Rio Grande Regional Water Planning Group
3rd Round of Regional Planning: 1st Phase

Task #3: Analyze Results of Demonstration Projects

Final Report
July 31, 2009

Submitted by:

engineering better communities

NRS Consulting Engineers, Inc.
Texas Registered Engineering Firm F-2705
1222 E. Tyler Avenue
Harlingen, TX 78550
Phone: 956-423-7409
Fax: 956-423-7482
www.nrsengineers.com

STATE OF TEXAS
JOSEPH W. NORRIS
49962
LICENSED
PROFESSIONAL ENGINEER

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Executive Summary

Since the last round of regional planning was complete, a number of demonstration projects have been undertaken. Included in these demonstration projects are two studies that will add substantial information to the regional water plan. First, the Harlingen Irrigation District undertook a comprehensive analyses aimed at evaluating on-farm water conservation. Second, a seawater reverse osmosis pilot study was performed by the Public Utility Board of the City of Brownsville. Each of these studies reflect previously recommended water management strategies for Region M.

Harlingen Irrigation District: Agricultural Water Conservation Demonstration Initiative
The Harlingen Irrigation District, through a grant from the Texas Water Development Board, has implemented a ten-year project in the lower Rio Grande Valley aimed at improving on-farm irrigation technologies and methods. The project began in 2005 and is scheduled for completion in 2014. Although this project is termed a demonstration project, there are actually five demonstration projects that make up the ADI: 1)drip and furrow flood irrigation in annual crops and multi-year crops, 2)surge, automated surface, and precision surface irrigation, 3) low elevation spray application, low pressure in canopy, and low energy precision application center pivot sprinkler demonstration sites, 4) automated and manual on-farm measurements systems, and 5) variable speed pump control and optimized delivery of on-farm demands.

The most gains in water conservation were observed for drip irrigated onions compared to furrow irrigation. In this case, the yield doubled, quality remained the same, and water use was reduced by 50%. When using poly-pipe verses open ditches, irrigators saw savings in terms of less labor and less water usage (5% to 40% less). Mini-pivots irrigation were shown to be effective in areas where the water table is shallow and in areas where the land is undulating.

The implementation of on-farm irrigation improvements has been a source of discussion. Implementation of on-farm water conservation measures will require individual agricultural producers to adopt new irrigation technologies and management practices. There has already been a degree of adoption of on-farm water conservation measures by producers in the Rio Grande Region. However, to achieve the recommended rates of implementation, it will be important to expand state and federal technical assistance programs, provide incentives, and/or financial assistance to irrigators. As it currently exists, the monetary incentive for implementing on-farm conservation is not in place for the irrigator. Even though water conservation is an important factor that many look at, the practice of farming is a business to most, and monetary incentives could drive the rate of implementation of on-farm conservation. Ultimately, the recommended on-farm incentive program will be directly hinged to the amount of funding made available for the implementation of any improvements.

The current agricultural climate in the region is such that the majority of irrigators are not willing to expend large amounts of money on such improvements. Therefore, State and Federal funding must continue to be allocated to such actions.

Preliminary results of the demonstration project indicate that on-farm conservation is a viable water management strategy for the Region. The demonstration project has proven that water consumption can be reduced by implementing on-farm conservation while maintaining crop yields similar to more water intensive irrigation methods (i.e. flood irrigation). The potential for sustained drought in the Region, combined with the uncertainty of Mexico's compliance with the 1944 treaty, should cause an enhanced evaluation of on-farm conservation implementation.

Brownsville Public Utilities Board: Texas Seawater Desalination Demonstration Project
In 2004, a Feasibility Study determined that the Lower Rio Grande Valley region would be confronted with a water supply deficit by 2050 and that seawater desalination was a viable alternative. In 2007, BPUB and TWDB partnered together to implement a seawater desalination Pilot Study. The pilot facility was located on the north shore of the Brownsville Ship Channel on land made available by the Port of Brownsville. The primary purpose of the pilot was to provide an opportunity to evaluate actual performance of proposed water treatment systems under site-specific conditions.

Because the objective of a seawater desalination project is to produce potable drinking water from the ocean, the Pilot Study established testing protocols approved by the Texas Commission on Environmental Quality (TCEQ). The performance of each pretreatment and primary treatment (reverse osmosis) process was then evaluated and documented. TCEQ requirements served as the base point for testing. However, the data required in order to meet these requirements does not provide all necessary information needed to accurately determine the most effective treatment technology for the full-scale facility.

The original study scope developed by BPUB and TWDB called for the comparison of two types of pretreatment technologies: 1) conventional (rapid mix/flocculation/clarification/filtration), and 2) ultrafiltration (a membrane-based technology). However, at the outset of the project, BPUB decided to increase the scope and value of the Pilot Study by including two additional membrane-based pretreatment units.

During the Pilot Study, source water quality was characterized at both potential full-scale site locations, including the inland site on the Brownsville Ship Channel and the ocean site off-shore of Boca Chica Beach in the Gulf of Mexico. In the ship channel, large fluctuations in turbidity and suspended solids were observed. These variations were attributed mainly to the passing of cargo ships in the Brownsville Ship Channel and predominant (southeasterly) wind direction and speed. Water quality in the Gulf of Mexico varied less, but samples were not taken during adverse weather conditions when variability would be expected to increase and overall quality decrease. Therefore, pilot data for the Gulf of Mexico do not reflect the worst-case water quality scenario for the open ocean that would occur during hurricane or other severe storm events.

During the Pilot Study, four pretreatment systems were subjected to protocol tests: 1) Eimco Conventional System, 2) GE Zenon Ultrafiltration, 3) Norit Ultrafiltration, and 4) Pall Microfiltration. With challenging raw water quality, each pretreatment system was tested at a number of operating conditions to document performance. The removal efficiency of potential membrane fouling agents (i.e., particulates, total organic carbon, etc.) was also measured and system reliability evaluated in terms of treatment consistency. Three of the four tested pretreatment units (conventional, GE Zenon, and Norit) failed to prove sustainable operation without exhibiting significant fouling tendencies and, in the extreme case, irreversible fouling on the membrane surface. The fourth pretreatment unit (Pall Microza system) did successfully operate for periods of 66 days and 72 days during two separate runs performing TCEQ Stage 2 and Stage 3 of the pilot protocols.

Three RO membranes were tested during the pilot study. The first set of membranes tested was Toray TM820C-400, a membrane designed to maximize boron rejection. The other two membranes tested were Toray TM820-400 and Filmtec SW30HR-LE-400i. With both the Filmtec SW30HR LE-400i and Toray TM820-400 elements, it was concluded that the RO system exhibited acceptable performance.

The Brownsville PUB pilot study proved that seawater desalination at the Brownsville Ship Channel is technologically feasible. Water quality in the Ship Channel was challenging with high levels of suspended solids and wide ranges of temperatures. However, a system of microfiltration and reverse osmosis proved effective at treating the challenging water to a finished water quality that meets or exceeds Texas Commission on Environmental Quality standards (both primary and secondary). On a region-wide basis, seawater desalination has the ability to provide a drought proof source of water to all users in the Region. The results of the Brownsville PUB pilot study indicate that seawater desalination is a feasible and recommended water management strategy for the region.

Purpose of Study

Since the last round of regional planning was complete, a number of demonstration projects have been undertaken. Included in these demonstration projects are two studies that will add substantial information to the regional water plan. First, the Harlingen Irrigation District undertook a comprehensive analyses aimed at evaluating on-farm water conservation. In the past regional plan, on-farm conservation was included as a water management strategy aimed at irrigation water users. Even though substantial amounts of water can be conserved by this method, implementation of on-farm conservation proved to be difficult given a lack of information available regarding implementation costs and potential water conservation amounts. In order to promote implementation, an analysis of the Harlingen Irrigation District project will be performed with the ultimate goal being to develop an on-farm incentive for implementation.

In addition to the on-farm study, a seawater reverse osmosis pilot study was performed by the Public Utility Board of the City of Brownsville. Seawater desalination was also recommended as a water management strategy in the previous round of regional planning.

Results of the seawater desalination pilot study will be analyzed and incorporated into the regional water plan to gain a better understanding as to the applicability of seawater desalination as a regional water management strategy.

Harlingen Irrigation District: Agricultural Water Conservation Demonstration Initiative

Methodology

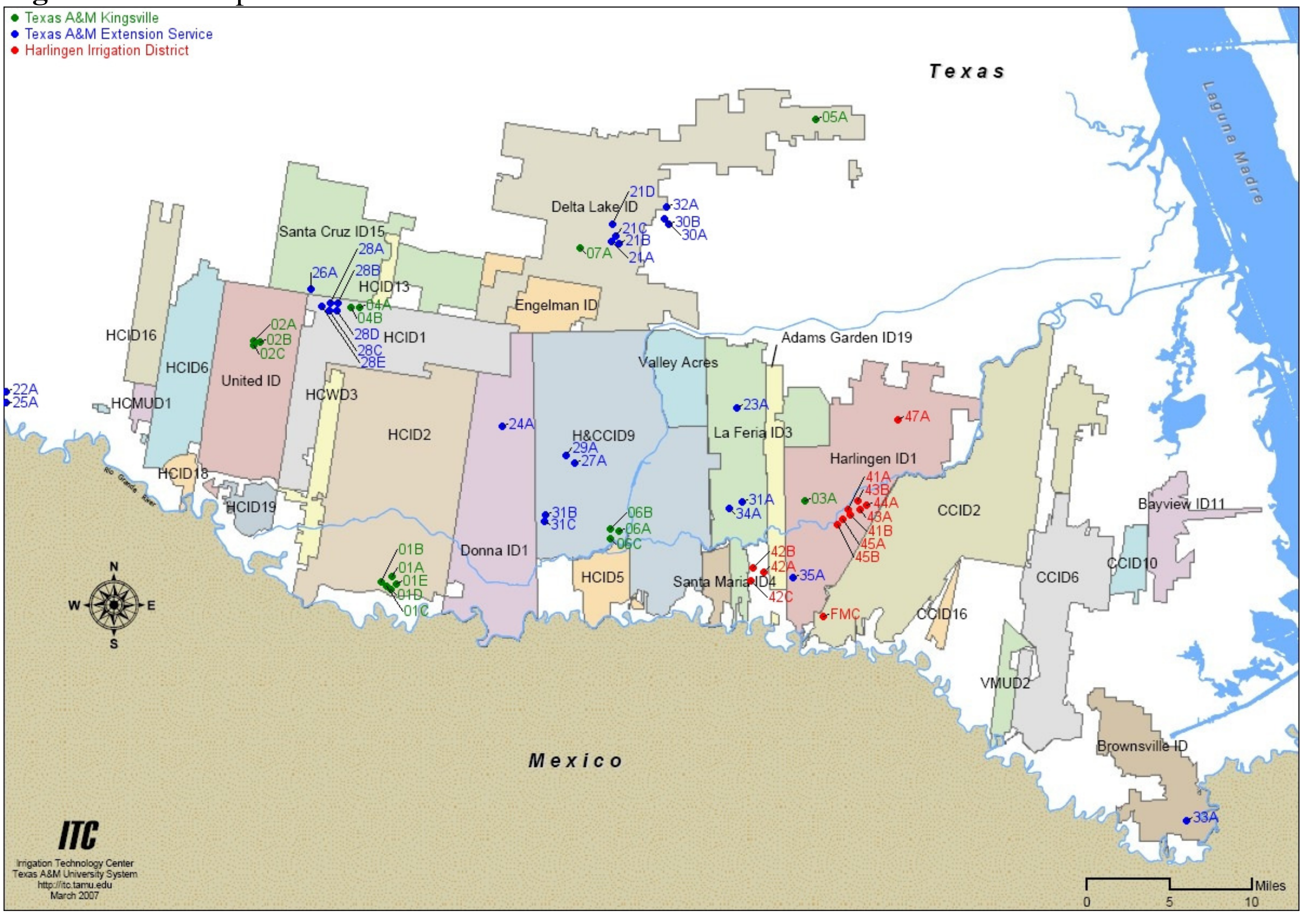
In the second round of Regional Planning, on-farm water conservation was recommended as a Water Management Strategy in which one could anticipate on-farm water savings to range from 125,194 acre-feet to 274,033 acre-feet. Overall, irrigation strategies (conveyance system improvements and on-farm improvements) could generate approximately 15 percent of the needed water for the region in the year 2060.

The Harlingen Irrigation District, through a grant from the Texas Water Development Board, has implemented a ten-year project in the lower Rio Grande Valley aimed at improving on-farm irrigation technologies and methods. As stated in the Three Year Summary Report to the TWDB, the Agricultural Water Conservation Demonstration Initiative (ADI) "is one way farmers and irrigation districts can take control of their water destiny by testing and developing techniques for irrigation and on-farm water efficiencies." The project began in 2005 and is scheduled for completion in 2014.

The ADI project is a culmination of a number of partners including Delta Lake Irrigation District, Texas A&M-Kingsville, U.S. Department of Agriculture – Natural Resources Conservation Service, Texas AgriLife Extension Service, Rio Farms, Inc., and agricultural producers in Cameron, Hidalgo, and Willacy counties.

Although this project is termed a demonstration project, there are actually five demonstration projects that make up the ADI: 1)drip and furrow flood irrigation in annual crops and multi-year crops, 2)surge, automated surface, and precision surface irrigation, 3) low elevation spray application, low pressure in canopy, and low energy precision application center pivot sprinkler demonstration sites, 4) automated and manual on-farm measurements systems, and 5) variable speed pump control and optimized delivery of on-farm demands.

Figure 1: Site Map of Demonstration Initiative

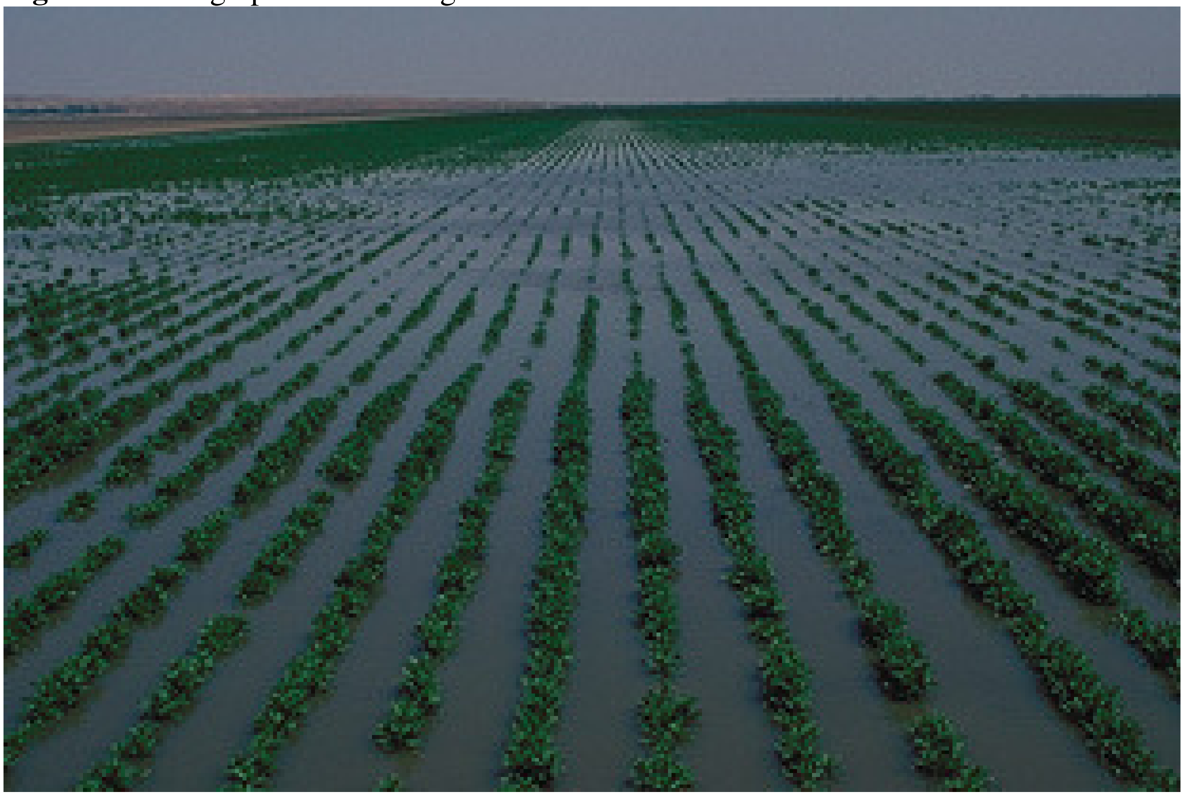


Results

Drip and Furrow Flood Irrigation in Annual Crops and Multi-Year Crops

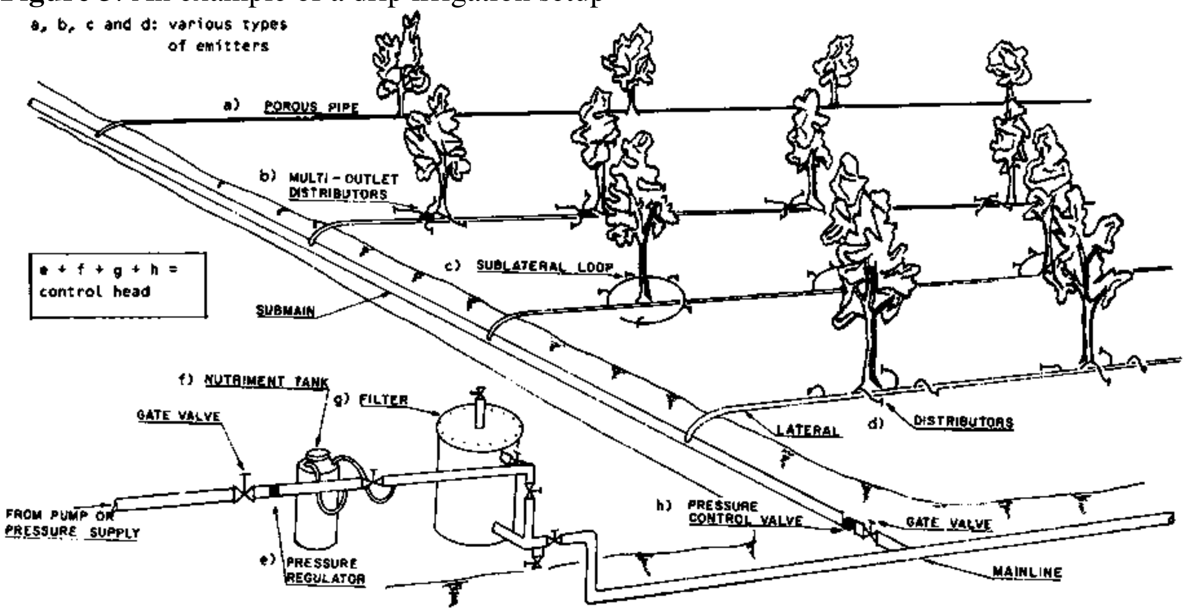
Over 3 years of data has been obtained ranging from rainfall, soil moisture levels, and crop yields. The Rio Red grapefruit crop was used as a control for the analysis. Seventeen (17) collaborating participants were used in this study. In the area, citrus is typically irrigated using the flood technique in which 0.6 acre-feet of water are applied to the ground per watering event. For the purpose of the study, three alternative methods of irrigation were tested: bordered flood, microject spray, and drip irrigation. Each irrigation method was tested at a prospective site. The results of the alternative irrigation technique were measured against the traditional flood irrigation average during the 2007-2008 growing season.

Figure 2: Photograph of flood irrigation



Source: Brigham Young University

Figure 3: An example of a drip irrigation setup



Source: Natural Resources Management and Environment Department

The following table gives a representative summary of water use:

Table 1: Water use summary for various on-farm delivery methods

Site	Acres	Irrigation Type	Trees per Acre	Total Irrigation	Total Irrigation	Water Savings
				gallons/acre	acre-feet per acre	acre-feet per acre
1a	50	Border field	115	832334	2.55	0.62
31a	9.4	Drip	116	610971	1.88	1.3
4b	38	Microjet	115	438270	1.35	1.83

The reported data indicates a significant drop in water volume using alternative technologies. When the data from alternative watering technologies is compared to standard flood irrigation, substantial water savings can be realized.

As important as evaluating various types of irrigation techniques may be, it is just as important to create an awareness of the technologies available to the irrigators. The ADI has been successful in collaborating with end users on the implementation techniques of various technologies. The results showed that an overwhelming majority felt that drip irrigation is the "most effective method of irrigation".

Surge, Automated Surface, and Precision Surface Irrigation

Surge irrigation technologies under this study have been applied to a number of different crops including sugarcane, cotton, corn, soybeans, and sorghum. Many farmers found the reduced flow as a result of using the surge valve, in addition to the necessity for increased management, to be cumbersome. However, surge irrigation was proven to reduce water use.

The surge technology allowed for user specified intervals to complete a single irrigation. By reducing the watering interval, a reduction in consumption was reported. However, there are certain drawbacks to this method. One, the technology is cumbersome and requires increased management. Two, the conveyance pipe (typically poly pipe) can rupture due to a rapid increase in flow. It was reported that a 27% reduction in water consumption was realized by utilizing surge irrigation. No other comparative data was made available.

LESA/LPIC/LEPA Center Pivot Sprinkler Demonstration Sites

It has been proven that "crop yields could be increased by 15% using the same amount or less water in most of" the demonstrations by scheduling irrigation. This could correlate to a savings of one, 8" irrigation per year when using water mark sensors and monitoring soil water content in grain and cotton crops.

Specific conclusions regarding the effectiveness of center pivot irrigation techniques were not available. However, it was reported that the distribution uniformity (DU), based on volumes collected ranged from 75.6% to 76.3% with a uniformity coefficient (UC) ranging from 82% to 85.8%.

The center pivot technology was only tested on pasture Bermuda grass, and data was not available as to the water savings associated with such a technique. However, it was reported that the cost of irrigating using center pivot was between $2.23 per acre-inch and $2.39 per acre-inch.

Figure 4: Photograph of center pivot technology

Source: Texas Water Development Board

Demonstration Summary

The most gains in water conservation were observed for drip irrigated onions compared to furrow irrigation. In this case, the yield doubled, quality remained the same, and water use was reduced by 50%. When using poly-pipe verses open ditches, irrigators saw savings in terms of less labor and less water usage (5% to 40% less). Mini-pivots irrigation were shown to be effective in areas where the water table is shallow and in areas where the land is undulating.

In addition to actual studies performed in the field, a major portion of the ADI program is associated with public perception, outreach, and training. The Harlingen Irrigation District operates a state-of-the-art meter calibration and training facility. New technologies can be tested at the site in simulated irrigation scenarios, and Irrigation District canal riders can be trained in the principals of water management. These two items combined, if utilized to the fullest extent, could prove highly effective at reducing water losses due to improper or absent water flow metering as well as reduce water spillage due to poor canal management.

In addition, a major component of the demonstration project is the installation of automated and manual on-farm measurements systems. Installed in 2006, the automated meter and telemetry system allows for real-time monitoring of data on the District's website. This allows irrigators and other water users to monitor water deliveries throughout the District. Information obtained here is being compared to manual collection.

Future Plans

It is anticipated that the ADI will be completed in 2014 with the demonstration phase being completed within 2 years. The final results of the demonstration phase will show farmers multiple water conservation options including on-farm delivery techniques. Supporting data in terms of water consumption and cost of conveyance will be evaluated. As of current, "the project has failed to provide a financial incentive to encourage the investment in these demonstrated technologies. Even though the demonstration sites are accepted as successfully providing alternatives to traditional irrigation practices, the risk is often too great for the farmer to commit to large scale changes."[1] It has been discussed that additional funding toward implementation would allow for the ADI group to discuss alternative water delivery mechanisms with the farmer with the ultimate goal being to educate irrigators as to the benefits.

Additional training events, using the recently constructed training facility, are being proposed. With equipment installed on site, the object of training would be to increase awareness of gate operation, automation, SCADA, flow measurement, flow management, and other methods for delivering water through a conveyance system. These training events would be perfectly suited to all levels of Irrigation District employees from canal riders to General Managers. In addition, the individual farmers would benefit from the plethora of training options available.

Figure 5: Automated flume gate and metering flume at the Harlingen Irrigation District training facility

Source: Harlingen Irrigation District

As the demonstration study progresses, additional information will be made available. Even though the study is not quite complete, it can be seen that alternative on-farm delivery techniques can be effective at reducing consumption.

[1] Harlingen Irrigation District, 2008

In addition, an increase in water delivery management using SCADA, automation, flow meters, and other technologies can increase delivery efficiencies. Ultimately, the preliminary results of the study support previous Regional Water Plan recommendations that on-farm conservation, as a water management strategy, could potentially generate approximately 15% of the needed water in the Region in 2060. As the study progresses, this inference could be tested with appropriate results.

Recommendations

On-farm Implementation

The implementation of on-farm irrigation improvements has been a source of discussion. Implementation of on-farm water conservation measures will require individual agricultural producers to adopt new irrigation technologies and management practices. There has already been a degree of adoption of on-farm water conservation measures by producers in the Rio Grande Region. However, to achieve the recommended rates of implementation, it will be important to expand state and federal technical assistance programs, provide incentives, and/or financial assistance to irrigators. As it currently exists, the monetary incentive for implementing on-farm conservation is lacking for the irrigator. Even though water conservation is an important factor that many look at, the practice of farming is a business to most, and monetary incentives could drive the rate of implementation of on-farm conservation.

In a White Paper produced by the Valley Water Summit titled "On-Farm Water Applications", nine potential solutions to increasing on-farm conservation were presented:

- Increase funding and cost-share programs via the TWDB or the EQIP to help fund on-farm irrigation conservation projects
    - Sponsor field-size demonstrations of new technologies
    - Help purchase on-farm technology
- Replace open canals with pipelines in the delivery system so water will be available at all times and at constant head pressures. This will allow for alternative on-farm technologies to be used including drip, micro-jet, sprinklers, etc.
- Increase the use of on-farm water measurement and price incentive programs
- Develop water marketing to facilitate water sales and transfers between Irrigation Districts
- Develop other sources of water
- Adopt water-saving application technologies and invest in related education for farmers
- Invest in agronomic and irrigation research, and modify production practices
- Require Mexico to comply with the 1944 Water Treaty
- Increase water rates for users to provide investment funding for infrastructure improvements

The report went on to describe ten potential pitfalls to on-farm solutions:

- Lack of concerted effort to obtain State and Federal funding to assist on-farm conservation
- Improvements in the infrastructure of Irrigation Districts may have to be made before on-farm conservation efforts will succeed.
- Reluctance to raise rates, due to political and economic concerns, will limit capital investment.
- Lack of conservation incentives: under non-volumetric rates, farmers do not receive the benefit of saving water
- ID rules and institutional constraints on moving water between districts
- High costs for on-farm water distribution systems
- Lack of knowledge and experience with improved on-farm water distribution systems
- Lack of research on optimal irrigation strategies for alternative crops in the region
- High-value crops tend to use large volumes of water
- Soil salinity is not necessarily reduced if the amount of water irrigation the fiels is reduced.

A key factor in analyzing on-farm efficiencies lies in the irrigation conveyance system. The degree to which on-farm water savings can be achieved is partially dependent upon improved efficiencies of irrigation conveyance and distribution facilities. The end-user can only conserve water that is made available to them, and the rate of conservation is linearly attached to the rate at which water is applied to the field. On-farm technologies that typically apply low volumetric flow rates to the field require a different conveyance system operation when compared to typical flood irrigation techniques which provide rapid, high flow rate watering.

The critique on a hesitation to proceed with wide-spread on-farm efficiency improvements provided in the Valley Water Summit White Paper is well founded, and progress is being made to address many of the issues laid forth. Many Irrigation Districts have implemented, or are in the process of implementing, volumetric pricing. In addition, funding has been put forward to increase understanding and testing of on-farm delivery methods (i.e. Agriculture Water Conservation Demonstration Initiative).

Modifying the cost of irrigation water could prove to be effective at curbing usage and spurring increased efficiency on the farm level. While this theory may be accurate, it may not be an available tool for many Irrigation Districts. A secondary approach of offering monetary subsidies to aid in the transfer of technology could be an effective approach. In many cases, a higher subsidy amount results in a greater probability of adopting improved on-farm irrigation technologies[2].

As the demand on surface water resources in the Region increases, the need to increase water efficiency (both conveyance and application) will increase as well.

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[2] Scheierling, Young, and Cardon – Can Farm Irrigation Technology Subsidies Effect Real Water Conservation?

A number of governmental agencies and entities can assist in the inevitable need to conserve irrigation water. These entities include the Texas State Soil and Water Conservation Board, the U.S. Department of Agriculture – Natural Resources Conservation Service, and Universities. The Texas State Soil and Water Conservation Board administers three key programs: Soil Water Conservation District Assistance, Water Quality Management Plan, and Brush Control programs. The USDA – NRCS offers support for water conservation programs including Conservation Innovation Grants, Conservation Security Program, Environmental Quality Incentives Program, Grassland Reserve Program, Farm and Ranch Lands Protection Program, Wetlands Reserve Program, and Wildlife Habitat Incentives Program. Local university programs include the Texas AgriLife Extension Service, Texas Water Resources Institute, and AgriLife Research[3].

Ultimately, the recommended on-farm incentive program will be directly hinged to the amount of funding made available for the implementation of any improvements. The current agricultural climate in the region is such that the majority of irrigators are not willing to expend large amounts of money on such improvements. Therefore, State and Federal funding must continue to be allocated to such actions.

When looking at the on-farm conservation as a recommended water management strategy, the previous Regional Water Plan included three methods for increasing water supply yield: farm level water measurement and metering, replacement of field ditches with poly/gates pipe, and adoption of improved water management practices and irrigation technologies. As detailed in the Fipps 2005 report, 60% of the Region needs improved management and irrigation technologies.

Quantifiable water conservation figures for the Region, based on the findings of the demonstration study, cannot be ascertained at this time. However, preliminary results of the demonstration project indicate that on-farm conservation is a viable water management strategy for the Region. The demonstration project has proven that water consumption can be reduced by implementing on-farm conservation while maintaining crop yields similar to more water intensive irrigation methods (i.e. flood irrigation). The potential for sustained drought in the Region, combined with the uncertainty of Mexico's compliance with the 1944 treaty, should cause an enhanced evaluation of on-farm conservation implementation. As is often the case, large-scale implementation of an unfamiliar technology takes incredible foresight.

[3] Texas Water Development Board – Agriculture Water Conservation: Best management Practices

Brownsville Public Utility Board: Texas Seawater Desalination Demonstration Project

Methodology

In 2004, a Feasibility Study determined that the Lower Rio Grande Valley region would be confronted with a water supply deficit by 2050 and that seawater desalination was a viable alternative (Dannenbaum and URS 2004). Based on data and information available at the time, the Feasibility Study estimated the total probable costs for a full-scale 25 mgd facility to be approximately $152 million. The study recognized that some form of supplemental (grant) funding would have to be provided to bridge the gap between what such a facility would cost and what local utilities could afford to pay. Since that time, substantial increases in the costs for fuel, electricity, steel, and petroleum-based products have been observed.

In 2007, BPUB and TWDB partnered together to implement a seawater desalination Pilot Study. The pilot facility was located on the north shore of the Brownsville Ship Channel on land made available by the Port of Brownsville. The primary purpose of the pilot was to provide an opportunity to evaluate actual performance of proposed water treatment systems under site-specific conditions. Piloting results would then be used to refine the designs and cost estimates for a full-scale (25 mgd) seawater desalination facility. The *Brownsville Seawater Desalination Pilot Project* operated from February 2007 to July 2008, and this Final Pilot Study Report presents its results and recommendations.

Two alternative site locations were considered for the pilot facility: Boca Chica Beach (coastal) and the Brownsville Ship Channel (inland approximately 11 miles) (Figure 6). Although the raw water quality was expected to be generally poorer at the ship channel site, the pilot facility was located there because of power supply, cost, security, and access considerations. As such, the site represents a worst-case source water quality testing scenario.

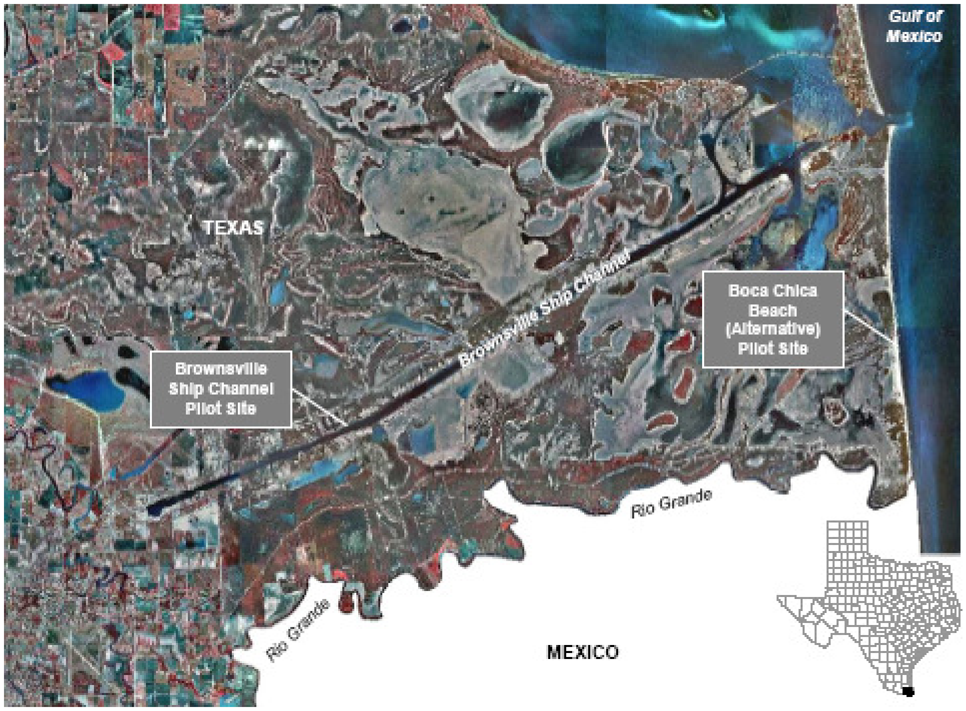

Figure 6: Location of the Brownsville Seawater Desalination Pilot Project

Because the objective of a seawater desalination project is to produce potable drinking water from the ocean, the Pilot Study established testing protocols approved by the Texas Commission on Environmental Quality (TCEQ). The performance of each pretreatment and primary treatment (reverse osmosis) process was then evaluated and documented. TCEQ requirements served as the base point for testing. However, the data required in order to meet these requirements does not provide all necessary information needed to accurately determine the most effective treatment technology for the full-scale facility. Prior to beginning the pilot, the goals listed in Table 2 were developed. Due to the unavailability of raw water quality data on a real-time basis, it was difficult to accurately determine piloting setpoints such as flux, backwash frequency, recovery, etc. The pilot team developed a testing plan that consisted of testing each treatment component on a stand-alone basis.

Table 2: Testing goals for pretreatment and RO systems

Performance Item	Pretreatment Goals	RO Goals
Silt Density Index	Filtrate <3.0 (100%) and <2.0 (95%)	-
Turbidity	Filtrate <0.2 NTU	-
Sustainable flux	Highest	Highest
Particle counts	Lowest	-
Influence on SWRO specific flux	Least	-
Chemical use	Lowest consumption	Least consumption
On-line time	Most utilization	-
Residuals	Least quantity and hazardous	-
Power consumption	Lowest	Lowest
Salt passage	-	Lowest
Cartridge filter change	-	Least frequent
Recovery	-	Greatest

The original study scope developed by BPUB and TWDB called for the comparison of two types of pretreatment technologies: 1) conventional (rapid mix/flocculation/clarification/filtration), and 2) ultrafiltration (a membrane-based technology). However, at the outset of the project, BPUB decided to increase the scope and value of the Pilot Study by including two additional membrane-based pretreatment units. The project budget was thereby increased by almost $1.0 million and funded by BPUB. This side-by-side comparison of four different pretreatment technologies resulted in an unprecedented level of study complexity (Figure 7 and Table 3).

LEGEND

1 Intake
2 Intake pumps
3 Norit ultrafiltration pretreatment unit
4 GE Zenon ultrafiltration pretreatment unit
5 Pall microfiltration pretreatment unit
6 Eimco conventional pretreatment unit
7 Pretreatment filtrate storage tanks
8 Reverse Osmosis treatment
9 Water storage tanks
10 Mixing tanks
11 Lagoon
12 Neutralization tank and discharge point
13 Discharge ditch
A Chemical storage building
B Operations building

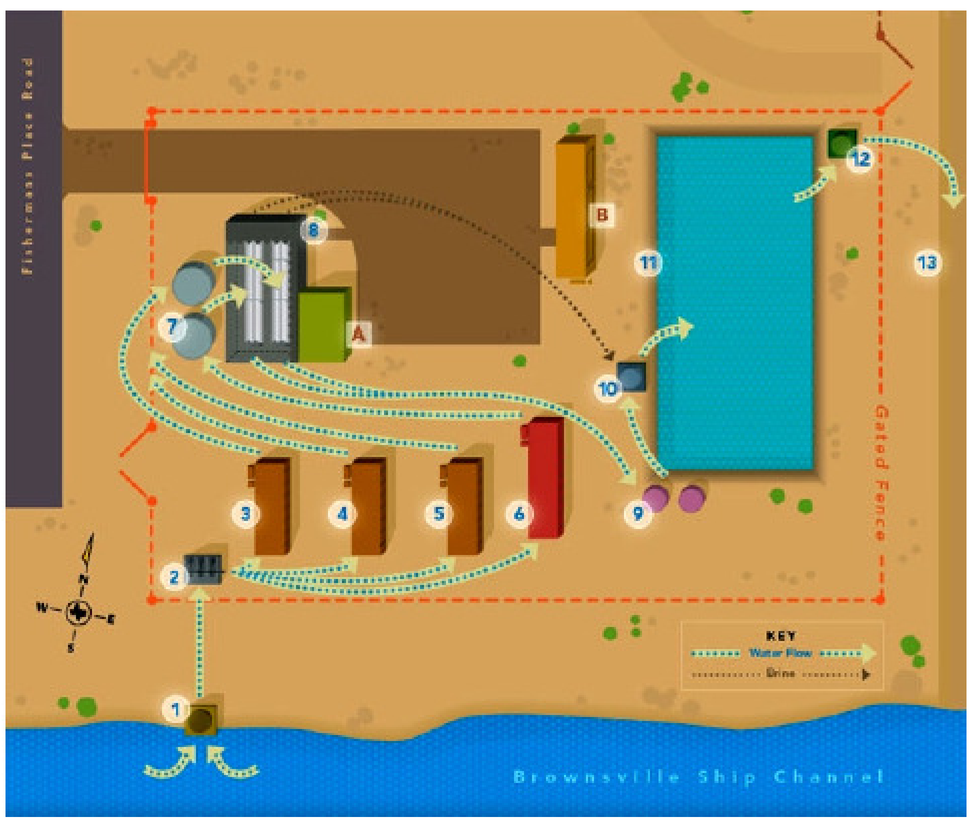

Figure 7: Layout of the Brownsville Seawater Desalination Pilot Project

Table 3: General specifications for pretreatment modules

Membrane Element Characteristic	GE Zenon UF	Norit UF	Pall MF
Active Membrane Area per Module (ft^2)	600	431	538
Flow Path (In-Out, Out-In)	Outside-In	Inside-Out	Outside–In
Number of Membranes	6	2/4	3
Molecular Weight Cutoff (Daltons)	100,000	350,000	-
Nominal Membrane Pore Size (microns)	0.02	0.05	0.10
Absolute Membrane Pore Size (microns)	0.1	0.075	NA
Membrane Material/Construction	PVDF	PES	PVDF
Membrane Hydrophobicity	Hydrophilic	Hydrophilic	Hydrophobic
Membrane Charge	Slightly Negative	Neutral	Slightly Negative
Design Operating/Vacuum Pressure (psi)	1 to 13	3.5 to 10.0	NA
Acceptable Range of Operating Pressures (psi)	1 to 13	0 to 14.5	Up to 43.5 psi
Acceptable Range of Operating pH Values	5 to 10	2 to 12	1 to 10
Maximum TMP for System (psi)	13	36	43.5
Maximum Permissible Feed Turbidity (NTU)	250	30	1,500
Chlorine/Oxidant Tolerance	Resistant to Hypochlorite, Chlorine dioxide, and $KMnO_4$	200 ppm continuous, 250,000 ppm hrs life time	Chlorine 10,000 mg/L, Oxidant Resistance
Suggested Cleaning Procedures	Sodium hypochlorite 500 ppm, 2 g/L of citric acid	Chlorine, Acid, Caustic	Air scrub, enhanced flux maintenance, CIP

Results

Raw Water Characterization

During the Pilot Study, source water quality was characterized at both potential full-scale site locations, including the inland site on the Brownsville Ship Channel and the ocean site off-shore of Boca Chica Beach in the Gulf of Mexico. In the ship channel, large fluctuations in turbidity and suspended solids were observed. These variations were attributed mainly to the passing of cargo ships in the Brownsville Ship Channel and predominant (southeasterly) wind direction and speed. Water quality in the Gulf of Mexico varied less, but samples were not taken during adverse weather conditions when variability would be expected to increase and overall quality decrease. Therefore, pilot data for the Gulf of Mexico do not reflect the worst-case water quality scenario for the open ocean that would occur during hurricane or other severe storm events. Tables 3 and 4 breakdown the raw water quality data obtained from the Ship Channel.

Figure 8: Photograph of the effect of a cargo ship passing on raw water turbidity in the Brownsville Ship Channel

Table 4: Summary raw water quality in the Brownsville Ship Channel, BPUB laboratory results for daily grab samples

Parameter	Number of Points	Maximum	Minimum	Average	95^{th} Percentile
Turbidity (NTU)	54,651	2,745	0.305	44.7	121.8
TOC (mg/L)	403	7.768	2.029	3.525	4.517
DOC (mg/L)	403	6.351	1.664	3.252	4.117
UV_{254} (cm^{-1})	404	0.13	0.019	0.047	0.07
Alkalinity (mg/L as $CaCO_3$)	404	318.5	109.4	140.96	155.2
Temperature (C)	449	31.8	14.5	25.0	30.0
Conductivity (mS)	445	55,500	28,400	48,100	53,800
TDS (mg/L)[a]	445	34,400	17,600	29,800	33,300
pH (SU)	448	8.66	7.12	8.01	8.27

[a] TDS was not tested on site. The information contained here was calculated using a conversion factor of 0.62 to convert conductivity to TDS. This conversion factor was calculated using laboratory testing data from an independent lab.

Table 5: Summary raw water quality in the Brownsville Ship Channel, independent laboratory results for periodic grab samples

Parameter	Units	No. of Points	Maximum	Minimum	Average	95th Percentile
Oil and Grease	mg/L	3	ND	ND	ND	N/A
Boron	mg/L	13	19.3	3.02	7.75	17.8
Strontium	mg/L	14	7.98	2.23	5.69	7.73
Calcium	mg/L	14	434	357	386	418
Iron	mg/L	14	22.1	ND	4.67	17.36
Magnesium	mg/L	14	1,330	911	1,135	1,310
Potassium	mg/L	13	684	417	487	661
Silica	mg/L	9	116	ND	24	29.5
Sodium	mg/L	14	10,500	6,390	8,468	10,175
Barium	mg/L	14	0.318	ND	0.086	0.242
Sulfate	mg/L	14	6,380	1,850	2,642	4,365
Fluoride	mg/L	13	ND	ND	ND	ND
Nitrate-Nitrogen, Total	mg/L	13	2.62	ND	2.62	1.048
Chloride	mg/L	13	25,500	13,900	17,083	24,360
SOCs	Mg/L	6	ND	ND	ND	ND
VOCs	mg/L	6	ND	ND	ND	ND
HAA5	mg/L	1	ND	ND	ND	ND
Bicarbonate (as $CaCO_3$)	mg/L	10	433	144	171	313
Carbonate (as $CaCO_3$)	mg/L	10	6.46	2.49	3	5.99
Color, True	PCU	9	10	ND	8	10
Color, Apparent	PCU	9	25	ND	12	25
Total Dissolved Solids	mg/L	14	46,800	28,100	30,515	39,585

Intake System

The Pilot Study utilized a wetwell, pumps, and intake screen to provide raw water form the ship channel to the pretreatment systems. Although this configuration was effective at the pilot-scale, a permanent intake system for a seawater desalination production facility will incorporate features that provide sufficient feed volume while minimizing the collection of suspended solids and protecting marine life. The recommended design includes a lengthy and wide constructed intake channel that connects the Brownsville Ship Channel to the intake screen assemblies and raw water pump station. This design would increase raw water settling time, thereby minimizing total suspended solids and turbidity introduced into the pretreatment systems. In addition, locating the facility on the south side of the ship channel may also reduce adverse water quality conditions imposed by prevailing southeasterly winds at the site.

Pretreatment System

A well designed pretreatment system is the most critical component of a successful seawater desalination facility. During the Pilot Study, four pretreatment systems were subjected to protocol tests: 1) Eimco Conventional System, 2) GE Zenon Ultrafiltration, 3) Norit Ultrafiltration, and 4) Pall Microfiltration. With challenging raw water quality, each pretreatment system was tested at a number of operating conditions to document loading rates, pressure losses, water production efficiency, filter backwash rates and frequencies, and chemical types and dosing rates.

The optimum operation of each pretreatment system was evaluated in terms of operational flux, temperature corrected flux, backwash frequency, and the frequency of chemical cleans. The removal efficiency of potential membrane fouling agents (i.e., particulates, total organic carbon, etc.) was also measured and system reliability evaluated in terms of treatment consistency.

Three of the four tested pretreatment units (conventional, GE Zenon, and Norit) failed to prove sustainable operation without exhibiting significant fouling tendencies and, in the extreme case, irreversible fouling on the membrane surface. It should be noted that the GE Zenon (ZW-1000) system was able to operate without performing a CIP for the minimum required 30 days. Fouling was present on the membranes due to the inability of the system to operate at greater than 15 gfd in a sustainable fashion. What is knows is that organic fouling occurs in seawater applications similarly to other surface water sources though the exact mechanism at Brownsville cannot be determined with the Zenon fiber.

The fourth pretreatment unit (Pall Microza system) did successfully operate for periods of 66 days and 72 days during two separate runs performing TCEQ Stage 2 and Stage 3 of the pilot protocols. Figures 9 and 10 show performance data of the Pall system at a flux of 25 gfd.

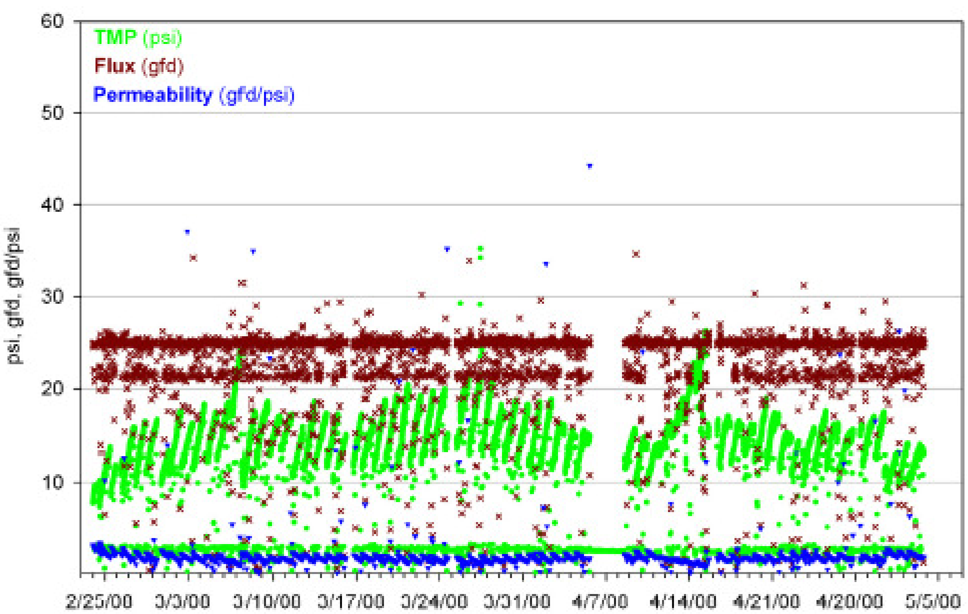

Figure 9: Operation at 25 gfd (TCEQ Stage 2), Pall MF membrane performance

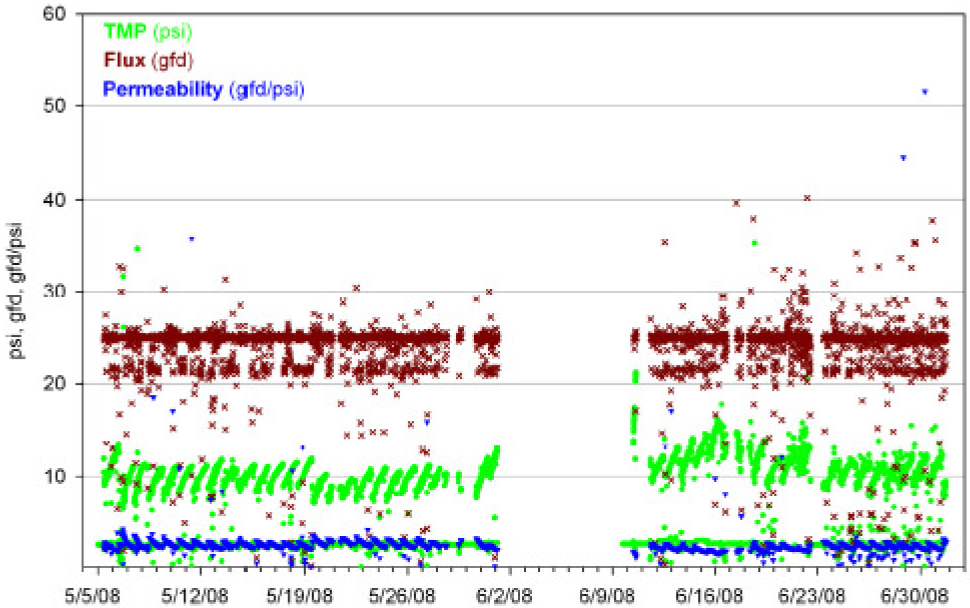

Figure 10: Operation at 25 gfd (TCEQ Stage 3), Pall MF membrane performance

The Pall pilot system utilized single, 200 micron Arkal 2" Spin Klin Automatic Disc Filter Battery. The prescreening surface area was 0.94 ft2. Backwashes were initiated once differential pressure reached or exceeded 3 psi. Over the course of the study, an average of 16 backwashes per day were performed with 3.6 gallons of water being user per backwash. This prescreening system provided consistent run time, and the only maintenance performed on the filter were manual cleans when the Pall unit was performing a CIP. Consistent prescreened flow was afforded to the Pall unit, and at no time during the pilot was the Pall unit shut down due to low prescreened flow.

The Pilot Study met the objective of developing a sufficient amount of real time information and data to demonstrate the technical feasibility of a successful pretreatment system. The following known conclusions apply to the successful pretreatment system for this Pilot Study:

1. The Pall Microza MF system proved to have the capability to operate under the worst case scenarios of high turbidity, TSS spikes, and variable raw water temperatures.
2. A flux of 25 gfd with a filtration duration per cycle of 15 minutes, daily EFMs utilizing 400 ppm of NaOCl, and a system recovery of 88.6% were determined to be the optimum operational settings for the design of a Pall MF system at this site specific location
3. The system is capable of sustainable operations for greater than 60 days at the optimum flux of 25 gfd without having to perform a CIP.
4. The Pall pretreatment system consistently removed greater than 97% of the raw water TSS.

5. The Pall MF system at 25 gfd achieved established testing goals and water quality guidelines of the pilot protocols which included:
    a. SDI<3.0 (100%) and <2.0 (95%)
    b. Filtrate turbidity of <0.2 NTU at the optimum flux
    c. >3-log removal for Giardia
    d. >2-log removal for Cryptosporidium

Reverse Osmosis System
Three RO membranes were tested during the pilot study. The first set of membranes tested was Toray TM820C-400, a membrane designed to maximize boron rejection. The other two membranes tested were Toray TM820-400 and Filmtec SW30HR-LE-400i. The testing setup consisted of a single-pass, single-stage design with 7 elements per pressure vessel. Each set of membranes was tested in a single pressure vessel. It was the objective to test the RO elements using pretreated seawater. The salt rejection, differential pressure, and permeate flow was measured routinely to determine the rate of fouling. It was the goal to maximize runtime between chemical cleans. In addition, the effectiveness of cartridge filters was analyzed.

With both the Filmtec SW30HR LE-400i and Toray TM820-400 elements, it was concluded that the RO system was able to perform without the need to clean for an equivalent of at least 69 days (118 calendar days) based on normalized permeate flow. Due to mechanical issues of the pretreatment system, steady pretreated flow was not available to the RO units. If the pretreatment units were able to provide ample flow to the RO train, it is possible that extended runtime, above the 90 days that was tested, would be possible.

The presence of biological growth in the RO piping was noticed throughout the testing. It was inferred that this growth caused premature fouling of the membranes. The presence of biological growth can lead to increases in differential pressure and salt passage as well as a decrease in normalized permeate flow.

The pilot met the objective of developing a sufficient amount of real time information and data to demonstrate the applicability of seawater desalination as a potential water management strategy. The following conclusions apply to the SWRO elements as tested at the pilot facility:

1. The Filmtec SW30HR LE-400i and Toray TM820-400 elements proved the ability to operate under severe conditions of high temperature variations and fluctuations in TDS
2. Operational conditions consisting of a flux of 8.2 gfd and a recovery of 48.8% allowed for operation of the RO elements for an extended period
3. The RO system for both membrane suppliers are capable of sustainable operations for up to 70 days at the optimum flux of 8.2 gfd and 48.8% recovery.
4. The RO membranes achieved finished water quality goals of turbidity (<0.1 NTU), THM formation potential (<40 ug/L), and compliance with current and anticipated future water standards.

Even though the testing results indicated proper performance, the following conclusions may apply to a full-scale facility. These conclusions were unfounded during pilot testing, but thorough research and testing indicates that they could be a part of a successful RO treatment scheme:

1. Cartridge filter changeout frequency of 90 days
2. The potential elimination of cartridge filters from the treatment scheme. Due to the inherent characteristics of MF/UF pretreatment, the possibility of substantial breakthrough is minimal. However, the impact of removing cartridge filters shall be researched with RO membrane manufacturers.
3. The use of a biocide could curb the impacts of biological fouling.
4. Chlorine dioxide could serve as a biogrowth control mechanism.

Ultimately, it was recommended that the full-scale design consist of an RO recovery of 45%, a flux of 8.1 gfd.

Concentrate Disposal

Two options for concentrate disposal were evaluated: deep well injection and diffusion into the Gulf of Mexico. Deep well injection is technologically feasible. However, it is costly. Diffusion into the Gulf of Mexico was analyzed on a desk top level. At a location approximately 2 miles offshore from Boca Chica Beach, modeling showed that the presence of a "dead zone" is extremely unlikely with a properly designed diffuser array.

Environmental Review and Permitting

The disposal of concentrate is a critical permitting issue. This is an issue that was addressed in previous Regional Water Plans. Permitting for diffusion into the Gulf of Mexico or deep injection wells appears to be viable both from a technical and permitting standpoint. Additional work may be necessary to address specific concerns of State and Federal agencies.

In addition to discharge permitting, other full-scale design and implementation components may require special permitting. The following agencies have been identified as having potential input into a full-scale design:

- Texas Parks and Wildlife Department
- Texas State Historic Preservation Office
- Texas General Land Office
- Texas Commission on Environmental Quality
- Texas Department of Transportation

In addition, county and local permits may be required for the implementation of a full scale facility.

Pilot Study Recommendations

Based on Pilot Study results, a full-scale (25 mgd) seawater desalination plant at the Brownsville Ship Channel would cost approximately $182 million (2008 dollars) (Table 1). To ensure long-term operational success of the plant, about 26 percent of this total accounts for a conservative pretreatment design consisting of conventional treatment elements ahead of the microfiltration pretreatment system.

Table 6: Comparison of Feasibility Study and Pilot Study total project cost estimates for a full-scale (25 mgd) seawater desalination plant.

Project Component	***Feasibility Estimate*** [a] *(2004)*	***Pilot Study Estimate*** *(2008)*
Desalination Plant	*$90,167,000*	*$126,612,000*
Concentrate Disposal System	*$30,583,000*	*$21,217,000*
Finished Water Transmission System	*$9,232,000*	*$12,180,000*
Project Implementation Costs	*$21,406,000*	*$22,400,000*
Total Capital Costs	***$151,388,000***	***$182,409,000***

[a] *Source: Dannenbaum and URS (2004).*

After considering the costs of other water supply alternatives available for the future needs of Brownsville, BPUB determined that it could afford up to $70 million for a 25 mgd seawater desalination project. This would leave an infeasible funding gap well over $100 million. In addition, the full anticipated regional water demand envisioned for the full-scale facility is not expected to materialize for several years. Therefore, it is recommended that a full-scale (25 mgd) seawater desalination facility not be implemented at this time due to the magnitude of the required funding gap and the current lack of full demand by BPUB and regional partners.

A phased project development approach will best mitigate the risks and uncertainties associated with seawater desalination. Such an approach will allow an evaluation of system performance over several years of operation prior to an investment in full-scale capacity. This data is expected to yield a more efficient overall treatment system design and lower the cost of future expansions as they occur. The demonstration facility will also include the capability for continuous testing of the latest desalination technologies for this and other future seawater desalination facilities along the Texas coast. Such technologies include applications for pretreatment, energy recovery, sustainable energy supply, and larger (potentially more efficient) RO membranes.

Recommendations

The Brownsville PUB pilot study proved that seawater desalination at the Brownsville Ship Channel is technologically feasible. Water quality in the Ship Channel was challenging with high levels of suspended solids and wide ranges of temperatures.

However, a system of microfiltration and reverse osmosis proved effective at treating the challenging water to a finished water quality that meets or exceeds Texas Commission on Environmental Quality standards (both primary and secondary).

In the second round of Regional Planning, seawater desalination was a recommended water management strategy for Brownsville PUB as well as the Laguna Madre Water District. The results of the pilot study concluded that seawater desalination is a technologically feasible method to provide sustained water sources for the Region. However, the extent of seawater desalination cannot be relegated to the coastal area. Previous regional water plans have shown a substantial deficit in water supplies, and Region M is particularly dependent on the Rio Grande to supply the majority of those supplies. Surface and groundwater supplies continue to be limited. Surface water in the Rio Grande is vulnerable to drought. In addition, the ongoing dilemma of Mexico abiding by their treaty obligations proves another harrowing water supply scenario for the Region. Groundwater is limited by individual well production and aquifer recharge rates.

On a region-wide basis, seawater desalination has the ability to provide a drought proof source of water to all users in the Region. The results of the Brownsville PUB pilot study indicate that seawater desalination is a feasible and recommended water management strategy for the region. However, economies of scale play a large part in the development of a desalination facility. Any entity that wishes to pursue seawater desalination as a water management strategy to meet future water supply needs shall perform an extensive evaluation. This evaluation should consist of the following items, at a minimum:

- Source water quality should be carefully analyzed. The desalination of seawater isn't a one size fits all treatment scheme. At different locations along the Gulf of Mexico, the water quality can contain various fouling characteristics. These fouling characteristics shall be evaluated thoroughly.
- Pretreatment is often considered the most critical component of any seawater desalination facility. Being the initial filtering component of the system, the pretreatment must be able to handle foulant loading rates at acceptable operational conditions. The main operational conditions include flux (flow per surface area of membrane) and recovery (net filtrate production as a function of gross filtrate production). In order to ensure sustained operation of the facility, special care shall be taken in designing the pretreatment system.
- Finished water quality shall meet all requirements of the TCEQ.
- Environmental compliance shall be carefully analyzed. It is recommended to begin dialogue with any and all applicable environmental agencies during the preliminary/pilot phase of the project.

References

Brownsville Public Utilities Board, Texas Water Development Board, Port of Brownsville, NRS Consulting Engineers. 2008. Final Pilot Study Report: Texas Seawater Desalination Demonstration Project.

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Available on-line at: http://www.twdb.state.tx.us/publications/AgConsBMPoverview.pdf

Responses to TWDB Comments on Draft Final Phase 1 Special Studies Reports
Rio Grande (M) Region-Specific Studies #3

1. The contract SOW, Task A states that *"a thorough analysis will be performed ……"*. Please provide the full analysis in the final report of the irrigation conservation demonstration projects' results, which will require that statistics be included and the numerical results be presented in an organized tabular and/or graphical format, as appropriate.

Additional information was included in the Final Report for the Harlingen ID Demonstration Study.

2. The contract SOW, Task A states that ……*this analysis will be used to develop an on-farm incentive for implementation of such strategies in the Regional Water Plan*. Please discuss how the analysis results can be used for this process in the final report.

Additional information was included in the Final Report (beginning on Page 10).

3. The contract SOW, Deliverables section for Task A states that *"In addition, recommendations will be developed by the Regional Water Planning Group regarding the development of an on-farm incentive program to increase implementation of such strategies throughout the region;"* In the final report, please include these recommendations and discuss the Region M on-farm incentive program that was developed. Also, please document whether or not the irrigation conservation demonstration projects' results support the regional water plan statements presented on page 1, paragraph 2.

Additional information was included in the Final Report (beginning on Page 10).

4. Page 1: Please consider providing pertinent information on the Agricultural Water Conservation Demonstration Initiative (ADI) demonstration project in the final report such as project's start and projected completion dates, at what stage in the data collection process was the project when data was analyzed for this report, defining the quality and reliability of the data used in this analysis; and project site description information such as the site map available at http://www.hidcc1.org/adi.

Additional information was included throughout the Final Report (pages 4, 5, 9, and 10)

5. The contract SOW, Task B states that *Results of the seawater desalination pilot study will be analyzed and incorporated into the regional water plan to gain a better understanding as to the applicability of seawater desalination as a regional water management strategy.* The page 5 discussion of the results of the study is

limited to financial considerations for a full-scale seawater desalination plant. Please include the technical aspects of the study in the final report.

Writeup was revised in the Final Report to incorporate comments (beginning on Page 13).

6. Pages 6-7: The *Advantages and Challenges* sections in the report are taken verbatim from a separate October 2008 report entitled "Final Pilot Study Report: Texas Seawater Desalination Demonstration Project" prepared by Brownsville PUB and NRS Consulting Engineers for TWDB. Please reference this prior study and appropriately reference all recommendations from it in the final report.

Writeup was revised in the Final Report (beginning on Page 13). References were included.

7. The contract SOW Deliverables section states that *recommendations will be developed by the Regional Water Planning Group regarding the feasibility of Seawater Desalination as a Region-wide Water Management Strategy*. In the final report, please document this process and discuss the Region M feasibility recommendations that were developed.

Text was added to the Final Report (pages 23 and 24).