "carrying water" provided by the irrigation water deliveries. Under these circumstances, the normal water losses due to such factors as seepage and evaporation could be proportionally substantial and could potentially disrupt the ability of municipal users to obtain their water. Another concern under these conditions is whether or not the existing diversion facilities on the Lower Rio Grande would be able to physically withdraw water from the river because of the potentially lower river levels.

Based on past history of operations, irrigation districts can divert, and have diverted, water from the Rio Grande even when there is no irrigation water being released from Falcon Reservoir. This may occur even though pumping efficiencies are negatively affected and the overall volumes capable of being pumped are limited. The water diverted from the river during these periods was municipal water only. Based on these historical data, irrigation districts would also be able to physically pump water from the river even if the only water flowing in the Rio Grande is water that has been released from Falcon Reservoir for municipal uses.[21]

Interviews with irrigation district managers indicate that the amount of push water needed varies greatly with the temporal nature of the deliveries, as well as the system configuration. Temporal aspects apply primarily among agricultural users whose demand varies between year round and seasonal. An irrigation system that is running nearly full with year-round deliveries will require much less push water than one whose deliveries vary seasonally, with the latter requiring frequent refilling to push the water to the delivery points.

The configuration of the system relates to the amount of push water needed because systems that include leaky and/or open canals will lose much more water during transport to seepage and evaporation than will systems that have adequately lined canals or pipelines. Clay-lined canals absorb a large quantity of water if previously dried out through both seepage through cracks and absorption of water into the clay. Evaporation and seepage rates are often included in the delivery charges paid by customers as “losses” and can range from 12 to 20%. A 2002 study by Texas A&M University calculated total “conveyance loss” (push water plus other losses) to be 41% of the water conveyed.[22] The change in elevation and head requirements within a system also contributes to push water requirements.

Reclamation administers the Lower Rio Grande Valley Water Resources Conservation and Improvement Act of 2000, as amended, and WaterSMART Water and Energy Efficiency Grants, which have provided matching funds to irrigation districts to make water conservation improvements such as relining canals and converting canals to pipes. In addition, the USDA works with agricultural water users to make conservation improvements in their onsite delivery systems and horticultural methods. These conservation measures were taken into account by Region M in its calculation of agricultural water demands.

Exact quantification of push water requirements would require hydraulic measurement of all of the irrigation systems in the region as well as a study of all intakes from the Rio Grande, the amounts of water often stored in natural basins such as resacas, and amounts actually delivered on a year-round basis. For the purposes of this report, this discussion of push water is included as a reminder that if some irrigation systems have severely reduced deliveries in times of extreme drought, there will be a requirement of additional water beyond stated municipal and agricultural demand necessary to push water supplies to their desired delivery points.

[21] 2010 Region M Regional Water Plan, pp. 3–121.

[22] Texas Cooperative Extension. *Alternative Approaches to Estimate the Impact of Irrigation Water Shortages on Rio Grande Valley Agriculture*, Weslaco, Texas. May 17, 2002.

The region's demand for manufacturing water is projected to increase from approximately 7,509 ac-ft/yr in 2010 to 11,059 ac-ft/yr by 2060 (figure 2-4 and table 2-6) primarily due to projected population growth in Cameron and Hidalgo Counties. The TWDB has no data to enable similar projections for Jim Hogg, Starr, and Zapata Counties, but shows that Cameron and Hidalgo Counties will account for 98% of the total manufacturing need.

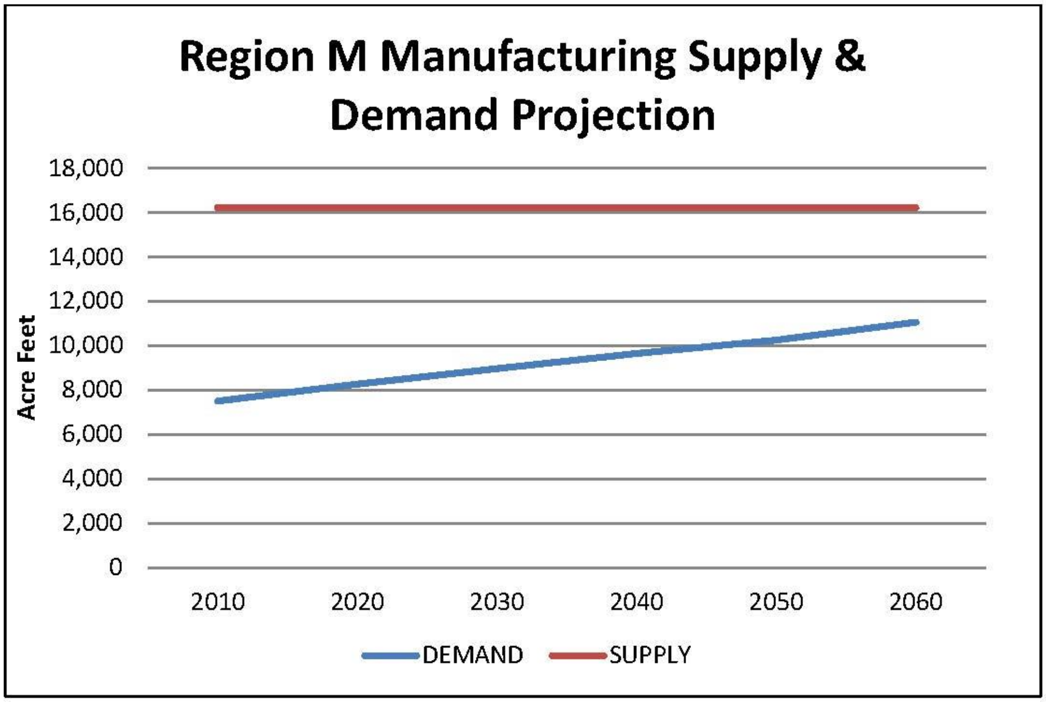

Figure 2-4: Projected manufacturing demand and supply.
Source: TWDB State Water Plan 2012.

Table 2-6: Projected Region M municipal, manufacturing, mining, and county-other water demands

	Demand (ac-ft/yr)					
County	**2010**	**2020**	**2030**	**2040**	**2050**	**2060**
Cameron	92,852	109,446	126,331	143,568	161,005	178,382
Hidalgo	120,088	146,971	177,257	209,917	246,907	285,542
Jim Hogg	917	954	981	997	982	946
Maverick	9,629	10,790	11,905	12,895	13,853	14,736
Starr	14,802	17,128	19,544	22,000	24,471	26,968
Webb	56,087	70,624	87,224	105,727	125,838	147,642
Willacy	3,354	3,558	3,737	3,875	3,997	4,070
Zapata	2,289	2,554	2,816	3,056	3,290	3,471
Total	**300,018**	**362,025**	**429,795**	**502,035**	**580,343**	**661,757**

Source: TWDB State Water Plan 2012.

The State's default demand projections for mining water were based on forecasts of future production levels (sorted by mineral category) and their water use rates. These production projections are derived from State and national historical water use rates and are constrained by accessible mineral reserves in the region. The demand for mining water represents less than 1% of the region's total water needs and is expected to remain relatively constant over the 50-year planning period (figure 2-5). The demand for mining water is currently greatest in Webb County (32.6%), Starr County (31%), and Hidalgo County (30.9%). In contrast, Willacy County has the lowest demand (less than 1%).

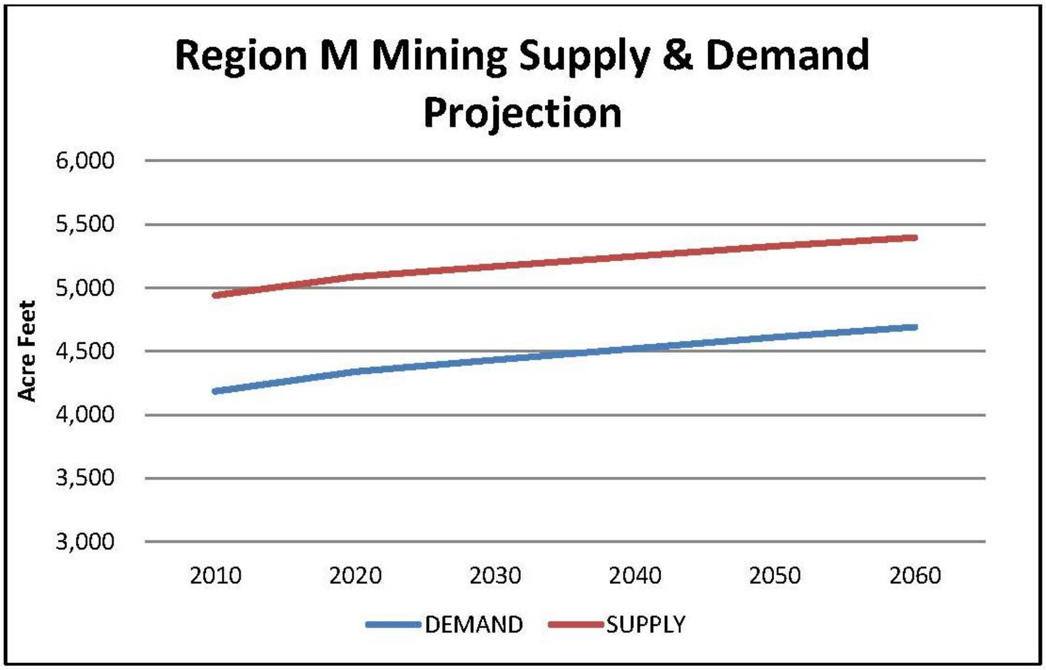

Figure 2-5: Projected mining demand.
Source: TWDB State Water Plan 2012.

Currently, there is concern that mining demands are underestimating water for oil and gas operations in the region. Areas that have traditionally not seen water demands for mining are seeing growth in use. The 2016 regional planning scope of work will examine this concern. Recent indicators show that water use for mining and for oil and gas activities in the study area have increased tenfold over current estimates and that supplies are based on some river diversions but are more dependent on groundwater, primarily fresh groundwater. Assessment of the usage and long-term effects of fracking demand is complicated by the fact that water use for oil and gas development is exempt from the GMA planning process.

The TWDB Guidelines for Planning [Exhibit B (4.2.4)] state a specific plan of research for estimating demand for water for creating steam for electric powerplants. The plan of research includes:

- Description of water-consuming systems currently used in power generation facilities
- Estimation of water consumption rates for each identified water-consuming system
- Correlation of current State population with current electric use by region
- Projection of electric power consumption requirements by county and for the State based on population projections
- Identification of current and potential water sources for demand by power generation
- Estimation of future water use by power generation
- Development and application of allocation methodology to derive demand projections by county

The annual demand for steam-electric water is projected to increase from 13,463 ac-ft/yr in 2010 to 32,598 ac-ft/yr in 2060 (figure 2-6). Most of this increase was expected to occur between 2000 and 2010 as a result of adding the new capacity for generating steam electric power in Cameron and Webb Counties. Cameron County makes up 12% of the demand, Hidalgo County accounts for 77%, and Webb County accounts for 11%. TWDB has no data about demand for steam-electric water in Jim Hogg, Maverick, Starr, Willacy, and Zapata Counties.

III. Projected Water Supply Deficit

The study area faces a projected shortage of water that is going to grow by 60% over the next 50 years. The biggest changes are in the conversion of irrigation water to municipal use. There was a projected shortage of 156,257 acre-feet in 2010 and 410,936 acre-feet of need (shortage) in 2060. This is shown on figure 2-7.

The objective of this Basin Study is to assess the impact of climate changes on future water availability and delivery capabilities and to develop alternate water supply options. The regional planning effort does not account for any potential impacts in projections due to climate variability. The following sections outline the methodology for how changes in hydrology were simulated in evaluating climate impacts on State water availability models for Texas.

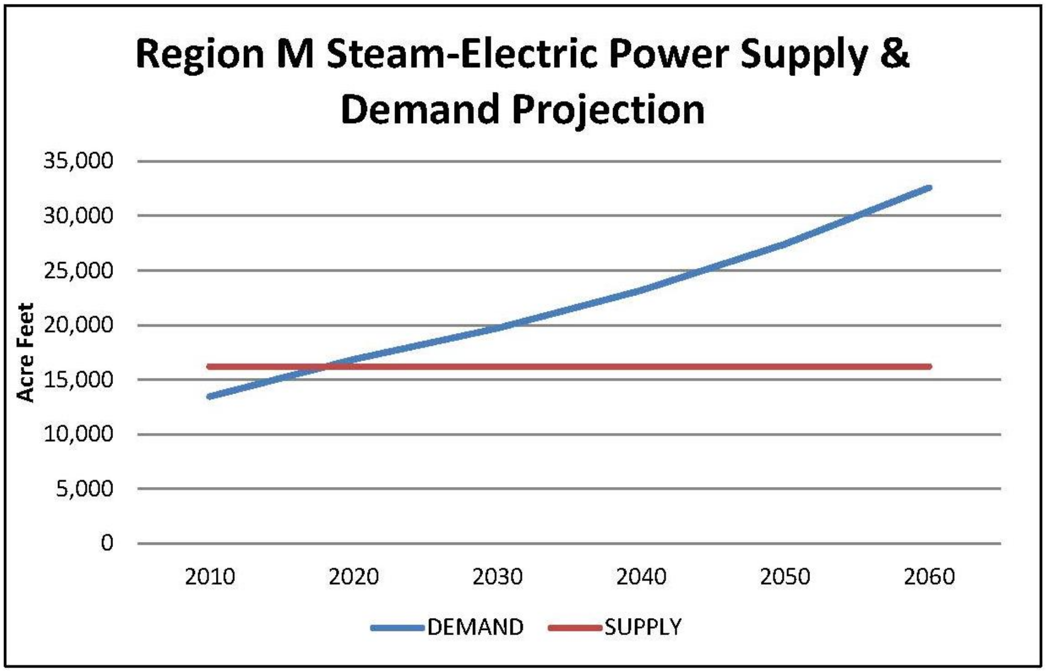

Figure 2-6: Projected steam-electric power demand and supply.
Source: Texas State Water Plan 2012.

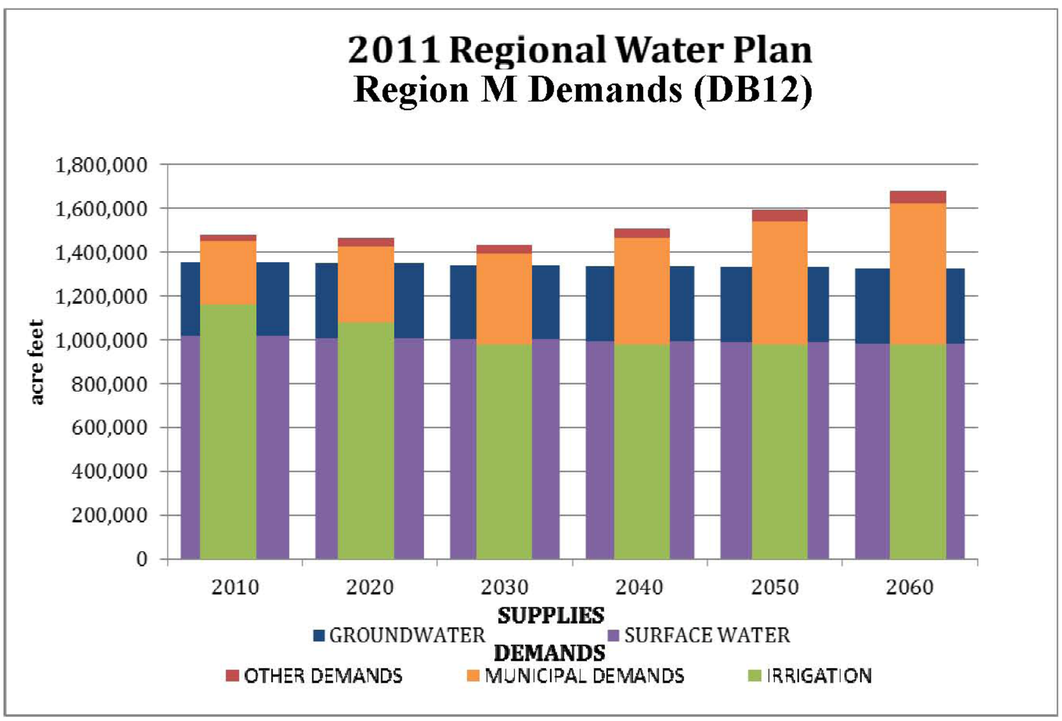

Figure 2-7: Existing and projected water supplies and demand.
Source: Texas State Water Plan 2012.

IV. Climate Change Variable Infiltration Capacity Methodology

This task included development of hydrologic projections of water supply, building upon existing data within the Region M Water Plan and relevant data sources. Future water supply projections were made using Climate Model Inter-comparison Project Phase 3 (CMIP-3) and the VIC, both of which are applicable to the entire Lower Rio Grande Basin in the United States and Mexico.
The CMIP-3 archive provides a 1/8° latitude by 1/8° longitude, or an approximately12-kilometer resolution grid on a monthly time-series of precipitation and temperature from 1950–2099 for 112 climate projections.

A. Global Climate Model

Future changes in climate variability and trends, and their influence on streamflow and basin water supply, have been studied by several researchers in recent years, and global climate model (GCM) future projections indicate that the climate may exhibit trends and increased variability over the next 50 years beyond what has occurred historically. The downscaled GCM-projected scenario is one presentation of this plausible future condition. As shown on figure 2-8, the approach to develop the downscaled GCM-projected scenario consists of emission scenarios, climate scenarios, and spatial downsizing to 12-kilometer grids.

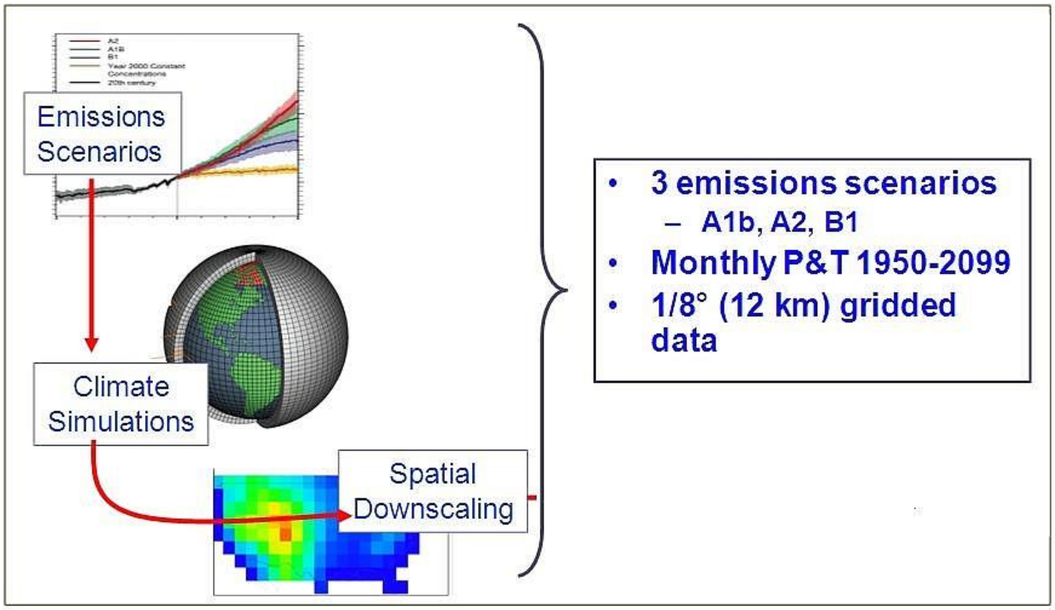

Figure 2-8: The downscaled GCM key elements.

The emission scenarios used in the downscaled GCM are emission scenarios A2 (high), A1B (medium), and B1 (low), and they reflect a range of future greenhouse gas (GHG) emissions. The A2 scenario is representative of high population growth, slow economic development, and slow technological change. It is characterized by a continuously increasing rate of GHG emissions, and features the highest annual emission rates of any scenario by the end of the 21st century. The A1B scenario features a global population that peaks mid-century and rapid introduction of new and more efficient technologies balanced across both fossil- and nonfossil-intensive energy sources. As a result, GHG emissions in the A1B scenario peak around mid-century. The B1 scenario describes a world with rapid changes in economic structures toward a service and information economy. GHG emission rates in this scenario peak prior to mid-century and are generally the lowest of the scenarios.

Emission scenarios exist that have both higher and lower GHG emissions than those considered in this study. However, the three scenarios included in the analysis span the widest range available for which consistent, comprehensive GCM modeling has been performed and for which downscaled climate information is available. Furthermore, while it is possible that higher rates of warming and resulting effects on streamflows are possible, it should be noted that the atmospheric response to emission increases is not immediate. Climate response to increases in GHG emissions would happen over decades-long time periods. Therefore, uncertainty in the projected climate system response due to increased emissions tends to be a greater determinant of the range of future climate conditions through mid-century.

B. Variable Infiltration Capacity Model

1. Land Surface Simulation

The VIC includes the physical characteristics of each 12-kilometer cell within the study area to simulate runoff and other water/land/atmosphere interactions at each grid cell. The VIC uses the climate projections along with land cover, soils, and elevation information to simulate hydrologic interactions, resulting in a prediction of runoff used in this study.

Because VIC does not simulate groundwater/surface water interaction, changes in groundwater recharge and discharge due to climate change were not estimated using VIC. The area is currently not affected by groundwater recharge as it relates to runoff from snowpack in the Rio Grande headwaters. However, the middle and lower reaches of the Rio Grande are rainfall-dominated regions, and changes in precipitation patterns could affect groundwater recharge events in the region. As part of this effort, temporal trends in precipitation and temperature and spatial distribution of precipitation and temperature across the study region was also analyzed for all 112 climate projections. The monthly historical change factor-corrected streamflows constitute the final set of future water supply projections that were then used in the water allocation model.

The hydrologic interactions are then routed to each of the 43 natural flow locations within the study area using a routing network derived from the topography (figure 2-9). These 43 locations are also matched to the WAM so that climate-affected runoff simulations could be calculated. These 43 control points are shown on figure 2-10 and are described in table 2-7. Note that the VIC control points are distributed in both Mexico and the United States and were subsequently included by both WRAP and WAM, giving a model of climate-affected flows on all major tributaries as affected by water rights for the entire Basin Study area.

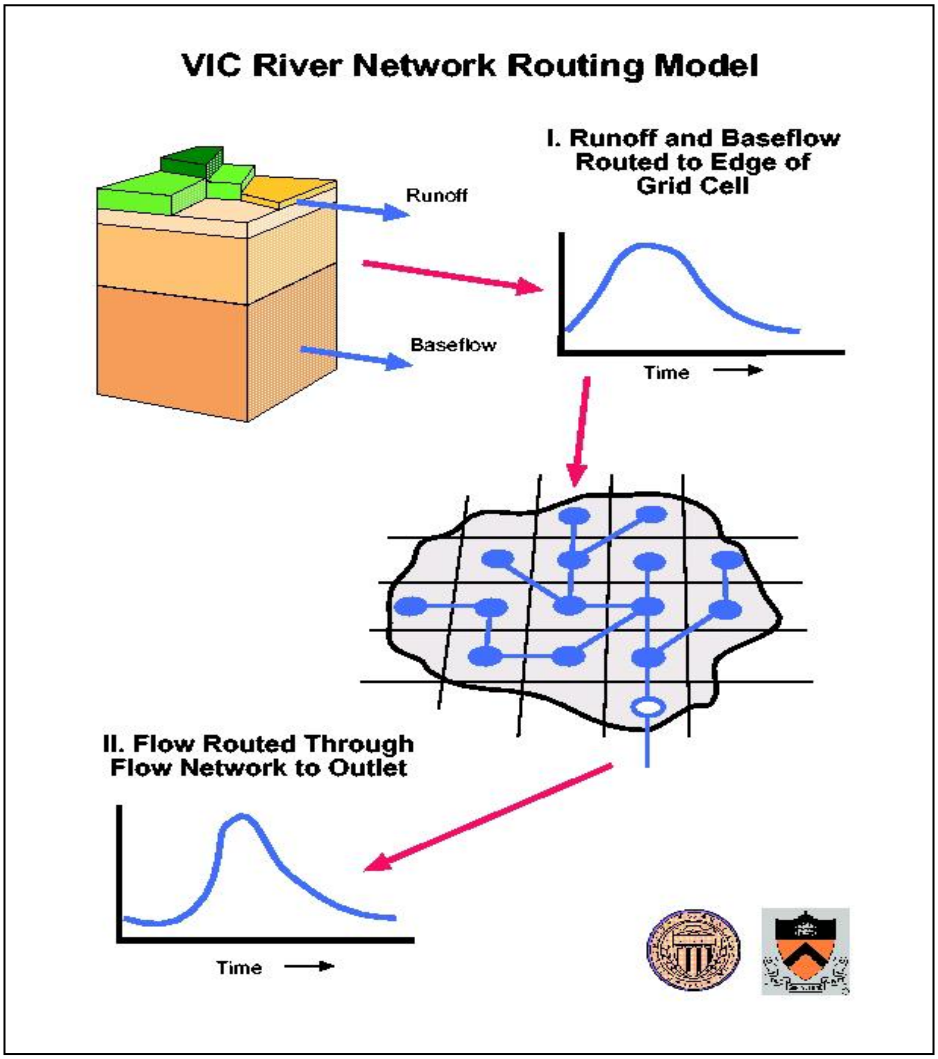

Figure 2-9: VIC river network routing mode.

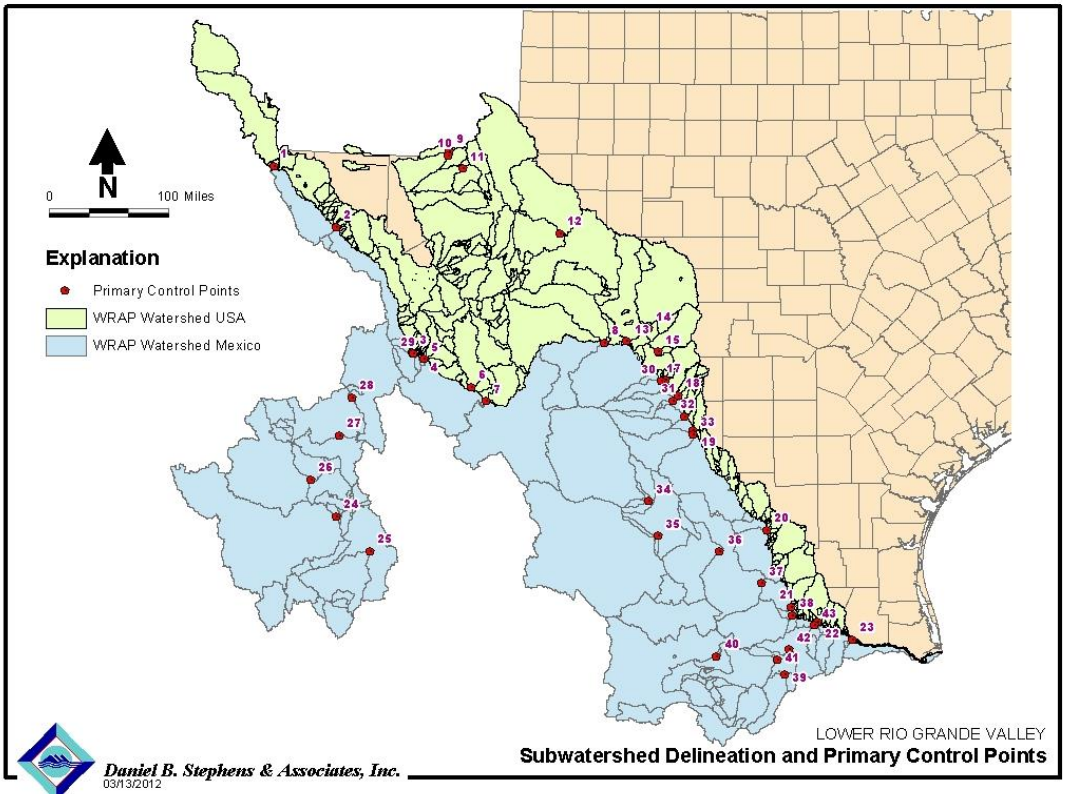

Figure 2-10: Figure water right control points used for flow distribution.

The result of this approach is 112 unique sequences of natural flow under future climate projections. However, the simulated natural flows can contain significant monthly and annual biases when compared to the natural flows of the historical period. Therefore, a monthly time factor correction is applied as described below.

2. Period Change Flow Adjustment Factors

The calculation of monthly changes in flow between a future hydrology period (2056–2085) and the reference hydrology period (1950–1999) was estimated using the following steps. The choice of the reference hydrology period (1950–1999) was determined based on two factors: (1) bias correction and spatial downscaling of GCM outputs and (2) model data availability in the WRAP/WAM. Although VIC projections exist until 2099, we chose a 30-year period surrounding the target year of 2070 (2056–2085), similar to the new planning horizon being undertaken by Region M.

Table 2-7: Station description for the 43 point locations

Site Number	*Latitude (dd)*	*Longitude (dd)*	*Site Description*
1	31.801669719000	-106.547071988000	RG at El Paso, TX
2	31.086125908200	-105.610587615000	RG at Fort Quitman, TX
3	29.600610000000	-104.451500000000	RG above Rio Conchos, TX
4	29.525962089800	-104.285559640000	Alamito Ck near Presedio, TX
5	29.518500000000	-104.286780000000	RG below Rio Conchos, TX
6	29.200110000000	-103.605850000000	Terlingua Ck near Terlingua, TX
7	29.034608983300	-103.390310000000	RG at Johnson Ranch, TX
8	29.780418598500	-101.760150000000	RG at Foster Ranch, TX
9	32.076223913100	-104.038565652000	Pecos at Red Bluff, NM
10	32.023190000000	-104.054564087000	Delaware near Red Bluff, NM
11	31.872790000000	-103.831690000000	Pecos near Orla, TX
12	31.113330000000	-102.417640000000	Pecos near Girvin, TX
13	29.802570000000	-101.442610000000	Pecos near Langtry, TX
14	29.963657424800	-101.146515451000	Devils near Juno, TX
15	29.678870000000	-101.002530000000	Devils near Pafford Crossing,TX
16	29.326802263700	-100.927217284000	RG at Del Rio, TX
17	29.333660228600	-100.891153061000	San Felipe Ck near Del Rio, TX
18	29.146230000000	-100.718950000000	Pinto Ck near Del Rio, TX
19	28.714002173900	-100.505823044000	RG at Piedras Negras, Coah
20	27.497543247000	-99.490027767700	RG at Laredo, TX
21	26.550340000000	-99.167900000000	RG below Falcon Dam
22	26.365480000000	-98.809300000000	RG at Rio Grande City, TX
23	26.138473159500	-98.335139739300	RG below Anzalduas Dam, TX
24	27.545455608700	-105.413431956000	Rio Conchos at Presa La Boquilla, CHI
25	27.138889310500	-104.917602315000	Rio Florido at Cd. Jimenez, CHIH
26	27.984570000000	-105.776630000000	Rio San Pedro at Villalba, CHIH
27	28.543113275800	-105.419717913000	Rio Conchos at Las Burras, CHIH
28	29.006231999700	-105.269394087000	Rio Conchos at El Granero, CHIH
29	29.573717603300	-104.432728955000	Rio Conchos at Ojinaga, COAH
30	29.325913402900	-100.951157178000	Arroyo de la Vacas at Cd. Acuna, COAH
31	29.080520000000	-100.793720000000	Rio San Diego near Jimenez, COAH
32	28.888067344500	-100.630568548000	Rio San Rodrigo at El Moral, COAH
33	28.680940001400	-100.523818262000	Rio Escondido at Villa de Fuente, COA
34	27.844616811800	-101.123390725000	Rio Sabinas at Sabinas, COAH
35	27.426254696000	-100.981434551000	Rio Nadadores at Progreso, COAH
36	27.232185855100	-100.139396783000	Rio Salado at Rodriguez, NL
37	26.836068086600	-99.562030000000	Rio Salado near Las Tortillas, TAMPS
38	26.452220435700	-99.147254781800	Rio Alamo at Cd. Mier, TAMPS
39	25.719140347700	-99.257600173900	Rio San Juan at El Cuchillo, NL
40	25.952413768900	-100.175280580000	Rio Salinas at Cienega de Flores, NL
41	25.911146625900	-99.351499122500	Rio Pesqueria at Los Herrera, NL
42	26.023828671900	-99.197846432300	Rio San Juan at Los Aldamas, NL
43	26.318071159500	-98.840033332400	Rio San Juan at Camargo, TAMPS

Step 1: For each projection and control point, mean monthly flows for the reference hydrology period (1950–1999) and the future hydrology period (2056–2085) are calculated.

Step 2: Calculate the change in mean monthly flows between the future period and the reference hydrology period for each projection for the given site. The percentage change (*PC*) in mean monthly flow for a given projection and site is calculated as follows:

$$PC = \frac{\left(\overline{Q}_{2056-2085} - \overline{Q}_{1950-1999}\right)}{\overline{Q}_{1950-1999}} \times 100$$

Where:

$\overline{Q}_{1950-1999}$ = The mean flow for a month for the given projection and site calculated from the 50 monthly values in the reference hydrology period, 1950-1999

$\overline{Q}_{2056-2085}$ = The mean flow for a month for the given projection and site calculated from the 30 monthly values in the future period

Step 3: Steps 1 and 2 were repeated for all 112 climate projections, and then the 5th, 50th, and 95th percentile values of the monthly percentage change in flows from all 112 projections were determined.

These portions capture the uncertainty (lower bound: 5th percentile; upper bound: 95th percentile) in changes to mean monthly flows between the reference hydrologic period (1950–1999) and the projected future hydrologic periods (2056–2085) with climate change effects. Therefore, in the future water supply analysis that follows in this report, the baseline surface water supplies are compared to projected future water supplies as reflected by the median (50^{th} percentile), 5^{th} percentile, and 95th percentile flow percentage change factors.

Using this approach of linking global and regional climate information, physically based hydrologic processes, streamflow routing, and systems modeling allows for a consistent linkage between climate and system responses that are desired as part of this overall study of future basin water supply reliability.

C. Variable Capacity Infiltration Surface Water Modeling Results

1. Hydroclimate Projections

a. Time-Series Plots

This set includes specific annual time-series plots for six projected hydroclimate indicator variables covering the period 1950–2099 (water years 1951–2099).

These plots provide a snapshot over time as to how a variable is changing—increasing trend, no change, or decreasing trend over time—along with the uncertainty envelope defined by the 112 climate projections. The six variables are:

- Annual total precipitation
- Annual mean temperature
- April 1 snow water equivalent
- Annual runoff
- December – March runoff
- April – July runoff

Three of these variables—annual total precipitation, annual mean temperature, and April 1 snow water equivalent—vary spatially (at 1/8° or ~12-kilometer grid resolution) across the basins, resulting in changes to runoff. To estimate total annual precipitation for the basin, basin-wide average precipitation (average across the grid cells in the basin) was first calculated for each month of the years 1950–2099. These monthly precipitation values then were summed for each water year 1951–2099 to obtain the annual total precipitation.[23]

To estimate basin mean temperature, the average temperature was calculated from all the grid cells in the basin for each month of the water years 1951–2099. These monthly temperatures for any given year were averaged to estimate the basin-wide annual mean temperature.

Runoff for each of the 43 control site locations (see table 2-7) was calculated for the annual timescale and for two seasonal timescales: (1) December – March total runoff, depicting winter season runoff conditions, and (2) April – July total runoff, depicting spring – summer runoff conditions. For each of the simulation years 1950–2099, monthly runoff was aggregated on a water year basis to calculate water-year-specific total annual runoff, December – March runoff, and April – July runoff.

The annual time-series plots for the six hydrologic indicator variables for all 112 projections were calculated, and the results are presented to reflect a "bell curve" of results. The middle of the curve is measured using the median, and the 5th and 95th percentile bounds from the 112 projections provide the lower and upper scenario limits through time.

Figure 2-11 shows the projection for six hydroclimate indicators for the Rio Grande below Falcon Dam: (1) annual total precipitation (top left), (2)annual mean temperature (top right), (3) April 1 snow water equivalent (middle left), (4) annual runoff (middle right), (5) December – March runoff season (bottom

[23] Water years begin on October 1 and end on September 30 of the following calendar year. For example, water year 1951–2099 is defined the period beginning October 1950–September 2099.

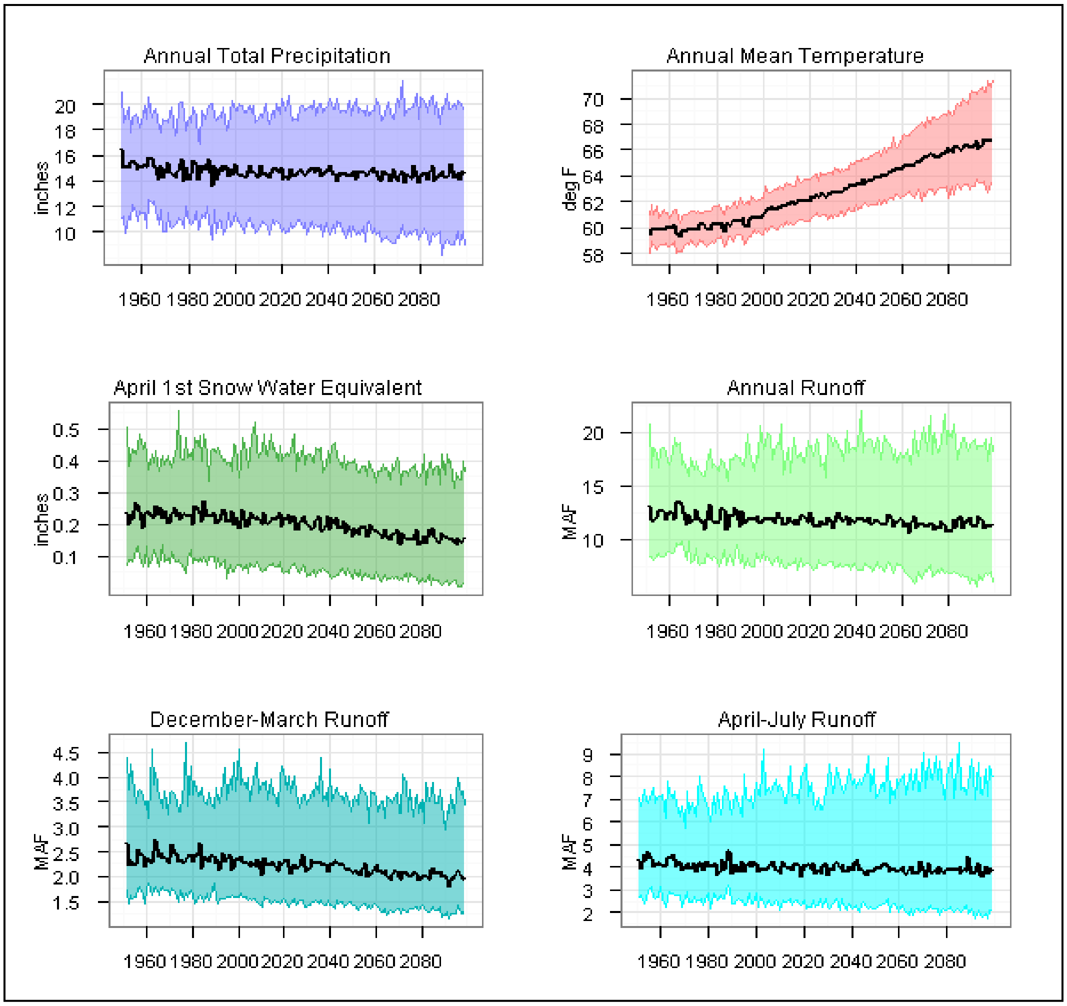

Figure 2-11: Projections for six hydroclimate indicators for the Rio Grande below Falcon Dam.

left), and (6) April – July runoff season (bottom right). The heavy black line is the annual time-series of 50th percentile values (i.e., ensemble-median). The shaded area is the annual time-series of 5th to 95th percentiles. This location was chosen because it is the most downstream point of the Rio Grande before withdrawals are made to meet the demands of the study area.

The annual total precipitation over the basin that reaches this site shows a declining trend over the period going out to 2099. The range of uncertainty appears to be largely the same over time. The mean annual temperature over the basin shows an increasing trend and a diverging uncertainty envelope over time. April 1 snow water equivalent also shows a decreasing trend. The annual runoff has a nominal declining trend. The winter season (December – March) runoff shows a declining trend, but the April – July (summer season) runoff practically shows no trend.

There is a large variation between the upper and lower trends regarding runoff as a result of these six factors and the limited interchange of surface water/ groundwater, which normally provides storage and gradual redistribution of runoff when more interaction is present. Therefore, the trend lines provide an understanding of expected rates of change in future supply conditions.

b. Spatial Plots

The next set of plots includes spatial plots of decade-mean precipitation and temperature. These plots show the spatial distribution for precipitation and temperature across the contributing sub-basins for the location Rio Grande below Falcon Dam. The spatial plots are developed on a water year basis for the reference decade, 1990s (water years 1990–1999). Spatial distribution of precipitation for the 1990s is presented as an ensemble median of the 112 projections. At each grid cell in the basin and for each of the 112 projections, average total precipitation was calculated by averaging total precipitation from the 10 water years 1990–1999. Next, for each grid cell, the ensemble median of the decade average total precipitation was calculated and used in developing the spatially varying precipitation plots.

The estimation of precipitation changes in each of the future decades—2020s (water years 2020–2029), 2050s (water years 2050–2059), and 2070s (water years 2070–2079)—was calculated as follows. At each grid cell in the basin and for each of the 112 projections, average total precipitation was calculated by averaging total precipitation from the 10 water years in the respective future decades. Then, for a given projection and at a given grid cell, the percentage difference between a given future decade average total precipitation and the reference 1990s decade average total precipitation was calculated. This percentage difference for a given cell was calculated only if the 1990s average total precipitation for that cell was greater than 0.01 millimeter. This step is necessary to eliminate potential division by a small value (say a value close to zero), which would result in a numerically large change of magnitude or a zero-divide numerical error (division by zero is not possible). Also, positive percentage change implies wetter conditions, while negative percentage change implies drier conditions than the 1990s reference decade.

After all projection-specific changes were calculated for a given future decade, the median change was calculated from the 112 projections. The median, or 50^{th} percentile, change provides a measure of the central tendency of change in decade average total precipitation in a given future decade from the reference 1990s decade (figure 2-12).

The upper parts of the basin show a continuing decrease in precipitation for all three future decades from the 1990s reference decade. The lower parts of the basin show some wetter conditions over the 2020s and 2050s, but by the 2070s, drier conditions than those in the 1990s are expected throughout the basin.

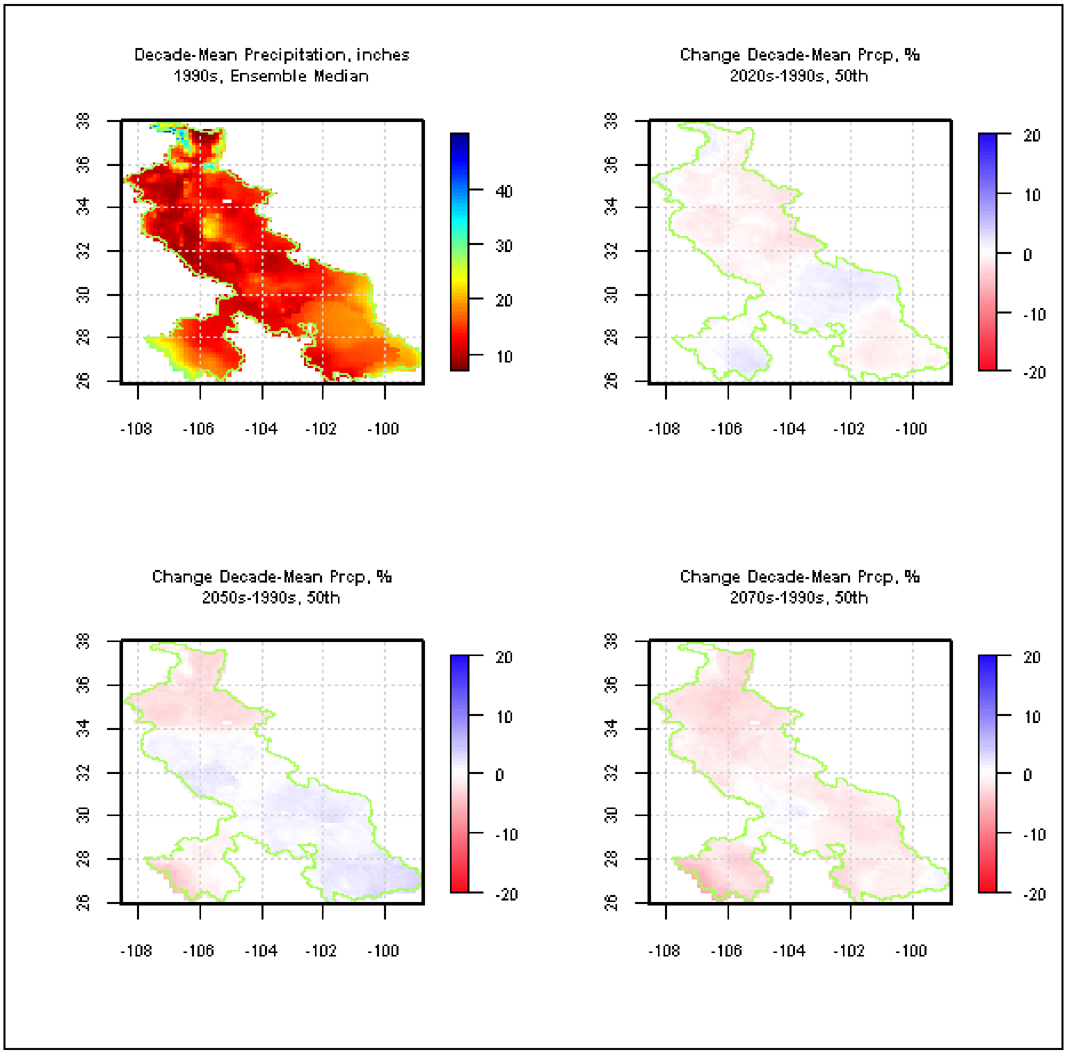

Figure 2-12: Spatial distribution of simulated decadal precipitation.

The calculations for the spatial distribution of mean temperature are similar to those for the spatial distribution of precipitation for the 1990s reference decade. However, mean annual temperature is first calculated from the 12 monthly values (in case of precipitation, it is the total precipitation) for each of the 10 water years and subsequently averaged to calculate the decade average mean annual temperature. The changes in mean annual temperature for the future decades are presented as magnitude changes and not as percentage changes (precipitation changes in future decades are expressed as a percentage). The median, or 50^{th} percentile, change from the 112 projections represents the central tendency in decade-mean temperature distribution.

Figure 2-13 shows the spatial distribution of simulated decadal temperature. These results show that the basin is expected to get hotter through the successive decades (2020s, 2050s, and 2070s) than it was in the 1990s reference decade. The vertical axes represent latitude, while the horizontal axes represent longitude.

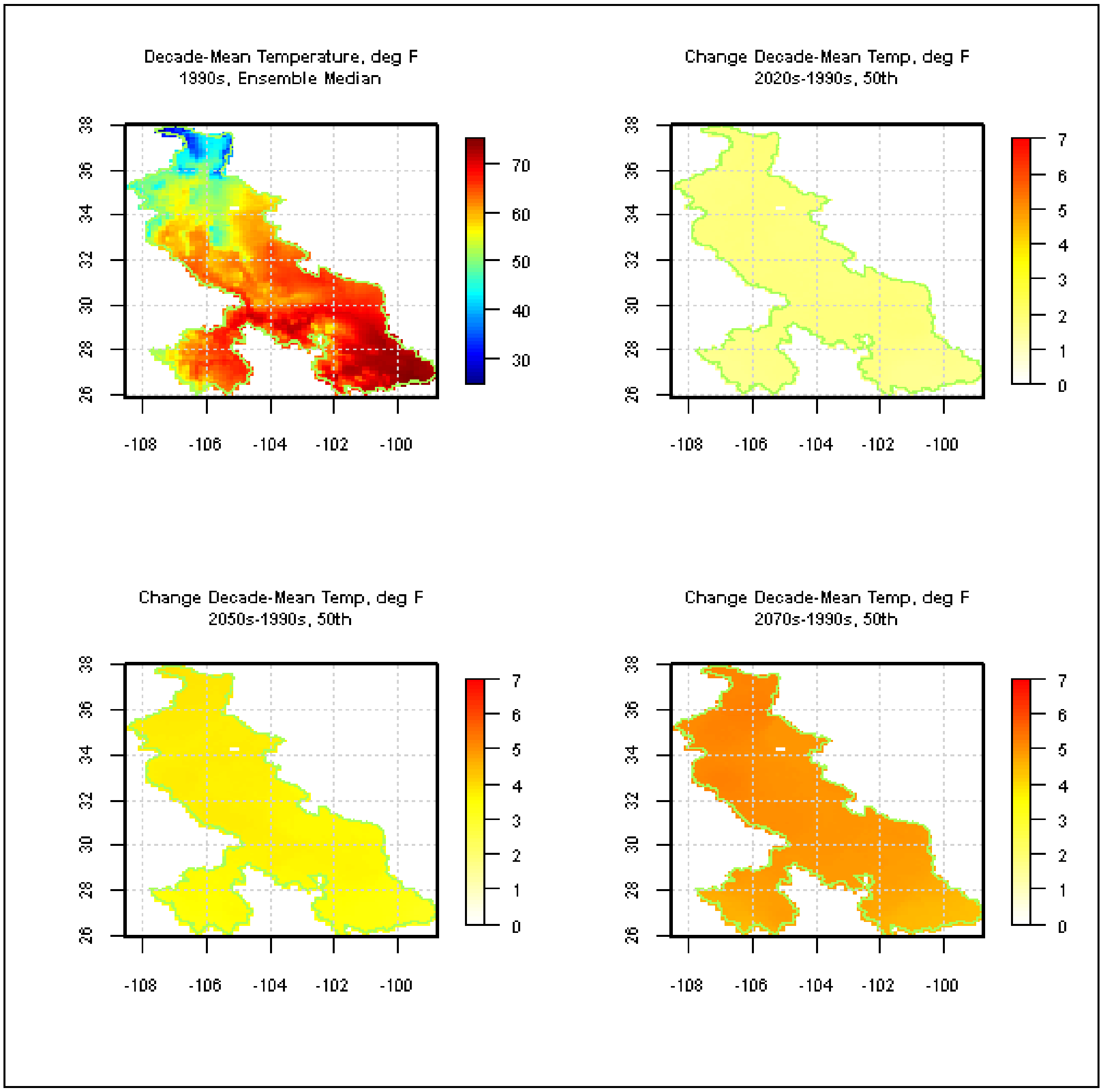

Figure 2-13: Spatial distribution of simulated decadal temperature.

2. Impacts on Annual and Seasonal Runoff

Similar to the calculations of precipitation and temperature changes, changes to annual and seasonal runoff were calculated for the 43 sites listed in table 2-7. Figure 2-14 shows mean annual and mean seasonal runoff change for the site Rio Grande below Falcon Dam.

Changes in mean runoff (annual or seasonal) are calculated for the three future decades—2020s, 2050s, and 2070s—from the reference 1990s decade. For the 2070s decade, there is a decline in the mean annual and seasonal runoffs from the 1990s decade; for the 2020s decade, the change in runoff is nominal.

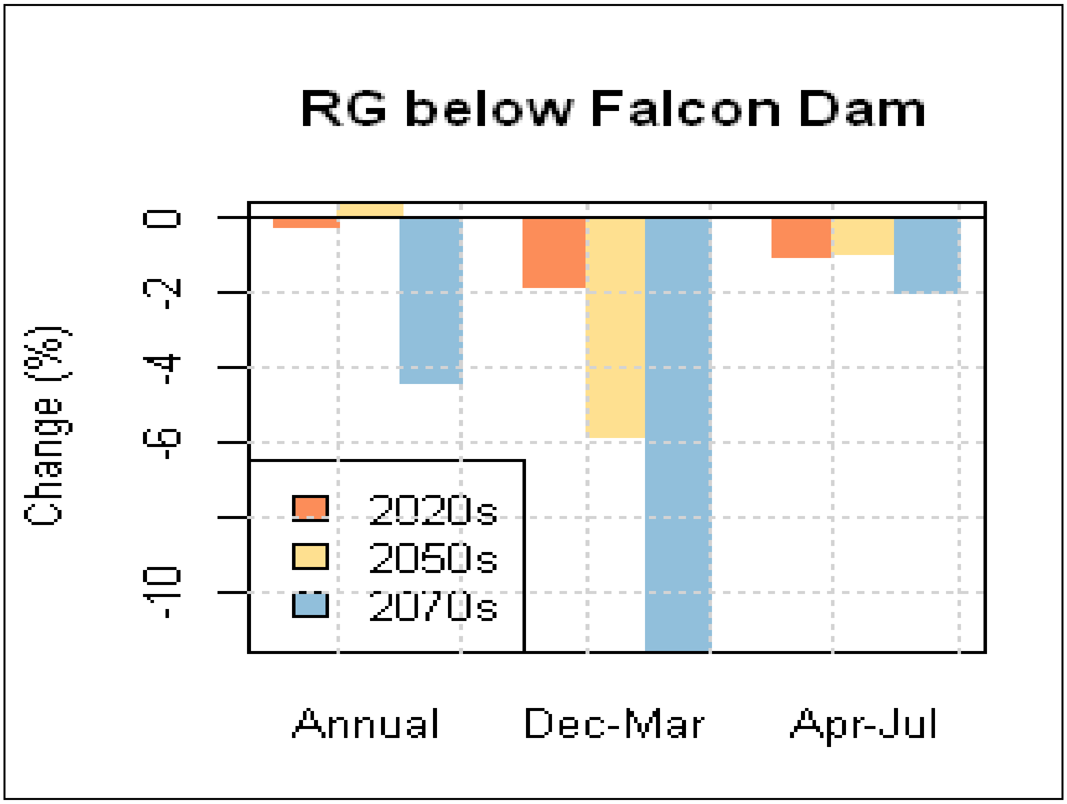

Figure 2-14: Simulated mean annual and mean seasonal runoff change.

3. Impacts on Reservoir Evaporation

Reservoir evaporation was estimated using the same approach used to estimate changes in streamflow between the future hydrologic period 2056–2085 from the reference hydrologic period, 1950–1999. Using the VIC open water evaporation output, change in monthly mean open water evaporation was estimated for each of the 112 climate projections and for each of the 25 reservoir sites used in the water allocation modeling effort. Next, median (50th percentile) and 95th percentile changes for each month were calculated from the 112 change factors for each of the reservoir sites. The summer season (June – August) change for the 50th percentile (median) from the 25 reservoir sites ranged from 0.85 to 3.72%, with a median change of 2.58%. Similarly, the summer season change for the 95th percentile from the 25 reservoir sites ranged from 6.55 to 12.55%, with a median of 9.61%.

To simplify the system reliability analysis, three values considered representative of the above VIC output trends were selected for comparison purposes: (1) no change in reservoir evaporation, (2) a 4% change in reservoir evaporation, and (3) a 10% change in reservoir evaporation. These reliability comparisons are displayed in table 2-9.

4. Climate-affected Impacts on Irrigation Demand

The VIC simulates reference evapotranspiration (ET_0) based on the Penman-Monteith (PM) method (Maidment, 1993).[24] As part of Reclamation's west-wide climate risk assessments,[25] which incorporated the VIC modeling effort, gridded (~12- x 12-kilometer) ET_0 estimates were developed for nearly the entire 17-State Reclamation region. Developing ET_0 using the PM method is based on the estimation of potential evapotranspiration using a reference surface (e.g., a well-defined crop surface). Example reference surfaces typically include crops such as short grass, alfalfa, or even the natural vegetation with specified crop characteristics such as crop height, vegetation resistance, albedo, and leaf area index. ET_0 estimates based on several of these reference surfaces are available from the West Wide Climate Risk Assessment hydrologic projections (a total of 112 projections) archive.[26] From a review of the Texas ET Network Web site,[27] we found that the standard crop used for the network is a cool-season grass that is 4 inches tall. Therefore, for estimating changes to evapotranspiration for the eight Region M counties, the short reference crop (grass) ET_0 from the WWCRA hydrologic projections archive was used.

In order to estimate evapotranspiration change for the 2070 period (2056–2085) from the reference period, 1950–1999, the first step was to identify all of the VIC grid cells specific to the eight counties of Region M. In the next step, mean monthly ET_0 values were calculated by spatially averaging VIC-simulated ET_0 values for each county. After estimating county-specific spatial mean ET_0 values, the statistical calculation of the expected change in evapotranspiration was performed using the same approach used to estimate changes in streamflow or reservoir evaporation between the future hydrologic period, 2056–2085, and the reference hydrologic period, 1950–1999, and using all the 112 hydrologic projections. Percentile changes (5th, 50th [or median], and 95th) for each county were first calculated for each month using the evapotranspiration changes estimated from all the 112 projections. Subsequently, mean change by month across the eight counties was used to depict evapotranspiration change across Region M.

The seasonal summary of changes to evapotranspiration for Region M shows that the median (estimated from the 112 projections) summer season (June – August) evapotranspiration will increase by about 4% for the 2070 period (2056–2085) from the 1950–1999 reference hydrologic period. The lower bound of change (5th percentile) for this season shows about a 1% decrease, and the upper bound

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[24] Maidment, David R. *Handbook of Hydrology*. New York: McGraw-Hill. 1993.

[25] "Reclamation – WaterSMART – West-wide Climate Risk Assessments Baseline Assessments." *Reclamation - WaterSMART - West-wide Climate Risk Assessments Baseline Assessments*. Web. July 5, 2012. <http://www.usbr.gov/WaterSMART/wcra/base.html>

[26] "Bias Corrected and Downscaled WCRP CMIP3 Climate and Hydrology Projections." *Bias Corrected and Downscaled WCRP CMIP3 Climate and Hydrology Projections*. Web. June 30, 2012. <http://gdo-dcp.ucllnl.org/downscaled_cmip3_projections/dcpInterface.html>

[27] "ITC - TexasET Network." *ITC - TexasET Network*. Web. June 30, 2012. <http://texaset.tamu.edu/>

of change (95th percentile) shows nearly a 14% increase. The change in evaporation was calculated to be the least in summer compared to other seasons. The median (50th percentile) projected change for the summer season as compared to the 1950–1999 reference period (4.38%) was calculated to be less than the calculated change for winter (8.93%), spring (10.55%), and fall (7.20%) seasons. A summary of Region M evapotranspiration changes is provided in table 2-8.

Table 2-8: Region M evapotranspiration change

Season	Months	Evapotranspiration change (%)		
		5th percentile	50th percentile	95th percentile
Winter	Dec – Jan – Feb	0.59	8.93	20.61
Spring	Mar – Apr – May	2.69	10.55	22.33
Summer	Jun – Jul – Aug	-1.01	4.38	14.04
Fall	Sep – Oct – Nov	1.61	7.20	15.03

These changes were incorporated into seasonal agricultural demand figures to show quantified increases, further exacerbating the future supply/demand imbalance for the study area. The results are seen on figure 2-15 for the baseline WAM Run 3 analysis and the three climate scenario derived changes in evapotranspiration. Agricultural demands would be expected to increase by approximately 18% for the 95th percentile climate change scenario over baseline demands. The projected demands were calculated using the evapotranspiration change values shown in table 2-8 and applying them to the 2012 State Water Plan irrigation demand projections. The seasonal evapotranspiration changes were annualized by spreading the percentages out over the year and multiplying the annual irrigation demand by the expected annual evapotranspiration percentage to estimate increases in irrigation demands based on climate changes.

D. Future Reliability of Facilities and Operations as Required by SECURE Water Act §9503(b)(3)

1. Summary

The Omnibus Public Land Management Act of 2009 (P.L. 111-11) Subtitle F – SECURE Water was passed into law on March 30, 2009. Also known as the SECURE Water Act, the statute establishes that Congress finds that adequate and safe supplies of water are fundamental to the health, economy, security, and ecology of the United States although global climate change poses a significant challenge to the protection of these resources.

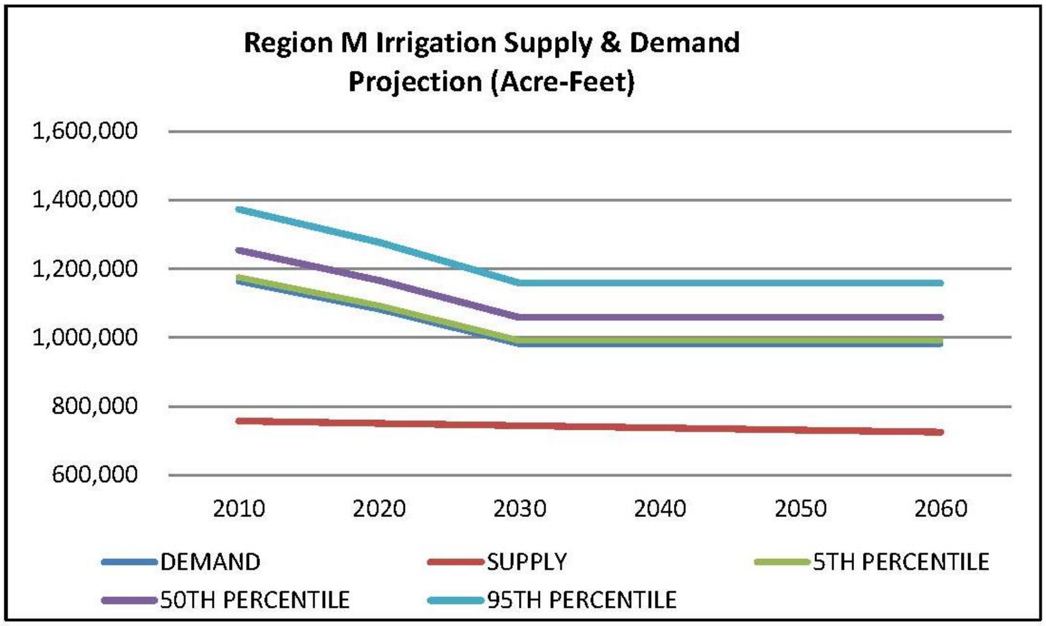

Figure 2-15: Projected irrigation demands based on climate change scenarios.

Reclamation does not own or operate reservoirs in the study area; therefore, the focus of this analysis is on the ability of the project partners to deliver water in the future as affected by climate change. The Region M Plan predicts a water supply shortage of 592,084 ac-ft/yr by 2060, which would result in 35% of water demands being unmet. The study has determined that climate change may likely increase this shortage by an additional 86,438 ac-ft/yr.

2. Climate Change Projections

Changes in water supplies due to climate change were based on the results of 112 gridded climate and hydrology projections developed for the planning year of 2070 with a time span of 2056–2085. The changes incorporated into the hydrology models for the Rio Grande Basin include flow impacts for the surface model as indicated by runoff impacts on flow and evaporation impacts on reservoirs. The following is a summary of the climate variability as simulated by the VIC:

- Precipitation is expected to increase from the 1990s level during the 2020s and 2050s but decline nominally during the 2070s.
- Temperature shows a persistent increasing trend from the 1990s level.
- April 1 snowpack (Upper Rio Grande Basin) shows a persistent decreasing trend from the 1990s level.

- Annual runoff shows some increase from the 1990s level to the 2020s, but then declines to the 2050s and 2070s.

3. Surface Water

The effect of potential climate change scenarios on the available surface water supplies from the Rio Grande were investigated using the Rio Grande WAM with modified naturalized flow inputs derived from the 112 climate change scenarios analyzed by Reclamation. Monthly median and 5th and 95th percentile flows from the 112 scenarios were used at all primary control points in the WAM to incorporate climate change effects into the monthly baseline naturalized flows for the 1940–2000 simulation period. For example, a value in the 5th percentile would have been exceeded by 95% of the other values, while a value in the 95th percentile would be exceeded by only 5% of the others.

The evaporation rates for this period included in the WAM data input files were also increased by 4 and 10% to provide an indication of the potential effects of varying evaporation rates due to climate change. As with flow, evaporation rates for nine climate change scenarios and the baseline were evaluated for surface water availability effects. No changes in demand due to climate change are incorporated into the surface or groundwater models, as management policy dictates the actual availability of both sources for future uses.

In total, 10 different sets of WAM input data were considered, 1 reflecting the historical baseline condition without climate change effects and 9 combinations of the 3 future flow conditions (median and 5th and 95th percentile flow factors) and 3 future evaporation conditions (baseline and 4 and 10% increases) with climate change effects. Table 2-9 describes the following scenario in the columns from left to right:

- Baseline
- Scenario 1 – Median climate-affected flow factors with evaporation same as baseline
- Scenario 2 – Median climate-affected flow factors with + 4% evaporation
- Scenario 3 – Median climate-affected flow factors with + 10% evaporation
- Scenario 4 – 5th percentile climate-affected flow factors (low) with evaporation same as baseline
- Scenario 5 – 5th percentile climate-affected flow factors (low) with + 4% evaporation

Table 2-9: WAM baseline and climate simulation results

SUMMARY OF TEXAS WATER RIGHTS RELIABILITIES AND OTHER RESULTS FROM RIO GRANDE WAM SIMULATIONS CONSIDERING DIFFERENT CLIMATE CHANGE SCENARIOS

RUN ID	BASELINE	1	2	3	4	5	6	7	8	9
FLOW SCENARIO	WAM RUN3	MEDIAN FLOW FACTORS			5TH PERCENTILE FLOW FACTORS			95th PERCENTILE FLOW FACTORS		
EVAPORATION SCENARIO	WAM RUN3	LOW Same as Baseline	MEDIUM Baseline + 4%	HIGH Baseline + 10%	LOW Same as Baseline	MEDIUM Baseline + 4%	HIGH Baseline + 10%	LOW Same as Baseline	MEDIUM Baseline + 4%	HIGH Baseline + 10%
MIDDLE & LOWER RIO GRANDE										
AMISTAD-FALCON WATER RIGHTS										
TOTAL AUTHORIZED DIVERSIONS										
Domestic-Municipal-Industrial	301,920	301,920	301,920	301,920	301,920	301,920	301,920	301,920	301,920	301,920
Class A Irrigation & Mining	1,624,004	1,624,004	1,624,004	1,624,004	1,624,004	1,624,004	1,624,004	1,624,004	1,624,004	1,624,004
Class B Irrigation & Mining	187,078	187,078	187,078	187,078	187,078	187,078	187,078	187,078	187,078	187,078
Total (Ac-Ft/Year)	2,113,002	2,113,002	2,113,002	2,113,002	2,113,002	2,113,002	2,113,002	2,113,002	2,113,002	2,113,002
MONTHLY PERIOD RELIABILITY										
Domestic-Municipal-Industrial	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
Class A Irrigation & Mining	55.1%	50.3%	50.1%	49.3%	18.2%	17.9%	17.6%	89.9%	89.6%	88.8%
Class B Irrigation & Mining	29.9%	28.1%	28.0%	27.6%	9.3%	9.3%	9.4%	75.8%	75.5%	75.1%
ANNUAL PERIOD RELIABILITY										
Domestic-Municipal-Industrial	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
Class A Irrigation & Mining	27.9%	23.0%	23.0%	21.3%	1.6%	1.6%	1.6%	78.7%	75.4%	75.4%
Class B Irrigation & Mining	11.5%	8.2%	8.2%	8.2%	1.6%	1.6%	1.6%	54.1%	54.1%	52.5%
AVERAGE VOLUME RELIABILITY										
Domestic-Municipal-Industrial	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
Class A Irrigation & Mining	66.7%	61.9%	61.7%	61.3%	31.3%	31.2%	31.0%	92.5%	92.3%	92.0%
Class B Irrigation & Mining	43.6%	40.9%	40.8%	40.5%	19.7%	19.7%	19.5%	80.2%	79.9%	79.5%
AVERAGE DELIVERY VOLUME										
Domestic-Municipal-Industrial	301,920	301,920	301,920	301,920	301,920	301,920	301,920	301,920	301,920	301,920
Class A Irrigation & Mining	1,083,211	1,005,258	1,002,011	995,514	508,313	506,689	503,441	1,502,204	1,498,956	1,494,084
Class B Irrigation & Mining	81,566	76,515	76,328	75,767	36,854	36,854	36,480	150,037	149,475	148,727
Total (Ac-Ft/Year)	1,466,697	1,383,693	1,380,259	1,373,201	847,087	845,463	841,841	1,954,161	1,950,351	1,944,731
RESERVOIRS U.S. FIRM ANNUAL YIELD										
All DMI, Irrigation & Mining Water Rights	1,032,123	983,781	977,131	968,039	628,155	620,750	610,179	1,509,056	1,501,655	1,491,107
AMISTAD-FALCON AVERAGE ANNUAL U.S. EVAPORATION LOSSES (Ac-Ft)	107,694	98,812	101,468	106,243	60,794	61,872	66,578	257,591	265,860	277,910
PRIOR APPROPRIATION RIGHTS										
IN TEXAS RIO GRANDE BASIN										
Total Authorized Diversions	1,062,655	1,062,655	1,062,655	1,062,655	1,062,655	1,062,655	1,062,655	1,062,655	1,062,655	1,062,655
AVERAGE VOLUME RELIABILITY	47.3%	42.1%	42.1%	42.0%	33.8%	33.8%	33.7%	50.6%	50.6%	50.6%

Source: WAM WRAP Run 3.

- Scenario 6 – 5th percentile climate-affected flow factors (low) with + 10% evaporation
- Scenario 7 – 95th percentile climate-affected flow factors (high) with evaporation same as baseline
- Scenario 8 – 95th percentile climate-affected flow factors (high) with + 4% evaporation
- Scenario 9 – 95th percentile climate-affected flow factors (high) with + 10% evaporation

With these sets of modified input data, simulations of water availability throughout the Rio Grande Basin were made using the WAM, and the results are shown in table 2-9 in a few different terms. First, the total authorized diversion is the total volume of all water rights held for this section of the Rio Grande. Reliabilities are assigned to classes of water rights on the Lower Rio Grande as a way to deal with the volume of total authorized maximum diversions being larger than the firm yield of the reservoirs. Table 2-9 shows both period and volume reliabilities for all DMI water rights and for all Class A[28] and Class B[29] irrigation and mining water rights that depend on Amistad and Falcon Reservoirs for their supply.

For the purpose of this study, the volume reliability percentage is defined as the average volume of water that a particular water right was able to divert during the 1940–2000 period, as simulated with the WAM, divided by the authorized maximum diversion amount for that water right. For example, in column 6 of table 2, for the 5th percentile flow factor (that point in the projected future flow distribution curve of which 95% of the results were higher), under the high evaporation scenario, only 19.5% of the Class B irrigation and mining water rights would be met due to low surface water conditions.

Period reliability is the percentage of time for which a particular diversion is available in light of the historical observations. This applies to monthly and annual time steps. Monthly period reliability is the percentage of time for which all monthly authorized diversions are met. The annual period reliability is the percentage of time for which annual authorized diversions are met. The annual period reliability decreases dramatically over the monthly reliability due to the larger number of data points in the monthly historical record. For the purpose of the following discussion, the average volume reliability is used.

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[28] Class A water right in the Rio Grande Basin for irrigation and mining use granted in the Adjudication in *State* v. *Hidalgo County Water Control & Improvement District No. 18.* If converted to a DMI water right, a Class A water right is converted to 50% of the existing water right.

[29] Class B water right in the Rio Grande Basin for irrigation and mining use granted in the Adjudication in *State* v. *Hidalgo County Water Control & Improvement District No. 18.* If converted to a DMI water right, a Class B water right is converted to 40% of the existing water right.

Firm yield is the maximum water volume a reservoir can provide each year under the drought of record conditions and is shown for each climate scenario. For information purposes, the average annual evaporation losses from Amistad and Falcon Reservoirs and the minimum storage remaining in these reservoirs as simulated with the WAM for the 1940–2000 period are presented for the baseline case and for each of the nine climate change scenarios.

WAM Run 3 baseline conditions represent the simulated present annual availability of surface water from the Amistad-Falcon Reservoir System based on the historical ability to divert during the 1940–2000 period and observed climate conditions. The present conditions are represented by updated water rights in the Rio Grande Basin and observed evaporation and precipitation conditions. The baseline yield and reliabilities do not represent future conditions or projections. The sedimentation impact on the reservoir over the projection horizon would need to be developed. In addition, the WAM water right file would need to be updated to reflect control points with change of use restrictions.

There is a difference in the total authorized diversions in this WAM Run 3 baseline simulation and the results reported in the 2011 Rio Grande Regional Water Plan. The difference is less than 1% in the overall yield of supplies and is due to updated water right files since the previous model runs used in the Regional Plan.

As shown in table 2-9, the water supply from Amistad and Falcon Reservoirs for the DMI water rights is 100% reliable because of the high priority assigned to these rights under the structure of the TCEQ's water rights administration rules for the Middle and Lower Rio Grande (the model predicts that adequate supply will exist under all climate scenarios to satisfy these rights). The Class A and Class B irrigation and mining rights have somewhat lower reliabilities because the available supplies of water for these rights from Amistad and Falcon Reservoirs are subject to allocation during periods of shortage, with the Class A rights allocated more water than the Class B rights. The reliabilities of the prior appropriation water rights generally fall in line with the Class A and Class B reservoir rights, except for the 95th percentile high-flow results (Scenarios 7, 8, and 9), where all of the Class A and Class B reliabilities are considerably higher.

From the average volume reliabilities, another metric can be generated: average volume diverted. Whereas firm yield was calculated as the largest volume that can be supplied with 100% reliability, average volume diverted is calculated by applying the average volume reliability to the total authorized diversions. This value represents the average volume that is likely to be diverted under each climate scenario.

The difference between the average volume diverted under the baseline conditions and the median flow, 4% increased evaporation scenario (Scenario 2), is 86,438 acre-feet (1,466,697–1,380,259). This represents the difference between the Amistad-Falcon modeled availability that is currently used in the planning process and the availability that is predicted under the median climate-affected availability model. This important figure is used later in this Basin Study as a representative of probable additional future supply imbalance that would result from climate change and, therefore, will play a major role in forming the planning objective.

The effects of the three levels of flows associated with future climate change are readily apparent among the different sets of reliabilities shown in table 2-9. As noted above, the available surface water supplies from Amistad and Falcon Reservoirs for DMI use are projected to remain firm (100% reliable) for all climate change scenarios. However, the following discussion illustrates climate-affected reliability changes, using examples from the "average volume reliability" rows of table 2-9. For the median flow factors (Scenarios 1, 2, and 3), reductions in the reliabilities of the Class A and Class B irrigation and mining rights are projected to be only about 5 and 3%, respectively. The indicated reliability reductions for these rights based on the 5th percentile flow factors (Scenarios 4, 5, and 6) are considerably greater—about 35 and 24%, respectively. In other words, the reliability will decrease from 66.7% to 31 and 19% for Class A and Class B rights, respectively. The 95th percentile flow factors (Scenarios 7, 8, and 9) result in significant increases in the reliability of these water rights—from 66.7% to 92.5 and 80.2%, about a 22 and 37% increase, respectively—as more water is available throughout the basin for these scenarios. For the prior appropriation water rights, the changes in reliability are projected to be reductions of about 5% for the median flow factor case (Scenarios 1, 2, and 3) and 13% for the 5th percentile flow factor case (Scenarios 4, 5, and 6), with an increase in reliability of about 3% for the 95th percentile flow factor case (Scenarios 7, 8, and 9).

The changes in the average evaporation losses from Amistad and Falcon Reservoirs are fairly significant between the different flow conditions presumably because of the significantly varying amounts of water stored in the reservoirs under the different flow ranges. The fact that under all of the scenarios simulated (including the baseline) the minimum amount of combined storage in Amistad and Falcon Reservoirs is at least 200,000 acre-feet relates to the fact that the TCEQ's reservoir storage rules for Amistad and Falcon Reservoirs require that a minimum DMI reserve pool be maintained to the extent practicable. The climate-impacted model results show that this level of storage is feasible throughout the study period.

In summary, the worst-case scenarios (Scenarios 4, 5, and 6) for climate impact on water availability in the Lower Rio Grande Basin for surface water result in declines of about 25 to 35% for irrigated agriculture and mining uses when compared to baseline conditions. Another way of looking at these declines is to surmise that projected worst-case reliability decreases in these sectors from 66.7 to 31.2% would result in less than one-half of the water being available as there is in the baseline calculation. Municipal and industrial water rights dependent on Amistad and Falcon Reservoirs are expected to have their full authorized supplies available.

Figure 2-16 is a comparison plot of the reliability of the delivery volume over an annual period to each water right category of use for the three climate scenarios. All three climate change scenarios incorporate a 4% increase in evaporation for the reservoir system. The median flow simulation (Scenario 2 from the discussion above) shows a reduction in the reliability of the agricultural rights to 61.7% for Class A and 40.8% for Class B rights. The 5th percentile simulation (Scenario 5 from the discussion above) decreases reliability to 31.2 and 19.7% for Class A and Class B, respectively. The 95th percentile simulation (Scenario 8 from the discussion above) shows an increase in reliability to 92.3% and 79.9% for irrigation rights.

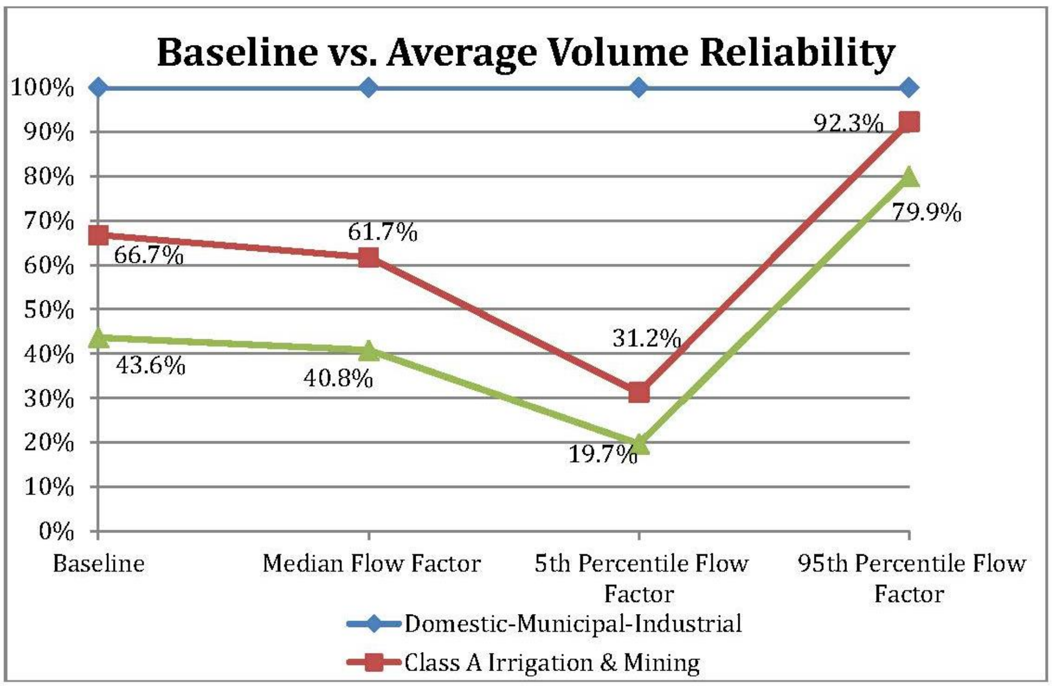

Figure 2-16: Baseline WAM versus average volume reliability.
Source: WAM Run 3 Climate Modified Runs, 2012.

Figures 2-17 and 2-18 compare reliabilities from the WAM for baseline Run 3 conditions to monthly and annual time periods. The monthly reliability is the comparison of monthly values for flow conditions modified with VIC parameters to historical observations on a monthly basis. The annual reliability is a comparison of baseline conditions to annual historical observations. The reduction in reliability from monthly (figure 2-17) to annual (figure 2-18) reflects the impact of low flow annual events. In other words, the lowest flow within an

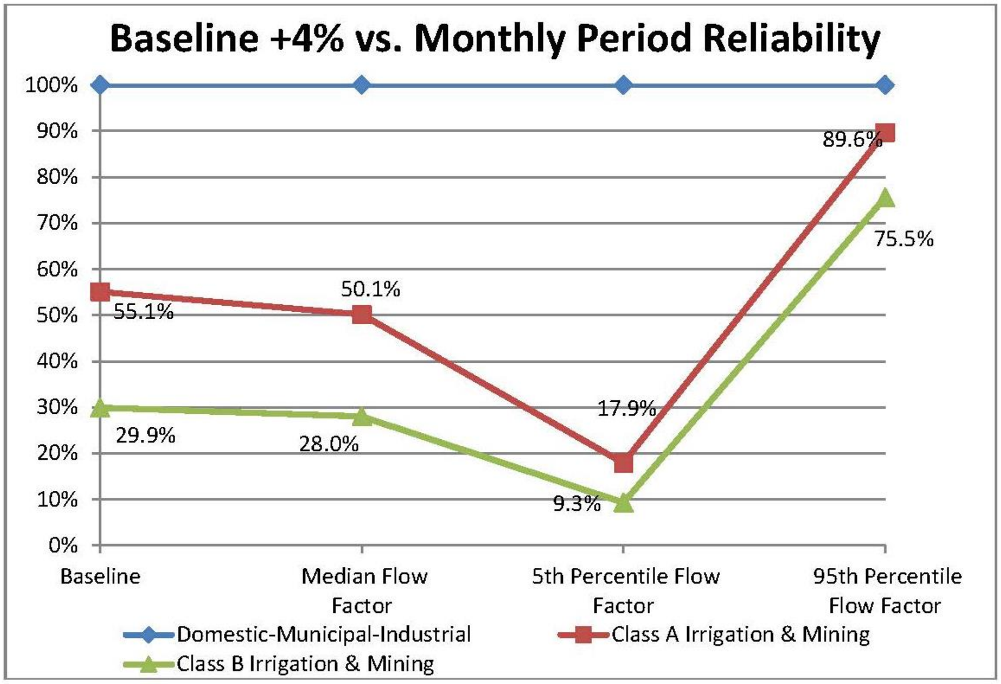

Figure 2-17: Baseline WAM versus monthly period reliability.
Source: WAM Run 3 Climate Modified Runs, 2012.

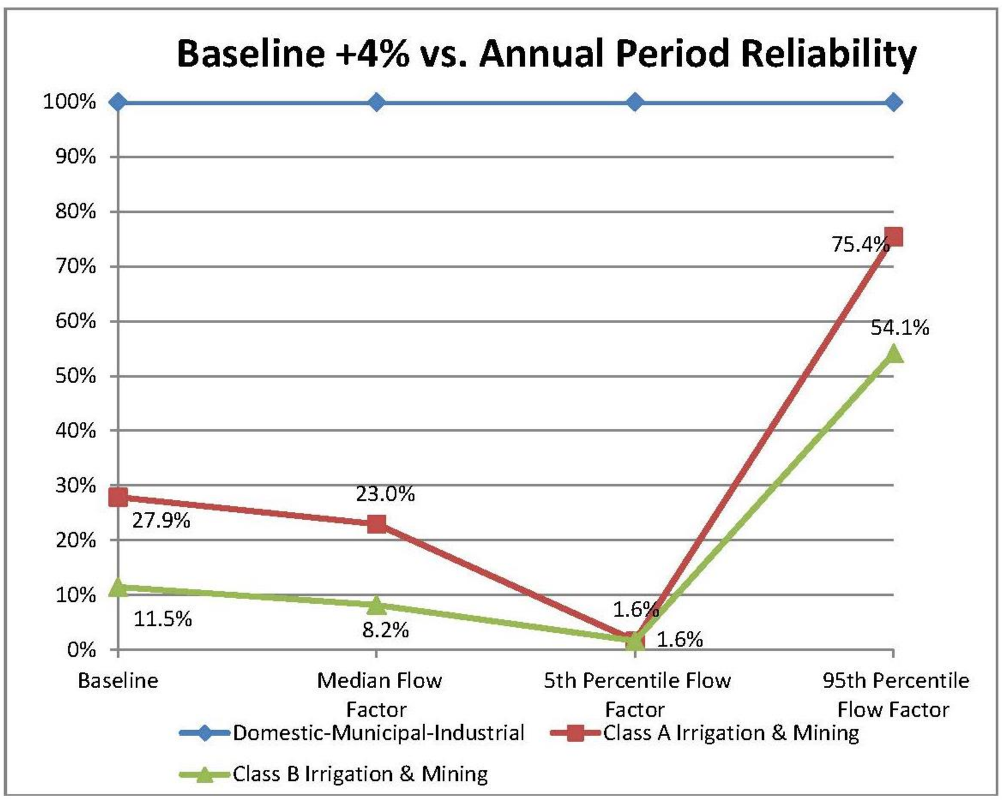

Figure 2-18: Baseline WAM versus annual period reliability.
Source: WAM Run 3 Climate Modified Runs, 2012.

entire year represents the annual reliability, as opposed to figure 2-16, where the reliability is averaged over the entire year. This can also be observed in the inflow record of the system.

As can be seen from figures 2-16 through 2-18, the annual period reliability of non-DMI surface water rights in the study area decreases to near 1 to 2% (nearly 99% nonreliable) during the worst-case climate change scenario (Scenario 8 from the discussion above), with monthly reliabilities in the 10% range. Under these conditions, delivery of irrigation water has ceased and municipal supplies are jeopardized due to the lack of push water to keep these supplies moving.

Figure 2-19 compares firm yield from the Amistad-Falcon Reservoir System based on the WAM Run 3 baseline simulation with firm yield results for the three climate scenarios. These firm yields can be assumed to represent current (2010) conditions and do not represent future projections due to the lack of impact from sedimentation rates and changes in the distribution of water demands. Firm yield for baseline conditions is 1,032,123 acre-feet; climate change impacts would reduce this amount to 620,750 acre-feet under the 5th percentile simulation, a 40% reduction in firm yield volume for the study area.

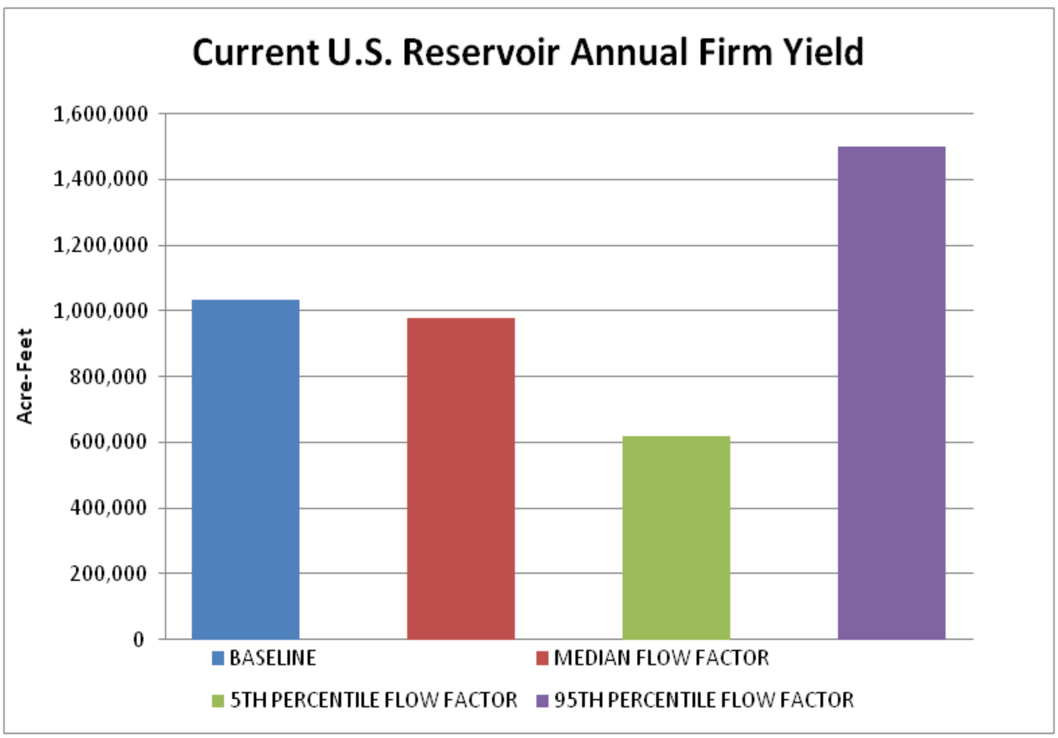

Figure 2-19: Amistad-Falcon Reservoir System U.S. firm annual yield comparison for baseline versus climate change impacts.
Source: WAM Run 3 Climate Modified Runs, 2012.

In summary, the climate-affected future supply situation for surface water indicates that the expected shortfall of over 300,000 acre-feet for municipal demands by the year 2060 (see figure 2-7) will be exacerbated in the median and 5^{th} percentile flow factor scenarios. The projection that present municipal water rights would be 100% reliable in future years as evidenced by our WAM runs is only possible at the expense of agricultural rights, which fall to 1.6% reliable in the annual climate-affected reliability projections (see figure 2-18). This reduction in irrigation flows also has serious impacts on the delivery of water to municipalities due to the need for push water. In combination with risks stemming from Mexico's ability to meet obligations to supply water under the Treaty, Rio Grande surface water poses significant reliability risks in the future.

4. Groundwater

The Groundwater Availability Model developed by the TWDB was used to conduct predictive simulations with adjusted recharge rates. Recharge rates used in the predictive model runs were based on simulations of future climate conditions provided by Reclamation and described above. Recharge is the only input file parameter for the GAM that is impacted by the results of the VIC simulation. It should be noted that because the process used to construct recharge estimates in the development of the groundwater model did not include temperature, temperature estimates from the VIC were not used to create new recharge datasets for predictive modeling.

In order to assess the impact of the 112 climate model runs on precipitation, indicator cells throughout the model domain were selected, and the average, median, maximum, and minimum precipitation totals from the 112 model runs were calculated. The selected cells were spread equally throughout the model domain. Because the recharge estimates for the 2011–2060 predictive model simulations that were developed by the TWDB were based on precipitation totals for 1963–1999, data for 1963–1999 were compared to 2011–2060 for the 112 climate model runs in order to use identical time periods in the analysis as were used in the development of the original input files.

The overall average and median of the 112 simulations completed by Reclamation showed very little change from 1963–1999 compared to 2011–2060 throughout the model domain. However, when evaluating the maximum and minimum values for each monthly time step within each of the 112 simulations, definite changes can be observed. The minimum values for each monthly time step tended to be 15 to 21% lower for 2011–2060 compared to 1963–1999, and the maximum values tended to be 15 to 19% higher for 2011–2060 compared to 1963–1999.

Based on these results, five simulations were run using the GAM:

- Run 1: Recharge decreased by 18%t
- Run 2: Recharge decreased by 9%
- Baseline: Recharge unchanged
- Run 3: Recharge increased by 8%
- Run 4: Recharge increased by 16%

These five scenarios represent the baseline (original) simulation completed by the TWDB to calculate groundwater availability and 50 and 100% of the changes in minimum and maximum monthly change in precipitation based on the 112 climate simulations provided by Reclamation. It is important to note that these increases and decreases in precipitation are much greater than the overall changes predicted in the VIC because the minimum and maximum of each month of the VIC were calculated. As noted above, the average and median precipitation remained virtually unchanged. These simulations should provide an assessment of the maximum possible impact of increasing and decreasing the precipitation on the recharge on the groundwater availability simulations based on the VIC simulations.

It is important to note that although the change in recharge does produce varying changes in the resulting water levels across the model area, due to the methodology that was used by both GMA 13 and GMA 16, which include the study area for this investigation, this will not result in a change in groundwater availability. This is because the DFC was selected by the GMAs based on the predetermined pumpage rates (i.e., availabilities) instead of the pumpage rates being based on the preselected DFCs. Therefore, a change in the recharge would only result in a different DFC being selected by the GMA, with the final groundwater availability remaining the same because many GMAs, including both GMA 13 and GMA 16, used predetermined amounts of pumpage in the groundwater flow models—amounts that were selected to approximate anticipated future demands. Predictive simulations were then run using these pumpage totals, and DFCs were determined based on these results. Table 2-10 provides a summary of the availability from the State Water Plan, along with the managed available groundwater, that resulted from the groundwater planning conducted by the GMAs.

Increasing and decreasing the recharge applied to the Groundwater Availability Model used to calculate groundwater availability estimates for the Rio Grande Valley region results in varying amounts of increasing and decreasing water levels in model simulations. The changes in water levels in the simulations are summarized in table 2-11, where Run 1 has the lowest recharge rate and Run 4 has the highest recharge rate (-18 to +16%). Table 2-11 shows that changes are generally lower in Cameron, Hidalgo, and Willacy Counties, where the

Table 2-10: Annual groundwater availability

County	State Water Plan annual availability (acre-feet)	Managed available groundwater (acre-feet)
Cameron	104,700	50,560
Hidalgo	62,530	41,926
Jim Hogg	4,980	24,414
Maverick	12,066	2,041*
Starr	19,600	7,526
Webb	35,176	23,917
Willacy	90,140	20,013
Zapata	12,500	7,999
Total	**341,692**	**176,355**

* Decreases from 2,041 to 1,531 acre-feet by 2060.
Source: GAM (Hutchison, 2011).

recharge rate is lower and more boundary conditions are present in the model to remove additional recharge and supplement reduced recharge from the groundwater budget. Changes in water levels (from the lowest to highest recharge simulations) are generally higher in Jim Hogg, Starr, and Webb Counties.

However, as described above, due to the methodology used by both GMAs that include the area of interest, the change in recharge will not result in a change in groundwater availability, but rather would result in a change in DFC with the same availability that has currently been calculated by the TWDB. It is important to note that the results of the groundwater availability from the Groundwater Availability Model simulations are for all available groundwater, including both fresh and brackish groundwater. In the study area, brackish groundwater is more prevalent than fresh groundwater, with as much as 80% of the total groundwater from the Gulf Coast aquifer occurring as brackish groundwater. This percentage is based on water quality observations from regional wells indicating source waters with TDS concentrations greater than 1,000 milligrams per liter (mg/L). The simulated average water level resulting from managed available groundwater, less water available, for the five climate-impacted recharge simulations (Runs 1, 2, 3, 4, and baseline) are shown in table 2-11. None of the recharge scenarios impact supplies more than the policy reflected in DFC-developed managed available groundwater volumes.

Table 2-11: Simulated average water level by county (in feet above mean sea level)

Layer 1 – Chicot Aquifer

	Run 1	Run 2	Baseline	Run 3	Run 4	Range
Cameron	-33.45	-32.82	-32.2	-31.64	-31.09	2.4
Hidalgo	-3.33	-2.04	-0.76	0.37	1.5	4.8
Jim Hogg	NA*	NA	NA	NA	NA	NA
Starr	NA	NA	NA	NA	NA	NA
Webb	NA	NA	NA	NA	NA	NA
Willacy	-16.56	-15.87	-15.19	-14.59	-13.99	2.6
Zapata	NA	NA	NA	NA	NA	NA

Layer 2 – Evangeline Aquifer

	Run 1	Run 2	Baseline	Run 3	Run 4	Range
Cameron	-50.96	-50.7	-50.43	-50.2	-49.97	1.0
Hidalgo	-5.19	-4.07	-2.95	-1.96	-0.98	4.2
Jim Hogg	150.73	156.21	161.68	166.54	171.4	20.7
Starr	78.42	81.97	85.53	88.68	91.83	13.4
Webb	294.83	305.74	316.64	326.33	336.03	41.2
Willacy	-156.48	-156.18	-155.87	-155.61	-155.34	1.1
Zapata	NA	NA	NA	NA	NA	NA

Layer 3 – Burkeville Confining System

	Run 1	Run 2	Baseline	Run 3	Run 4	Range
Cameron	-11.79	-11.67	-11.55	-11.44	-11.34	0.4
Hidalgo	31.22	32.19	33.16	34.02	34.88	3.7
Jim Hogg	99.65	103.69	107.74	111.32	114.91	15.3
Starr	73.54	76.46	79.38	81.97	84.55	11.0
Webb	NA	NA	NA	NA	NA	NA
Willacy	-15.5	-15.41	-15.32	-15.25	-15.17	0.3
Zapata	NA	NA	NA	NA	NA	NA

Layer 4 – Jasper Aquifer

	Run 1	Run 2	Baseline	Run 3	Run 4	Range
Cameron	**-11.67**	-11.55	-11.43	-11.33	-11.23	0.4
Hidalgo	32.53	33.49	34.46	35.31	36.16	3.6
Jim Hogg	161.18	164.82	168.45	171.68	174.91	13.7
Starr	118.53	120.84	123.15	125.2	127.24	8.7
Webb	383.25	386.08	388.91	391.42	393.92	10.7
Willacy	-15.23	-15.15	-15.06	-14.98	-14.9	0.3
Zapata	NA	NA	NA	NA	NA	NA

Layer 5 – Yegua-Jackson Aquifer

	Run 1	Run 2	Baseline	Run 3	Run 4	Range
Cameron	NA	NA	NA	NA	NA	NA
Hidalgo	88.03	89.38	90.72	91.9	93.07	5.0
Jim Hogg	183.4	186.86	190.31	193.38	196.44	13.0
Starr	164.42	166.26	168.1	169.73	171.35	6.9
Webb	427.51	428.67	429.83	430.86	431.88	4.4
Willacy	NA	NA	NA	NA	NA	NA
Zapata	402.84	403.92	404.99	405.94	406.88	4.0

Layer 6 – Queen City/Sparta/Carrizo-Wilcox Aquifers

	Run 1	Run 2	Baseline	Run 3	Run 4	Range
Cameron	NA	NA	NA	NA	NA	NA
Hidalgo	NA	NA	NA	NA	NA	NA
Jim Hogg	NA	NA	NA	NA	NA	NA
Starr	NA	NA	NA	NA	NA	NA
Webb	393.77	394.17	394.56	394.91	395.26	1.5
Willacy	NA	NA	NA	NA	NA	NA
Zapata	NA	NA	NA	NA	NA	NA

* NA = “Not applicable” and means that the model layer is not present in the county.
Note: Run 1 has the lowest recharge rate, and Run 4 has the highest recharge rate.

CHAPTER 3: PLANNING OBJECTIVE AND WATER MANAGEMENT STRATEGIES

I. Planning Constraints

A. Competition with Supply and Demand in Mexico

Seventy-eight percent of the watershed that feeds the Falcon and Amistad Reservoirs, which in turn supply the water for the study area, is in Mexico. Historically, Mexico has not always been able to meet its obligations under the governing Treaty due to drought and its own competing uses for tributary waters. Figure 3-1 shows the estimated volumes of water delivered to the United States from Mexico between 1988 and 2012, averaged over 5-year periods. The terms of the Treaty require a resetting of the 5-year monitoring period whenever the levels in the reservoirs reach conservation stage; therefore, not all of the lines represent 5-year periods. All lines that end below the diagonal red line represent 5-year periods in which Treaty obligations were not met. Some periods are less than 1 year, particularly following heavy rains.

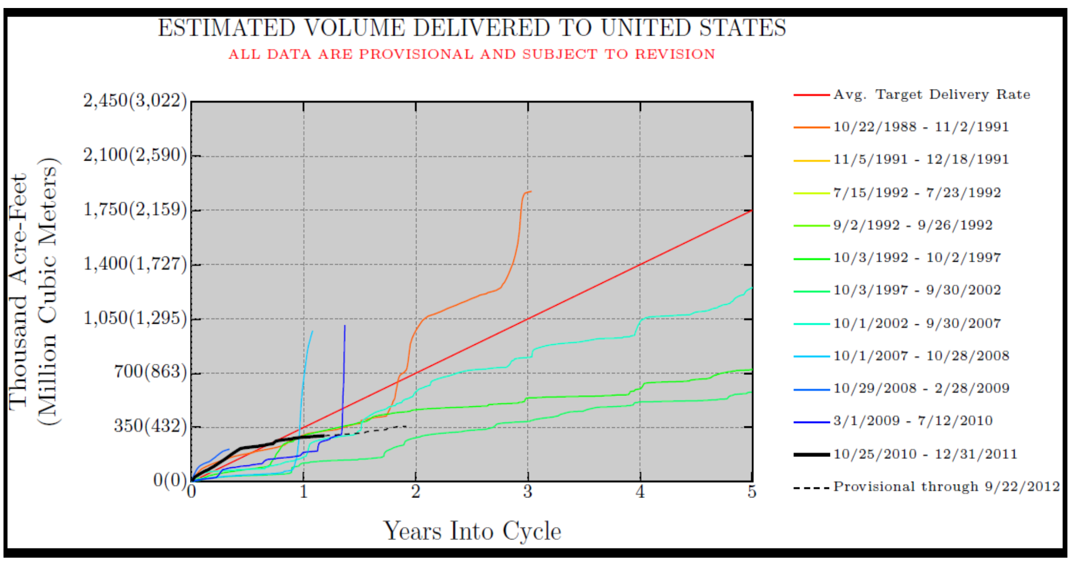

Figure 3-1: Volume of water delivered to the United States under the International Boundary Agreement.
Source: International Boundary and Water Commission.

Conclusion: The reliability of the Rio Grande to meet future needs in the study area is severely compromised by a growing gap between demand and availability and the potential for diminishing supplies due to climate change and competing use from Mexico.

B. Groundwater Supplies

Fresh groundwater supplies are severely limited by the fact that approximately 80% of the wells in the study area yield only brackish supplies according to the Region M Plan. That means that of the 176,355 ac-ft/yr of managed available groundwater (sustainable yield) designated by the study area's Groundwater Management District, about 141,084 acre-feet are brackish.[30]

Recent indicators show that water use for fracking in the study area has increased tenfold over current Region M Plan estimates (42,000 ac-ft/yr compared to 4,200 ac-ft/yr).[31] Supplies for fracking come from some river diversions, but are more dependent on groundwater, primarily fresh groundwater. Although such usage may wane by 2030 when the current oil development boom in the northern portions of the study area may cease, groundwater recharge in the study area is insignificant, and the demand for fracking water is expected to affect fresh groundwater supplies throughout the planning horizon. An assessment of the usage and long term effects of fracking demand is complicated by the fact that water use of oil and gas development is exempt from Texas groundwater regulation.[32]

Conclusion: Brackish groundwater supplies are four times (80 versus 20%) more plentiful than fresh groundwater supplies and have much fewer competing demands.

C. Temporal Aspects

The study area's warm climate provides for a year-round growing season. In addition, M&I demand (which includes landscape watering and residential/ commercial uses) varies little year round. Because the demands are constant, irrigation districts that serve agricultural, municipal, and industrial demand report

[30] 2011 Region M Plan, Chapter 4, Section 4.5.7.1 Strategy Description. The section states that about 80% of the 822 wells contain TDS that exceeds 1,000 mg/L. The volume of brackish water is not known, but it is assumed to be 80% of the available groundwater.

[31] This trend has been noted by the TCEQ Watermaster at Region M and RGRWA board meetings.

[32] Under Texas Water Code §36.117, production or injection wells drilled for oil and gas are exempted from regulation.

difficulty diverting water flows in order to perform both maintenance and system improvements. Since demand for the Rio Grande waters exceeds supply year round, there is no season when the supply balance will not need amelioration.

The planning horizon for this Basin Study is through the year 2060. While assessments of supply imbalance are based on the planning horizon, imbalances already exist and are expected to worsen between now and 2060.

Conclusion: The planning objective should require a solution that provides a year-round source of water that provides for solution(s) as soon as they can be practically available, but with a goal of being operational and feasible throughout the planning horizon.

D. Locational Aspects

The largest municipal, manufacturing, and mining users are further down river in Hidalgo and Cameron Counties and upriver in Webb County (figure 3-2). The majority of the demand in Webb County was from the city of Laredo, which is not an RGRWA member, and they have opted out of this study. There are over 100 miles and two other counties between Webb County and the nearest of the three counties specified by RGRWA. Demand from these users is expected to grow rapidly during the planning horizon, while demand from the agricultural group is expected to decline due to projected urbanization (table 3-1).

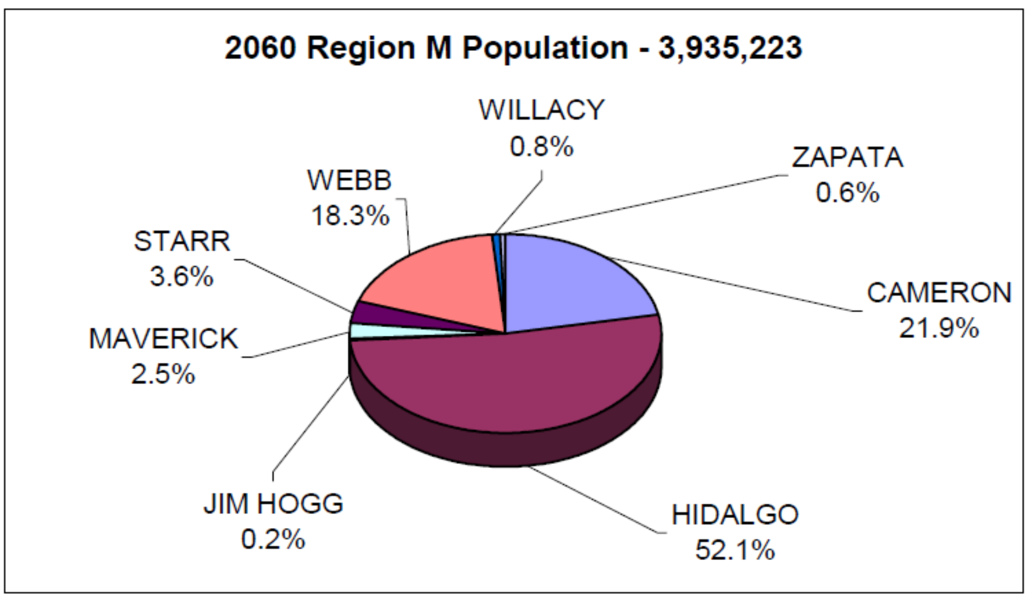

Figure 3-2: 2060 projected Region M population by county.

Table 3-1: Municipal, livestock, steam-electric, and manufacturing demand distribution among Region M counties

County	Domestic, municipal, and industrial demand (ac-ft/yr)					
	2010	2020	2030	2040	2050	2060
Cameron	97,772	116,386	135,962	155,561	175,228	194,212
Hidalgo	133,510	168,469	205,661	246,179	290,700	337,115
Jim Hogg	1,421	1,484	1,534	1,574	1,562	1,523
Maverick	9,965	11,399	12,771	13,987	15,121	16,072
Starr	14,913	17,555	20,291	23,060	25,807	28,457
Webb, not including Laredo	6,537	7,346	8,792	10,404	12,196	14,141
Willacy	3,610	3,913	4,191	4,418	4,576	4,658
Zapata	2,777	3,077	3,377	3,660	3,915	4,104
Total	**270,505**	**329,629**	**392,579**	**458,843**	**529,105**	**600,282**

Source: TWDB State Water Plan 2012.

Conclusion: The planning objective should require a solution that provides water supplies in one or more of the following counties: Cameron, Willacy and Hidalgo.

E. Quantitative Aspects

To be effective, the planning objective for this Basin Study should also define the minimum quantity of water to be supplied by the selected alternative(s). The WAM baseline and climate simulation showed the volumes that are likely to be delivered in a range of evaporation and flow scenarios, including a baseline for comparison. The volume reliabilities are expressed as percentages of each class of water right that would be delivered under that climate scenario. A comparison of the volume to be diverted under the baseline scenario, 1,466,696 acre-feet, and the volume that is predicted to be delivered under the median climate variability scenario, 1,380,258 acre-feet, indicates a difference of 86,438 acre-feet. It is proposed that this be an approximate minimum volume of water supplied by the selected strategy/strategies.

Conclusion: The projected difference between the baseline and median climate scenarios, approximately 86,438 acre-feet, will serve as a minimum of water to be supplied by the selected water management strategy (WMS).

Based on the above discussion, the following goals are recommended in formulating a planning objective:

- **Reduce dependency on the Rio Grande:** The overappropriation of Rio Grande water rights, climate variability-affected Rio Grande supply projections, anticipated decreased firm yield of its reservoirs, projected worsening supply imbalance, and increasing competing demand from Mexico result in the need for supply alternatives that reduce dependency on the Rio Grande.

- **Preserve existing water rights:** The overappropriation of current supplies and the primacy of DMI rights over agricultural rights are exacerbated by the interdependent relationship of irrigation "push water" needed to enable delivery. Furthermore, recognition of valid uses that contributes to the health and economic vitality of the study area result in a guiding principle against adoption of an alternative that would benefit one user group to the detriment of another user group.

- **Preserve downstream flows for irrigation/push water/environmental reasons:** While not a regulatory requirement, the preservation of downstream flows for environmental and other users is a worthwhile constraint in itself and especially valuable in an area prone to drought and possible reduced flows from climate change.

- **Contain actions that are within the reasonable control of study sponsors:** The strategies selected by members of this Basin Study must involve relatively low risk in terms of being within the discretion of study partners to implement. For example, although a Treaty is in place, past performance and jurisdictional barriers indicate that there is high risk in involving alternatives that call for operational changes in Mexico.

II. Planning Objective

Based on the findings, conclusions, and constraints described above, the following planning objective emerges that defines the parameters of *where, how measured, and for whom* alternative sources should be developed:

> Alleviate projected water supply imbalances in the study area by developing one or more alternatives in Cameron, Willacy, and Hidalgo Counties that will (1) provide a minimum of 86,438 acre-feet of water year round by 2060; (2) protect existing water rights; (3) be compatible with regulations, policies, and environmental law; and (4) contain actions that are within the reasonable control of study sponsors.

III. Water Management Strategies from the Region M Plan

The relationship is strong between the Region M Plan[33] and this Basin Study. The Regional Plan is the product of stakeholder vetted information compiled by subject matter experts. In addition, all previous chapters of this Basin Study have been vetted as technical memoranda through the Region M Planning Team at their public meetings. The 2010 Region M Plan, as endorsed by the State of Texas and incorporated into the State Water Plan, recommends a portfolio of WMSs to ameliorate supply imbalances in the study area (figure 3-3). Because the WMSs were formulated to address the future supply imbalances that are incorporated into this Basin Study, and have been previously subjected to rigorous analysis based on local capabilities, they represent an excellent starting point for meeting the third requirement of this Basin Study: development of appropriate adaptation and mitigation strategies to meet future water demands.

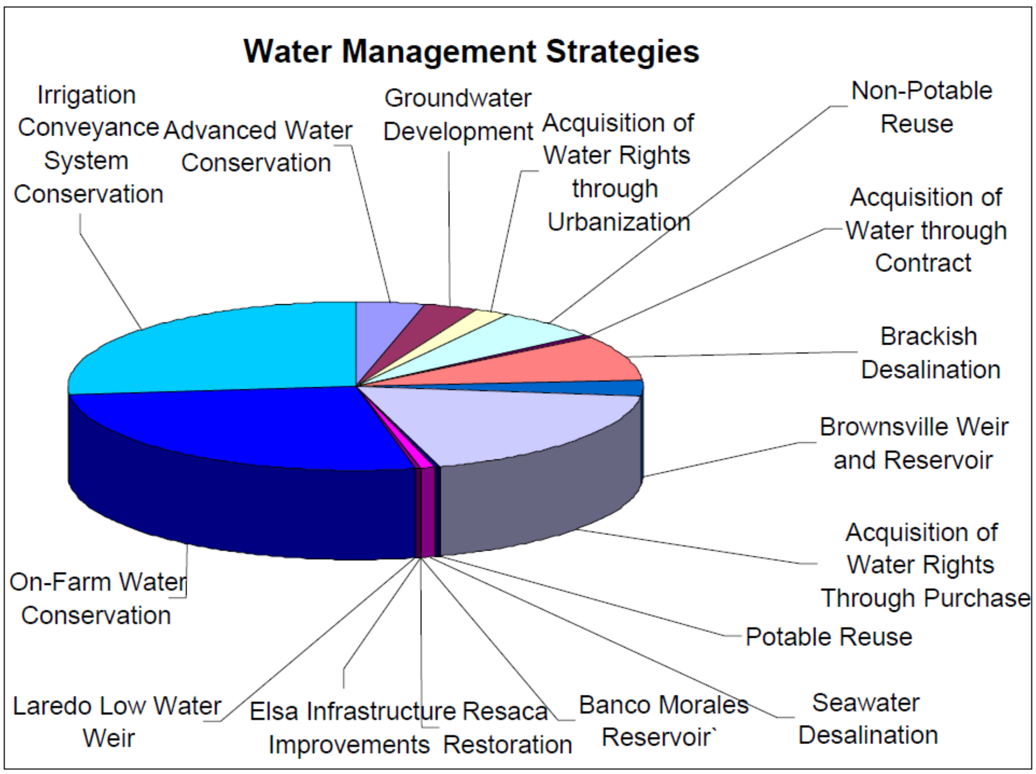

Figure 3-3: Region M Plan-recommended WMS potential supply contribution.

[33] The Texas State and Regional Planning Process is described in chapter 1, section A, subsection 1: "Local Planning Process."

These WMSs represent conservation efforts and capital projects addressing reuse, groundwater sources, and optimization of the surface water distribution system. The amount of water to be supplied by these WMSs, as estimated by the Region M Planning Group, was based on the shortfalls expected by each WUG associated with the WMS. These projected supplies are not incorporated into the WAM and had no influence on the projected future water rights reliabilities.

The study is limited by scope and budget to investigate those strategies that specifically address the potential for climate change, which has been indicated by the study. Using the planning objective described in this technical memorandum, a selection of WMSs that meet those specific constraints have been investigated further in the study. One of the key constraints is that the selected WMS must reduce dependency on the Rio Grande. The growing need to develop alternative water sources within control of the study partners was expressed by RGRWA and confirmed by the study analysis.

Nevertheless, the most robust solution to the expected shortages in the study area will also include the continued development of the range of strategies recommended by Region M, many of which would increase the efficiency of the use of Rio Grande supplies. Together, the study may enable development of water sources independent of the Rio Grande, and the development of the other WMSs in the State Plan may provide more efficient use of Rio Grande supplies.

A. Evaluation Criteria

The WMSs that best meet the planning objective of the study are evaluated in the discussion below. Each major component of the planning objective has been matched to a major criterion of the *Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies* (P&Gs) (U.S. Water Resources Council, 1983), which govern the planning of all Federal water projects. Although the WMSs are not Federal projects, the policies established by these P&Gs are appropriate for use in this Basin Study. These criteria are:

- **Effectiveness:** The extent to which an alternative reliably meets the planning objective by alleviating a specified problem and achieving goals.
- **Acceptability:** The workability and viability of an alternative with respect to how compatible it is with authorities, regulations, policies, and environmental law.
- **Completeness:** The extent to which an alternative accounts for all necessary investments or other actions to ensure realization of goals.

- **Efficiency:** The extent to which an alternative is cost effective. We will introduce this criterion after the initial screening undertaken in this planning objective rationale and then determine how well the alternatives that meet the planning objective also meet the efficiency criterion.

The demonstrated future water supply imbalance that needs to be addressed, and the planning constraints that are specific to the study area, are addressed by the evaluation criterion in the following manner:

1. Effectiveness

Effectiveness measures the extent to which an alternative reliably meets the planning objective by alleviating a specified problem and achieving goals. Specifically, effectiveness was measured in terms of improving reliability by reducing dependency on the Rio Grande River. In addition, the temporal (year round) and locational (Cameron, Willacy, and Hidalgo Counties) aspects described above were considered.

2. Acceptability

Acceptability measures the workability and viability of an alternative with respect to how compatible it is with authorities, regulations, policies, and environmental law. Specifically, acceptability was measured in terms of protecting existing water rights and in meeting the planning objective to preserve downstream flow.

3. Completeness

Completeness measures the extent to which an alternative accounts for all necessary investments or other actions to ensure realization of goals. Completeness was measured in terms of implementation potential within the reasonable control of study sponsors.

B. Water Management Strategies

1. Role of Conservation

The State Water Plan contains two conservation-based WMSs for the study area: advanced water conservation and on-farm and irrigation water system conservation.

a. Advanced Water Conservation

Advanced water conservation methods were analyzed and evaluated by Region M based on the best management strategies developed by the Texas Water

Development Board Water Conservation Implementation Task Force. As defined in the Best Management Strategies Guide,[34] strategies for municipal water users included a residential clothes washer incentive program, school education, public information, landscape irrigation conservation and incentives, and water wise landscape design and conversion programs, among others.

After conversations with various municipal water users in the region, it was determined that the most feasible advanced conservation methods were public information, school education, and the installation of higher efficiency residential clothes washers.

- **Public information/school education**

  Advanced water conservation through public information and school education is both a short-term and long-term conservation measure. In the short term, individuals may realize the benefit of water conservation themselves, resulting in increased water savings. In the long term, the affected individual may encourage additional water conservation among peers and family alike. This strategy is especially effective when combined with other conservation measures.

- **Residential clothes washers**

  In 2001, the Unites States Department of Energy adopted a two-step phase-in of higher efficiency standards for residential clothes washers. In 2004, all clothes washers manufactured were required to be 20% more efficient than the previous standard. In 2007, all clothes washers manufactured were required to be 35% more efficient than the previous standard. Water conservation will be a direct result of increased efficiency.

  Because this WMS is dependent on the compliance of individual citizens, landowners, and commercial interests, and is not directly under the control of the Basin Study partners, this WMS would be better pursued through other opportunities as a component of a portfolio of strategies specifically targeted to alleviate the predicted supply imbalance in the study area. In fact, there are a number of Government-funded programs, such as Reclamation's WaterSMART Water and Energy Efficiency Grants, with the potential to implement conservation programs. In addition, conservation by municipal utilities are incorporated in the State-required water conservation plans of municipal water providers in Texas.[35]

[34] Texas Water Development Board Water Conservation Implementation Task Force, Report 362, "Water Conservation Best Management Practices Guide." November 2004.
[35] http://www.twdb.texas.gov/conservation/municipal/plans/index.asp

b. On-farm and Irrigation System Water Conservation

On-farm water conservation offers a large potential to reduce the volume of water used for irrigation in agriculture. Technologies and methods currently available for on-farm water conservation include conversion to plastic pipe, low energy precision application, irrigation scheduling using an evapotranspiration network, drip irrigation, metering, unit pricing of water, use of water efficient crops, and other options.

The Irrigation Technology Center (ITC) of Texas A&M University was responsible for providing data for this WMS. The data were gathered by investigating both the effects of on-farm conservation in this region and the extent to which irrigation demands could be reduced through adoption of on-farm water conservation measures. These measures included farm-level water measurement and metering, replacement of field ditches canals with poly pipe, and adoption of improved water management practices and irrigation technologies. It should be noted that the investigation conducted by Texas A&M University provides documentation that 54% of agricultural water delivered within the region is measured or metered on a farm-level. Also, 36% of the agricultural water applied in the region is through poly or gated pipe, and 30% is applied using advanced water management practices and/or improved irrigation technology.

Water saving estimates were prepared for two scenarios: on-farm water savings without improvements to irrigation conveyance and distribution facilities and on-farm savings with such improvements. The amount of water that reaches the field turnout is partially dependent upon conveyance efficiency, which also influences the type of on-farm water conservation measures that can be applied.

According to the Texas Project for AgWater Efficiency,[36] as much as 80% of all agricultural conservation in the Lower Rio Grande area occurs within irrigation district conveyances. For example, insufficient "head" at the delivery point, also related to previous "push water" discussions in this Basin Study, can make it difficult to deliver irrigation water evenly over the span of a field no matter what irrigation methods or technologies are used. Approximately 50% of the area experiences insufficient head. Similarly, certain irrigation technologies, such as drip and microirrigation, require near continuous delivery of relatively small amounts of water. Most existing irrigation conveyance and distribution systems were designed to deliver large volumes of water over relatively short time periods.

Diminishing agricultural land use in the study area by 2060 could result in much smaller potential savings than projected by the Region M Plan. The region's annual demand for irrigation water is projected to decrease from 1,163,633 ac-ft/yr in 2010 to 981,749 ac-ft/yr in 2030 and then are projected to remain flat through 2060 (see table 3-1). This lower demand estimate arises

[36] http://texasawe.org/

primarily from the anticipated spreading urbanization, which is predicted to reduce irrigable acreage, primarily in Cameron and Hidalgo Counties, and other factors including costs, economics, and competition. Conversion of irrigation rights to municipal and domestic use also carries a reduction in the allocation amount according to water right class. Consequently, total water demand for irrigation in the region is projected to fall over time from the current 82.9% of the overall water demand to 59.1% by 2060. The conversion from irrigation to municipal use is one of the key factors driving the decline described above.

As noted in the Region M Plan, many of the related on-farm and irrigation system actions require legislative acts enabling funding or changes in past congressional funding obligations for which there has been a longstanding history of insufficient action. For example, the Lower Rio Grande Valley Water Resources Conservation and Improvement Act of 2000, as amended, authorized $55 million in Federal cost-sharing funds for water conservation improvement projects to be undertaken by irrigation districts in the study area. However, congressional appropriations of funds have virtually ceased, and although about $19.8 million in matching funds have been paid, about $4.7 million is currently owed to the districts, and a number of authorized projects remain yet to be accomplished.

This conservation-based WMS would also be better pursued through other opportunities; it is a vital component of a portfolio of strategies specifically targeted to alleviate the predicted supply imbalance in the study area. As is the case of the advanced water conservation WMSs, there are a number of Government-funded programs, such as Reclamation's WaterSMART Water and Energy Efficiency Grants, with the potential to implement conservation programs.

2. Strategies Receiving Further Evaluation

The following WMSs were evaluated according to the planning constraints as represented by three criteria: effectiveness, acceptability, and completeness.

a. Reuse

EFFECTIVENESS	Reuse is an effective way to utilize existing reliable supply streams of water and alleviate the supply imbalance.
ACCEPTABILITY	Protects downstream flows and water rights. Effluent from existing water treatment plants is not returned to the Rio Grande.
COMPLETENESS	This WMS is within the reasonable control of the study partners via existing financial, managerial, and engineering mechanisms.

Reuse can be divided into direct versus indirect and potable versus non-potable. As a WMS, reuse of reclaimed water provides a water supply benefit when reclaimed water is treated and reused rather than being disposed of.

Reuse depends on effluent, and the most likely source would be municipal treatment plants. Although the waters treated in these plants likely came from the Rio Grande, the water usage of municipalities is predicted to increase dramatically, and effluent as a source is thus considered very reliable. Reuse could transform effluent that is currently discharged to the Arroyo Colorado into a supplemental supply stream that could be returned to the Rio Grande. No reuse options that require dilution with Rio Grande waters are included in this discussion, but the selected indirect reuse strategies could use the Rio Grande as a conveyance for recycled water.

The climate-affected supply reliability analysis discussed in this Basin Study is based on WAM Run 3, which represents the full authorization simulation which assumes that all water users utilize their full maximum water rights authorization with no return flows. It is used by the State of Texas to evaluate applications for perpetual water rights and amendments and regional water planning supplies. The effluent from existing treatment plants is conveyed through the Arroyo Colorado and, thus, not an inflow to the Rio Grande. This simulation does not include any quantification of municipal return flows (water treatment plant effluent), which would require further investigation.

Direct potable reuse of reclaimed water refers to the intentional reuse of highly treated wastewater effluent as a source for potable uses (“toilet to tap”). While it is technically feasible to produce potable quality water from municipal wastewater effluent, direct potable reuse is just recently beginning to gain regulatory and public acceptance. This strategy will likely become more and more feasible over time both as the costs decrease and public and regulatory acceptance increase.

Non-potable direct reuse is defined as the application of wastewater effluent directly from the waste treatment plant to the point of use for non-potable purposes such as irrigation without co-mingling with State waters. This strategy requires a detailed assessment of the type and location of demands for non-potable water.[37] Users are categorized based on the level of treatment required for that application. This strategy is most likely to be successfully implemented by the end user, be it a municipality or industry, and not the best aligned with the scope of the study.

With indirect reuse, treated recycled water is returned to the environment and mixes with other waters for an extended period of time. The blended water may be diverted to a water treatment plant before it is distributed. The mixing and

[37] Type I and Type II reclaimed water categories are outlined in TCEQ §§210.33. Type I requires a higher standard of treatment; therefore, any Type I reclaimed water may also be utilized for any of the Type II uses. Specific quality standards for both reclaimed water categories are outlined in TCEQ §§210.33. The treatment required for each use is dependent on the initial effluent water quality, but typically primary effluent can only be used for Type II applications, and secondary effluent can only be used for both Type I and Type II applications. The cost of treatment is significantly higher for Type I water.

travel time provides several benefits: (1) sufficient time to ensure that the treatment system has performed as designed with no failures, (2) opportunity for additional treatment through natural processes such as sunlight and filtration through soil, and (3) increased public confidence that the water source is safe. Indirect reuse is currently practiced around the country and elsewhere in Texas where surface water supplies are deliberately augmented with treated wastewater effluent or reclaimed water.

b. Brackish Groundwater Desalination

EFFECTIVENESS	Reduces dependency on the Rio Grande by developing a new water source that can be located throughout the desired areas.
ACCEPTABILITY	Protects downstream flows and water rights. Existing brackish desalination plants in Texas and in the study area have demonstrated that they can be built within regulations, policies, and environmental law.
COMPLETENESS	This WMS is within the reasonable control of the study partners via existing financial, managerial, and engineering mechanisms.

Desalination of brackish groundwater is most commonly accomplished through reverse osmosis (RO). A full-scale RO system to treat brackish groundwater would require pretreatment, which would include a cartridge filtration system to remove minimal suspended solids. Acid and a silica scale inhibitor would also be added to prevent scale formation. A full-scale system would be expected to have a membrane life of approximately 5 years. Chemical cleaning of the membrane would be required approximately one to four times per year.

Concentrate from the RO system must be disposed of in an environmentally acceptable manner. Most of the current or proposed systems utilize drainage canal discharge, which ultimately will discharge into the Laguna Madre or the Gulf of Mexico. Other options include disposal to a sewer system and deep well injection.

c. Seawater Desalination

EFFECTIVENESS	Reduces dependency on the Rio Grande by developing a new, reliable water source.
ACCEPTABILITY	Protects downstream flows and water rights. Existing seawater desalination plants in the United States and a pilot project in Texas have demonstrated that they can be built within regulations, policies, and environmental law.
COMPLETENESS	This WMS is within the reasonable control of the study partners via existing financial, managerial, and engineering mechanisms.

There are several types of desalination methods to treat seawater. In addition to membrane technologies, methods include thermal processes such as multistage flash distillation, multiple-effect distillation, and vapor compression. These energy-intensive processes are more common in the Middle East where fuels are more abundant.

Membrane technologies are more prevalent today using RO. This process is also energy intensive when semipermeable membranes are used. For higher TDS found in seawater, high pressures are used to separate the seawater into fresh water and a concentrated byproduct. The RO process is the most common form of desalination of seawater. A typical pressure for seawater with 35,000 mg/L TDS could be in excess of 1,000 pounds per square inch (psi). That compares to less than 200 psi for 3,000 mg/L TDS groundwater. The higher TDS plants yield less than 50% of the water supplied. The remaining 50% is the concentrated byproduct. This compares to approximately 80% with the lower brackish water facilities. Surface water intakes will require additional pretreatment of suspended solids prior to the RO treatment.

d. Fresh Groundwater Development

EFFECTIVENESS	Reduces dependency on the Rio Grande by developing a new water source that can be located throughout the desired areas.
ACCEPTABILITY	Protects downstream flows and water rights. Existing well technology is proven. Can be built within regulations, policies, and environmental law.
COMPLETENESS	This WMS is within the reasonable control of the study partners via existing financial, managerial, and engineering mechanisms.

The Gulf Coast aquifer contains fresh and brackish groundwater. The southern Gulf Coast Groundwater Availability Model indicates that groundwater is available from the aquifer in this area. Well production estimates range from 0.29 to 0.86 MGD (200 to 600 gallons per minute). The quality of the groundwater is expected to meet most standards for public water supplies and requires minimal treatment. If required, the groundwater may be mixed with treated surface water to improve water quality.

About 80% of 822 wells contain TDS measurements that exceed 1,000 mg/L. The average for all of the results is 2,204 mg/L, and the median for all of the results is 1,618 mg/L. Based on the groundwater quality assessment completed for the Gulf Coast aquifer, it is expected that about 20% of the wells in Region M would contain fresh water and about 80% would contain brackish water. The GAM does not estimate the volume of brackish groundwater in storage.

Therefore, it is assumed that the 80% of the available groundwater supplies will be brackish (>1,000 mg/L TDS) and about 20% would be fresh water (<1,000 mg/L TDS).[38]

The amount of fresh groundwater available is directly in competition with use for fracking. Although availability may be lower than expected, the fact that it does not depend on the Rio Grande, and would potentially require less treatment than brackish groundwater or seawater, makes fresh groundwater worthy of further consideration.

3. Implications for International Cooperation

The Good Neighbor Environmental Board (GNEB) was created in 1992 by the Enterprise for the Americas Initiative Act, P.L. 102-532. The purpose of the board is to "advise the President and the Congress on the need for implementation of environmental and infrastructure projects (including projects that affect agriculture, rural development, and human nutrition) within the States of the United States contiguous to Mexico in order to improve the quality of life of persons residing on the United States side of the border." In its 8th report (2005), *Water Resources Management on the U.S.-Mexico Border*, the GNEB identified numerous challenges of working in international watersheds. As the 8th report noted, "Effective management of water resources is less than straightforward virtually everywhere, but in the U.S.-Mexico border region, it might be said that the task is particularly challenging. An arid climate, the presence of poverty, rapid population growth, aging infrastructure, an international border, and laws in both countries that were put into place in earlier times under different circumstances are just a few of the potential roadblocks."

Those challenges remained in 2012, when the 15th report recommended that Interior (including Reclamation), the USDA, the U.S. section of the IBWC, and the United States Environmental Protection Agency (EPA) continue to take a cooperative binational approach to watershed level management. This specifically includes the IBWC continuing to lead discussions with Mexico on finding common areas for the sustainable management of shared water resources, including protection of the quality of life and the environment in both countries. The IBWC has been a regular attendee and participant at the regularly scheduled Basin Study presentations at meetings of the RGRWA Board of Directors, which were held monthly during the first year of the study, and every other month since. In addition, the Basin Study Manager presented the project findings on supply, demand, and predicted climate change for the study area at a meeting of the IBWC on October 10, 2012.

[38] 2011 Region M Plan, Chapter 4, Section 4.5.7.1 Strategy Description.

As stated in *Climate Vulnerability and Adaptive Strategies Along the Rio Grande/ Rio Bravo Border of Mexico and the United States,*[39] and also as found by this Basin Study, decreasing runoff and streamflow in Mexico's arid north bordering the Rio Grande threaten not only Mexican irrigation and food production but also Treaty-obligated deliveries to the Rio Grande. We believe that the portfolio of solutions offered by this Basin Study are good examples of proactive climate change adaptation strategies that also meet the international cooperation goals established by the GNEB. Developing solutions that are not dependent on the Rio Grande as a water source not only make sense for the study area in meeting the planning objective, they also alleviate future competition for waters that are largely sourced from Mexico and are vulnerable in terms of both climate change and increased demand from both sides of the river.

C. Evaluation Outcome

The goal of this study is to find a WMS that will best address the needs in the study area. The increasing demand from DMI users, which demand high reliability, can be best met by sources that are less impacted by a variable climate. The results of this study incorporating comprehensive hydrological, water rights, and climate modeling lend credence to the RGRWA's stated desires to find supply solutions that are not dependent on the Rio Grande.

Finally, it is worthy of reiteration that the most robust solution to the expected shortages in the study area will also include the continued development of the range of strategies recommended by Region M, many of which would increase the efficiency of the use of Rio Grande supplies when implemented by WUGS and government entities at all levels.

[39] Hurd, Brian. Universities Council on Water Resources, Journal of Contemporary Water Research & Education, Issue 149. December 2012.

CHAPTER 4: ALTERNATIVES FORMULATION REPORT

I. Objective

Previous chapters of this study report have discussed:

- Hydrologic projections of future water supply and demand in the face of the changing climate
- Development of a planning objective and planning criteria to guide the evaluation of options
- Evaluation of how existing water and power infrastructure will perform in the face of changing water realities
- Formulation of a range of alternative regional water management options to meet the planning objective

The planning objective was established to set the goals for the recommended strategy:

> *Alleviate projected water supply imbalances in the study area by developing one or more alternatives in Cameron, Willacy, and Hidalgo Counties that will (1) provide a minimum of 86,438 acre-feet of water year round by 2060; (2) protect existing water rights; (3) be compatible with regulations, policies, and environmental law; and (4) contain actions that are within the reasonable control of study sponsors.*

The following WMSs were recommended in the previous chapter for further evaluation:

- Seawater desalination
- Fresh groundwater development
- Brackish groundwater desalination
- Non-potable reuse

The goal of alternatives formulation is to determine which among the four recommended WMSs best meet the planning objective and should be studied in more detail, including but not limited to, site selection, preliminary engineering and cost estimates, and financial capability. This determination will be made by characterizing each of the four WMSs in more detail as it relates to established screening criteria.

II. Limitations of the Characterization Process

The characterization of the WMS was based on the information available for each of the four WMSs in the Region M Plan. Because of the scope of the study, the characterization is limited and intended only as a starting point for the evaluation of the WMS. The limitations of the characterization process are as follows:

- **WMSs evaluated:** The study is limited by scope and budget to investigate those strategies that specifically address potential water deficits related to climate change that have been identified by the study. One of the key constraints is that the selected WMS must reduce dependency on the Rio Grande. The growing need to develop alternative water sources within control of the study partners was expressed by RGRWA and confirmed by the study analysis. *Nevertheless, the most robust solution to the expected shortages in the study area will include the continued development of the range of strategies recommended by Region M, many of which would increase the efficiency of the use of Rio Grande supplies.*

- **Regional analysis:** Some of the strategies could be implemented in a wide range of locations, and the specifics of the location will affect everything from the scale of production to the permits required.

- **Potential for subjectivity:** The screening criteria used in the characterization process were relatively prescriptive; however, there was still some room for subjectivity when selecting the appropriate ratings for each evaluated option.

- **Uncertainty:** The characterization was performed based on limited and high-level analyses. Therefore, knowledge of items such as costs, permit requirements, and long-term feasibility are still highly uncertain.

III. Water Management Strategies Evaluation

In the analysis below, one WMS, brackish groundwater desalination (BGD), which best meets the goals of the study within the study budget, is recommended for further study.

One of the primary outcomes of this study is a recommendation regarding which alternative(s) may be viable for further study in a Reclamation-sponsored SECURE (Science and Engineering to Comprehensively Understand and Responsibly Enhance) Feasibility Study as authorized under P.L. 111-11 (i.e., SECURE Water Act). SECURE feasibility studies represent the final planning phase of Reclamation's WaterSMART Basin Study Program and entail more detailed investigations, design, and cost estimates.

A. Seawater Desalination

Brownsville Public Utilities Board (BPUB) and Laguna Madre Water District have already confirmed the feasibility of seawater desalination along the Texas Gulf Coast through detailed investigations and pilot testing, and design and cost estimates of proposed facilities have already been produced. Other counties within the study area, including Hidalgo County, did not include seawater desalination as a WMS in the most recent 2010 Region M Water Plan, perhaps due to their relative farther distance from the Gulf Coast, and instead have proposed less costly options such as water reuse and BGD.

B. Fresh Groundwater Development

Fresh groundwater is an important resource that should be considered in any water purveyor's portfolio of water supply options in the study area. As stated in the Task 4 Technical Memorandum, the 2010 Region M Plan found that about 20% of the 822 groundwater wells in the study area yield fresh groundwater (<1,000 mg/L TDS). Therefore, of the 176,355 ac-ft/yr of managed available groundwater (sustainable yield) designated by the study area's Groundwater Management District, about 35,271 acre-feet are expected to be freshwater.[40] This amount is reduced to 12,094 ac-ft/yr when totaling the estimated fresh groundwater available in the three counties specified in the planning objective (Cameron, Hidalgo, and Willacy) as shown in table 4-1.

Table 4-1: Fresh groundwater yield by county

County	Cameron	Hidalgo	Jim Hogg	Maverick	Starr	Webb	Willacy	Zapata
Yield (ac-ft/yr)	2,947	9,147	65	0	4,188	7,918	0	0

Due to the limited number of production wells in the study area, the exact location of the 12,094 ac-ft/yr of fresh groundwater remains unknown. According to the 2010 Region M Plan, TDS trends in groundwater do not exist at the

[40] 2011 Region M Plan, Chapter 4, Section 4.5.7.1 Strategy Description.

regional level as indicated by the highly variable TDS levels across wells in the area. This highlights the need for site-specific exploration activities to determine the best locations for fresh groundwater development.

Another factor to consider is the rising use of fresh groundwater associated with oil and gas exploration activities (i.e., hydraulic fracturing) in the study area. Although the 2010 Region M Plan estimated fresh groundwater use for oil and gas activities to total only 4,200 ac-ft/yr, current efforts to revise the Region M Plan site have greatly increased that estimate by more than double[41] (table 4-2).

Table 4-2: Adjusted DRAFT mining projections (total water demand, ac-ft/yr)

Region	County	2020	2030	2040	2050	2060	2070
M	Cameron	65	68	47	31	15	7
M	Hidalgo	2,445	3,203	3,888	4,592	5,385	6,339
M	Jim Hogg	93	97	72	53	34	22
M	Maverick	1,988	2,737	2,933	2,302	1,674	1,217
M	Starr	571	697	775	858	961	1,091
M	Webb	3,862	3,008	2,257	1,537	690	502
M	Willacy	49	51	38	28	18	12
M	Zapata	85	89	66	49	31	20
M	**TOTAL**	9,158	9,950	10,076	9,450	8,808	9,210

Efforts to quantify use for fracking are complicated by the fact that water use for oil and gas development is exempt from Texas groundwater regulation.[42]

C. Comparison of Brackish Groundwater Desalination and Non-potable Reuse

Brackish groundwater desalination and non-potable reuse appear to be more viable in terms of meeting the planning objectives and thus are described in more detail in table 4-3. Given the multiple locations identified in the Region M Plan for both of these WMSs, and in order to maximize economies of scale, they are conceptualized as *regional* in nature. In the case of brackish groundwater

[41] Draft Region M Mining Demands Technical Memorandum, February 20, 2013, Black & Veatch Corp.

[42] Under Texas Water Code §36.117, production or injection wells drilled for oil and gas are exempted from regulation.

Table 4-3: Alternatives evaluation matrix

Evaluation Criteria		Alternative Concept			
Criterion	**Description**	**Regional Brackish Groundwater Desalination**	**Score (1 to 5)***	**Regional Water Reuse**	**Score (1 to 5)***
Effectiveness	**Extent to which an alternative reliably meets the planning objective**				
Water quantity	*Extent to which alternative can provide up to 86,000 acre-feet per year of water in Cameron, Willacy or Hidalgo Counties*	Dependent on availability in selected locations. Approximately 280,000 ac-ft of available brackish groundw ater in the Three-County area.	5	Assuming that 35% of the DMI usage is recoverable return flow , 75,700 AcFt could potentially be available for treatment and reuse in the 3-county target area. Treated w ater TDS may be too high for some uses.	3
Water reliability	*Extent to which quantity reduces dependency on the Rio Grande, is drought proof, secure for the planning horizon, and not subject to reduction/loss*	Independent of the Rio Grande River; considered a "new supply" that is drought proof and not subject to reduction/loss, assuming w ater rights are secured	5	Because most raw M&I w ater supply emanates from the Rio Grande River, w astew ater effluent also indirectly depends on the Rio Grande River, and is therefore subject to potential loss and lack of reliability.	3
Constructability	*Challenges associated with construction*	Locating ideal area for w ellfield, potential challenges in delivery/distribution from that location, disposal of concentrate, but it is a proven technology in use in the area.	4	Depends on the adaptability of existing w astew ater treatment plants, extent of treatment required, and identification of suitable users and the delivery to those users. High TDS levels in w astew ater effluent emanating from raw w ater w ithdraw n from the Rio Grande is expected to require advanced w ater treatment prior to reuse.	4
Servicability	*Challenges associated with operations and serviceability*	Issues associated w ith disposal of concentrate, RO maintenance, membrane fouling, etc, as w ell as energy requirements, may present operations and serviceability challenges	3	Operations and serviceability challenges limited to the extent of treatment and appurtenant infrastructure required.	4
			4.25		***3.5***
Acceptability	**The workability and viability of an alternative with respect to how compatible it is with authorities, regulations, policies, and environmental law**				
Protects existing water rights	*Extent to which satisfaction of existing water rights assigned to WUGs are not harmed.*	No impacts expected on existing surface w ater rights; little competition for brackish groundw ater.	5	Not aw are of surface w ater rights in the Arroyo Colorado w hich w ould be affected by reduced return flow s.	5
Impacts on instream flows	*Extent to which flows of the Rio Grande or Arroyo Colorado Rivers would impacted*	No impact expected on the Rio Grande; Impacts could be beneficial to the Arroyo Colorado depending on brine disposal methodology and saline requirements of the river	5	No impact expected on the Rio Grande; Reduction in instream flow s in the Arroyo Colorado expected due to reduced return flow s	4
Impacts on water quality	*Extent to which water quality of the Rio Grande or Arroyo Colorado Rivers, as well as bay/estuaries would be impacted*	Brine could be disposed of via the Arroyo Colorado, and impacts on the river remain unknow n, w ith potential to benefit the salinity of the costal estuaries.	4	Likely to benefit the Arroyo Colorado by decreasing nutrient loading, w hich has been identified as an issue in the river.	5
Impacts on fish & wildlife	*Extent of potential impacts on fish and wildlife habitat, sensitive areas, or T&E species*	Direct impacts include construction of facilities, w ellfields, and distribution pipelines. Operational impacts associated w ith brine disposal unknow n.	4	TDS accumulation in irrigated soils anticipated, w ith potential to affect ecology. Impacts of reduced instream flow s of the Arroyo Colorado due to reduced return flow s unknow n.	4
Stakeholder acceptance	*Extent to which study stakeholders view an alternative as favorable*	TBD	5	TBD	5
			4.6		***4.6***
Completeness	**Extent to which an alternative accounts for all necessary investments or other actions to be implemented**				
Control	*Extent to which implementation potential is within the reasonable control of study sponsors*	Expected to be w ithin the reasonable control of study sponsors.	4	Expected to be w ithin the reasonable control of study sponsors.	4
Coordination	*Extent to which multi-organizational coordination would be needed for construction and operation*	Coordination w ith TCEQ expected for pilot testing and brine disposal.	3	Coordination w ith TCEQ expected for application permits; coordination w ith end users expected in terms of identifying users and applications; coordination w ith irrigation districts if using canals for conveyance,	2
Risk	*The degree of engineering uncertainty and associated risk, as well as additional investigations that are needed to reduce risk*	Moderate degree of engineering uncertainty associated w ith source quantity and location, piloting, and brine disposal. Additional investigations required.	3	Moderate degree of engineering uncertainty associated w ith source quantity and location, as w ell as w ith conveyance. Additional investigations required.on advanced w ater treatment needs w here applicable. Some regulatory uncertainty remains in terms of emerging contaminants identified on EPA's CCL3 List	3
Permitting	*Extent to which facilities would require permits or clearances which entail risk that could affect the timely or successful completion of the project*	Timing of implementation through permitting associated w ith piloting, production w ells, and bring disposal.	3	Timing of implementation through permitting associated w ith use and application of reclaimed w ater.	4
			3.25		***3.25***
		TOTAL SCORE	***12.1***	TOTAL SCORE	***11.35***

* 1 = Least favorable, 3 = moderate, and 5 = most favorable.

desalination, wells in different locations could feed into a large centralized plant, located with minimized distance from the water recipients, with consideration for either pipeline or canal conveyance, or a combination of both. Co-location with, or modification of existing raw water treatment plants, should also be considered.

In the case of non-potable reuse, existing treatment plants could be modified as necessary to meet the needs of potential customers, and utilize joint transportation facilities, as well. However, as described in table 4-3, it is contemplated that high salinity of treated effluent may result in making transport via irrigation canals an untenable solution.

In either WMS, the ability to utilize existing infrastructure and interconnections could increase cost effectiveness. The criteria in the evaluation matrix are based on the planning criteria described in chapter 3.

IV. Conclusion and Next Steps

Based on the ranking of criteria in table 4-3, BGD appears to be the strategy best suited for a more detailed investigation in this study.

The next chapter will establish criteria for the evaluation of one or more BGD facilities in the study area, including the addition of cost of service, which represents the overall efficiency criterion in the aforementioned P&Gs.

CHAPTER 5: ALTERNATIVES EVALUATION

I. Objective

A range of WMSs was evaluated, and BGD was selected for more detailed study. This chapter evaluates the future with no action and concepts for regionalized BGD based on effectiveness, acceptability, completeness, and efficiency.

II. Evaluation Criteria

The guidelines for selection of a BGD concept are based on the P&Gs:[43] effectiveness, acceptability, completeness, and efficiency. Three BGD concepts are discussed in this chapter in terms of these criteria, but only one concept was selected for a preliminary engineering design and cost estimate. This is the first time that cost considerations have entered the analysis in this study as efficiency.

A. Efficiency

Efficiency is described as an alternative's cost effectiveness, which is developed based on a preliminary engineering design and cost estimating. The TWDB's UCM was used for the selected concept for comparability with other Texas water projects.[44] Being the first time that a cost analysis has been completed, this is the first application of the efficiency criterion in this report. Capital costs for a well field, RO treatment plant, and transmission pipelines were assessed for the selected concept. Alternatives that were not selected for preliminary design and cost estimates are discussed based on literature and similar examples.

III. Regional Brackish Groundwater Desalination Concepts

Three BGD concepts were formulated to provide the minimum 86,438 acre-feet (77 MGD) of production described in the planning objective. This target

[43] U.S. Water Resources Council. *Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies*. Government Printing Office, Washington, DC. 1983.

[44] http://www.twdb.state.tx.us/waterplanning/rwp/planningdocu/

represents approximately 40% of the municipal shortages projected by the regional water planning process for 2060 (table 5-1; figure 5-1) and is based on a projected decrease in available surface water due to climate variability (chapter 2).

Table 5-1: 2011 Regional Water Plan – Region M water supply and demand projections

County	Gap between supply and demand[1]					
	2010	**2020**	**2030**	**2040**	**2050**	**2060**
Cameron, Hidalgo, and Willacy County municipal shortages						
Cameron	12,662	-3,381	-19,927	-36,805	-54,003	-71,011
Hidalgo	25,379	-499	-29,951	-61,957	-98,689	-136,989
Willacy	5,741	5,291	4,890	4,543	4,208	4,039
Total	43,782	1,411	-44,988	-94,219	-148,484	-203,961
Cameron, Hidalgo, and Willacy County irrigation shortages						
Cameron	-135,322	-117,907	-97,340	-99,398	-101,458	-103,359
Hidalgo	-193,535	-140,067	-71,203	-74,538	-77,873	-80,952
Willacy	-24,035	-25,389	-26,126	-26,443	-26,760	-27,052
Total	-352,892	-283,363	-194,669	-200,379	-206,091	-211,363
Cameron, Hidalgo, and Willacy County other shortages[2]						
Cameron	-1,106	-1,447	-2,097	-2,800	-3,520	-4,443
Hidalgo	2,934	-1,187	-3,875	-7,086	-10,904	-15,582
Willacy	-25	-25	-25	-25	-25	-25
Total	1,803	-2,659	-5,997	-9,911	-14,449	-20,050

[1] Negative decadal total is a shortage.
[2] Other includes manufacturing, mining, livestock, and steam-electric WUGs.

The Southmost Regional Water Authority (SRWA) is an association of six entities that operate a groundwater desalination plant to provide drinking water to residents of Brownsville and surrounding communities. SRWA was used as a template for the study because of their success with BGD and regional collaboration. SRWA was set up to provide a reliable source of drinking water, and the desalination plant was designed to provide approximately 40% of the member cities' demands (the remainder is met with Rio Grande water). The SRWA Desalination Plant is not designed for peak loads, but operates at full capacity at all times, and variable demands of the region are met with surface water. While the BPUB has the majority ownership and user base, the SRWA Desalination Plant is jointly funded by and serves all six member entities. In a region impacted by drought, SRWA provides a template for regional water systems to provide stability.

Three concepts for regional BGD were developed for this study with the goal of providing a portion of the region's demands: (1) one 77-MGD facility serving a large portion of the three-county area, (2) expansion of existing BGD facilities,

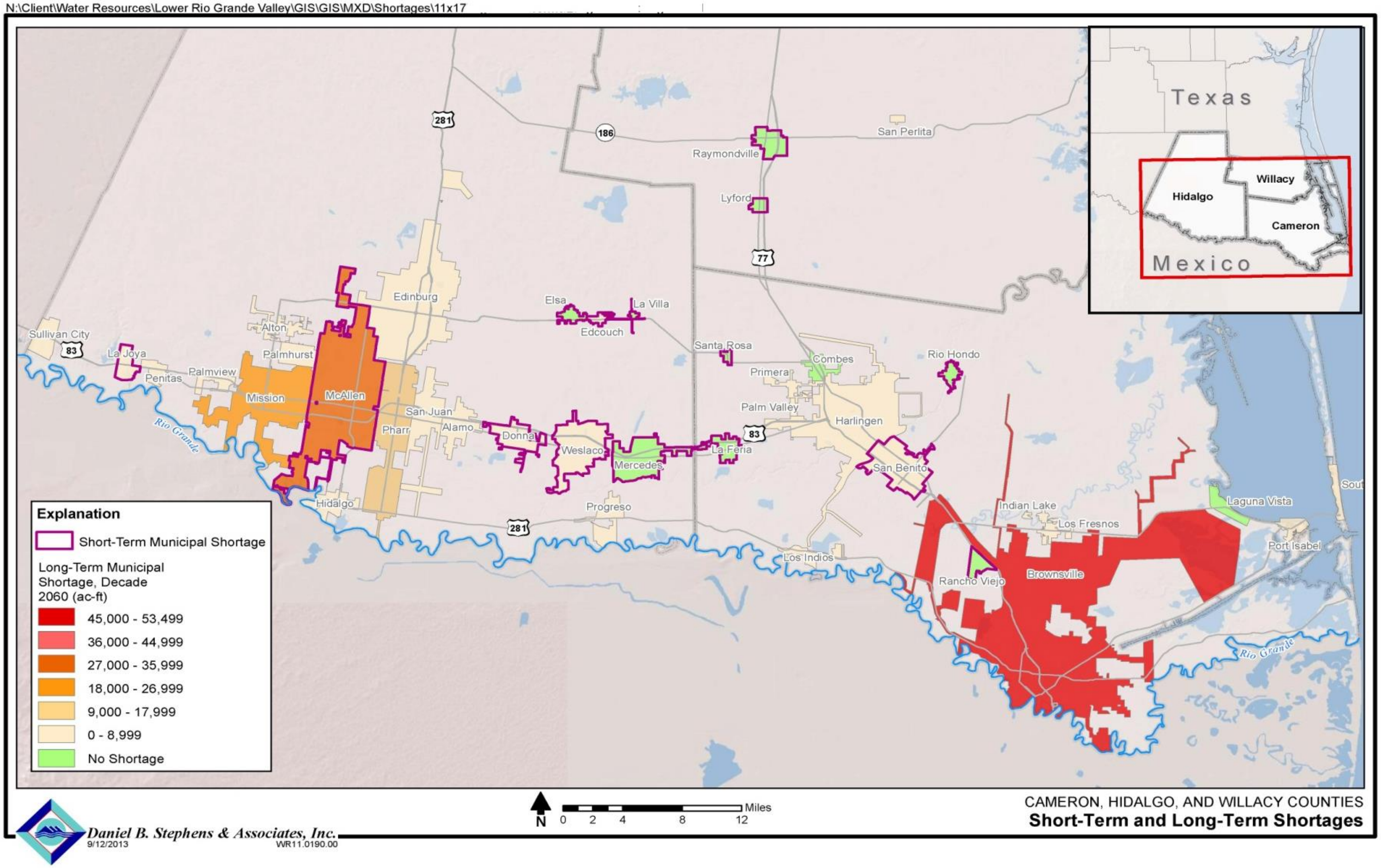

Figure 5-1: Short-term and long-term shortages.

and (3) regional BGD systems designed to meet a portion of the municipal demands of area cities by 2060. Section IV of this chapter explains the cost estimation process, and chapter 6 explores metrics of affordability given the demographics of the region and the estimated capital and O&M costs.

A. Single Regional BGD Facility

EFFECTIVENESS	Concerns of insufficient aquifer productivity to meet target production.
ACCEPTABILITY	Concerns of subsidence from geographically concentrated well fields.
COMPLETENESS	A single facility could be implemented by the study partners.
EFFICIENCY	Decreased efficiency due to conveyance costs.

It is considered unlikely that there is an area of the aquifer that would be sufficiently productive to supply a single regional BGD facility; therefore, a single regional BGD facility fails the effectiveness criterion. For this reason alone, this concept could be eliminated from further consideration. Currently, the largest groundwater desalination facility in the United States is the Kay Bailey Hutchison Desalination Plant in El Paso, Texas, which produces 27.5 million gallons of fresh water daily.

In terms of acceptability, the likelihood of subsidence would be much greater with BGD pumpage concentrated around one facility.[45] The cost (efficiency) would be increased at construction in order to build or expand trunk lines to and among all of the groups of municipalities, and the delivery costs associated with pumping would significantly increase energy use. The single facility concept was not evaluated further because of significant concerns at an initial evaluation level.

B. Expansion of Existing Groundwater Desalination Facilities

EFFECTIVENESS	Capacity of existing facilities may be too small to effectively expand to meet the target production volume.
ACCEPTABILITY	Distributed well fields and plants could meet acceptability objectives.
COMPLETENESS	The expansion necessary may not be feasibly implemented by the study partners.
EFFICIENCY	The degree of expansion could be more expensive than a similarly sized new facility.

[45] For information about subsidence, the USGS Web site provides an overview with specific references to Texas and south Texas (http://ga.water.usgs.gov/edu/earthgwlandsubside.html).

There are a number of wholesale water providers in the three-county region, four of which operate BGD plants that use RO to supply drinking water to municipalities and rural areas. Many of these facilities are not running at full capacity because Rio Grande water is available to users at a much lower cost than treated groundwater. In other cases, the limiting factor is the capacity of existing well fields. Appendix B contains detailed information for each existing desalination facility in the region. The locations of these plants are shown on figure 5-2.

In order to expand the existing facilities to provide an additional 77 MGD, significant well field, treatment capacity, conveyance, and concentrate disposal expansions would be required. The total average production of the existing facilities is approximately 17.25 MGD, so an additional 77 MGD would be more than five times the existing capacity. Expansion by more than 400% (in order to meet the planning objective) is considered an ineffective supply strategy. However, expansion of existing facilities and networks where possible is considered a viable first step to meeting immediate regional demands.

In order for expansion to be a viable option for a given facility, many factors must be considered. Many existing facilities were built with room for expansion to a particular scale, or a specified final buildout size, which can be used in an initial assessment of capacity for expansion. For example, North Alamo Water Supply Corporation (NAWSC) facilities were designed for a final buildout of twice their current capacity (not the average production listed in table 5-2), which could yield approximately 10 additional MGD. Many of the facilities are either not operating at full capacity or are unable to expand to full capacity because of the inability of users to pay for more expensive water.

Some trunk lines from the facilities may be sufficient to handle increases in flow, but interconnects and the capacities of existing systems will need to be thoroughly assessed. Bottlenecks will need to be identified within municipal systems, and the connection points between trunk lines and municipal systems will need to be identified. Because the proposed increases are so great, significant pipeline capacity upgrades would likely be required.

Any plan that includes expansion of existing facilities would require an agreement between a political subdivision and the WSC to facilitate funding. (WSCs are not eligible for tax-exempt bonding, but portions of a project that serve exclusively municipalities could be eligible.)

While expansion of existing systems is not a viable approach to meeting the total planning objective, expansion of viable facilities should be pursued as a cost-effective first step toward providing reliable water to the region.

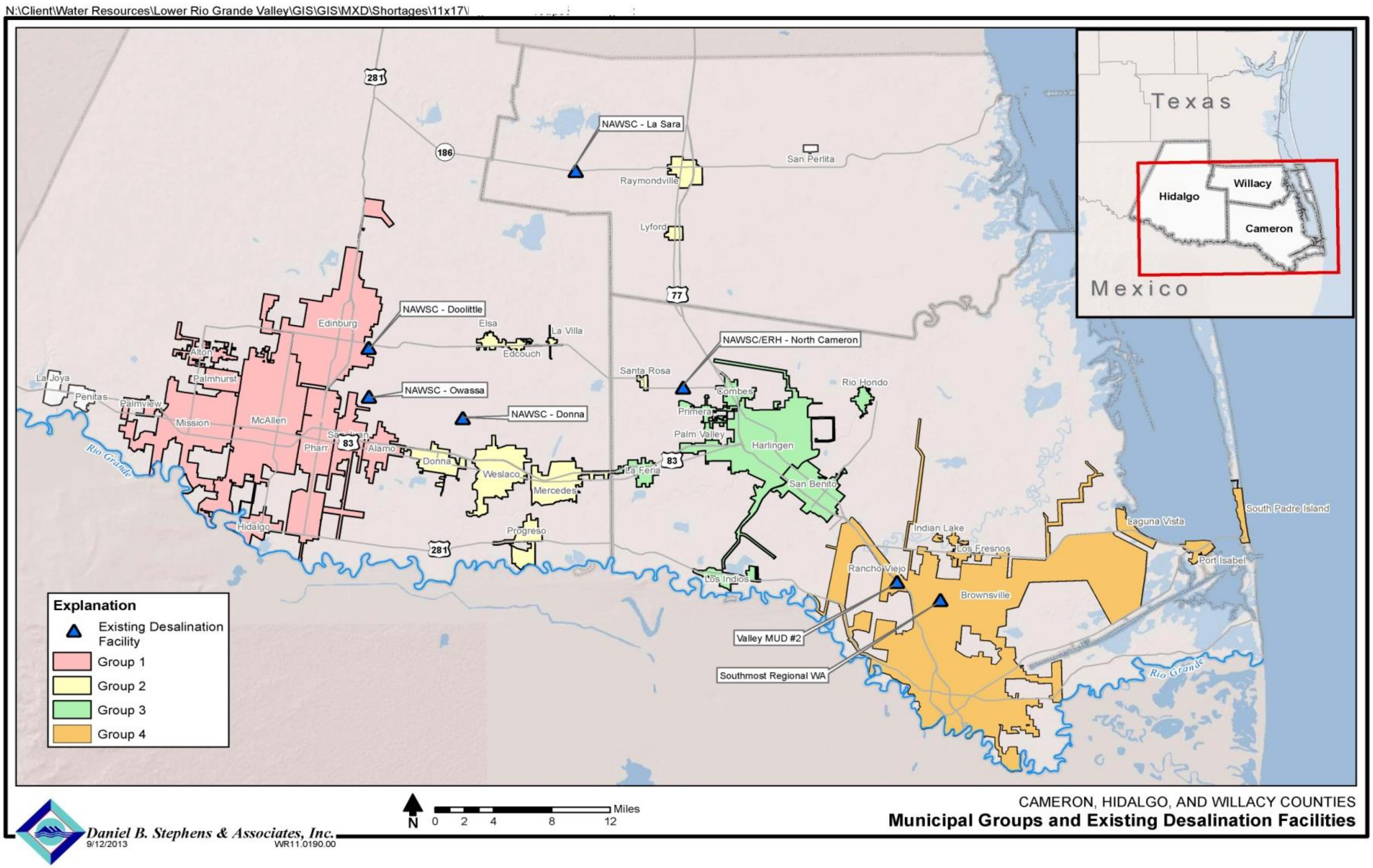

Figure 5-2: Municipal groups and existing facilities.

Table 5-2: BGD facilities in the region

Operator	Facility name	Limiting factor	Current average production (MGD)
NAWSC	La Sara	Cost of production	1.0
	Victoria Road, Donna	Cost of production	2.0
NAWSC	Doolittle	Cost of production	3.5
NAWSC	Owassa	Well field capacity	2.0
NAWSC/ERHWSC	North Cameron	Well field capacity	1.0
SRWA	SRWA	Treatment and well field capacity (expanding to 11 MGD in 2013)	7.0
Valley MUD #2	VMUD, Olmito	Unknown	0.75
		Total	**17.25**

C. Three Regional BGD Systems

EFFECTIVENESS	Distributed systems could feasibly provide the target production volume to municipal groups.
ACCEPTABILITY	Brine disposal may be challenging depending on the particular location, but regional precedent is set for surface water discharge.
COMPLETENESS	Distributed facilities could be implemented by the study partners.
EFFICIENCY	Systems may be more cost effective for some municipal groups than others, but distributed facilities appear to be most efficient in operational costs.

Site selection criteria (appendix C) were created to guide the development of the concept for desalination plants serving distinct population centers or groups. The site selection guidelines incorporate a range of factors that were considered for each location. The evaluation includes the total demands and populations served, how each alternative could fit into the existing infrastructure, and the environmental factors that may be an issue with each location.

The study area was divided into four major groups based on proximity and existing interconnecting pipelines and transfer agreements (see figure 5-2). Each of the groups was evaluated based on vulnerability to drought (towns that have been in danger of losing access to water within 6 months according to the TCEQ's 180-day drought watch list[46]) and projected average annual shortages as shown in the 2012 State Water Plan.

Group 4, the group including Brownsville, shows the greatest projected shortage in 2060, but because the SRWA Desalination Plant is operating at full capacity and currently undergoing expansion, the communities that are served by this facility (and therefore the group) are not included in this BGD concept. It is recommended that an expansion of the SRWA facilities be considered as a component in any regional water supply plan.

Total municipal demands for the three remaining groups are shown in tables 5-3 through 5-5. The distribution of demands among the groups was used to distribute proposed supplies. The proposed systems would provide a baseline of availability; similar to SWRA, the planning objective minimum of 86,438 would meet approximately 40% of municipal demands.

Table 5-3: Group 1 municipal demand (acre-feet)

Municipality	2020	2030	2040	2050	2060
Alamo	3,022	3,808	4,675	5,667	6,684
Alton	4,153	5,061	6,056	7,135	8,268
Edinburg	11,617	14,414	17,248	20,594	24,023
Hidalgo	1,515	1,945	2,418	2,961	3,517
McAllen	34,930	40,903	47,260	54,363	61,885
Mission	14,063	17,419	20,960	25,064	29,269
Palmhurst	1,789	2,497	3,263	4,099	4,957
Palmview	1,199	1,570	1,967	2,414	2,873
Pharr	11,550	13,948	16,595	19,445	22,491
San Juan	4,665	5,956	7,384	9,031	10,720
Group 1 total	**88,503**	**107,521**	**127,826**	**150,773**	**174,687**

A phased approach was adopted in which the 2040 demands were used to drive Phase 1 and 2060 demands used to drive Phase 2. Proportional demand calculations are used to develop proposed delivery volumes (table 5-6), and the 2060 proposed delivery meets and exceeds the planning objective minimum of 86,438 acre-feet. All of the quantities are cumulative; Phase 2 includes the total (Phase 1 plus Phase 2) project quantities when construction is phased (well field and treatment plant).

[46] http://www.tceq.texas.gov/drinkingwater/trot/droughtw.html

Table 5-4: Group 2 municipal demand (acre-feet)

Municipality	2020	2030	2040	2050	2060
Donna	2,755	3,073	3,431	3,843	4,293
Mercedes	2,163	2,298	2,440	2,634	2,852
Progresso	717	867	1,037	1,234	1,436
Weslaco	6,658	7,523	8,481	9,566	10,731
Edcouch	599	666	743	831	927
Elsa	1,237	1,306	1,380	1,476	1,582
La Villa	242	241	239	239	242
Lyford	351	368	382	398	412
Raymondville	1,701	1,715	1,717	1,730	1,743
Santa Rosa	376	429	478	531	588
Group 2 total	**16,799**	**18,486**	**20,328**	**22,482**	**24,806**

Table 5-5: Group 3 municipal demand (acre-feet)

Municipality	2020	2030	2040	2050	2060
Combes	229	256	281	309	341
La Feria	1,031	1,214	1,403	1,587	1,777
Harlingen	13,306	14,814	16,364	17,998	19,662
Los Indios	271	311	354	396	439
Palm Valley	407	400	393	389	387
Primera	732	856	989	1,121	1,255
Rio Hondo	459	490	520	556	593
San Benito	5,484	6,050	6,630	7,241	7,863
Group 3 total	**21,919**	**24,391**	**26,934**	**29,597**	**32,317**

Table 5-6: Proposed delivery volumes

Group	Annual supply volume (acre-feet)	
	Phase 1	Phase 2
Group 1	51,600	70,400
Group 2	8,400	10,300
Group 3	11,100	13,200
Total	**71,100**	**93,900**

The Texas Public Utility Commission allows power to be purchased at wholesale rates if the purchaser can connect directly to the generation facility. With a new facility, there is the potential to co-locate with a powerplant and purchase power at wholesale pricing. (The specifics of this rule are being determined by TWDB at the time of this writing.) Co-location with a powerplant could not only decrease energy costs, but may also improve the reliability of power, which has incurred significant maintenance costs in other RO plants in the region. The importance of reliable and inexpensive power was used to choose locations for facilities and is addressed in the site selection criteria.[47]

As with all BGD options, there are unknowns associated with groundwater quality and availability that will have to be addressed on a site-by-site basis and which may impact the plant and well field location. The site selection criteria (appendix C) do address groundwater productivity, and each site was evaluated in these terms.

The benefits of building and then operating multiple plants concurrently would include shared design components and shared staff. A scalable design could be tailored to each site, potentially saving some costs associated with initial design. A regional maintenance and operations team could operate multiple facilities and share some staff, increasing the expertise available at a given facility for a fractional cost.

IV. Facility Cost Analysis

A. Methodology

The UCM was developed by HDR Engineering, Inc., and Freese and Nichols, Inc., for the TWDB to aid in preparing regional water planning-level cost estimates. The UCM is capable of estimating costs to construct infrastructure and to implement noninfrastructure strategies such as conservation and drought management. The UCM was created with the goal of ensuring consistent cost estimates across the 16 planning regions that form the State Water Plan. Appendix D includes a detailed discussion of how the UCM was used.

The modules were developed for common types of WMSs in regional water planning. The Costing Form and Summary are created by entering basic project information, such as the length of a pipeline or whether the project has a pump station or treatment plant, into the modules. The spreadsheet provides historical costs linked to costing curves to develop the line item Costing Form and Summary. This study selected the UCM due to its Texas-centric cost

[47] The secondary environmental impacts of the power generation method chosen are not evaluated here, but should be considered.

curves, comparability to other regional projects, and acceptability to the TWDB if the study partner or other entities pursue State funding of some or all of the options discussed.

B. Approach

The RGRWA elected at its public meeting of July 10, 2013, to pursue a cost analysis of the three regional BGD systems. These three groupings of municipalities were based on geographical proximity and some existing water buyer-seller relationships.[48] Figures 5-3, 5-4, and 5-5 show the proposed facility locations and pipeline layouts for each group.

Three types of facilities for each group were included in the analysis to determine an estimated capital cost and annual debt service, operations, and maintenance costs. The three types of facilities are:

- Well fields
    - Well construction
    - Field piping
- Brackish desalination plants
    - Brine disposal
- Transmission pipelines
    - Pump stations

The following assumptions were used for each type of facility. Unless noted, the assumptions are default values in the UCM.

- Brackish desalination RO plant
    - Target TDS = 500 mg/L based on EPA secondary drinking water standards

[48] 2012 State Water Plan, Texas Water Development Board, http://www.twdb.state.tx.us/waterplanning/swp/index.asp

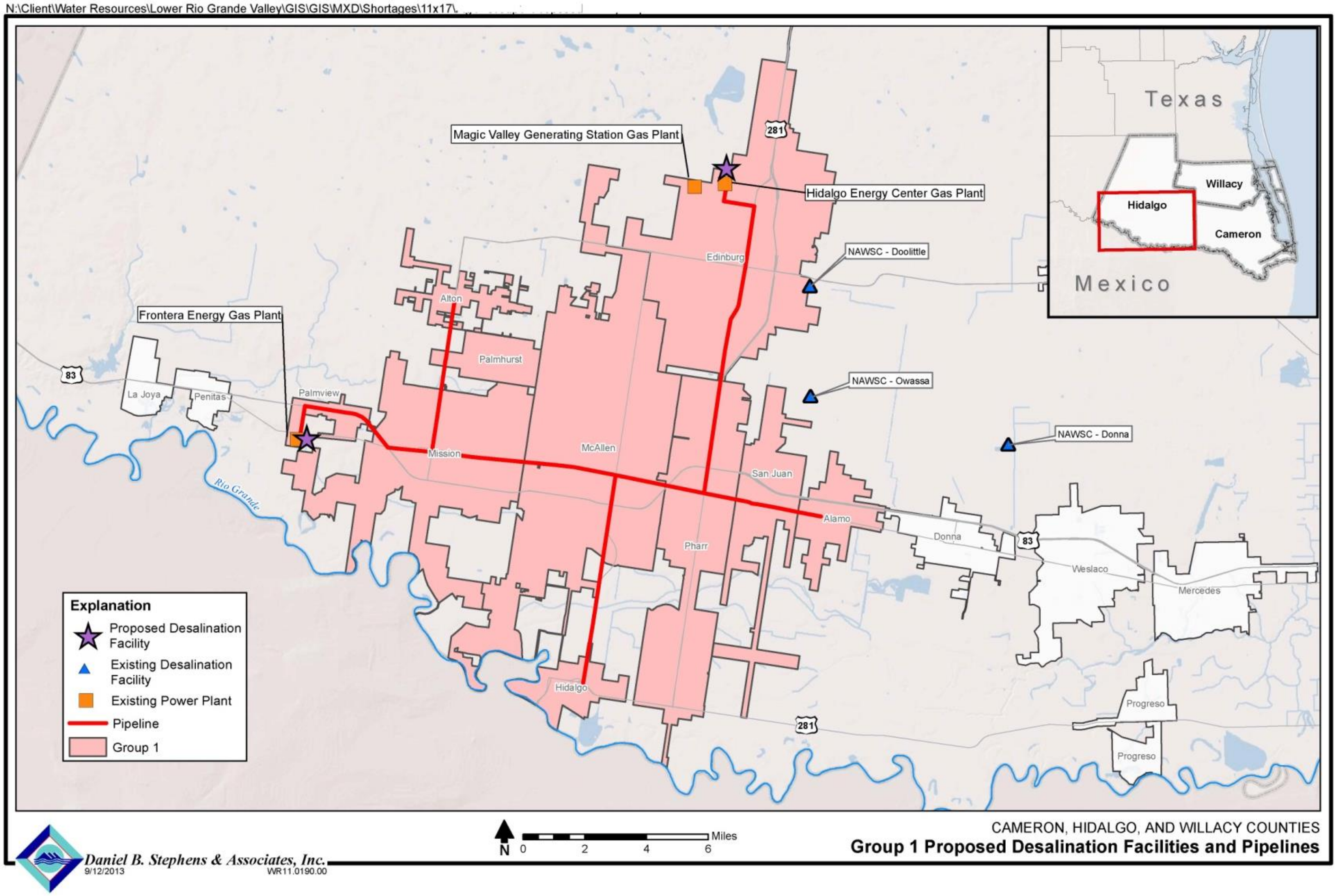

Figure 5-3: Group 1 – Proposed facilities and pipelines.

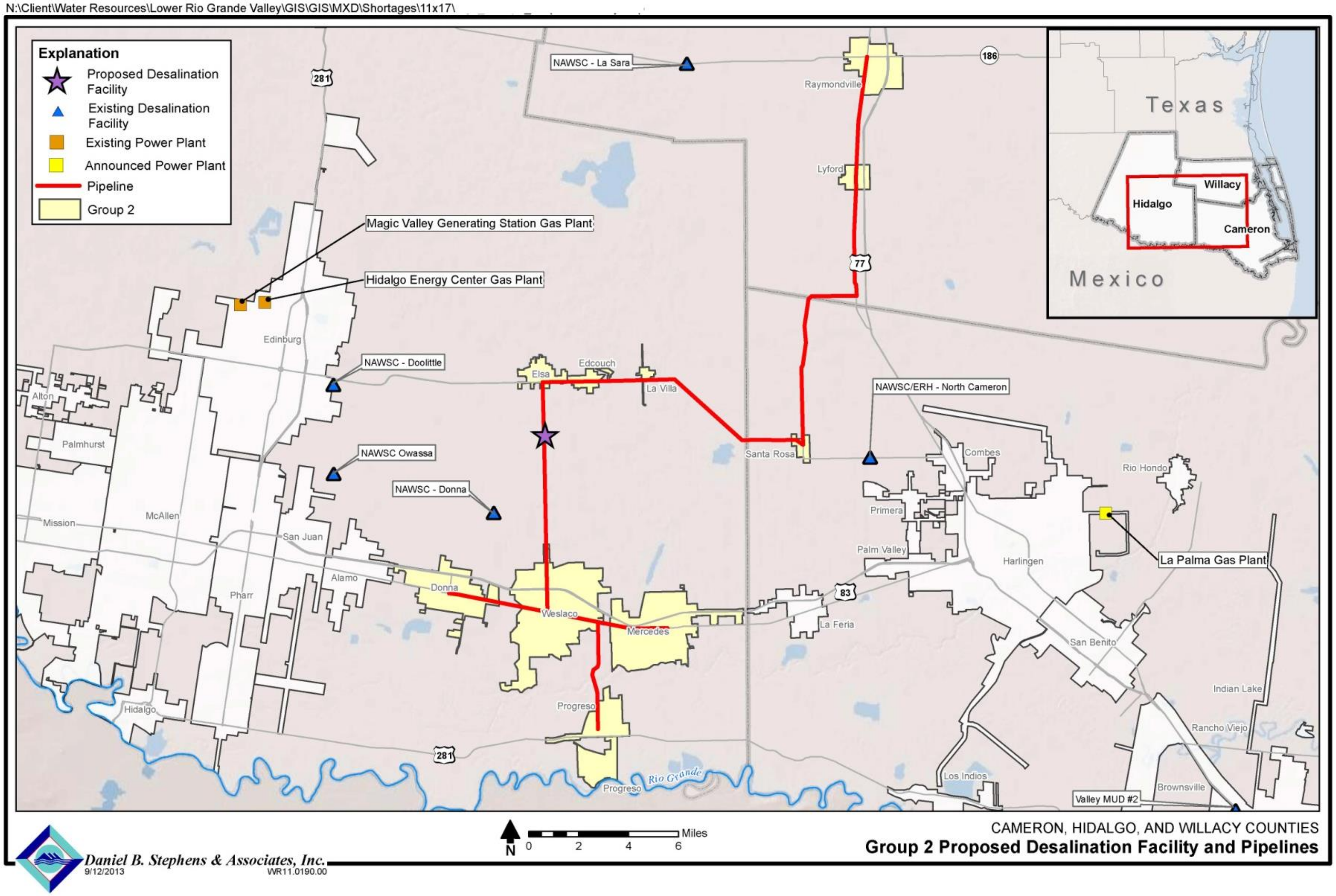

Figure 5-4: Group 2 – Proposed facilities and pipelines.

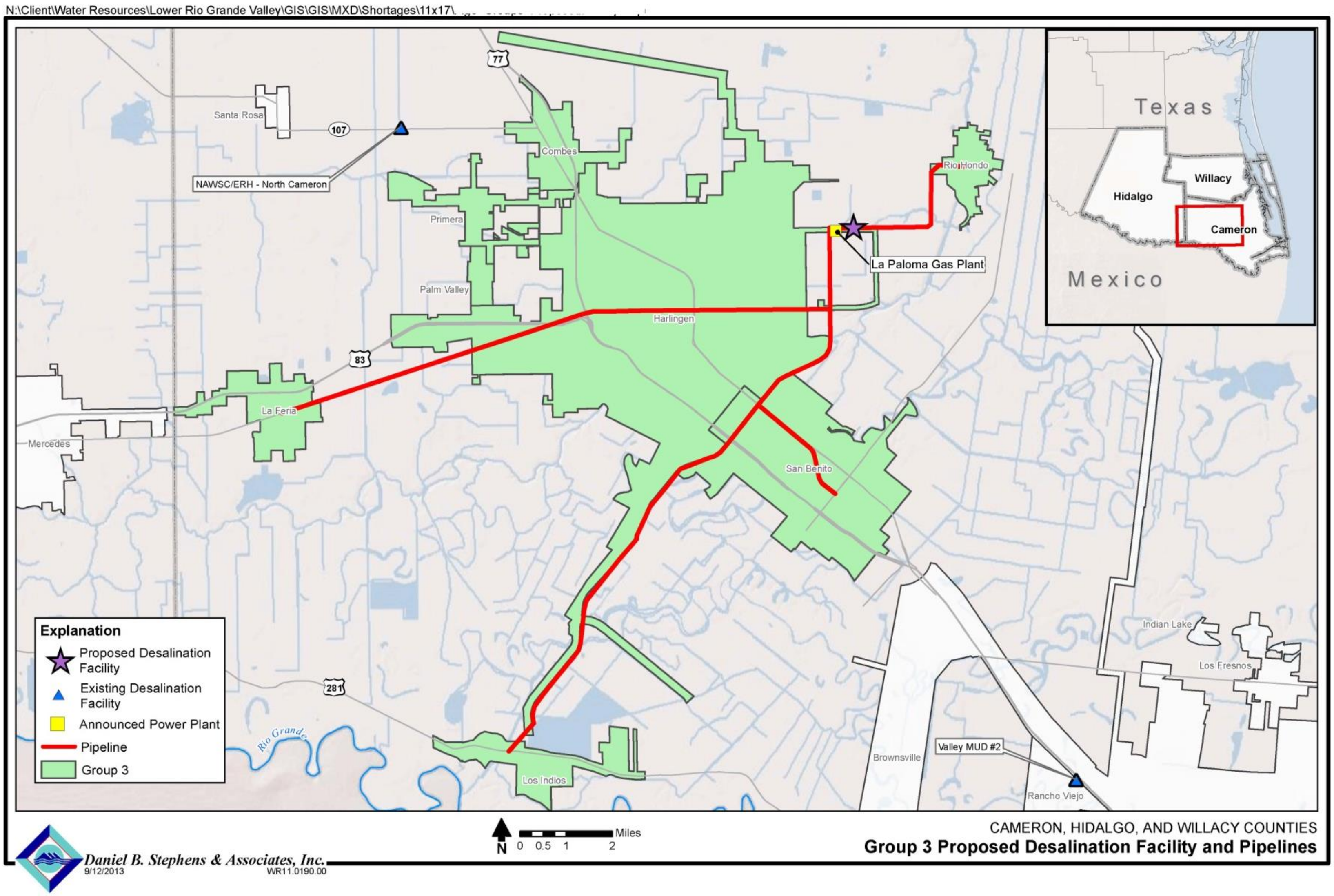

Figure 5-5: Group 3 – Proposed facilities and pipelines.

    - Initial TDS of 3,500 mg/L from the Gulf Coast aquifer[49, 50]
    - 75% RO efficiency (membrane recovery)
    - 15% of the product water will be blended raw water
        - Calculated based on feed TDS and product water target of 500 mg/L
        - Accounts for overall estimated TDS
    - O&M costs based on a cost curve in UCM
- Transmission pipelines
    - 25 psi residual head at delivery locations for treated water
    - 15 psi residual head at delivery locations for raw water
    - 150 psi maximum pipeline pressure (exceptions listed in the following sections)
    - Target velocity range between 3.5 and 7 feet per second
    - Pipeline, tank, distribution, and well O&M = 1.0% pipeline and well capital cost
    - Intake and pump stations O&M = 2.5% pump station capital cost
- Well field
    - Average static water elevation in the Gulf Coast aquifer = 100 feet below ground surface
    - Average drawdown: 20 feet[51]

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[49] Chowdhury and Mace, "Groundwater Resource Evaluation and Availability Model for the Gulf Coast aquifer in the Lower Rio Grande Valley of Texas. Report 368," TWDB. 2007.

[50] An additional investigation of groundwater in the vicinity of Group 3 by Collier Consulting, Inc. (August 2013), was presented by ERHWSC in review of the first draft of this study. That study, using electrical resistance measurements, found TDS levels significantly higher than those found in the TWDB study. As stated in the technical sufficiency memo (appendix A), there are many factors that would be required prior to pre-build site selection, including groundwater quality sampling.

[51] Ibid.

- Average production of well in the Gulf Coast aquifer = 400 gallons per minute[52]

- Average spacing between wells = 1 mile

- Average length of collector pipe = 1,000 feet

The proposed delivery volume for Group 1 was too large to reasonably be produced by one facility and well field, even in two phases, so two plants were designed to serve Group 1 (see figure 5-3). For all groups, the proposed locations were adjacent to a powerplant where possible (Groups 1 and 3). Engineering judgment was applied to site the BGD plant in a location that was economical considering the predicted availability of brackish groundwater and the location and magnitude of demands when co-location with a powerplant was not an option (Group 2). The distribution lines are designed to reach a central location in each municipality with the assumption that the municipality would handle storage and distribution to users. Storage was distributed to municipalities to facilitate response to variations in demand and emergency or fire demands.

The NAWSC RO plants use a gravity-fed network of drainage ditches that empty into the Laguna Madre to dispose of the RO concentrate. At the time of this writing, none of the RO concentrate levels exceed the surface water discharge permit requirement of a maximum of 12,720 mg/L TDS, so no blending is required. Occasionally, the Donna plant will require blending of raw water with concentrate to meet their regulatory effluent requirement. Concentrate from Owassa, Doolittle, and North Cameron does not require blending with raw water prior to surface water discharge. In accordance with the permit requirements, influent water TDS (no maximum) is monitored at all four plants. Sulfate and sulfite are also monitored (no maximum) in the RO concentrate at the Owassa plant, and selenium (no maximum) is monitored at the Doolittle plant. The discharge permits require that all of the constituents listed above be analyzed on a bi-weekly basis.

For the purposes of this study, an initial TDS level of 3,500 mg/L was assumed for the Gulf Coast aquifer based on TWDB's groundwater database reports for the Gulf Coast aquifer in Hidalgo County. The target TDS for finished water is 500 mg/L, based on the UCM, which meets the EPA's secondary drinking water guidelines. The brine salinity was approximated by UCM to be 14,000 TDS, which is above the maximum for surface water discharge permits. Because raw water TDS is regionally variable, this discrepancy is noted but not addressed directly. If the brine does not meet surface water discharge limits, raw water would be blended with the discharge stream. Because the project includes a 15%

[52] Chowdhury and Mace, 2007.

contingency for well field pumping capacity, this is assumed to be feasible within the project design. Therefore, it is postulated that the proposed plants will be able to discharge brine effluent to adjacent drainage facilities, and no costs have been added to the UCM, which defaults to this scenario. Project costs could increase significantly if future studies determine that brine discharge to adjacent drainage facilities is not feasible.

BGD plants were sited near existing powerplants where possible to take advantage of wholesale energy prices, although for the sake of a conservative estimate, power rates are based on the U.S. Energy Information Administration, which listed an average retail price for industrial users in Texas as 5.93 cents per kilowatthour, updated in May 2013.[53] If co-location with an existing powerplant was not feasible, as was the case for Group 2, then engineering judgment was applied in order to site the BGD plant in a location that was economical considering the predicted availability of brackish groundwater and the location and magnitude of demands.

C. Quantities

Tables 5-7 through 5-15 detail the size of pipelines and brackish desalination plants required to serve each group. All of the quantities are cumulative; Phase 2 includes the total (Phase 1 plus Phase 2) project quantities when construction is phased (well field and treatment plant).

D. Costs

Tables 5-16 through 5-19 detail the total costs for each group as calculated with the above assumptions and quantities in the UCM. Detailed information about the inputs used for the UCM is included in appendix D.

The costs presented in this section represent capital costs required to build and operate the proposed facilities in Phase 1 and Phase 2. Phase 1 is intended to begin construction in 2020, and the duration of construction is assumed to be 5 years (table 5-16). The Phase 1 well fields and plants are scaled to provide a portion of the demands for each group in 2040, but the Phase 1 transmission pipelines and pump stations for all groups are sized for the Phase 2 production, thus yielding significant cost savings when the plants are expanded. Phase 2 would include an expansion of the well fields and treatment facilities beginning in 2040, and increased delivery pumping, but no additional transmission piping (table 5-16). Because the transmission pipeline and the right-of-way (ROW)

[53] http://www.eia.gov/electricity/monthly/epm_table_grapher.cfm?t=epmt_5_6_a

Table 5-7: Group 1 well field

Phase 1	Per plant	Two plant total
Total wells:	60	120
Well field piping (feet)		
6-inch	60,000	120,000
8-inch	5,280	10,560
10-inch	5,280	10,560
14-inch	10,560	21,120
18-inch	10,560	21,120
20-inch	10,560	21,120
24-inch	15,840	31,680
30-inch	36,960	73,920
36-inch	42,240	84,480
42-inch	21,120	42,240
Total (feet)	**218,400**	**436,800**

Phase 2	Per plant	Two plant total
Total wells:	81	162
Well field piping (feet)		
6-inch	81,000	162,000
8-inch	5,280	10,560
10-inch	5,280	10,560
14-inch	10,560	21,120
18-inch	10,560	21,120
20-inch	10,560	21,120
24-inch	15,840	31,680
30-inch	36,960	73,920
36-inch	42,240	84,480
42-inch	52,800	105,600
48-inch	26,400	52,800
Total (feet)	**297,480**	**594,960**

Table 5-8: Group 1 distribution pipelines

Design diameter (inches)	Length (linear foot)
10	35,904
12	21,542
16	16,051
18	9,504
20	15,312
30	31,627
36	56,971
42	34,532
Total	**221,443**

Table 5-9: Group 1 brackish desalination plant

ID	Design capacity (MGD)	
	Phase 1	Phase 2
Plant 1	23.0	31.4
Plant 2	23.0	31.4

Table 5-10: Group 2 well field

Phase 1		Phase 2	
Total wells:	20	**Total wells:**	25
Well field piping (feet)		**Well field piping (feet)**	
6-inch	20,000	6-inch	25,000
10-inch	10,560	10-inch	10,560
14-inch	10,560	14-inch	10,560
18-inch	10,560	18-inch	10,560
20-inch	10,560	20-inch	10,560
24-inch	10,560	24-inch	15,840
		30-inch	5,280
Total (feet)	**72,800**	**Total (feet)**	**88,360**

Table 5-11: Group 2 distribution pipelines

Design diameter (inches)	Length (linear foot)
6	48,893
8	141,504
10	45,672
18	34,954
Total	**271,023**

Table 5-12: Group 2 brackish desalination plant

ID	Design capacity (MGD)	
	2020	**2060**
Plant 1	7.5	9.2

Table 5-13: Group 3 well field

Phase 1		**Phase 2**	
Total wells:	27	**Total wells:**	31
Well field piping (feet)		**Well field piping (feet)**	
6-inch	27,000	6-inch	31,000
10-inch	10,560	10-inch	10,560
14-inch	10,560	14-inch	10,560
18-inch	10,560	18-inch	10,560
20-inch	10,560	20-inch	10,560
24-inch	15,840	24-inch	15,840
30-inch	10,560	30-inch	10,560
Total (feet)	**95,640**	**Total (feet)**	**99,640**

Table 5-14: Group 3 distribution pipelines

Design diameter (inches)	Length (linear foot)
6	73,498
8	43,613
12	14,045
14	24,552
20	30,254
Total	**185,962**

Table 5-15: Group 3 brackish desalination plant

ID	Design capacity (MGD)	
	2020	2060
Plant 1	9.9	11.8

Table 5-16: Phasing description for each type of facility

Cost component	Phase 1	Phase 2
Construction period	2020–2025	2040–2042
Capital costs		
Transmission pump stations	Transmission pump stations and pumping required for Phase 1	Incremental increase in pump station capacity and pumping costs
Transmission pipelines	Phase 2 capacity	No additional pipelines required
Wells and well field piping	Phase 1 capacity	Incremental increase to meet Phase 2 capacity
Brackish desalination plant	Phase 1 capacity	New co-located facility to meet the increase in capacity required for Phase 2
Associated project costs		
Engineering and feasibility studies, legal assistance, financing, bond counsel, and contingencies	Percentage of total Phase 1 capital costs	Percentage of Phase 2 capital costs associated with expansions of well field and treatment plant
Environmental and archaeology studies and mitigation	Percentage of total Phase 1 capital costs	Percentage of Phase 2 capital costs associated with expansions of well field and treatment plant
Land acquisition and surveying	Land acquisition plus 10% land cost for surveying: all transmission ROW, all transmission line pump stations, Phase 1 treatment plant and well field	Incremental increase in well field and treatment plant land plus 10% of land cost for surveying
Interest during construction	4% for 5 years, 3.75% return on investment (ROI)	4% for 2 years, 3.75% ROI
Annual costs		
Debt service	Phase 1 costs, 2020–2040	Phase 2 costs, 2040–2060
Operation and maintenance		
Well, pipeline, pump station	Percentage of Phase 1 pipe and pump costs	Percentage of total pipe and pump costs (Phase 1 and Phase 2)
Water treatment plant	Cost curve, based on Phase 1 costs	Cost curve, based on Phase 1 and Phase 2 (total) costs
Transmission pumping energy costs	Phase 1 pumping energy required	Total pumping energy required (Phase 1 and Phase 2 pumps)

Table 5-17: Group 1 costs

Cost Estimate Summary: Group 1 Water Supply Project Option March 2012 Prices Bureau of Reclamation Lower Rio Grande Basin Study		
Cost based on ENR CCI 9268 for March 2012 and a PPI of 185.2 for March 2012		
Item	**Estimated costs for Phase 1**	**Estimated costs for Phase 2**
Transmission pump stations	$10,255,000	$3,262,000
Transmission pipeline (41.9 miles at buildout)	$45,919,000	$0
Well fields (wells, pumps, and piping)	$79,817,000	$22,170,000
Two water treatment plants (31.4 MGD and 31.4 MGD at buildout)	$101,589,000	$45,034,000
Total cost of facilities	**$237,580,000**	**$70,466,000**
Engineering and feasibility studies, legal assistance, financing, bond counsel, and contingencies (30% for pipes and 35% for all other facilities)	$80,857,000	$24,663,000
Environmental and archaeology studies and mitigation	$3,607,000	$910,000
Land acquisition and surveying	$2,126,000	$167,000
Interest during construction (4% for 5 years with a 3.75% return on investment	$34,444,000	$4,089,000
Total cost of project	**$358,614,000**	**$100,295,000**
Annual cost		
Debt service (5.5%, 20 years)	$30,009,000	$8,393,000
Operation and maintenance		
Wells, pipelines, pump stations	$1,514,000	$1,817,000
Water treatment plant	$19,786,000	$25,882,000
Transmission pumping energy costs ($0.0593/kilowatthour)	$4,094,000	$6,470,000
Purchase of water (ac-ft/yr at $/acre-foot)	$0	$0
Total annual cost	**$55,403,000**	**$42,562,000**
Available project yield (ac-ft/yr)	51,600	70,400
Annual cost of water ($ per acre-foot)	$1,074	$605
Annual cost of water ($ per 1,000 gallons)	$3.29	$1.86

Table 5-18: Group 2 costs

Cost Estimate Summary: Group 2 Water Supply Project Option March 2012 Prices Bureau of Reclamation Lower Rio Grande Basin Study		
Cost based on ENR CCI 9268 for March 2012 and a PPI of 185.2 for March 2012		
Item	**Estimated costs for Phase 1**	**Estimated costs for Phase 2**
Transmission pump stations	$4,996,000	$1,190,000
Transmission pipeline (51.3 miles at buildout)	$11,716,000	$0
Well fields (wells, pumps, and piping)	$9,908,000	$2,175,000
Water treatment plant (9.2 MGD at buildout)	$20,272,000	$5,680,000
Total cost of facilities	**$46,892,000**	**$9,045,000**
Engineering and feasibility studies, legal assistance, financing, bond counsel, and contingencies (30% for pipes and 35% for all other facilities)	$15,826,000	$3,166,000
Environmental and archaeology studies and mitigation	$1,747,000	$115,000
Land acquisition and surveying	$2,073,000	$18,000
Interest during construction (4% for 5 years with a 3.75% return on investment	$7,070,000	$525,000
Total cost of project	**$73,608,000**	**$12,869,000**
Annual cost		
Debt service (5.5%, 20 years)	$6,159,000	$1,077,000
Operation and maintenance		
Wells, pipelines, pump stations	$341,000	$393,000
Water treatment plant	$3,948,000	$4,779,000
Transmission pumping energy costs ($0.0593 $/kilowatthour)	$790,000	$1,054,000
Purchase of water (ac-ft/yr at $/acre-foot)	$0	$0
Total annual cost	**$11,238,000**	**$7,303,000**
Available project yield (ac-ft/yr)	8,400	10,300
Annual cost of water ($ per acre-foot)	$1,338	$709
Annual cost of water ($ per 1,000 gallons)	$4.11	$2.18

Table 5-19: Group 3 costs

Cost Estimate Summary: Group 3 **Water Supply Project Option** **March 2012 Prices** **Bureau of Reclamation Lower Rio Grande Basin Study**		
Cost based on ENR CCI 9268 for March 2012 **and a PPI of 185.2 for March 2012**		
Item	**Estimated costs for Phase 1**	**Estimated costs for Phase 2**
Transmission pump stations	$4,871,000	$2,319,000
Transmission pipeline (35.2 miles at buildout)	$9,538,000	$0
Well fields (wells, pumps, and piping)	$14,141,000	$2,175,000
Water treatment plant (11.8 MGD at buildout)	$26,333,000	$5,905,000
Total cost of facilities	**$54,883,000**	**$10,399,000**
Engineering and feasibility studies, legal assistance, financing, bond counsel, and contingencies (30% for pipes and 35% for all other facilities)	$18,732,000	$3,639,000
Environmental and archaeology studies and mitigation	$1,501,000	$116,000
Land acquisition and surveying	$1,516,000	$19,000
Interest during construction (4% for 5 years with a 3.75% return on investment	$8,143,000	$603,000
Total cost of project	**$84,775,000**	**$14,776,000**
Annual cost		
Debt service (5.5%, 20 years)	$7,094,000	$1,236,000
Operation and maintenance		
Well, pipeline, pump station	$359,000	$438,000
Water treatment plant	$5,129,000	$5,821,000
Transmission pumping energy costs ($0.0593/kilowatthour)	$741,000	$949,000
Purchase of water (ac-ft/yr at $/acre-foot)	$0	$0
Total annual cost	**$13,323,000**	**$8,444,000**
Available project yield (ac-ft/yr)	11,100	13,200
Annual cost of water ($ per acre-foot)	$1,200	$640
Annual cost of water ($ per 1,000 gallons)	$3.68	$1.96

land acquisition will be completed in Phase 1, and because the Phase 2 expansions are smaller scale, the duration of construction for Phase 2 is predicted to be considerably shorter at 2 years.

All financing for capital expenditures are assumed to have a 20-year term, so the costs for each phase are separate. A basic annuity payment is assumed on the capital cost.[54] Annual costs are shown with debt service and O&M in tables 5-16 through 5-19.

V. Other Considerations

A. Administration

Regionalization of water supplies will require cooperation among entities and possibly creation of regional entities. The existing structures administering public water supplies in the region, including irrigation districts, municipal water systems, wholesale water providers, and WSCs will need to all be involved in the development of regional systems. One potential structure for a regionalized system is to create an overarching organization that manages a network of desalination facilities and their delivery systems.

The RGRWA could function as a political subdivision in order to receive public funding and is currently investigating the process to become designated as a wholesale water provider. The potential benefits to cooperation with an existing entity that produces RO water include a technical knowledge base, experience, and institutional structures in place that could be used and built upon.

B. Combination of Alternatives

It is likely that some combination of new facilities and expansion of existing facilities will be the best path forward for the region. Expansion of existing facilities, where conditions allow, will likely be the most cost-effective option to meet short-term demands. Where new plants can potentially be sited adjacent to power generation plants, there may be significant cost savings in O&M (inconsistencies in power delivery, which have been responsible for significant maintenance expenses in the existing RO facilities, may be alleviated with a direct connection).

Alternatives not considered here that should also be evaluated include improvements to delivery systems and increases in conservation. A coordinated

[54] Annuity payment = (present value x interest rate per period)/(1-(1+rate per period)^(-number of periods)).

effort to expand interconnections between water users could significantly improve water service in the region and optimize the stabilizing impact of new desalination facilities.

C. Desalination to the Level of Raw Rio Grande Water

One idea that was considered was to desalinate groundwater only to the level of TDS found in Rio Grande water. The existing conveyance network for Rio Grande water is extensive, both for agricultural and municipal and industrial uses, and would be used as a cost-saving measure to deliver M&I water to nearby cities. By matching the quality of the surface water that is already in the canals, RO water could be blended with surface water, delivered using existing infrastructure to municipal water treatment facilities, and treated along with the surface water before delivery to municipal customers.

However, the salinity of the Rio Grande is still generally within the limits of potable water, and existing treatment is focused on turbidity and organics. Few if any constituents other than salts are expected in the brackish groundwater, so when it is treated to an acceptable TDS, it will be potable. There is no real distinction between a level of treatment that is comparable to TDS in Rio Grande water and potable TDS, so desalination to some lesser degree would not be a cost savings and would not be appropriately handled by existing municipal water treatment facilities.

D. Conveyance

Many irrigation districts in the region are in the process of upgrading conveyance infrastructure for irrigation and municipal water deliveries with the assistance of Reclamation. As the updates are put into place, facilitating interconnectedness and regionalization should be considered as one of the operation goals. Coordination with local entities and a regional, comprehensive plan for these investments will be critical to building efficient and long-lasting systems.

CHAPTER 6: AFFORDABILITY REPORT

I. Introduction

The regional desalination alternative is assessed here using Technical Memorandum Number EC-2009-02, “Evaluation of Economic and Financial Feasibility of Municipal and Industrial Water Projects,” by Steven Piper (Reclamation, 2009). The capability of the region to pay for a new M&I water supply is evaluated based on the median household income in the area and the percentage of a median family income that could be considered reasonable for water users to pay compared with the cost of proposed projects. This section attempts to capture at least some of the potential funding scenarios.

A. Affordability Thresholds

The percentage of household income that a user can pay for water is the most common way to estimate an affordability threshold. The EPA, the Department of Housing and Urban Development (HUD), and USDA Rural Development conducted studies that estimated the percentages of household income spent on water that represents the upper limits to affordability. These results are displayed in table 6-1.

Table 6-1: Affordability threshold

Source of estimate	Capability to pay (%)	Type of income
EPA	1.5–2.5	Median household income
HUD	1.3	Median household income
USDA	0.5	Median household income *if annual income is less than 80% of State median*

Four affordability threshold scenarios were used to estimate available funds based on a percentage of household income: 0.5%, 1.5%, 2.0%, and 2.5%. These costs will be compared with the cost estimates for desalination in each grouping.

B. Household Income Calculations

Census data from the Texas State Data Center were used to estimate the income in the region served. The median household income was used because the data are the most localized income data available. Statewide data would be inappropriate, because the Lower Rio Grande Valley is socioeconomically distinct from many other areas in Texas.

Table 6-2: Median household income

County	Median income[1]	Percentage of State median household income
State of Texas average	**$50,043**	**—**
Cameron	$32,156	64%
Hidalgo	$32,479	65%
Willacy	$22,894	46%

[1] U.S. Census Bureau, 2007–2011 American Community Survey. All income in 2011 dollars.
http://factfinder2.census.gov/faces/tableservices/jsf/pages/productview.xhtml?pid=ACS_11_5YR_DP03

All three counties in the study area have median incomes notably lower than the State median household income; therefore, a range of capabilities to pay (0.5 to 2.5% of median household income) were considered in the affordability analysis rather than assuming a single value.

II. Affordability Analysis

In order to assess affordability, the median household income was multiplied by the number of households to obtain the total yearly household income for each municipality. For the purposes of this analysis, each household is assumed to rely on existing facilities for 60% of the water supply, with the remaining 40% supplied by new facilities. Therefore, the ability of each grouping to pay for new sources was calculated to be 40% of the overall ability to pay for water, which ranges from 0.5 to 2.5% of the median annual household income as discussed above. The results are shown in tables 6-3 through 6-5.

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Table 6-3: Group 1 – Ability to pay

Municipality	Population, decade 2010	Median household income	Number of households	40% of yearly available funds for water			
				0.5% of median income	1.5% of median income	2.0% of median income	2.5% of median income
Alamo	20,915	$32,479	5,810	$377,406	$1,132,218	$1,509,624	$1,887,030
Alton	12,342	$32,479	3,428	$222,676	$668,028	$890,704	$1,113,380
Edinburg	71,940	$32,479	19,983	$1,298,056	$3,894,167	$5,192,223	$6,490,279
Hidalgo	84,742	$32,479	23,539	$1,529,046	$4,587,139	$6,116,185	$7,645,232
McAllen	132,267	$32,479	36,741	$2,386,622	$7,159,866	$9,546,488	$11,933,109
Mission	68,351	$32,479	18,986	$1,233,293	$3,699,878	$4,933,170	$6,166,463
Palmhurst	9,144	$32,479	2,540	$164,993	$494,980	$659,973	$824,967
Palmview	6,258	$32,479	1,738	$112,897	$338,691	$451,588	$564,485
Pharr	65,969	$32,479	18,325	$1,190,355	$3,571,066	$4,761,421	$5,951,777
San Juan	39,074	$32,479	10,854	$705,054	$2,115,162	$2,820,217	$3,525,271
				$9,220,398	**$27,661,195**	**$36,881,593**	**$46,101,992**

Table 6-4: Group 2 – Ability to pay

Municipality	Population, decade 2010	Median household income	Number of households	40% of yearly available funds for water			
				0.5% of median income	1.5% of median income	2.0% of median income	2.5% of median income
Donna	17,830	$32,479	4,953	$321,737	$965,211	$1,286,948	$1,608,685
Edcouch	4,076	$32,479	1,132	$73,532	$220,597	$294,130	$367,662
Elsa	6,267	$32,479	1,741	$113,092	$339,276	$452,368	$565,459
La Villa	1,361	$32,479	378	$24,554	$73,662	$98,216	$122,771
Lyford	2,335	$22,894	687	$31,456	$94,369	$125,825	$157,282
Mercedes	15,775	$32,479	4,382	$284,646	$853,938	$1,138,584	$1,423,230
Progresso	6,348	$32,479	1,763	$114,521	$343,563	$458,084	$572,605
Santa Rosa	3,472	$32,156	1,021	$65,663	$196,988	$262,650	$328,313
Raymondville	10,071	$22,894	2,798	$128,115	$384,344	$512,459	$640,574
Weslaco	32,862	$32,479	9,128	$592,937	$1,778,810	$2,371,746	$2,964,683
				$1,750,253	**$5,250,758**	**$7,001,011**	**$8,751,263**

Table 6-5: Group 3 – Ability to pay

Municipality	Population, decade 2010	Median household income	Number of households	40% of yearly available funds for water			
				0.5% of median income	1.5% of median income	2.0% of median income	2.5% of median income
Combes	3,089	$32,156	909	$58,460	$175,379	$233,838	$292,298
Harlingen	69,214	$32,156	20,357	$1,309,199	$3,927,598	$5,236,798	$6,545,997
La Feria	7,954	$32,156	2,339	$150,426	$451,277	$601,703	$752,129
Los Indios	1,418	$32,156	417	$26,818	$80,454	$107,272	$134,091
Palm Valley	1,400	$32,156	412	$26,497	$79,490	$105,986	$132,483
Primera	3,973	$32,156	1,169	$75,181	$225,542	$300,723	$375,904
Rio Hondo	2,223	$32,156	654	$42,060	$126,180	$168,240	$210,300
San Benito	26,922	$32,156	7,918	$509,222	$1,527,667	$2,036,890	$2,546,112
				$2,197,863	**$6,593,588**	**$8,791,450**	**$10,989,313**

The ability to pay (assuming 40% of 0.5–2.5% of annual median household income) is compared with the annual costs for implementation of Phase 1 and Phase 2 for each grouping on an annual basis. As shown in table 6-6, 40% of 2.5% of the median annual income for each grouping is nearly equal to the annual Phase 2 cost and covers a major portion of the Phase 1 annual cost. Therefore, with supplemental funding from State or Federal sources, it is likely the new improvements could be sustained in part by a percentage of household income. Since all three counties in the study area have median incomes notably lower than the State median household income, a lower percentage of household income may be a more realistic estimate, and the need for supplemental funding is greater. A range of State and Federal funding mechanisms are summarized in the next section.

Table 6-6: Groups 1–3: Comparison of annual costs to ability to pay

Planning group	Annual cost		Ability to pay (40% of yearly available funds for water			
	Phase 1	Phase 2	0.5% of median income	1.5% of median income	2.0% of median income	2.5% of median income
Group 1	$55,403,000	$42,562,000	$9,220,398	$27,661,195	$36,881,593	$46,101,992
Group 2	$11,238,000	$7,303,000	$1,750,253	$5,250,758	$7,001,011	$8,751,263
Group 3	$13,323,000	$8,444,000	$2,197,863	$6,593,588	$8,791,450	$10,989,313

III. Funding

A range of State and Federal funding mechanisms are summarized that may be available to the region.

A. Drinking Water State Revolving Fund

The TWDB utilizes the Drinking Water State Revolving Fund to provide loans at below-market interest rates or with principal forgiveness to qualifying entities for planning, acquisition, design, and construction of water supply infrastructure projects. Eligible applicants include publicly and privately owned community public water systems, including cities, districts, and other political subdivisions; nonprofit WSCs; and nonprofit, noncommunity public water systems. Additional subsidies are available for disadvantaged communities, very small systems, and green projects.

B. Rural Water Assistance Fund

The TWDB administers the Rural Water Assistance Fund, created in 2001 by the 77th Texas Legislature. The program is authorized under Texas Water Code Chapter 15, Subchapter R, and governed by TWDB rules in 31 Texas Administrative Code Chapter 384. The fund is designed to assist small rural utilities in obtaining low-cost financing for water and wastewater projects. The TWDB offers tax-exempt, attractive interest rate loans with long-term finance options. Eligible borrowers are defined as "rural political subdivisions." They include nonprofit WSCs, districts, and municipalities serving a population of 10,000 or less, and counties in which no urban area has a population exceeding 50,000. Rural political subdivisions may also partner with a Federal agency, a State agency, or another rural political subdivision to apply for funding.

C. State Participation Program

The State Participation Program enables the TWDB to provide funding and assume a temporary ownership interest in a regional water, wastewater, or flood control project when the local sponsors are unable to assume debt for an optimally sized facility. The program is authorized under Texas Water Code Chapter 16, Subchapters E and F, and governed by TWDB rules in Texas Administrative Code Title 31 §363, Subchapter J. The TWDB may acquire an ownership interest in the water rights as well as the facilities. The TWDB requires that the project sponsor repurchase the TWDB's interest in the project under a payment schedule that allows for the deferral of principal and interest payments.

The program is intended to encourage the optimum regional development of projects by funding excess capacity for future use where the benefits can be documented and where such development is unaffordable without State participation. The goal is to allow for the "right sizing" of projects in consideration of future needs. For new water supply and State Water Plan projects, the TWDB can fund as much as 80% of project costs provided that the local sponsor finances at least 20% of the total project cost from sources other than the State Participation Account and that at least 20% of the total capacity of the proposed project serves existing needs. On other State Participation projects, the TWDB can fund as much as 50% of costs provided that the local sponsor finances at least 50% of the total project cost from sources other than the State Participation Account and that at least 50% of the total capacity of the proposed project serves existing needs. In both cases, State participation funding is limited to the portion of the project designated as excess capacity. Although it is not required, the local sponsor usually acquires a loan from the TWDB for the local sponsor's portion of the project funding.

D. Water Infrastructure Fund

The Water Infrastructure Fund provides financial assistance for the planning, design, and construction of State Water Plan and Regional Water Plan projects. The 2012 State Water Plan estimated that $53 billion will need to be spent by regional and local water supply entities between 2010 and 2060 to meet the additional water supply needs of the State. Of that amount, Regional Water Planning Groups have estimated that more than $26 billion in financing will need to come from the State.

To apply for financial assistance, the applicant must be a political subdivision of the State. Political subdivisions include municipalities, counties, river authorities, special law districts, water improvement districts, water control and improvement districts, irrigation districts, WSCs, and groundwater districts. Eligible applicants also include nonprofit WSCs. Projects must be recommended WMSs in the most recent TWDB-approved Regional Water Plan and approved State Water Plan, as has the BGD facilities analyzed by this study. Funds may not be used to maintain a system or to develop a retail distribution system.

E. Economically Distressed Areas Program

The 71st Texas Legislature (1989) passed comprehensive legislation that established the Economically Distressed Areas Program to be administered by the TWDB. The program is authorized under Texas Water Code §16, Subchapter J, and §17, Subchapter K, and is governed by the TWDB rules in Texas Administrative Code Title 31 §363. The program provides financial assistance in the form of a grant or a combination grant/loan to provide water and wastewater services to economically distressed areas where services do not exist or systems do not meet minimum State standards. The program also includes measures to prevent future substandard development. The 81st Texas Legislature (2009) passed further legislation that allows funds from the Economically Distressed Areas Program to be used to pay for first-time water and wastewater connections for homes in areas served by the program. The homes must meet additional Federal low-income criteria.

F. Regional Water Supply and Wastewater Facilities Planning Program

The TWDB offers grants to political subdivisions of the State of Texas for studies and analyses to evaluate and determine the most feasible alternatives to meet regional water supply and wastewater facility needs, estimate the costs associated with implementing feasible regional water supply and wastewater facility alternatives, and identify institutional arrangements to provide regional water supply and wastewater services for areas in Texas.

The proposed planning must be regional in nature by inclusion of more than one service area or more than one political subdivision. All proposed solutions must be consistent with applicable regional or Statewide plans and relevant laws and regulations.

Development of a water conservation plan is strongly encouraged to be included as a specific task in the scope of work for proposed planning areas without a board-approved water conservation plan. Texas Water Development Board population and demand projections must be used to determine future needs in the planning process unless adequate justification is provided (and accepted) for using projections other than of the TWDB.

Financing of the program is through the TWDB's Research and Planning Fund. The RGRWA is currently pursuing a grant through this program and is hopeful that the results of this study will be instrumental in securing additional funding for the development of regional BGD facilities.

IV. Conclusion

The initial estimates of cost indicate that there is potential for BGD in the lower three counties of the Rio Grande Valley. With the projected growth and the predicted climate variability, it will be necessary to develop new sources of water in this region. Future evaluation of the affordability of BGD should consider the debt obligations held by the member cities, the range of rates that are paid for potable water in the area, and the opportunities to partner with existing operators and providers. The existing, complex network of providers and rate structures could potentially be simplified and drinking water provided on a larger scale than has traditionally been done in the region. There is precedent in other parts of Texas for regionalization, and the associated benefits of shared expertise and efficiency of scale are realized in other systems.

Appendices

A Technical Sufficiency Memo
B Existing Desalination Plant Data
C Site Selection Criteria Table
D Unified Cost Model Methodology and Assumptions

Appendix A

Technical Sufficiency Memo

United States Department of the Interior

BUREAU OF RECLAMATION
P.O. Box 25007
Denver, CO 80225-0007

IN REPLY REFER TO:

PR-J-8.10
86-68190

SEP 12 2013

MEMORANDUM

To: Environmental Protection Specialist, Oklahoma-Texas Area Office
Attn: TX-Gerber (JGerber)

From: Andrew Tiffenbach, Mechanical Engineer
Water Treatment Group

Subject: Technical Service Center review of the *Lower Rio Grande Valley Basin Study Alternatives Evaluation and Affordability Report* prepared by Daniel B. Stephens and Associates, Inc.

The Technical Service Center (TSC) has reviewed the *Lower Rio Grande Valley Basin Study Alternatives Evaluation and Affordability Report* dated September 11, 2013 (including appendixes and supporting documentation) and has determined the work to be technically sufficient.

A summary of our findings are as follows:

The proposed project infrastructure and preliminary cost estimates described in the report were developed using the Unified Costing Model (UCM), which is an Excel-based tool developed by the Texas Water Development Board to aid in preparing regional water planning-level cost estimates in Texas. Due to the complexities of the proposed project, the report authors expanded UCM Excel workbooks in order to properly account for all proposed infrastructure items over the phased build-out period. These UCM expansions were reviewed and found to be consistent with the calculations and assumptions used elsewhere in the model. The inputs used in the UCM were found to be consistent with the methodology and assumptions described in the report.

Given the preliminary nature of this study, the assumptions made in the report seem reasonable, although as noted throughout the report, there are many aspects of the proposed project that will require additional investigation including, but not limited to:

- Aquifer capacity and water quality
- Facility locations and number of facilities
- Concentrate disposal
- Pipeline alignment, and
- Project phasing

These aspects could have significant impacts on the proposed project infrastructure and cost. Further evaluation is recommended as a part of the next phase of the project.

cc: TX-Trevino (MTrevino), TX-Balcombe (CBalcombe), 86-68190 (KDahm), 86-68270 (SPiper)

Appendix B

Existing Desalination Plant Data

Desalination Facility Data Sources

1. NRS Consulting Engineers, Inc
   - Data as provided by facility owner: November 2008
   - Last updated: February 2009

2. TWDB Desalination Plant Database
   - Information for the database was gathered primarily through interviews with plant operators and survey forms
   - Last updated by TWDB staff in 2010
   - Contact Innovative Water Technologies at 512-463-7932 for questions

List of Acronyms

NRS - NRS Consulting Engineers, Inc.
TWDB - Texas Water Development Board
MGD - Millions of Gallons per Day
TDS - Total Dissolved Solutes
GW - Groundwater
MUD – Municipal Utility District
WSC – Water Supply Corporation

NAWSC - Donna

Address: 6031 North Victoria Road, Donna, TX 78537
County: Hidalgo
Client: North Alamo Water Supply Corporation (NAWSC)
Year Built: 2012
Water Use: Drinking

Production and Capacity:

Desal Production Avg (mgd)		Desal Production Capacity (mgd)		Plant Production Avg (mgd)		Plant Production Capacity (mgd)		Estimated Build-out Capacity (mgd)
NRS	TWDB	NRS	TWDB	NRS	TWDB	NRS	TWDB	NAWSC
No Data	2	2	2	No Data	2.25	2.5	2.25	4.5-5

Concentrate Production and Blending Volume:

Concentrate Production Avg (mgd)		Blending Volume (mgd)	
NRS	TWDB	NRS	TWDB
No Data	0.66	0.5	No Data

Costs:

NRS					
Capital Costs			Operational Costs		
Construction Costs	Implementation Costs	Total Project Cost	Annual Dept Service (per 1k gals)	Annual O&M Cost (per 1k gals)	Annual Total Water Cost (per 1K gals)
60,005,000	?	?	n/a	n/a	n/a

<u>TWDB Data:</u>
Process Type: RO
Water Source / Raw Water TDS (mg/l): GW / 4000
Blending: Yes
Pre-treatment: Cartridge Filter
Post-treatment of Concentrate / Permeate: Blending / Blending; Gas Removal; Adjustment of pH; Corrosion Control; Disinfection
Membrane Manufacture: Hydranautics
Membrane in Service (years): 1
Membrane Recovery: 0.75
Feed pressure (psi): 150
Target TDS of Final Permeate (ml/l): 150
Concentrate Disposal: NoData

Valley MUD #2

Address: PO Box 939, Olmito, TX 78575
County: Cameron
Client: Valley MUD
Year Built: 2000
Water Use: Drinking

Production and Capacity:

Desal Production Avg (mgd)		Desal Production Capacity (mgd)		Plant Production Avg (mgd)		Plant Production Capacity (mgd)		Estimated Build-out Capacity (mgd)
NRS	TWDB	NRS	TWDB	NRS	TWDB	NRS	TWDB	Valley MUD #2
No Data	0.26	0.25	0.5	No Data	0.75	0.25	1	?

Concentrate Production and Blending Volume:

Concentrate Production Avg (mgd)		Blending Volume (mgd)	
NRS	TWDB	NRS	TWDB
No Data	0.06	0	No Data

Costs:

NRS					
Capital Costs			Operational Costs		
Construction Costs	Implementation Costs	Total Project Cost	Annual Dept Service (per 1k gals)	Annual O&M Cost (per 1k gals)	Annual Total Water Cost (per 1K gals)
750,000	165,000	915,000	0.80	0.60	1.40

<u>TWDB Data:</u>
Process Type: RO
Water Source / Raw Water TDS (mg/l): GW / 3500
Blending: Yes
Pre-treatment: Cartridge Filter; Scaling Control
Post-treatment of Concentrate / Permeate: No Post-treatment / Blending; Gas Removal; Adjustment of pH; Disinfection
Membrane Manufacture: Hydranautics
Membrane in Service (years): 5
Membrane Recovery: 0.75
Feed pressure (psi): 210
Target TDS of Final Permeate (ml/l): 400
Concentrate Disposal: Surface Water Body; Land Application

NAWSC - Doolittle

Address: 420 South Doolittle Road, Edinburg, TX 78539
County: Hidalgo
Client: North Alamo Water Supply Corporation
Year Built: 2008
Water Use: Drinking

Production and Capacity:

Desal Production Avg (mgd)		Desal Production Capacity (mgd)		Plant Production Avg (mgd)		Plant Production Capacity (mgd)		Estimated Build-out Capacity (mgd)
NRS	TWDB	NRS	TWDB	NRS	TWDB	NRS	TWDB	NAWSC
No Data	3	3	3	No Data	3.5	3.5	3.5	7

Concentrate Production and Blending Volume:

Concentrate Production Avg (mgd)		Blending Volume (mgd)	
NRS	TWDB	NRS	TWDB
No Data	0.25	0.5	No Data

Costs:

NRS					
Capital Costs			Operational Costs		
Construction Costs	Implementation Costs	Total Project Cost	Annual Dept Service (per 1k gals)	Annual O&M Cost (per 1k gals)	Annual Total Water Cost (per 1K gals)
8,825,000	1,150,000	9,975,000	0.63	0.50	1.13

<u>TWDB Data:</u>
Process Type: RO
Water Source / Raw Water TDS (mg/l): GW / 2500
Blending: Yes
Pre-treatment: Cartridge Filter; Scaling Control
Post-treatment of Concentrate / Permeate: Blending / Blending; Gas Removal; Adjustment of pH; Disinfection
Membrane Manufacture: Toray
Membrane in Service (years): 2
Membrane Recovery: No Data
Feed pressure (psi): 130
Target TDS of Final Permeate (ml/l): 500
Concentrate Disposal: No Data

NAWSC - La Sara

Address: 6606 Hwy 186, Raymondville, TX 78580
County: Willacy
Client: North Alamo Water Supply Corporation
Year Built: 2005
Water Use: Drinking

Production and Capacity:

Desal Production Avg (mgd)		Desal Production Capacity (mgd)		Plant Production Avg (mgd)		Plant Production Capacity (mgd)		Estimated Build-out Capacity (mgd)
NRS	TWDB	NRS	TWDB	NRS	TWDB	NRS	TWDB	NAWSC
No Data	1	1	1	No Data	1.2	1.25	1.2	2.4-2.5

Concentrate Production and Blending Volume:

Concentrate Production Avg (mgd)		Blending Volume (mgd)	
NRS	TWDB	NRS	TWDB
No Data	No Data	0.25	No Data

Costs:

NRS					
Capital Costs			Operational Costs		
Construction Costs	Implementation Costs	Total Project Cost	Annual Dept Service (per 1k gals)	Annual O&M Cost (per 1k gals)	Annual Total Water Cost (per 1K gals)
2,000,000	243,000	2,243,000	0.39	0.75	1.14

TWDB Data:
Process Type: RO
Water Source / Raw Water TDS (mg/l): GW / NoData
Blending: No
Pre-treatment: Cartridge Filter; Scaling Control
Post-treatment of Concentrate / Permeate: Blending / Blending; Gas Removal; Adjustment of pH; Disinfection
Membrane Manufacture: Hydranautics
Membrane in Service (years): 5
Membrane Recovery: NoData
Feed pressure (psi): 130-170
Target TDS of Final Permeate (ml/l): 500
Concentrate Disposal: NoData

NAWSC - North Cameron / Hidalgo Water Authority

Address: 14995 State Hwy 107, Harlingen, TX 78552
County: Cameron
Client: North Alamo Water Supply Corporation
Year Built: 2006
Water Use: Drinking

Production and Capacity:

Desal Production Avg (mgd)		Desal Production Capacity (mgd)		Plant Production Avg (mgd)		Plant Production Capacity (mgd)		Estimated Build-out Capacity (mgd)
NRS	TWDB	NRS	TWDB	NRS	TWDB	NRS	TWDB	NAWSC
No Data	1	2	2	No Data	1.15	2.25	2.5	4.5-5

Concentrate Production and Blending Volume:

Concentrate Production Avg (mgd)		Blending Volume (mgd)	
NRS	TWDB	NRS	TWDB
No Data	0.287	0.25	No Data

Costs:

NRS					
Capital Costs			Operational Costs		
Construction Costs	Implementation Costs	Total Project Cost	Annual Dept Service (per 1k gals)	Annual O&M Cost (per 1k gals)	Annual Total Water Cost (per 1K gals)
6,200,000	845,000	7,045,000	0.69	0.50	1.19

<u>TWDB Data:</u>
Process Type: RO
Water Source / Raw Water TDS (mg/l): GW / 3500
Blending: Yes
Pre-treatment: Cartridge Filter; Scaling Control
Post-treatment of Concentrate / Permeate: Blending / Blending; Gas Removal; Adjustment of pH; Disinfection
Membrane Manufacture: Hydranautics
Membrane in Service (years): 3
Membrane Recovery: 0.75
Feed pressure (psi): 170
Target TDS of Final Permeate (ml/l): 200
Concentrate Disposal: Surface Water Body

NAWSC - Owassa

Address: 1108 E. Owassa Rd, San Juan, TX 78589
County: Hidalgo
Client: North Alamo Water Supply Corporation
Year Built: 2008
Water Use: Drinking

Production and Capacity:

Desal Production Avg (mgd)		Desal Production Capacity (mgd)		Plant Production Avg (mgd)		Plant Production Capacity (mgd)		Estimated Build-out Capacity (mgd)
NRS	TWDB	NRS	TWDB	NRS	TWDB	NRS	TWDB	NAWSC
No Data	1.5	3	1.5	No Data	2	3.5	2	4-7

Concentrate Production and Blending Volume:

Concentrate Production Avg (mgd)		Blending Volume (mgd)	
NRS	TWDB	NRS	TWDB
No Data	No Data	0.5	No Data

Costs:

NRS					
Capital Costs			Operational Costs		
Construction Costs	Implementation Costs	Total Project Cost	Annual Dept Service (per 1k gals)	Annual O&M Cost (per 1k gals)	Annual Total Water Cost (per 1K gals)
6,600,000	900,000	7,500,000	0.47	0.50	0.97

<u>TWDB Data:</u>
Process Type: RO
Water Source / Raw Water TDS (mg/l): GW / 2000
Blending: Yes
Pre-treatment: Cartridge Filter
Post-treatment of Concentrate / Permeate: Blending / Blending; Gas Removal; Adjustment of pH
Membrane Manufacture: Toray
Membrane in Service (years): 1.5
Membrane Recovery: No Data
Feed pressure (psi): 130
Target TDS of Final Permeate (ml/l): 500
Concentrate Disposal: No Data

Southmost Regional Water Authority

Address: PO Box 3270, Brownsville, TX 78523
County: Cameron
Client: Southmost Regional Water Authority
Year Built: 2004
Water Use: Drinking

Production and Capacity:

Desal Production Avg (mgd)		Desal Production Capacity (mgd)		Plant Production Avg (mgd)		Plant Production Capacity (mgd)		Estimated Build-out Capacity (mgd)
NRS	TWDB	NRS	TWDB	NRS	TWDB	NRS	TWDB	SRWA
No Data	5.3	6	6	No Data	5.3	7.5	7.5	27.5

Concentrate Production and Blending Volume:

Concentrate Production Avg (mgd)		Blending Volume (mgd)	
NRS	TWDB	NRS	TWDB
No Data	2.2	1.5	No Data

Costs:

NRS					
Capital Costs			Operational Costs		
Construction Costs	Implementation Costs	Total Project Cost	Annual Dept Service (per 1k gals)	Annual O&M Cost (per 1k gals)	Annual Total Water Cost (per 1K gals)
23,000,000	4,200,000	27,200,000	0.80	1.28	2.08

<u>TWDB Data:</u>
Process Type: RO
Water Source / Raw Water TDS (mg/l): GW / 3500
Blending: Yes
Pre-treatment: Cartridge Filter; pH Adjustment; Scaling Control
Post-treatment of Concentrate / Permeate: Blending / Blending; Gas Removal; Adjustment of pH; Corrosion Control; Disinfection
Membrane Manufacture: Hydranautics
Membrane in Service (years): 5
Membrane Recovery: 0.75
Feed pressure (psi): 160-180
Target TDS of Final Permeate (ml/l): 500
Concentrate Disposal: Surface Water Body

Appendix C

Site Selection Criteria Table

Appendix C- Brackish Desalination Siting Criteria Data Summary

DATUM	PURPOSE	DATA SOURCE
1) Regional Supply and Demand Analysis, including:		
a) Regional population	Future demand	DB12, Internal GIS analysis
b) Long term municipal shortages averaged over region	Future Demand	DB12, Internal GIS analysis
c) Short term vulnerability to drought	Immediate and future demand	NOAA, TCEQ, Watermaster
d) Interconnectivity between existing distribution networks	Joint Regional Use	Facility operators, Irrigation District Managers
e) Regional supplies		
i) Existing Facilities (1) Existing Groundwater Desalination Facilities		
(a) Wellfield (i) Location (ii) Facility capacity, land on site, any planned expansions? (iii) MAG limitation?	Current production and additional capacity	DB12, TCEQ Water Supply System Database, Directly from facility operators
(b) Treatment Plant (i) Location (ii) Power source and limitations (iii) Capacity, available land on site, any planned expansions? (iv) If planned, on what basis (adopted Cap Improvement Budget, etc.)	Current production and additional capacity	DB12, TCEQ Water Supply System Database, Directly from facility operators
(c) Storage (i) Location (ii) Capacity, any planned expansions? (iii) If planned, on what basis (adopted Cap Improvement Budget, etc.)	Current production and additional capacity	DB12, TCEQ Water Supply System Database, Directly from facility operators

(d) Distribution (i) Location (ii) Capacity, any planned expansions? (iii) If planned, on what basis (adopted Cap Improvement Budget, etc.) (iv) Available ROW	Current production and additional capacity	DB12, TCEQ Water Supply System Database, Directly from facility operators
(e) Power Infrastructure (i) Proximity to existing generators (ii) Existing Capacity (iii) Cost ($/kwh) (iv) Potential for renewable/dedicated power source	Current production and additional capacity	
(f) Contractual agreements and service areas	Joint Regional use	DB12, TCEQ Water Supply System Database, Directly from facility operators
(g) Brine disposal method (i) Location receiving brine (ii) Conveyance method and distance (iii) Current capacity/ expansion potential (iv) (see also Regulatory)	Capacity, joint regional use/ future use	TCEQ Water Supply System Database, Directly from facility operators
(2) Existing (other) water treatment facilities (a) Source (i) Volume (ii) Quality (b) Treatment type (c) Service area (d) capacity	Could provide infrastructure for desalinated water	TCEQ Water Supply System Database, Directly from facility operators
(1) Existing (other) wastewater treatment facilities (a) Source (i) Volume (ii) Quality (b) Treatment type (c) Service area (d) capacity	Treatment or disposal of brine	TCEQ Water Supply System Database, Directly from facility operators

2) Legal, regulatory, and institutional factors a) Analysis of water providers and potential for regional distribution oversight/management	Joint Regional Use	CCN data, RGRWA Input, discussions with local organizations/officials/facility managers
b) Environmental impacts		
i) site specific impacts on natural environment of new plant or expansion, and new pipelines or storage reservoirs	Potential NEPA issues	
3) Aquifer analysis (Supplemented by the TWDB BRACS study)		
a) Available volumes	Availability for treatment	TWDB Productive Aquifer areas map, GAM model data -> GIS saturated thickness map
b) Quality	Required extent/cost of treatment	TWDB TDS map/data (what is already published), BRACS Study not likely to be complete within timeline.
c) Accessibility i) Depth ii) Distance to users	Difficulty/Cost implications	Internal GIS analysis, BRACS study not available within timeline, but may be useful for later analysis.

Appendix D

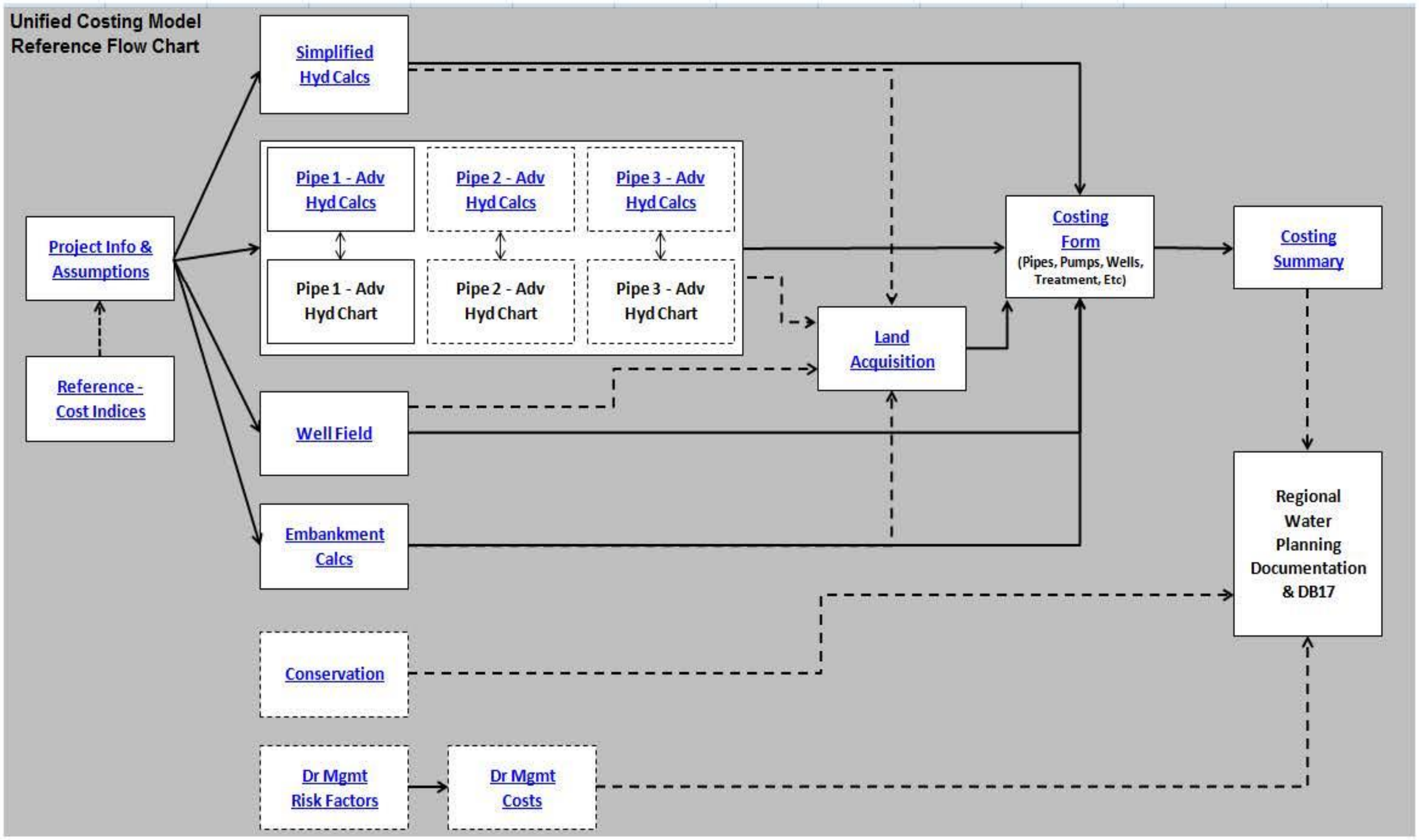
Unified Cost Model Methodology and Assumptions

Appendix D: Unified Cost Model Methodology and Assumptions

The Unified Costing Model (UCM) was developed by HDR Engineering, Inc. and Freese and Nichols, Inc. for the Texas Water Development Board (TWBD) to aid in preparing regional water planning-level cost estimates. The UCM is capable of determining costs to construct infrastructure as well as implement non-infrastructure strategies such as conservation and drought management. The UCM was created with the goal of ensuring consistent cost estimates across the 16 planning regions that form the State Water Plan. The UCM is composed of 11 costing modules that produce a line-item Costing Form. Figure 1 depicts the Quick Reference Guide which provides a good overview of the UCM's modules workflow. The modules include:

- Quick Reference Guide
- Project Information and Assumptions
- Simplified Hydraulics
- Advanced Hydraulics
- Well Field
- Embankment Calculations
- Land Acquisition
- Costing Form
- Cost Summary
- Conservation
- Drought Management Risk Factor

Figure 1: UCM Quick Reference Guide



The modules were developed for common types of water management strategies and associated facilities in regional water planning. The Costing Form and Summary are created by entering basic project information into the modules, such as the length of a pipeline or whether the project has a pump station or treatment plant. The spreadsheet provides historical costs linked to costing curves to develop the line-item Costing Form and Summary. This Study selected the UCM for compatibility with the TWDB's project selection and grant process.

There are 6 UCM workbooks for the project in total. The Phase 1 workbooks include only the proposed Phase 1 costs (See Table 16 in Chapter 5). The Both Phases workbooks include all proposed project costs, and show the costs per phase in the Unlocked Costing Summary. Both Phases workbooks include two wellfield tables: a "Total Wellfield" tab with the buildout scenario, and a "P2 Wellfield" tab which calculates the incremental expansion of the wellfield.

Project Assumptions

- Rate of Return on Investments = 3.75%
- Construction Period = 5 years (Phase 1) and 2 years (Phase 2). This is based on the phasing plan, which includes all transmission pipeline and land acquisition in Phase 1, only wellfield, pump station, and treatment capacity expansion in Phase 2. (A detailed explanation of phasing is in Chapter 5, Table 16.)
- Power Costs = $0.0593/kW-hr, based on US EIA Energy Cost guidance for industrial power users in Texas.

Simplified Hydraulics

The UCM was developed to handle fairly simple distribution pipe networks, but did not handle the degree of pipe branching that was required for regional facilities. The Simplified Hydraulics tab was created for this project in order to account for the pipe and pump requirements for all portions of the pipe network. The Simplified Hydraulics Calculation that was included with the UCM does a per-pipe calculation, and the workbook was revised so that multiple lengths of pipe could be evaluated simultaneously.

The pipe segments are described only by length, diameter, and beginning and endpoint elevations, and do not take any intermediate rises into account. Pipe diameters were sized in order to meet flow velocity and pressure targets.

Because the treatment plants are not designed to handle peak loads, and the distribution to individual users is the domain of the municipalities, the pipelines are designed with the UCM default peaking factor of 1.05 (to account for maintenance downtime). All design volumes are based on 40% of the municipal demand for the city (2040 for Phase 1, 2060 for Phase 2), rounded for simplicity.

Assumptions:

- Target Flow Velocity in Pipes 3.5 fps < v < 7 fps
- Maximum Pipeline Pressure = 150 psi, except for sections noted below where 300 psi pipe was used in some sections (see Group 2)
- Peaking Factor = 1.05
- 25 pounds per square inch (psi) residual head at delivery locations for treated water
- Pipeline & Well O&M = 1.0% pipeline and well capital cost
- Pump Station O&M = 2.5% pump station capital cost
- All "soil" and "rural" conditions were assumed for pipeline costs

The capital costs, required horsepower, and annual energy demands for each pump station associated with particular segments of pipeline were calculated in the UCM.

Group 1

The demand was split evenly between Plants 1 and 2, with both plants supplying McAllen. The pipelines are designed so that both plants could potentially deliver water to the entire area, as a means of including some redundancy into the system, however both plants deliver to McAllen (the largest user).

Design Delivery Volumes

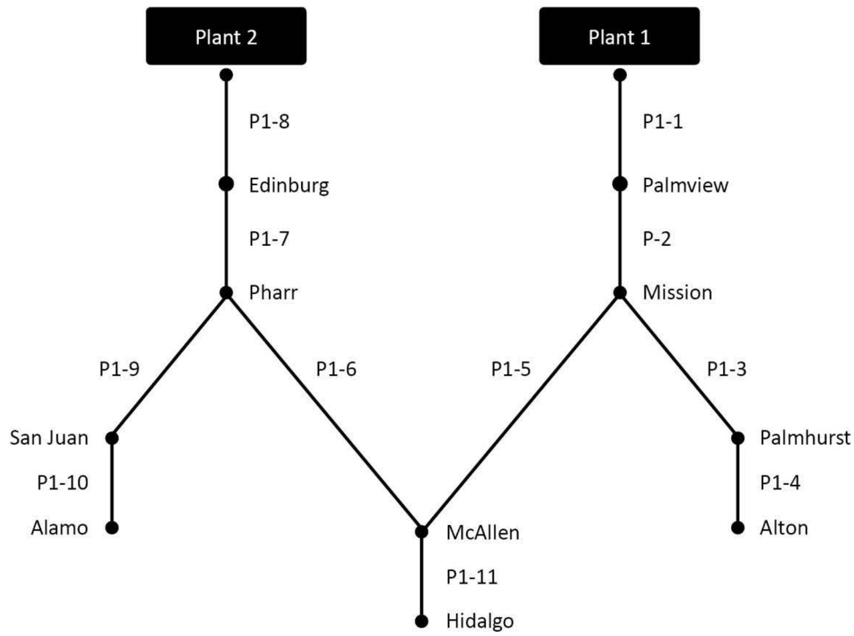
2040 Capacity (acft/yr)		
Municipality	Plant 1	Plant 2
Alamo		1,900
Alton	2,500	
Edinburg		6,900
Hidalgo	1,000	
McAllen	11,700	7,300
Mission	8,400	
Palmhurst	1,400	
Palmview	800	
Pharr		6,700
San Juan		3,000
TOTAL	25,800	25,800

2060 Capacity (acft/yr)		
Municipality	Plant 1	Plant 2
Alamo		2,700
Alton	3,400	
Edinburg		9,700
Hidalgo	1500	
McAllen	15,300	9,500
Mission	11,800	
Palmhurst	2,000	
Palmview	1,200	
Pharr		9,000
San Juan		4,300
TOTAL	35,200	35,200

The group 1 total production (for both plants) is 51,600 acft/yr, and the total for group 2 is 70,400 acft/yr.

Plant 1 is co-located with the Frontera Energy Center Gas Plant and Plant 2 is co-located with the Magic Valley Generating Station.

GROUP 1



Pipe Segments

Pipe ID	Design Dia.	Start	End	Start El.	End El.	Length (miles)
P1-1	42	Plant 1	Palmview	116	145	3.27
P1-2	36	Palmview	Mission	145	139	3.29
P1-3	16	Mission	Palmhurst	139	159	3.04
P1-4	12	Palmhurst	Alton	159	160	2.03
P1-5	30	Mission	McAllen	139	119	5.99
P1-6	20	Pharr	McAllen	112	119	2.9
P1-7	36	Edinburg	Pharr	95	112	7.5
P1-8	42	Plant 2	Edinburg	89	95	3.27
P1-9	18	Pharr	San Juan	112	106	1.8
P1-10	12	San Juan	Alamo	106	98	2.05
P1-11	10	McAllen	Hidalgo	119	101	6.8

Segment P1-11 did not meet the pipeline velocity targets for Phase 1 flows. Because of the limitations of the pipelines tool with respect to pipe sizes and the uncertainty associated with pumping requirements, these segments were left as-is.

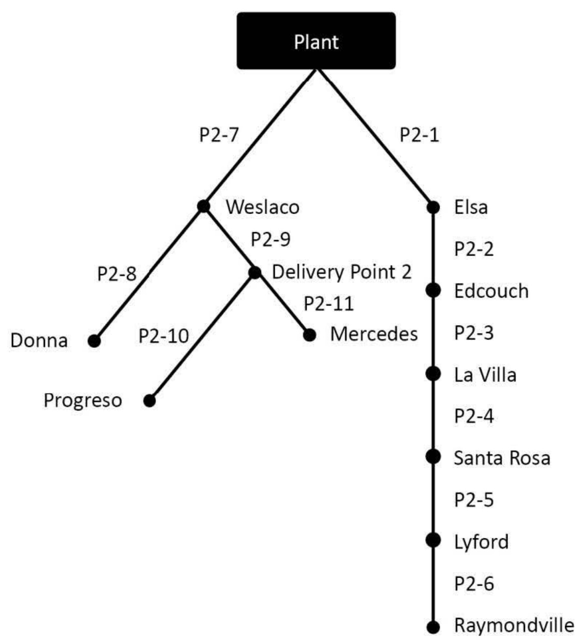
Group 2

Because small quantities of water were delivered long distances, the hydraulics in this system required that five sections of pipeline be increased to 300 psi pressure class in order to avoid additional pumping stations.

Design Delivery Volumes

Municipality	2040 (acft/yr)	2060 (acft/yr)
Donna	1,400	1,800
Edcouch	300	400
Elsa	600	700
La Villa	100	100
Lyford	200	200
Mercedes	1,000	1,200
Progresso	500	600
Santa Rosa	200	300
Raymondville	700	700
Weslaco	3,400	4.300
TOTAL	8,400	10,300

GROUP 2



Pipe Segments

Pipe ID	Design Dia.	Start	End	Start El.	End El.	Length (miles)
P2-1	10	Plant	Elsa	67	68	2.7
P2-2	8	Elsa	Edcouch	68	60	2.02
P2-3	8	Edcouch	La Villa	60	56	1.99
P2-4	8	La Villa	Santa Rosa	56	48	7.37
P2-5	8	Santa Rosa	Lyford	48	33	12.6
P2-6	6	Lyford	Raymondville	36	32	4.88
P2-7	18	Plant	Weslaco	67	76	6.62
P2-8	10	Weslaco	Donna	76	92	3.86
P2-9	10	Weslaco	Delivery pt. 2	76	71	2.09
P2-10	6	Delivery pt. 2	Progresso	71	69	4.38
P2-11	8	Delivery pt. 2	Mercedes	71	68	2.82

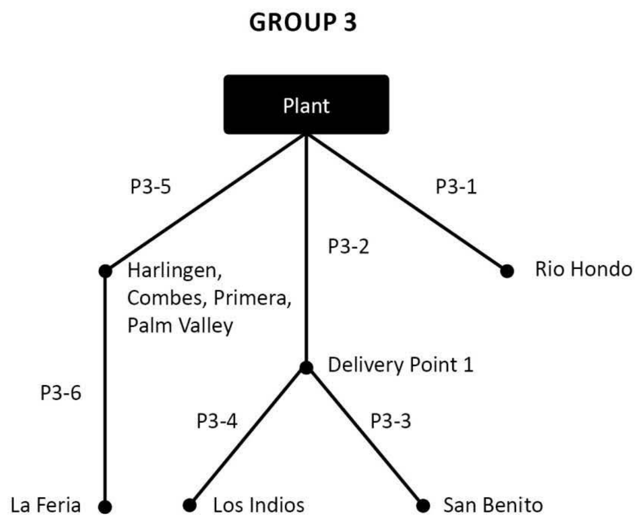
There are five segments of pipeline that required an increase from 150 to 300 psi rated pipeline: segments 2-4, 2-5, 2-6, 2-7, and 2-10. Costs for those segments were adjusted based on the 1.24 multiplier for increased pressure rating in the cost calculations on the Simplified Hydraulics tab, and those costs used to override the cost in the Unlocked Costing Form.

Group 3

The delivery volume for Harlingen includes that for Combes, Palm Valley, and Primera because Harlingen has established infrastructure to supply water to these municipalities. Any expansions to infrastructure required by the growth in demand would be made regardless of the source of water (new facilities proposed here or Rio Grande).

Design Delivery Volumes

Municipality	2040 (acft/yr)	2060 (acft/yr)
La Feria	500	700
Harlingen	6,600	7,900
Combes	200	200
Primera	400	600
Palm Valley	200	200
Los Indios	200	200
Rio Hondo	300	300
San Benito	2,700	3,100
GROUP3 TOTAL	11,100	13,200



Pipe Segments

Pipe ID	Design Dia.	Start	End	Start El.	End El.	Length (miles)
P3-1	6	Plant	Rio Hondo	31	26	4.36
P3-2	14	Plant	Delivery pt. 1	31	39	4.65
P3-3	12	Delivery pt. 1	San Benito	39	36	2.66
P3-4	6	Delivery pt. 1	Los Indios	39	58	9.56
P3-5	20	Plant	Harlingen	31	41	5.73
P3-6	8	Harlingen	La Feria	41	56	8.26

There are three segments of pipeline where the pipeline did not meet the minimum design target for flow velocity (segments 3-1,3- 4, and 3-6). Because of the limitations of the pipelines tool with respect to pipe sizes and the uncertainty associated with pumping requirements, these segments were left as-is.

Land Acquisition

The "Advanced" method for costing land acquisition was selected. The Texas A&M University (TAMU) Real Estate Center website, (link in the UCM workbook) provides for land value per acre. Land Market Area (LMA) section 32 was used, which covers the Lower Rio Grande Valley (Hidalgo, Cameron, and Willacy counties). "Nominal median price per acre" was used, as the "real" numbers are actually 1966 dollars with inflation. The 2012 number of $3,961 was rounded up to a **unit land cost of $4,000 per acre**.

Since the ROW width is the same over the entire project, a **permanent ROW width of 40 feet** was used (this will safely accommodate 2' to 4' diameter pipe).

The administrative costs associated with cells C7, C9, C10, and C11 were estimated based on engineering judgment. These categories are weighted based on percentages of the total number of parcels – percentages are fixed by the UCM workbook (cannot be modified).

From the TAMU real estate center, the median tract size is 39 acres (or just more than 16 tracts per square mile [640 acres]). If the tracts were laid out on a grid, a straight pipeline would cross 4 tracts (square root of 16). Due to pipeline direction changes and uneven tract boundaries, add at least 50% so assume **6 parcels per mile**.

Administrative cost per parcel is assumed to be **$1K, $5K, and $10K**, respectively, for base, condemnation, and trial costs.

Costs for the non-pipeline components of the project were estimated to be $5,000 per acre. Note, administrative costs are not added into these numbers by UCM. The land costs for other facilities will be estimated at $5,000 per acre, assuming a 20% administrative cost.

All "soil" and "rural" conditions were assumed for land acquisition and pipeline costs.

Unlocked Well Field

Phase 1 and Both Phases workbooks show the well field design for the total wells at each phase. The Both Phases workbooks have two tabs: one for the Total Well Field, and P2 Well Field, which describes the incremental increase in well field costs. The expansion is assumed to have a separate branch of trunkline, rather than extend from the end of the Phase 1 wellfield.

The well field module did not allow for more than 12 wells, and was unlocked and adjusted to accommodate enough wells for all portions of this project. All of the calculations remained as in the original UCM, except for the pumping requirements (based on total dynamic head (TDH), column N). Unlocked Well field was calculating TDH based on each trunk line segment bringing the water up to pressure from zero at each segment, as though there was a break. This was adjusted so that the feeder lines (from the wellhead to the trunk line) delivered water at 15 psi (the minimum pipeline pressure) and the trunk line pumping was only designed to overcome friction losses along the trunk line.

Assumptions:

- Avg. Static Water Elevation = 100 ft below ground surface
- Avg. drawdown = 20 ft, from the TWDB's R368 Gulf Coast Aquifer GAM report, June 2007.
- Avg. Flow Per Well = 400 gpm

- Source Water TDS = 3500 mg/L
- Fraction of Raw Water to Desalination = 85%
- RO Efficiency = 75%
- Peaking Factor = 1.0

It is not clear if the capital costs for pumps on the trunk lines are included in the UCM calculation, but the user guide states that each well can be considered an individual, or stand alone, pump station for sizing purposes. To account for uncertainty in capital costs modification to the TDH assumes the minimum 15 psi pressure is achieved throughout the trunk line and capital costs for trunk line pressures are included in the well head sizing.

Unlocked Costing Form and Unlocked Costing Summary

Notes are included for most formula changes or cost overrides in Column J.

Systems that do not require surface water intake structures set the pump Intake for pipelines to $0, based on the UCM guidance.

Pump station costs for Phase 2 (as shown in the Both Phases workbook) are only due to the increase in capacity, and are linked to the Simplified Hydraulics tab, where the pumping summary is copied in from Phase 1 and the incremental difference is taken so that the cost does not represent the construction costs for two small facilities where there is one larger facility built in two phases. Treatment plant costs and wells costs for Phase 2 are estimated as new facilities.

Pipeline costs and associated land acquisition costs were taken out for Phase 2 in the Both Phases Simplified Hydraulics and Costing Form since these items are all covered in Phase 1.

The Associated Project Costs listed in the Costing Form of the Both Phases workbooks (Unlocked Costing Form, rows 203 – 233) were zeroed out for additional pump stations, pipeline ROW, and the Environmental and Archaeology Studies and Mitigation formulas were adjusted so that they only refer to the incremental increase in land area that would be developed in Phase 2.

The annual O&M costs that are based on the total capital cost of the system were linked either to the Total Well Field or to the Costing Summary data copied from the Phase 1 workbook.

The Highway and Stream crossings section was completed for the Phase 1 costs, and was based on maps available and the number and size of roads along the path of the pipelines. A tab "Crossings," was created which shows how many crossings were counted for each segment of pipe, the size of pipe, and the cost (based on UCM costs, hidden "Cost Tables" tab). The path of these pipelines may be able to be adjusted for a significant cost savings, especially in the more developed areas. Note: there are no stream crossings in the Highway and Stream crossing section of UCM, and none were included in this cost estimate.

The Phase 1 costs are copied and pasted from the Phase 1 workbook, and all other costs linked in keeping with the design of the UCM, but were changed to reference the Simplified Hydraulics instead of the Advanced Hydraulics tab, and the appropriate well field tab.