HARLINGEN IRRIGATION DISTRICT

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FINAL REPORT

Agricultural Water Conservation Demonstration Initiative in the Lower Rio Grande Valley

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TWDB Final Report for Agricultural Water Conservation Grant Contract #0503580013

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List of Abbreviations

Ac	Acre
ADI	Agricultural Water Conservation Demonstration Initiative
AF	Acre Feet
AFY	Acre Feet per Year
APS	American Phytopathological Society
ASA	American Society of Agronomy
ASHS	American Society for Horticultural Science
BMP	Best Management Practices
CSSA	Crop Science Society of America
CWP	Crop Weather Program
District	Harlingen Irrigation District
ET	Evapotranspiration
EQIP	Environmental Quality Incentives Program
FARM	Financial and Risk Management Assistance Program
FMC	Flow Meter Calibration
FY	Fiscal Year
GIS	Geographic Information System
Gpm	Gallons per minute
HID	Harlingen Irrigation District
IBWC	International Boundary Water Commission
IPPC	International Plant Protection Convention
LESA	Low Elevation Spray Application
LRGV	Lower Rio Grande Valley
NACTA	North American Colleges & Teachers of Agriculture
NBF	Narrow Border Flood
NCFI	Net Cash Farm Income
NPS	Non-Point Source
NRCS	National Resources Conservation Service
RGBI	Rio Grande Basin Initiative
RGRWA	Rio Grande Regional Water Authority
SCADA	Supervisory Control and Data Acquisition
SSSA	Soil Science Society of America
SVC	Surge Valve Cooperative
TAMUK	Texas A&M University Kingsville
Texas AWE	Texas Project for Ag Water Efficiency
TCEQ	Texas Commission on Environmental Quality
TFF	Trench Furrow Flood
TWDB	Texas Water Development Board
TWRI	Texas Water Resources Institute
TSSWCB	Texas State Soil and Water Conservation Board
USBOR	United States Bureau of Reclamation
USCID	United States Committee on Irrigation and Drainage
USDA	United States Department of Agriculture

1. Executive Summary

Increasing efficiency of the conveyance and application of irrigation water is of utmost importance to the future of agriculture in the Lower Rio Grande Valley. The ten-year Agricultural Water Conservation Demonstration Initiative grant enabled the Harlingen Irrigation District and its partners to identify technologies that make the best use of limited water supplies and limited budgets. The District has already improved their operations with water- and time-saving technologies, and through a comprehensive outreach program, has shared the project's findings with growers and irrigation district personnel in the region and beyond.

Citrus. Field demonstrations and analyses showed that narrow border flood (NBF), microjet spray and drip irrigation all use significantly less water than the traditional large-pan flood method of irrigating citrus. However, narrow border flood exhibited several advantages over the others: (1) During drought, NBF uses less water than microjet spray or drip; (2) NBF is significantly less costly to establish; (3) NBF produces higher yields of better quality than traditional large-pan flood, drip or microjet; and (4) Due to the better yields and low cost of implementation, NBF increases net cash farm income, even with current low water prices.

Row Crops. Using surge valves can reduce water usage in furrow irrigation from 22 to 52 percent for a variety of major crops, while maintaining solid yields. However, with the current low cost of water and lack of volumetric pricing in many districts, it is difficult for farmers to justify the added cost of the valves. If volumetric pricing is introduced and water prices rise as projected, the money-savings from reducing water usage would more than cover the cost of the valves, leading to higher net cash farm income.

District Improvements. Using telemetry and supervisory control and data acquisition (SCADA), the Harlingen Irrigation District has networked its pumps, gates, water sensors and other components of its conveyance system. This allows for real-time monitoring of canal conditions and rapid response to changing conditions, reducing losses and improving overall efficiency. The system includes 37 low-cost automated gates that the District developed from off-the-shelf parts to replace their heavy, wooden manual gates. These auto-gates are easily operated remotely with an iPad or computer and produce results in a fraction of the time.

Technology Transfer. The District has found that one of the best ways to get the word out about the project findings is through hands-on demonstrations. The District's auto-gates, telemetry and SCADA are all on display at the Rio Grande Center for Ag Water Efficiency, where they can be demonstrated in a working flume system. The Center provides trainings for district personnel, demonstrations for growers, and calibration of a number of meter types.

The District and its partners organized more than 20 events, from workshops and field demonstrations to the large Irrigation Expos of 2010 and 2011. Project team members also participated in more than 50 conferences and smaller meetings, presenting the project's findings and manning exhibit booths. Factsheets and newsletters were distributed at these events and through the mail and online as well. A plethora of information can be found on the project's website (TexasAWE.org), which also includes a series of videos, news articles, and instructional manuals. These materials, along with the project website and Rio Grande Center for Ag Water Efficiency, will continue to help the agricultural community in the Lower Rio Grande Valley get the most out of the available water supply, long after the end of the project grant.

2. Overview

The ten-year Agricultural Water Conservation Demonstration Initiative, as carried out by the Harlingen Irrigation-Cameron County No. 1 (the District) with funding from the Texas Water Development Board, has been a game-changer for agricultural water efficiency in the Lower Rio Grande Valley. From 2005 through 2015, this project enabled advances in the knowledge and practice of water saving technologies and management techniques, both at the district and on-farm levels, resulting in significant water savings, as shown in Table 2-1 below.

Table 2-1. Estimated improvements in water-use efficiency resulting from project activities each year.

Season	Acre-Feet Saved	Acre-Feet Before Improvement	Estimated Efficiency Improvement
2014-2015	3,648	72,968	5%
2014-2015	2,658	51,740	5%
2013-2014	390	1,384	28%
2012-2013	None, due to drought		
2011-2012	20,000	82,500	24%
2010-2011	3	11	27%
2009-2010	667	8,338	8%
2008-2009	8	58.25	13%
2007-2008	170	576	29%
2006-2007	71	447	16%
2005-2006	19	102	19%

One of the main discoveries from this decade-long study was that numerous opportunities for agricultural water conservation lie within the irrigation districts themselves. As project lead, the District initiated a number of changes in the way it manages and delivers water within its own conveyance system. Automation and other technological improvements were key to their increased efficiency.

Additionally, the project gave regional agricultural experts the rare opportunity to test a broad set of irrigation practices at on-farm demonstration sites over multiple years' time and amidst the Valley's unique weather patterns and mix of soil types. Some results were very encouraging. The project documented a number of low-cost methods for managing on-farm irrigation that actually improve product quality and enhance net farm income in addition to saving water.

These enhancements and demonstrations produced valuable information for other surface water irrigation districts and Valley growers—and came at an opportune time for the Lower Rio Grande Valley. According to the Rio Grande Valley Regional Water Planning Group's 2016 Preliminary Plan, "irrigation represents the largest water demand in Region M (1.4 million acre-feet/year in 2020), but is projected to decrease as a result of both urbanization of lands and increasing pressure on the region's water resources. Supplies available to irrigators are curtailed significantly in drought years." Water shortages in recent years have also been exacerbated by the lack of water releases from Mexico.

Agriculture in Texas has always been and will continue to be a foundation of our state's economy. It is the biggest driver of the economy in the Valley, a $396 million industry, and is heavily reliant on irrigation water. To ensure the continued viability of agriculture in Texas, the farmer will need to do more with less water in the coming years.

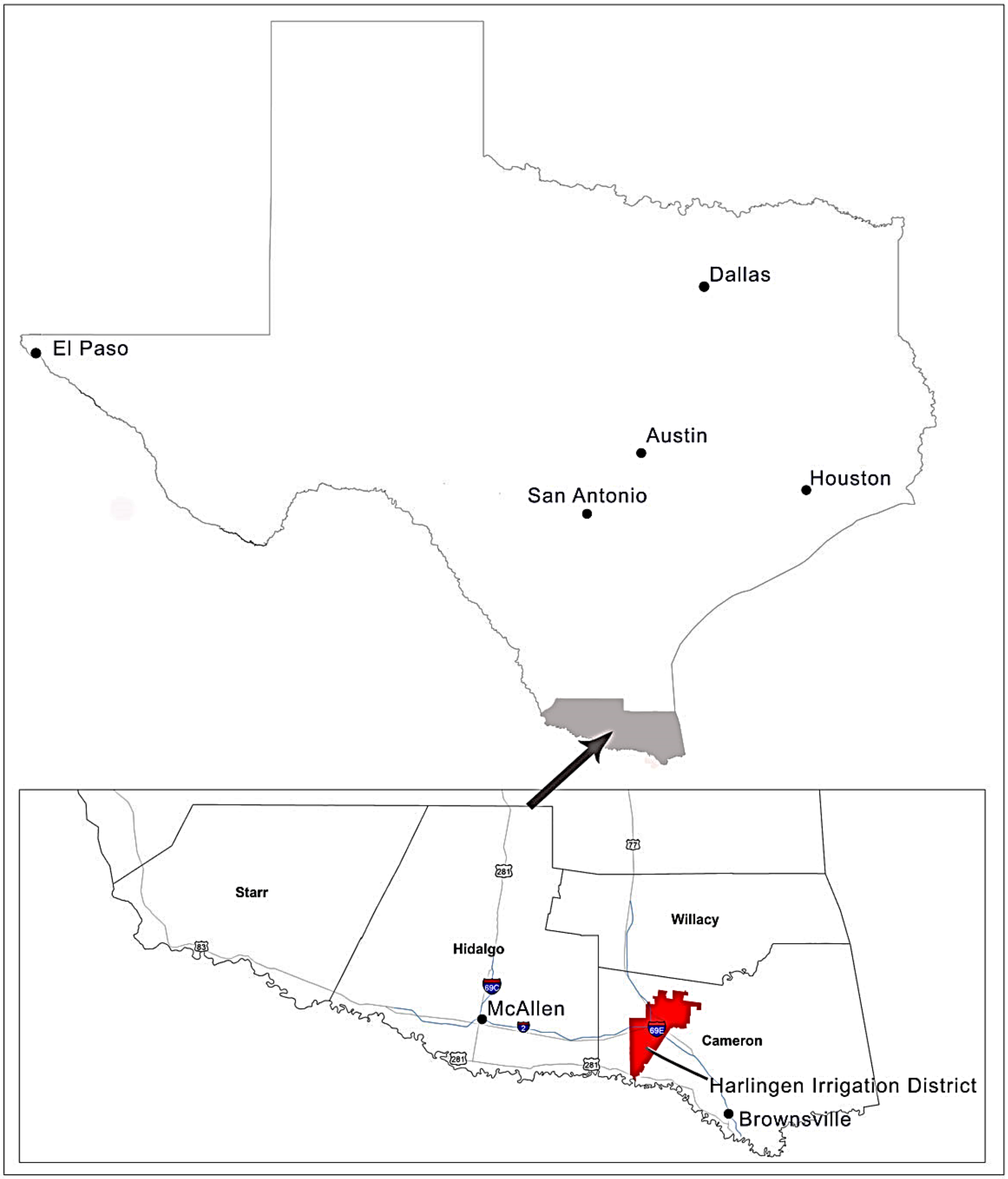


Figure 2-1 Context map of the Harlingen Irrigation District.

Fortunately, there are many opportunities for increasing the efficiency of district operations and on-farm irrigation. The District has taken major steps in making its delivery system more efficient. Its canals, pipelines, auto-gates, and pump houses are now fully integrated into a streamlined, automated system networked by telemetry stations and controlled from a master computer system, which can be accessed remotely by district personnel. The automated system allows for precise delivery of water to producers and quick response to their needs. Examples of these efficient technologies, such as the automated gates developed by the District from off-the-shelf parts, are on display at the Rio Grande Center for Ag Water Efficiency in Los Indios. Building instructions for the gates are also available online (TexasAWE.org) or from the District office.

The study of on-farm irrigation techniques has been a cooperative effort between the District, area growers, and researchers from Texas A&M University-Kingsville and Texas A&M AgriLife Extension Service. The project partners established demonstration sites on existing farms and orchards throughout the region, evaluating the efficacy of large-pan flood, furrow-flood, surge, narrow border flood, drip, microjet spray, and overhead sprinklers. Furrow-flood and large-pan flood have been practiced in the Valley for some time and are the traditional standards to which the other methods in the study were compared. The researchers also monitored crop yield to ensure that quality and quantity could be maintained with the various irrigation techniques.

Significant water savings were observed with several methods, most notably surge irrigation and narrow border flood. Surge, which is used in row crops as an alternative to furrow-flood, used 52 percent less water than furrow irrigation in surgarcane. In seed corn, surge irrigation produced water savings of 28 percent, and two cotton studies demonstrated savings of 22 percent and 31 percent.

Narrow border flood, used mainly in citrus orchards as an alternative to large-pan flood, was found to use 36 percent less water. It is easy and affordable to implement, requiring only the construction of earthen berms between tree rows.

Of course, water-saving irrigation methods will only be used if they make financial sense for the grower. AgriLife Extension conducted fiscal analyses, assessing the economic viability of various irrigation practices. In citrus, narrow border flood, drip and microjet were all shown to increase net cash farm income over large-pan flood because they all produced higher yields. A 2013 analysis by AgriLife Extension showed that with grapefruit, the projected 10-year average net cash farm income for narrow border flood was 5.4 percent more than for microjet, 27.1 percent more than drip, and 67.9 percent more than flood. This study assumed volumetric pricing and water costs rising annually (Young and others).

Of the three tested alternatives to large-pan flood, narrow border flood was shown to be the most economically attractive, especially considering up-front installation costs are significantly higher with drip or microjet spray. Researchers at the Texas A&M-Kingsville Citrus Center have continued refining these water saving technologies, testing several modifications including partial root-zone drying and trench furrow-flood. Partial root-zone drying in particular has shown promising results, with a 41 percent water savings compared to conventional dual-line drip and microjet system configurations, achieved without compromising fruit yield or quality.

However, due to the low cost of water, the efficiencies achieved through the use of some irrigation technologies do not justify the expense of the changes in operation required. With surge irrigation, economic benefits are only seen in 10-year projections that assume rising water prices over time. Additionally, many districts sell water on a per-irrigation event basis, rather than by volume, eliminating the financial benefit to reducing water usage.

To help address this cost barrier to a proven efficient practice, the District partnered with the Rio Grande Regional Water Authority to establish the Surge Valve Cooperative with funding from the U.S. Bureau of Reclamation. Through the end of the Agricultural Water Conservation Demonstration Initiative project, the Surge Valve Cooperative distributed surge valves at a greatly reduced price to area growers, allowing farmers to reduce water use without taking on financial risk.

Another significant area of the Agricultural Water Conservation Demonstration Initiative research was irrigation scheduling, which allows farmers to be more precise in their irrigation application. For example, farmers can use a combination of online tools and in-field equipment to calculate crop water demand by monitoring crop evapotranspiration and measuring moisture levels of the soil. In 2011, project researchers found that some farmers were applying between 7 and 27 more acre-inches to their sugarcane fields than necessary to make up the rainfall deficit. With more than 40,000 acres of sugarcane under cultivation in the Lower Rio Grande Valley, between 20,000 and 90,000 acre-feet of water could be saved with proper irrigation management.

These alternative methods have the potential to significantly increase the efficiency of agricultural water management and use in the Lower Rio Grande Valley. To that end, the project partners have engaged in extensive education and outreach to farmers and irrigation districts. Workshops and field days have provided hands-on demonstrations for growers and farm staff. The Rio Grande Center for Ag Water Efficiency, described in Section 4, provides a much-needed regional classroom for trainings and equipment demonstrations for growers and district personnel.

In 2010 and 2011, the Agricultural Water Conservation Demonstration Initiative team produced two Texas Irrigation Expos to bring agricultural water efficiency findings to irrigation district board members and managers, as well as to producers. Project partners also presented findings at conferences throughout South Texas and even across the United States and abroad. The District engaged WaterPR to develop educational materials that could be distributed at events, by mail, and online. The Agricultural Water Conservation Demonstration Initiative project was renamed the Texas Project for Ag Water Efficiency and a website (TexasAWE.org) was created to publicize the project and house materials such as videos, factsheets, instructional guides, newsletters and reports. These educational materials will continue to be valuable far past the end date of the project.

The Agricultural Water Conservation Demonstration Initiative grant enabled the District and its local partners to find viable water-efficient solutions for Lower Rio Grande Valley's unique agricultural landscape. The study delivered field-tested solutions to producers and districts as they faced a changing environment and economy. Water shortages are a growing problem in the region and will continue to increase in severity as demand grows across water user groups throughout the basin. Increased demand will likely place upward pressure on the cost of water and lead to greater interest in volumetric pricing. Both scenarios are likely to increase the adoption of efficient on-farm practices, making the Texas Project for Ag Water Efficiency project results and educational materials increasingly important to the Texas agricultural industry in the years to come.

3. History and purpose

Water is in high demand in the Rio Grande Valley—in recent years, farmers have seen cuts in allocations due to prolonged drought, a lack of water released into the Rio Grande from Mexico, and growing demand from non-agricultural users. To address this issue, the Harlingen Irrigation District-Cameron County No. 1, under the auspices of a grant from the Texas Water Development Board, sponsored the *Agricultural Water Conservation Demonstration Initiative* to study the maximization of on-farm surface water use efficiency by integration of on-farm methodologies and district delivery system technologies.

The ten-year project included participation by the Delta Lake Irrigation District, Texas A&M University-Kingsville, United States Department of Agriculture Natural Resources Conservation Service, Rio Farms, Inc., AgriLife Extension and agricultural producers in Cameron, Hidalgo and Willacy counties. The project goal was to assist in the implementation of the agricultural water conservation management strategies identified in the Rio Grande Regional Planning Group (Region M) Approved Regional Water Plan and the Texas State Water Plan, and to supplement on-going conservation efforts in the Lower Rio Grande Valley.

According to the 2001 Rio Grande Regional Water Plan, which was the current plan at the start of the Agricultural Water Conservation Demonstration Initiative project, "supply shortages for the irrigation sector are particularly acute" and were projected to increase from approximately 580,000 acre-feet per year in 2001 to nearly 605,000 acre-feet by 2050. Six of the eight irrigation water user groups in the Rio Grande Region were projected to have shortages during the 50-year planning period (Cameron, Hidalgo, Maverick, Starr, Willacy, and Zapata Counties).

Under *Recommended Strategies for Reducing Projected Irrigation Shortages*, the report says, "agriculture is an important industry to the Rio Grande region and is anticipated to remain as a key aspect of the overall economic wellbeing of the area. Meeting irrigation water needs is considered vital to the success of the agricultural industry. It is reported that in 1999, a 20% shortage in water for irrigation resulted in the loss of $400 million to the State's economy and the loss of 8,000 jobs locally. Because of the economics of farming, the amount that irrigators can afford to pay for water is limited. Consequently, development of new water supply sources for irrigated agriculture—whether surface or groundwater—is not seen as a viable strategy. There nevertheless are strategies that could significantly reduce irrigation demand or increase the availability of water for irrigation…. The current studies have confirmed the findings of previous investigations—there are significant opportunities to reduce irrigation water demands through the implementation of efforts to reduce water losses in irrigation district conveyance and distribution facilities, and through the implementation of measures to improve on-farm water use efficiency."

This emphasis on improving efficiency both on-farm and in-district continued in subsequent Regional Water Plans, including the Rio Grande Regional Planning Group's Preliminary 2016 Plan. It states, "the increased pressure on water available for irrigation, combined with the way that water is allocated in drought years, has been difficult for farmers across the region, especially those with perennial crops and citrus or pecan trees. There is a shift toward urbanization and diversification of the economy, but agriculture still plays a major role in the region."

The preliminary plan for 2016 encourages more efficient use of irrigation water, arguing that "making better use of the water that is available is critical to helping farmers through drought, and the Rio Grande Regional Planning Group recommends continued research, education, demonstration, and large-scale implementation of these and any other irrigation conservation measures that farmers find to be appropriate."

The 2002 State Water Plan, which was the current Water Plan when the Agricultural Water Conservation Demonstration Initiative project began, also focused on conservation to close the demand gap for agriculture. "The Planning Groups recommended changing of crop varieties and types, utilizing genetic engineering, voluntarily converting irrigated acreage to dry-land production, utilizing conservation tillage methods, installing efficient irrigation equipment, and lining of irrigation canals to ensure efficiency of delivery systems for meeting future irrigation demands. Additional conservation techniques include laser leveling of fields and automated water delivery control systems."

The 2012 State Water Plan continued to emphasize the need for more efficient use of water. "Conservation strategies for municipal and irrigation water users account for approximately 43 percent of the water associated with the region's recommended strategies. Irrigation conservation strategies account for the majority of these savings, through Best Management Practices including water district conveyance system improvements and on-farm conservation practices."

The importance of increased water-use efficiency in agriculture is as great today as it was when this Agricultural Water Conservation Demonstration Initiative project began, if not more so. The irrigation methods and in-district improvements that have been proven in the field through this project will help the Lower Rio Grande agricultural sector navigate the water-supply challenges ahead. The project partners have made substantial progress in spreading the word about the benefits of these proven technologies, and created educational materials and other resources that will be available online long after the end of the Agricultural Water Conservation Demonstration Initiative project.

4. Rio Grande Center for Ag Water Efficiency

In 2005, the District began work on a water meter calibration facility, modeled after the only other two such facilities in the United States—one in California, the other in Florida. The facility was designed to basically replicate field situations where measuring water volume was critical—for both growers and other irrigation districts. While metering water is not yet mandated in the Lower Rio Grande Valley, it is understood as a best practice and having a mechanism to test the actual measuring device (the meter) was a priority for this grant.

As other educational needs and opportunities were realized throughout the grant period, the meter calibration facility grew into what is now known as the Rio Grande Center for Ag Water Efficiency. Co-located at District's main pumping station in Los Indios, the Rio Grande Center for Ag Water Efficiency is also used for training irrigation district personnel and for demonstrations of technology, like the District's custom-built automated canal gates. The Rio Grande Center for Ag Water Efficiency is Texas's only meter calibration facility with working flumes, multiple pipe sizes, and the ability to control variable water flow rates through the system. It is expected to continue as an essential location for testing and training on agricultural water efficiency for years to come.

A central feature of the Rio Grande Center for Ag Water Efficiency is a working flume system equipped with District-designed automated gates controlled by a Supervisory Control and Data Acquisition system. Visitors can see the technology in action and talk with District personnel experienced in their construction, use and installation. The Rio Grande Center for Ag Water Efficiency is equipped to calibrate meters for other irrigation districts, and also demonstrates a number of different meter types. These hands-on demonstrations are complemented by technology workshops in the adjacent classroom, which also hosts trainings and meetings.

The facility was designed and engineered by Axiom-Blair Engineering, one of the project partners who also developed the capacity to provide real-time flow data from the metering and telemetry system and data from the District's water use accounting system on the District's website. (See Section 5 for more information).

4.1 Initial project construction

The first step in the construction of the Rio Grande Center for Ag Water Efficiency was the purchase of a 12,000 gallon per minute diesel engine driven pump to supply calibration water to the facility. The pump was installed in an adjacent existing pump house. The construction of the facility itself began in April 2006, with the District acting as the prime contractor. The design called for a 60' x 100' x 12' open-sided building, which the District purchased pre-fabricated. Once the building shell was erected, District personnel began construction of the office and meeting room facilities, which were completed in November 2006.

Rio Grande Center for Ag Water Efficiency.

The District began construction of the water conveyance portion of the facility in June 2006 with the construction of the water diversion box. This box is used to divert Rio Grande water pumped from the inlet channel to three pipelines: one to feed the open channel flume, one to feed the closed pipe manifold, and one to discharge to the inlet channel. The overflow from the headwall is diverted back to the inlet channel. Once the diversion box was completed, work started on the open channel flume, designed to demonstrate and calibrate open channel water measurement devices. The flume discharges into the inlet channel allowing for recirculation of water. Four eight-inch discharge pipes were placed along the outside of the flume for canal turnout simulation.

4.2 Control and automation

After the completion of the construction phase, the District concentrated on the automation of the facility. At the Center, a computer was installed with software to allow facility operators to demonstrate methods of total canal automation and control, as well as perform meter calibration. The District also designed and installed a Supervisory Control and Data Acquisition system, a 48- to 24-channel patch panel to route data in and out of the control room, and a wireless interface for communication with external devices such as laptop computers.

The District began by designing automated gates and controllers for the open channel flume. The development of these low-cost alternatives for canal gate automation was funded by a TWDB Agricultural Water Conservation grant. Four automated gates installed in the flume control water levels in each reach of the canal, and they can be controlled manually or remotely by computer. The Supervisory Control and Data Acquisition pack can be programmed to maintain a certain level throughout the canal. Four acoustic level transmitters constantly monitor water levels, and when the volume of water to the canal increases, the gates react and open.

The District also installed four discharge pipes (one per reach) in the flume to simulate field turnouts. When these turnouts open, the automated gates react to maintain a constant level in the canal. This is used for canal-rider training and teaching the basics of canal management. The Supervisory Control and Data Acquisition system that controls the auto-gate is used to demonstrate the use of Programmable Logic Controllers in canal automation.

4.3 Center components

4.3.1 Open channel flume

The open channel flume, pictured below, was fitted with automated gates and several measurement devices, the first being a sharp crested weir. This weir is monitored by the canal automation software using an acoustic level transmitter. Flow measurement is essential when calibrating other flumes such as the circular flume used for tail water measurement in the demonstration sites.

A SonTek Argonaut SW was donated to the project and installed in the third reach of the canal. It is used to monitor flows and demonstrate the many alternatives to open channel flow measurement. The flow data is displayed in the lab using the Rio Grande Center for Ag Water Efficiency’s computer.

A donated Rubicon Gate demonstrates alternatives to open channel flow measurement as well as automatic gate control alternatives.

Flume inlet with sharp crested weir.

Flume with water showing auto-gate.

Training in session at the Rio Grande Center for Ag Water Efficiency.

4.3.2 Closed pipe manifold

The closed pipe manifold was designed to calibrate insertion type meters for pipe sizes ranging 6-inch to 24-inch in diameter, and many flow meter configurations. At the inlet of the manifold are two Siemens certified 6000 Mag flow meters: a 24-inch meter for high flows and a 12-inch meter for low flows. Lengths of 10-inch aluminum pipe were placed into the manifold using adapters, allowing for the installation of 10-inch meters used in aluminum pipe. Two catch basins were added to the discharge of the manifold to allow for the calibration of riser insertion meters. These catch basins are typical of the irrigation turnouts in the District. This configuration allows the calibration of 12-, 14- and 15-inch propeller meters, which are used throughout the District, as well as in many other districts in the Rio Grande Valley. A propeller meter was also installed along with a transit time meter to demonstrate the advantages and disadvantages of both meters. This configuration is also used to demonstrate the calibration process.

A length of clear PVC pipe was placed in the 12-inch section of the manifold to illustrate the problem associated with debris in irrigation water.

Closed pipe manifold.

4.3.3 Calibration tank

In addition to the Mag meters, the District constructed a calibration tank to measure the flow of water volume over time. It was equipped with a level transducer and air control valves to control and monitor flow in and out of the tank. Software was written to enable water input and discharge to be controlled from the lab. Water can be diverted from the open channel flume or the closed pipe manifold into the tank for a more precise flow measurement.

4.3.4 Pump control

To better control flow through the calibration facility, the District developed and installed a variable speed controller for the supply pump motor. The controller includes a Supervisory Control and Data Acquisition pack, throttle controller, and an acoustic level transmitter to monitor water level in the constant head tank. The variable speed pump is controlled from the master control computer located in the lab.

Manifold discharge and calibration tank.

4.3.5 Catwalk and viewing platform

The District constructed a catwalk and viewing platform for access to and viewing of the demonstration area.

Training class photo on the catwalk.

4.3.6 Lab and meeting room

The meeting room features a projector and screen for use during classes, workshops and meetings. A large LCD display connected to the lab's master control computer and visible to the meeting room illustrates the calibration process and other technologies.

Center for Ag Water Efficiency meeting room.

5. In-district improvements

The Harlingen Irrigation District (the District) has taken major steps in improving its canal system to better serve its producers through more efficient management of the water it delivers. The District's 40 miles of canal, 200 miles of pipeline, 37 auto-gates, and 36 re-lift pump houses are now fully integrated into a streamlined, automated system networked by telemetry stations and remotely controlled from a master computer system. This system is accessible by canal riders and other personnel through any electronic communications device—cell phone, computer or iPad, which allows for precise delivery of water to producers and quick response to their needs.

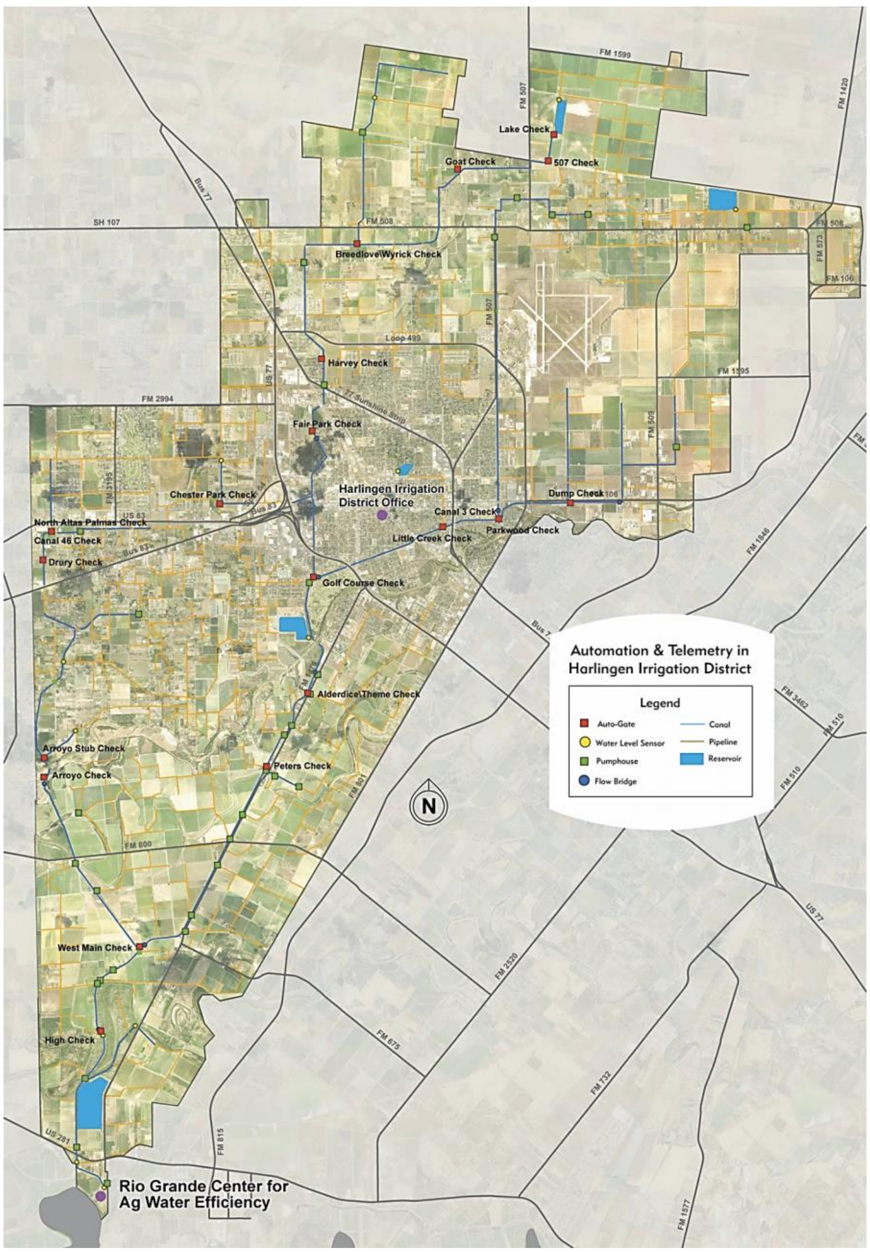


Figure 5-1. **Map of Harlingen Irrigation District.**

5.1 Automated gates & telemetry = water savings

The District's operations have become considerably more efficient with the telemetry and canal automation improvements undertaken by the District and funded by the Texas Water Development Board and the United States Bureau of Reclamation.

In 2005, the District began installing a multi-million dollar automated meter and telemetry system to allow for monitoring and reporting all of its water deliveries. The keys to this system are:

- Telemetry (automatic measurement and transmission of data from remote sources by wire or radio or other similar means); and
- Supervisory Control and Data Acquisition

The District networked its pumps, gates, water sensors, and other components of its conveyance system by means of telemetry stations remotely controlled via Supervisory Control and Data Acquisition. This comprehensive information system allows for real-time monitoring of canal conditions.

The next step was to install automated gates that could respond quickly to changing conditions. With a TWDB Agricultural Water Conservation grant, the District developed and tested its own prototype of an automated gate made of lightweight aluminum and featuring push-button controls. The first gates were installed in 2009 and the efficiencies were immediately apparent: the auto-gate was considerably easier to operate and produced results in a fraction of the time needed to manually change the original heavy wooden gates. The new, automated gates allow for more responsive and, thus, more efficient management of irrigation deliveries. Since 2009, the District has replaced its manual gates with 37 automated gates, all custom-made and installed by district staff.

Automated gates in action.

The gates have sharply curtailed losses in deliveries from canals overflowing into drainage ditches. This is especially true in remote areas of the District, where lateral canals can easily overflow if the gate controlling the flow is not adjusted or shut in a timely manner. In the past, this situation could not be corrected until the canal rider physically inspected the canal. Now, with monitoring equipment strategically placed at selected points along the canal, staff are notified within minutes if the canal reaches a critical condition, and can use the automated system to correct the condition immediately.

This efficiency translates into considerable water savings. Based on historical use of the lateral canal and the maximum number of irrigation heads that can be used in an irrigation period, the District estimates that one overflowing weir, if left uncorrected, can potentially lose six to ten acre feet of water over a 24-hour period. The District's canal system has seven overflow weirs; the automated gates are estimated to save between 40 and 70 acre-feet of water per irrigation period. In 2011, after one year of operating the automated system, the District saw an increase in efficiency of more than 20 percent, saving approximately 20,000 acre feet of water.

Remote control of the gates also translates into considerable savings of staff time and effort. Now canal riders can make adjustments from a variety of linked-in devices rather than driving to remote points within the 88 square miles encompassed by the District. And by maintaining a consistent level in the canals, farmers can irrigate their fields faster and use the water more efficiently.

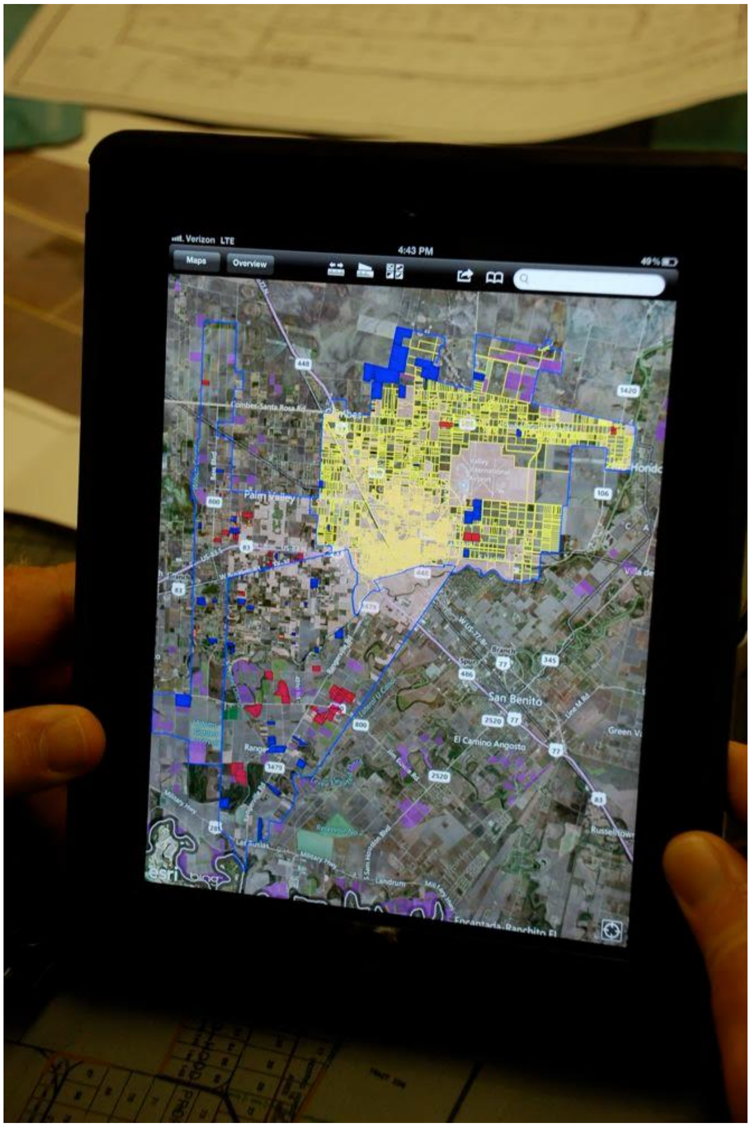
The auto-gate design uses readily available, off-the-shelf components for a low cost of $3,500 per gate (including actuators and controllers). Adding the full complement of Supervisory Control and Data Acquisition features brings the total cost to about $10,000 per gate—still well below the price tag for commercially available automatic gates. As an added value, the time and costs for the district to build and install its own automated gate system qualified as a "local match" for cost-sharing grants from the Texas Water Development Board and the United States Bureau of Reclamation.

Detailed instructions for the gates, along with parts lists, drawings, and other supporting information, are available to other districts for free from the Texas Project for Ag Water Efficiency website and from the District office. These auto-gates have been adopted by El Paso Irrigation District and Lower Colorado River Authority for use in their conveyance systems.

5.2 Geographic Information System software enables more accurate water tracking

The District also has realized a major advancement by integrating Geographic Information System software into its operations. In 2012, District replaced the application it previously used for displaying district maps and water use information with ESRI's ArcGIS for desktop (ArcMap). With this software, the District can catalog, map, and analyze its geographic information and publish maps and data in a way that makes them easily accessible for canal riders. The easy-to-use web maps turn data into information that staff can use in real-time on the job from any telecommunications device.

In addition, canal riders always have up-to-date information on water orders and canal conditions, whether in the office or out in the field. As water orders are made, the associated block of land is highlighted on the District map, providing canal riders with an up-to-date, visual reference. This enables them to monitor water sales throughout the District, ensuring growers are applying water to the correct parcel and buying the proper amount of water for each parcel.



Canal riders can monitor flows to each parcel in the Harlingen Irrigation District.

Proper accounting of irrigated properties is important in the Rio Grande Valley, especially in a drought. If for some reason the District is required to allocate water, properties that have not been irrigated in the past two years run the risk of not receiving an allocation. The Geographic Information System technology and the maps created based on the District's water accounting data have been very useful in ensuring that all properties located in the District receive the irrigation water to which they are entitled, and that growers do not suffer because of an accounting mistake. This also gives the District Watermaster a better grasp of the water ordered at any time throughout the day, which allows him to more efficiently order water for the entire district.

The District also replaced netbooks that canal riders had previously used to monitor operations with iPads. The iPad has proven to be a much more efficient platform. Canal riders can access the telemetry system from the field to adjust gates and view canal information, as well as act on water tickets. They also can mark and post locations of leaks directly to the District map as well as post and view pictures of trouble areas. With ArcMap, District also has better control of data storage and greater flexibility in creating and maintaining all maps in-house.

5.3 Online real-time data helps producers make irrigation decisions

In 2005, the District launched a website to make data and services more accessible to its producers. Axiom-Blair Engineering initially programmed the website to display flow measurement data from the telemetry server in real-time. Additional meters and rain gauges were linked to the web as those devices became operational. The site provides real-time data on rainfall and soil moisture content to assist producers in scheduling the timing and amount of irrigations.

Software was developed to allow farmers secure access to on-farm flow meter records, water use charges, and water billing from the District's accounting system. However, the user interface for accessing charges and billing information proved to be very cumbersome, and was not being used by the farmers. That website feature was discontinued in 2010 and the District is currently assessing other potential uses for that data, including integrating it into the geographic information system.

6. On-farm improvements

The maximization of on-farm surface water use efficiency in the Lower Rio Grande Valley was one of the central goals of the ten-year Agricultural Water Conservation Demonstration Initiative project. The Harlingen Irrigation District (the District) and a number of local partners teamed up to evaluate the efficacy of existing alternative irrigation methods in the unique South Texas environment, comparing them with more traditional irrigation methods such as large-pan flood and furrow-flood. Each method was evaluated on multiple demonstration sites, assessing water use, crop yield, and economic viability.

The bulk of research was performed at demonstration sites on existing fields and orchards in Cameron, Hidalgo and Willacy counties. Beginning in 2005, the project researchers worked with agricultural producers to establish sites that represented a variety of crops, soils, and field conditions, and that could be closely monitored for water use and crop quality.

The research partners, described below, focused on identifying methods that would not only be water-efficient, but also easy to implement in commonly grown crops, with an emphasis on practices that are cost effective and therefore more likely to be adopted by a large number of growers.

Research partners:

- The District studied surge irrigation, subsurface low-pressure drip irrigation, overhead sprinklers, and the more traditional furrow-flood irrigation. Surge was studied in sugarcane, cotton and field corn. Low-pressure drip was studied in cotton, and various overhead sprinklers were tested with turf grass and grass pastures.
- Texas A&M University-Kingsville and AgriLife studied large-pan flood, polypipe furrow/flood, drip, narrow border flood and microjet spray irrigation. Their sites encompassed a variety of crops including young and mature citrus (grapefruit, orange and tangerine), onions, celery, tomato, corn, cotton and sorghum.
- AgriLife also looked at irrigation scheduling using water-needs calculations from soil moisture data and evapotranspiration estimates from local evapotranspiration network systems.
- Economic evaluations of the tested on-farm technologies were performed by the AgriLife Financial and Risk Management Assistance program.

6.1 Surge, low-pressure drip and overhead sprinklers

The District evaluated surge irrigation, subsurface low-pressure drip irrigation, and overhead sprinklers, comparing them with the more traditional furrow-flood irrigation. A full list of demonstration sites is available in Appendix A. The District found significant drawbacks with both low-pressure drip and overhead sprinklers, but surge irrigation proved to be highly efficient, as well as economically advantageous to adopt over the long term.

6.1.1 Overhead sprinklers & low-pressure, sub-surface drip

Pressurized irrigation systems like overhead sprinklers use much less water than furrow-flood, apply water with high uniformity, and have lower labor costs. However, the initial cost for equipment is high and ongoing energy demands are substantial. The District established four demonstration sites with overhead sprinkler systems—one Low Elevation Spray Application pivot, one mini-pivot, one side-roll sprinkler, and one water cannon. The goal was to study water use, energy use, irrigation uniformity, and cost-efficiency. Unfortunately, the agricultural producer partners quickly determined that implementing a long-term commitment to these systems was not financially viable or advantageous, and thus did not continue with the research, and all but one site was abandoned. Rather than establish new demonstration sites, the researchers decided to discontinue the study of overhead sprinklers since they were expensive and energy-intensive to operate. Farmers had to lift the water multiple times, and it was decided that the energy and expense required to lift and pressurize the water outweighed the potential water savings.

The District also established two demonstration sites, comprising 2.6 acres and 17 acres, using low-pressure sub-surface drip for growing cotton. These sites were used for only one season as the technology was quickly found to be problematic when used with unfiltered surface water, rather than with cleaner groundwater. These systems were originally designed to be used with water low in total suspended solids in order to avoid emitter clogging.

6.1.2 Surge irrigation

Surge irrigation is a modified form of furrow-flood irrigation that employs a surge valve between two lengths of polypipe. In furrow-flood irrigation, which is commonly used in the Lower Rio Grande Valley in crops such as cotton, sugarcane and seed corn, water is typically lost to seepage or runoff at the end of the row. The longer the row, the longer the water takes to reach the far end of the field, and the more infiltration occurs below the effective rootzone of the crop. A great deal of water is lost beyond the roots of the crop.

Surge valve with solar-powered controller.

With surge irrigation, the amount of water infiltrating is greatly reduced. A solar powered timer switches the surge valve and the water from one side of the field to the other. The first application flows down a short portion of the row, then water is sent the same distance down the other side. This process is repeated until water has reached the end of the row on both sides. These intermittent quick shots of water effectively seal the soil, so each subsequent water release flows faster over the surface of the already-wetted soil, reducing infiltration water loss below the rootzone. This method allows a more precise application of water, and when employed properly, can also lead to a significant reduction in the volume of tailwater loss.

A growing body of research has found that surge irrigation's intermittent application of water can make water distribution more uniform, while at the same time reducing the total volume of water applied, and diminishing water losses from runoff and nutrient and agrochemical loss from fields.

However, studies have also shown that the surge effect is very dependent on soil conditions. In particular, surge often works less well with fine-textured, cracking soils, the type most often found in the drainage areas of the Lower Rio Grande Valley. Prior to the Agricultural Water Conservation Demonstration Initiative study, field evaluation of surge irrigation in the region had been limited, so this research filled an important gap.

To begin the surge study, the District established three demonstration sites in 2005 on farms growing sugarcane, cotton, and fall corn. Meters were used to measure the applied water amounts as well as any tailwater flowing from the end of the rows. Soil moisture sensors measured how deeply the water infiltrated into the soil profile. These sites were compared to fields using three different methods of flood irrigation – fall corn and sugarcane using traditional furrow-flood irrigation with polypipe, coastal Bermudagrass using flood irrigation with an open permanent ditch, vegetables furrow irrigated with gated aluminum pipe, and corn with large-pan flood irrigation. Over the course of the project, the District monitored surge and furrow-flood on 10 demonstration sites totaling 328 acres. A full list of demonstration sites can be found in Appendix A.

The District also studied the effectiveness of fertilizer distribution with surge and furrow-flood irrigation. Soil samples were taken before and after the fertigation event to compare the distribution of fertilizer in each field. Sixty-four percent more nitrate made its way into the soil in rows irrigated with surge than it did in rows irrigated with furrow-flood (111 parts per million versus 40 parts per million). The vast majority of nitrates were found in the first foot of soil, but small amounts infiltrated into the second and third foot of soil, though slightly less in the surge-irrigated rows.

Water efficiency findings

After eight years of research in the Lower Rio Grande Valley, the project researchers found that surge irrigation used significantly less water than traditional furrow flood. In sugarcane, surge irrigation used 52 percent less water than furrow irrigation. In seed corn, surge irrigation produced water savings of 28 percent; two cotton studies demonstrated savings of 22 percent and 31 percent (Table 6-1).

Table 6-1. On-farm demonstration results for surge vs. furrow irrigation.

	Volume of water used/acre (in acre-inches)		
Crop (date)	**Furrow**	**Surge**	**Savings with surge**
Sugarcane (2005)	20.68	14.64	52%
Cotton (2005)	19.53	13.48	31%
Seed Corn (2007)	23.95	17.31	28%
Cotton (2010)	18.00	14.00	22%

Water applied using surge irrigation was also found to infiltrate more evenly than that applied using furrow-flood, which is often characterized by deep percolation due to unequal infiltration. In other words, in furrow-flood, water at the front of each row where the irrigation is applied continues to percolate deeper as water flows to the end of the row. Consequently, infiltration is much deeper at the start of the row than at the end. This is generally not the case with surge because the effect of having reduced infiltration rates over at least a portion of the field is that advance rates are increased, preventing excessive percolation.

Therefore, the infiltrated volume of water during an irrigation event is an important measure of the relative performances of surge and furrow-flood. As shown in Table 6-2 below, a 2012 study comparing surge (Surge 1 and 2) and furrow-flood (Continuous 1 and 2) in two irrigation events on a 30-acre sugarcane field showed that less water was applied with surge irrigation: the maximum amount applied totaled 3.5 inches with surge compared to 4.4 inches with furrow-flood. Surge irrigation allows higher application efficiencies and higher irrigation uniformity because less water is required to complete the advance phase.

Table 6-2. Furrow-flood vs. surge irrigation in four plots.

Event	**Application rate**		**Input volume**	**Runoff**	**Infiltrated volume**	**Application depth**	**Application efficiency**
	GPM[a]	Ac-in per hr[b]	Ac-ft[c]	Ac-ft	Ac-ft	**(inches)**	**(%)**
Cont. 1	1580	3.5	12.53	1.58	10.95	4.4	87.4
Cont. 2	1361	3.0	10.32	0.44	9.88	4.0	95.7
Surge 1	1454	3.2	7.08	0.84	6.24	2.5	88.1
Surge 2	1331	2.9	8.96	0.30	8.66	3.5	96.6

[a] GPM = gallons per minute

[b] Ac-in per hr = acre-inches per hour

[c] Ac-ft = acre-feet

Monitoring and managing water application events are also keys to irrigation efficiency—even water-saving technologies can waste water if not used properly. Once the targeted application depth is applied, irrigation needs to be shut off to reduce runoff and deep percolation. The researchers closely monitored and managed all irrigation events, yielding high application efficiencies with very little runoff. As shown in Figure 6-1 on the next page, the maximum runoff produced was 12.6 percent (from furrow-flood). Surge irrigation produced slightly less runoff, about one-half.

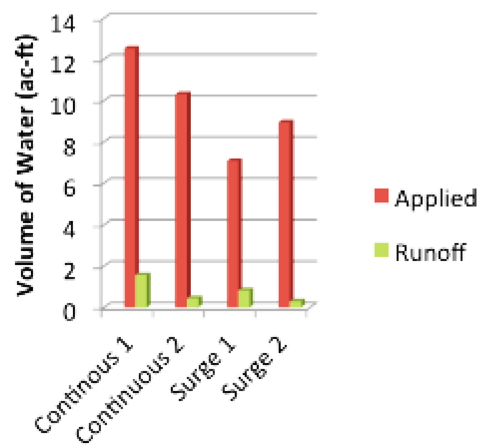


Figure 6-1. **Volume of applied water and runoff in furrow-flood versus surge irrigation in four plots.**

Surge irrigation is especially promising for early-season irrigations, as well as shallow-rooted crops, where high infiltration rates with furrow-flood can result in low application efficiencies.

Broader implications

As part of the process that produced the 2011 Rio Grande Regional Water Plan, Texas Water Development Board economists calculated the acreage and water use of irrigated crops in the Region M planning area. Some 27 percent of the total amount of water used for all irrigation is consumed by cotton and sugarcane, two crops where surge valves have produced demonstrated water savings.

- According to Texas Water Development Board, 42,000 acres in the region are planted in sugarcane and 59,000 acres in cotton.
- In sugarcane, the Texas Project for Ag Water Efficiency studies found that surge valves produced 52 percent savings in water consumption. If all 42,000 acres of sugarcane fields in the region were irrigated using this method, water savings could amount to 56,000 acre-feet per year.
- In cotton, savings of 22 percent were realized in one study and 31 percent in the other. Using surge valves for all 59,000 irrigated acres of cotton could produce water savings as high as 30,000 acre-feet per year.
- Through the Surge Valve Cooperative, described further in the Education and Outreach chapter, 28 surge valves were distributed to local farmers, each of which was capable of irrigating 50 acres at a time. Based on average irrigation amounts for furrow flood irrigation in the District, compared to actual irrigation amounts on the surge demonstration site, each valve can save 17.75 acre-feet of water per irrigation. The 28 valves in operation are projected to save a total of almost 497 acre-feet per irrigation.

The information obtained from the surge research will also continue to help educate farmers on water savings potential. Project data on infiltration was put to use in the WinSRFR surface irrigation tool developed by the United States Department of Agriculture's Agricultural Research

Service. This computer model is used to train farmers and develop guidelines on how they can manage their irrigation systems more efficiently and conserve water. The system graphically illustrates the infiltration and runoff processes when different flow rates and irrigation times are used during the simulation. The surface irrigation model is generally used to determine the optimum irrigation time and flow rate for achieving desired performance criteria when soil infiltration is known.

Economic findings

While significant water savings can be achieved through the use of surge irrigation, there is currently little economic incentive to adopt the technology—economic benefits are only seen in 10-year projections that assume rising water prices over time. According to economic analyses conducted by specialists from the AgriLife Financial and Risk Management Assistance program, the cost of water in the Lower Rio Grande Valley is currently too low to justify producers investing up to $2,200 for the valve and meter. With no significant differences in crop yields, the additional costs of a surge system reduces the net returns per acre compared to furrow-flood. Additionally, many districts sell water on a per-irrigation event basis, rather than a volume basis, eliminating any financial benefit to reducing water usage. Existing state laws indicate that irrigation water is to be sold by volume, but a lack of metering equipment makes these laws unenforceable. The current price of water is too low to justify districts implementing a metering program.

Water shortages are a growing problem in the region and will continue to increase in severity as demand grows across water user groups throughout the basin. Increased demand will likely place upward pressure on the cost of water and lead to greater interest in volumetric pricing. Both scenarios are likely to increase the adoption of efficient on-farm practices, including surge irrigation.

Financial and Risk Management Assistance program analyses have shown that as the price of water rises, surge valves become more economical than furrow-flood. In the 2011 Financial and Risk Management Assistance Focus paper 2011-2, “Furrow vs. Surge Irrigation in Cotton Assuming Restricted Water Availability in the Lower Rio Grande Valley,” results indicate that incentives to invest in and adopt surge irrigation begin at $2.34 per acre-inch for in-district pricing.

In the Financial and Risk Management Assistance Focus Series paper 2013-4, “Water Savings and Higher Profit Margins Possible in Cotton and Other Field Crops in the Lower Rio Grande Valley,” economist Mac Young evaluated data on the amount and cost of water used plus expenses for labor and equipment required for furrow and surge in irrigated cotton, using actual 2013 water pricing scenarios in the Lower Rio Grande Valley.

- “In-district” pricing (meaning the district owns the water rights) at $18 per acre-foot, or $1.50 per acre-inch; and

- "Out-of-district" pricing (where water is purchased from another district or grower owning the water rights, often during times of water shortage in the home district) at $37/acre-foot with 15 percent water loss and a $18/acre-foot pumping charge, or $5.40 per acre-inch.

This case study assumes rising water prices throughout the 10-year projection period, as well as volumetric pricing. As shown in the following Table 6-3, the analysis found over a ten-year period that despite a $2,000 price tag for a surge valve, under both scenarios, "the additional cost of a surge valve is covered by the water cost savings from using less water." Furthermore, "the NCFI (net cash farm income) advantage of surge over furrow improves significantly as the price for irrigation water increases," a situation becoming increasingly more common due to drought and reduced inflows into the Rio Grande. Under this scenario, surge irrigation produces a 10-year average cash flow of $363 per acre, 56 percent higher than furrow.

Table 6-3. Surge beats furrow in cotton: lower costs and higher cash flow.

	In-district water* ($1.50/acre-inch)		**Out-of-district water* ($5.40/acre-inch)**	
Cost per acre per year	Furrow	Surge	Furrow	Surge
Water	$27.00	$21.00	$97.20	$75.60
Polypipe and labor	37.00	37.00	37.00	37.00
Surge valve (over 10 yrs)	-	5.13	-	5.13
Total costs/acre	**$64.00**	**$63.13**	**$134.20**	**$117.73**
10-year average financial indicators	Furrow	Surge	Furrow	Surge
Total cash receipts/acre	$1,024	$1,024	$1,024	$1,024
Total cash costs/acre	892	891	985	963
Net cash farm income/acre	132	133	39	61
Cumulative 10-year cash flow/acre	$1.368	$1.382	$252	$363
Cumulative 10-year cash gain/acre	-	$14	-	$111

*Based on actual 2013 water-pricing scenarios in the Lower Rio Grande Valley: *"In-District"* = grower owns the water rights at $18/AF; *"Out-of-District"* = grower acquires water from another district at $37/AF with 15% water loss plus $18/AF pumping charge

An earlier analysis of surge in sugarcane (Financial and Risk Management Assistance Focus Series paper 2013-1) found economic incentives for using surge in sugarcane. Ten-year average financial indicators showed surge with a three percent net cash farm income advantage, even with the lower in-district price of $1.32 per acre-inch. With out-of-district prices, the advantage increased to almost 19 percent.

In-district water prices were the same in 2014 as 2013. If tighter water supplies and higher pricing persists, and metering is used to manage water supplies and delivery by irrigation districts, then surge irrigation may be more widely accepted by producers as a viable alternative.

Surge Valve Coop participants with their new surge valves.

In summary, the economic incentives for producers to switch to surge irrigation systems will likely be determined by the future availability and cost of water in the Lower Rio Grande Valley.

In the meantime, a grant from the United States Bureau of Reclamation made it possible for Lower Rio Grande Valley growers to receive surge valves for a reduced price of $300 along with training from District grant partners. More information about this program can be found in the Education and Outreach chapter.

6.2 Narrow border flood, drip and microjet spray

Texas A&M University-Kingsville and AgriLife studied large-pan flood, polypipe furrow/flood, drip, narrow border flood and microjet spray irrigation. The project managers, Dr. Shad Nelson of Texas A&M University-Kingsville and Dr. Juan Enciso of AgriLife in Weslaco, partnered with local growers to establish demonstration sites encompassing between 520 and 812 acres, depending on the year. The sites grew a variety of crops including mature citrus (grapefruit, orange and tangerine), onions, cantaloupes, celery, tomato, corn, cotton, sorghum, turf and pastures. See Appendix A for a full list of demonstration sites.

The purpose of collecting data on these demonstration sites was to establish a “baseline” to represent actual water use in the Lower Rio Grande Valley, so the researchers did not redirect the water management practices of the growers.

To assist in monitoring water use and crop water consumption, each demonstration site was equipped with soil moisture sensors and real-time automatic data-logging units. Soil moisture sensing devices measured the depth to which irrigation water moved within different cropping systems and soil types. These instruments were relatively inexpensive and easy to use, enabling growers to know ‘real-time’ soil moisture data in the field at the push of a button.

On-site rain gauges were also supplied and attached to data-logging equipment to determine the amount of rainfall from rain events, assist in calculating total annual rainfall, and to help growers distinguish between rainfall and irrigation events, since soil moisture sensors respond to both in the field. Significant rainfall events observed in the soil profile assisted growers in making irrigation scheduling changes. This data was collected and monitored in tandem with the water metering equipment. Water meters were supplied at each location to keep track of the quantity of water applied during an irrigation event, as well as the total applied during the growing season at each site.

6.2.1 Citrus

Citrus production is a major part of the Lower Rio Grande agricultural industry, valued at approximately $45.8 million annually (Ribera and others). Data collected from collaborating growers' citrus demonstration sites provided meaningful results about alternative irrigation practices to the traditional 'large-pan' flood irrigation practice, which is prevalent in Lower Rio Grande Valley citrus production. This is the standard to which alternative irrigation methods – narrow border flood, microjet spray, and drip – were compared.

The large-pan method involves flooding the entire grove with approximately six inches of water, between four and ten times per year depending on annual precipitation. Figure 6-2 on the following page includes seven figures that illustrate the difference between narrow border flood and large-pan, or traditional flood. Orchards using traditional large-pan flood typically have three to five rows of trees irrigated between raised berms (Fig. 6-2-1a). Cultivation practices between tree rows lead to lower soil elevation than underneath the citrus trees' canopy, which alters water flow (Fig. 6-2-1b). Water typically has to fill up the lower elevations between the tree rows and down the entire length of the row before the water fills in underneath the tree canopy. Non-uniform watering occurs underneath the trees as water rises to meet the highest soil surface level underneath the tree canopy (Fig.6-2-1c). Citrus irrigators wait until the entire soil surface is covered with water, resulting in deep percolation and loss of fertilizer and pesticides beyond the rooting depth of trees (Fig. 6-2-1d).

Traditional large-pan flood.

Narrow border flood.

Generally, one inch of water moves chemicals such as pesticides 6 to 12 inches into the soil profile, so a single 6-inch irrigation event moves the chemicals 3 to 6 feet into the soil, depending on soil type. This is a concern not only because those chemicals can no longer do their job, but also because the water table in the region is often only 5 feet below the surface, so the chemicals can leach into the groundwater.

Narrow Border Flood involves minor modifications to large-pan flood irrigation and has been shown to result in dramatic water savings. Raised berms are established between each tree row (Fig. 6-2-2a) that channel water down the row and underneath the tree canopy at a faster rate, minimizing deep percolation, and ensuring that the water reaches the trees' drip-line where the roots can absorb it (Fig. 6-2-2b). By reducing the surface area that gets flooded, farmers can irrigate effectively with less water. This technique also keeps fertilizer, fungicide and herbicide closer to the trees where they are needed, allowing growers to reduce the amount used.

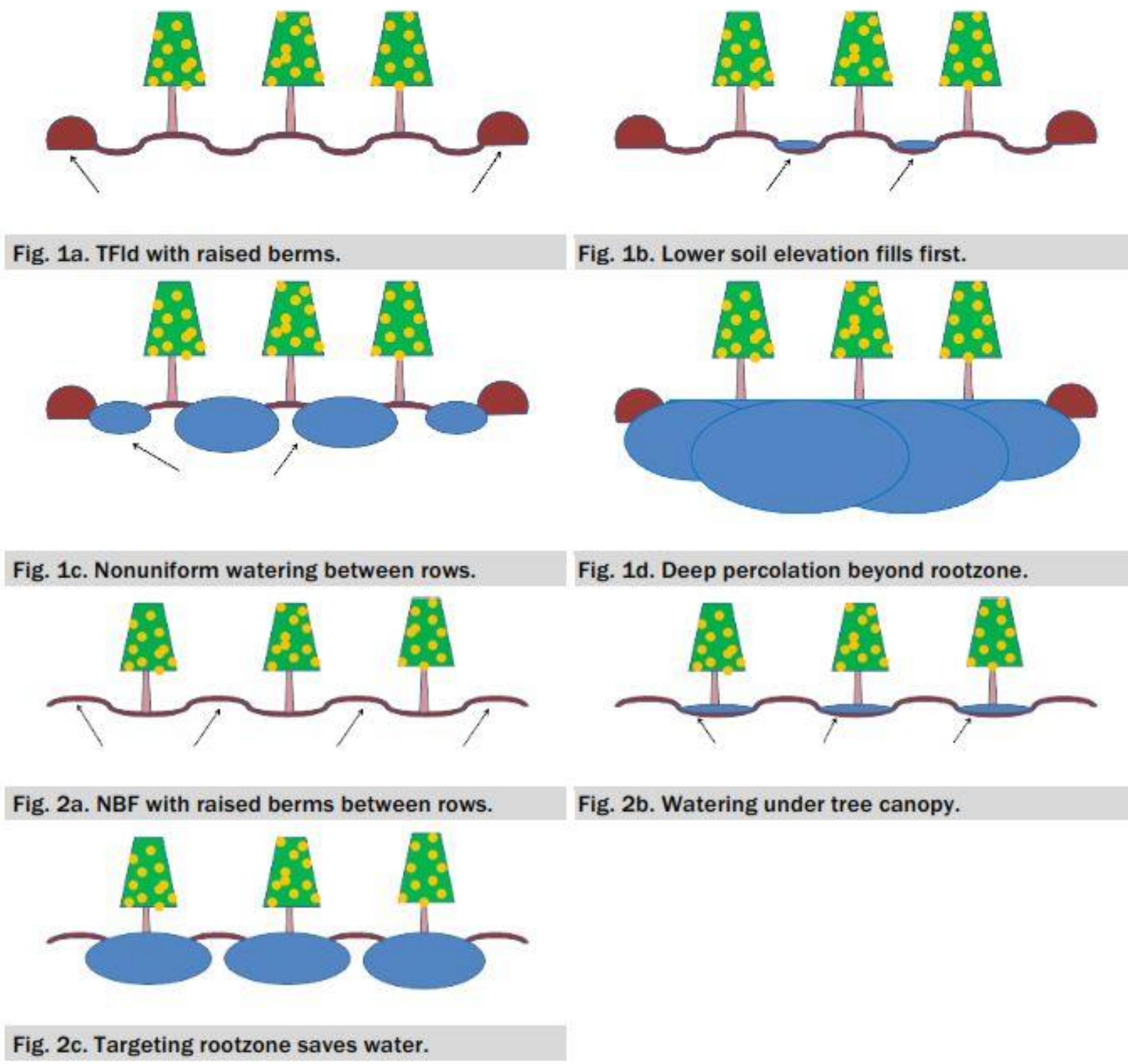


Figure 6-2. **Large-pan flood compared to narrow border flood. (1a-1d; 2a-2c).**

The other two alternative irrigation methods tested were microjet spray and drip. Microjet is good at targeting water underneath the tree canopy where most feeder roots are located, and can easily irrigate the entire root zone. Researchers also evaluated dual and single line drip systems, which are most commonly run parallel to the tree rows. A drip irrigation system can save water because it wets only about 33 percent to 50 percent of the surface area. In addition, a drip system can apply fertilizer quickly, efficiently and uniformly (Enciso and others).

Drip irrigation systems require filtration to prevent emitter clogging, so many farms have settling ponds where sediments and small particles from the pumped canal water can settle out. The water is then filtered before entering the irrigation lines. Water retention ponds and cisterns are also helpful for holding water for later use, especially in the Lower Rio Grande Valley where districts deliver water on a per-event basis. Since microjet and drip systems are typically turned on weekly, and more so during times of drought, ordering a water delivery every week is both costly for the growers and an inefficient use of water.

Water savings

Over the course of the study, the researchers encountered a broad spectrum of weather conditions from extended, severe drought to high rainfall years and flooded fields. Thus, the data collected provides an adequate picture of the weather extremes that farmers must adjust to in the Lower Rio Grande Valley.

From the start, it was clear that the alternative irrigation practices of narrow border flood, microjet and drip provided water savings over large-pan flood. Data collected from on-farm demonstration sites from 2005-2009 indicated that the average amount of irrigation water applied annually was 36.6 inches with large-pan flood, 27.3 inches with narrow border flood, 24.4 inches with microjet spray, and 22.9 inches with drip. Each irrigation method was tested on four different demonstration sites during that period. All three alternatives proved to be better options than large-pan flood. In subsequent years of the study, however, narrow border flood would emerge as the clear winner in regards to water savings, especially during times of drought -- the most water-efficient, the most economical and easy to implement.

Results from demonstration sites in 2013 showed the biggest water savings coming from narrow border flood, which used 16 inches less water per growing season than large-pan flood, 9 inches less than dual-line drip and 3 inches less than microjet, as shown in Table 6-4 below.

Table 6-4. Water savings from modifying traditional flood irrigation with efficient alternatives.

Irrigation method (with total acreage of demonstration sites)	**Water applied** (average inches/acre)	**Demonstrated water savings**			**Potential savings valley-wide** (acre-feet)
		Inches/acre	**AF/acre**	**Total (AF)**	
Large-pan flood (105 acres)	48.0	-	-	-	-
Narrow border flood (108 acres)	**32.0**	**16**	**1.33**	**143.6**	**37,240**
Dual-line drip (16.6 acres)	41.0	7	0.58	9.6	16,240
Microjet (15.5 acres)	35.0	13	1.08	16.7	30,240

Note: All data from 2013 harvest season; Water savings = (inches applied with large-pan flood) – (inches applied in alternate methods); Acre-feet/acre = inches/acre ÷ 12.

Narrow border flood used less water than microjet or drip in part because during the extreme drought of 2011 through mid-2013, growers using drip and microjet spray turned on their systems more often and for longer periods than they had during more normal rainfall years. Also, researchers found that growers with mature citrus trees needed to use two drip lines per row rather than relying on a single drip line, and consequently ended up using more water. Single-line drip is sufficient for trees that are irrigated that way from a young age, but changing mature trees from flood irrigation or dual-line drip to single-line drip causes significant stress.

2012 harvest results for Rio Red Grapefruit showed that microjet, dual-line drip and narrow border flood irrigation can all produce high yields, and that narrow border flood did so using the least amount of water, as shown in Table 6-5 below. Fields irrigated via microjet used 10 percent and 14 percent more water than narrow border flood; those using dual-line drip used 16 percent and 19 percent more water. Fields irrigated via traditional flood used 26 percent and 32 percent more water than narrow border flood.

Table 6-5. Yield and water use for 2012 Rio Red grapefruit harvest.

Grower	Irrigation method	Water to crop (inches)			Excess water over NBF	Yield (tons/acre)
		Irrigation	Rain	Total		
"A" North	Narrow border flood	36	5.7	41.7		**27.8**
"A" South	Narrow border flood	36	5.7	41.7		18.2
"B"	Microjet	45	1.2	46.2	10%	**26.3**
"C"	Microjet	47	1.7	48.7	14%	18.1
"C"	Dual line drip	48	1.7	49.7	16%	16.3
"B"	Dual line drip	50	1.2	51.2	19%	**26.0**
Citrus Center	Traditional flood	54	2.1	56.1	26%	20.0
"C"	Traditional flood	60	1.7	61.7	32%	17.0

Project researchers further evaluated narrow border flood compared to large-pan flood in 2012, conducting a replicated study using two identical plots. They metered the total amount of water required to irrigate tree rows by each method in three separate irrigation events for three rows of trees occupying the same area. The results complemented the previous findings from the demonstration sites. As shown in Table 6-6 below, narrow border flood used 35 percent less water. The technique also moved water more efficiently across the field.

Table 6-6. Comparison of water use in narrow border flood and traditional large-pan flood irrigation.

Flood irrigation method	Irrigated 3-row area (acre)	Time to irrigate area (hours)	Water applied (gallons)	Water applied (acre-feet)	Water applied (acre-feet/acre)
Traditional (TF)	0.73	1.87 (±0.29)	31,738	0.50(±0.09)	0.68
Narrow Border (NBF)	0.59	0.69(±0.12)	25,818	0.32(±0.07)	0.44
TF - NBF	0.14	1.18	5,920	0.18	0.24

The data shown in Table 6-6 shows water savings from a single irrigation event. Depending on rainfall, citrus growers will flood irrigate between five and 11 times each year. If narrow border flood were applied to the entire 28,000 acres under citrus production in the region, it would save between 33,600 and 73,920 acre-feet per year.

Economic findings

Economic analysis of eight years of project data (2005-2012) has shown that in addition to water savings, there are economic incentives to adopt narrow border flood, microjet spray and drip technologies. The economic incentives are especially evident when taking into account fruit quality and yields. The economic analysis confirmed that these alternative irrigation methods maintain the quantity of yields while actually improving yield quality, meaning higher net cash farm income for producers.

In the Financial and Risk Management Assistance Focus Series paper 2013-5, “Increased Water Use Efficiency and Profitability in Citrus Production Possible in the Lower Rio Grande Valley,” grapefruit results show that narrow border flood, microjet and drip have an economic advantage over large-pan flood. Grapefruit growers make their money on the amount of fruit that is sold to the fresh market. The fresh market ‘pack-out’ is classified into two categories, ‘fancy’ and ‘choice.’ Fruit in the fancy category brings a higher price to the grower. Fruit that is not sold to the fresh market is largely processed for juice. In most years the amount of money obtained by the grower for grapefruit juice is nearly equal to the input costs to grow the fruit, so the juice market for grapefruit does not provide the grower any economic gain. The grapefruit growers in the Lower Rio Grande Valley who have a higher percentage of pack-out going to the fresh market will end up with the highest economic gains.

Looking at the average yields and pack-out from growers in 2005 through 2012, AgriLife Financial and Risk Management Assistance program researchers found the highest average amount of fruit going to the fancy category was from orchards using narrow border flood (48%), followed by drip (47.3%), microjet (46.4%), and lastly large-pan flood (45.8%).

Furthermore, farmers using narrow border flood had much less fruit on average sent to the juice market (28.1%), compared to the other irrigation methods (31.9-36.5%). Therefore, the highest profits growers received from the packing sheds were going to growers using narrow border flood irrigation practices. Also, narrow border on average had the highest projected 10-year net cash farm income and cumulative pre-tax cash flow, followed by micro-jet and drip.

Specific results included:

- Projected 10-year average net cash farm income for narrow border flood was 5.4% more than micro-jet, 27.1% more than drip, and 67.9% more than flood.
- Narrow border flood’s advantage over conventional flood is largely reflective of higher average yields (21.2 tons/acre vs. 18.9 tons/acre).
- The net cash farm income advantage over microjet and drip is largely linked to costs of systems.
- Average cash costs were $2,040/acre for narrow border flood, 5.6% less than drip and 6.85% less than microjet.
- Projected 10-year cumulative pre-tax cash flow balance for border flood was 5.5% more than microjet, 27.3% more than drip, and more than double that for flood.

Table 6-7. **Economic benefits of modifying traditional flood irrigation with efficient alternatives.**

Irrigation method	Pack-out scenario	10-Year Averages per Acre: Total cash receipts	Total cash costs	Net cash farm income	Cumulative 10-year cash flow/acre
Flood	**High**	$3,330	$2,200	$1,130	$12,040
	Average	3,010	2,200	810	8,550
	Low	2,600	2,200	400	4,220
Narrow border flood	**High**	$3,970	$2,160	$1,810	**$19,180**
	Average	3,530	2,160	1,360	**14,460**
	Low	3,440	2,160	1,280	**13,560**
Drip	**High**	$3,520	$2,280	$1,240	$13,170
	Average	3,350	2,280	1,070	11,360
	Low	3,160	2,280	880	9,330
Microjet	**High**	$3,650	$2,310	$1,330	$14,160
	Average	3,600	2,310	1,290	13,700
	Low	3,390	2,310	1,080	11,490

Crop prices calculated from actual 2005-2012 net prices received by collaborators, adjusted for harvest, packing, and commission charges: $285.80/ton for fancy; $99.52/ton for choice; $5.44/ton for juice. (Young and others)

For citrus growers who are currently using large-pan flood irrigation, a switch to narrow border flood would be the most cost effective. Narrow Border Flood can be implemented at a significantly lower cost and without major changes to current flood irrigation practices. Plus, the change will most likely result in a financial gain, with more fruit going to the fresh market and in the fancy category. This is because narrow border flood targets the water to where the tree roots are located, thus preventing the loss of fertilizer and agrochemicals between tree rows that is common with traditional large-pan flood irrigation. Typically, the initial up-front installation costs for a drip or microjet spray system ($1,500 to $3,000 per acre) make them a less attractive option for citrus growers, and are typically only used by Lower Rio Grande Valley growers who have land that is unable to be laser leveled.

Refining water-saving irrigation methods in citrus

Building on demonstrated successes in citrus irrigation, Dr. Shad Nelson and the Texas A&M University Kingsville Citrus Center focused established new field sites in Monte Alto and Weslaco, TX in 2013, funded in part by Texas Water Development Board. The sites were designed to allow for the long-term assessment of alternative strategies and technologies for further reducing water use while maintaining fruit yield, quality, and shape under drought and other water stress conditions. These strategies have included single vs. dual-line drip irrigation, partial root-zone drying, and trench furrow flood.

Impressive results already are evident with “partial root-zone drying” with drip and microjet spray. In partial root-zone drying, irrigation occurs one week on one side of selected trees and on the other side the following week. Alternating irrigations so that only one half of the tree is irrigated at a time creates conditions of water stress. The roots sense these conditions, causing the tree to respond with increased stomatal closure, thus reducing transpiration. The first year’s data showed 41 percent water savings compared to dual-line drip and microjet spray system configurations without compromising fruit yield or quality.

Table 6-8. Partial root-zone drying enhances low water use irrigation systems.

Irrigation method	**Water use** (gallons/yr/tree)[d]	**Yield** (lb/tree)	**Fruit diameter** (in)	**Juice** (%)	**Brix**[c]
Microjet spray	4,887 ± 396 [a]	324.1 [a]	3.43 [a]	38.2 [a]	11.2 [a]
Dual-line drip	5,019 ± 528 [a]	317.5 [a]	3.43 [a]	39.9 [a]	11.0 [a]
Partial root-zone drying	3,038 ± 264 [b]	364.2 [a]	3.41 [a]	38.7 [a]	11.2 [a]

Note: Data shown represents one year's results from replicated rows and tree for fruit quality assessment only
[a] = No statistical difference between treatments
[b] = Statistical different at the 95% confidence level when compared to numbers designated with ([a])
[c] = Sugar content expressed as total soluble solids
[d] = Gallons of water applied per year per tree

The Texas A&M University Kingsville Citrus Center also set up a new site that is being used to demonstrate variations on narrow border flood, including "trench furrow flood". This practice entails cutting a trench on each side of the tree along the outer drip line of the tree in order to apply water more precisely down the tree row at the trees' outer root zone. Water runs down the length of the trench to the end of the row until the trench is full and then percolates into the soil from the trench, with lateral water movement throughout the soil profile and rootzone after infiltration.

Researchers have also combined partial rootzone drying with trench furrow flood, alternating irrigations between the trench on one side of the tree and the trench on the other, though no conclusive results are yet available. This may also be a better option than narrow border flood for mature trees accustomed to large-pan flood irrigation. Changing a mature grove from large-pan flood to narrow border flood can be stressful on tree roots that reside near the dripline of the outer tree canopy.

Researchers are also studying whether trench irrigation on raised beds can save water and at the same time reduce root rot (*Phytopthora*), a predominantly soil-borne pathogen that causes tree decline and death. The fungal spores that lead to root rot are commonly spread by traditional flood irrigation practices. Results from this work have been promising: after one year, trees planted in raised beds with permeable black tarp and side-channel furrow have shown greater tree canopy density, increased trunk diameter size, increased water retention in the soil, and reduced *Phytopthora* fungal spores in soil near the trunk in comparison to trees planted in flat ground without a tarp.

Other findings

Tile drains in newly established citrus orchards:
Newly established trees in South Texas are commonly planted after minor site preparation and land leveling. One demonstration site planted orange trees after installing tile drains every 30 feet. The site was known to drain poorly and had sections with very high salt. Despite these challenges, the orange trees after two years looked extremely healthy and were growing vigorously under a single-line drip irrigation system. They reached full production after four to five years, much earlier than the industry standard of seven to eight years.

Effect of water stress and irrigation timing on citrus pest management and water use:
A study was performed on irrigation timing before and after chemical application in citrus groves to control citrus pests. Pest assessments in conjunction with determination of pesticide movement in soil and uptake in citrus trees resulted in the finding that soil moisture status prior to chemical application will dictate chemical efficacy. Preliminary findings suggest that avoiding irrigation near chemical application will prevent chemical loss, improve pest control efficacy, and save water by reducing the need to irrigate at least one 0.5 acre-foot flood irrigation event per year.

6.2.2 Drip in field crops

Project researchers studied drip in field crops including onions, honeydew melons, peppers, tomatoes, fall corn and cotton. There have been some promising results in onions, where drip technology has shown water savings as well as economic incentives.

Dr. Juan Enciso of AgriLife Extension compared drip to furrow-flood in onions on two sites. Using drip more than doubled yields and increased onion size while using less water. The sites irrigated with drip produced a 219 percent yield higher than that obtained with furrow-flood, including more “large” and “colossal” onions, which usually command a higher price. The “large” onion yield was 287 percent higher with drip, and the “colossal” onion yield was 207 percent higher than for furrow-flood on the first site. On the second site, furrow-flood produced no colossal onions, but some were produced with drip. While drip has been shown to produce higher onion yields, a formal economic analysis of the operation’s overall viability has not been conducted.

Besides onions, no other field crop tested in this study demonstrated a significant difference in yields between drip and furrow-flood irrigation. The added cost of purchasing and installing a drip system therefore reduced the net returns per acre compared to furrow-flood, making drip not economically viable. In the case of cotton, the Financial and Risk Management Assistance Focus Series paper 2007-4 “Impact of Volumetric Pricing for Cotton Comparing Furrow vs. Drip Irrigation in the Lower Rio Grande Valley” shows that even if the cost of water were to reach $5 per acre-inch, there would still be no economic incentive to switch to drip technology. This is despite the fact that drip was shown to use less than half the amount of water as furrow-flood in cotton. Drip irrigation would have to generate additional revenues through higher yields to be a viable investment.

6.3 Irrigation scheduling

Another important aspect of increasing efficiency is determining the best time to irrigate. Farmers can use available tools to calculate crop water demand by, for example, monitoring crop evapotranspiration and measuring the moisture level of the soil. This allows farmers to ensure crops are getting the water they need while avoiding over-use of water and energy. A good example is sugarcane, where project researchers found in 2011 that some farmers were applying between 7 and 27 more acre-inches than necessary to make up the rainfall deficit. With more than 40,000 acres of sugarcane under cultivation in the Lower Rio Grande Valley, between 20,000 and 90,000 acre-feet of water could be saved with proper irrigation management: calculating irrigation scheduling, using proper flow-rates per furrow, and decreasing runoff losses.

One key to properly scheduling irrigation is knowing the water demand, linked to the evapotranspiration of each crop. Networks like the Crop Weather Program and South Texas Weather provide evapotranspiration data specific for local conditions in Texas; both are projects of AgriLife Research. They provide the evapotranspiration rate for the main crops found in the Lower Rio Grande Valley including sugarcane, cotton, citrus, corn, sorghum, watermelon, onions, cantaloupe, and cabbage.

Each network uses a series of strategically placed weather stations to measure local rainfall and calculate evapotranspiration from climate data including air temperature, relative humidity, incoming radiation, and wind speed. In 2013, a weather station was installed at the Rio Grande Center for Ag Water Efficiency and connected to the South Texas Weather's network, increasing the breadth of data collected.

Soil water sensors can be used as a complement to weather station data or on their own. The sensors give farmers an understanding of when irrigation is needed, and can also be useful in determining how effective an irrigation application was, since they can be placed at varying depths in the soil, showing how far down the water reached.

At the Citrus Center, soil moisture monitoring has shown much promise as a means to assist growers with irrigation scheduling. For example, in partial root-zone drying, trees are irrigated when soil moisture levels reach a certain point, as measured by the sensors. Knowledge of soil moisture status is an essential component in the water conservation efforts. As growers become more familiar with the sensors and the actual soil moisture levels of their crops over time, they will be able to make more informed irrigation timing decisions and reduce over-watering.

7. Education and outreach

Education and outreach has been a vital component of the ten-year Agricultural Water Conservation Demonstration Initiative project in order to convey key information on research and demonstration results to agricultural producers, other irrigation districts, relevant commodity groups, government agencies, and regional and state policy makers. The primary goal for all outreach has been to promote the easy-to-implement, low-cost water efficiency and conservation strategies that the project has demonstrated on-farm and in-district. The secondary goal has been to show that substantial efforts are being made by the agricultural sector to conserve water, and to prepare for a future when the agricultural industry in Texas will be forced to do more with less.

Education and outreach activities began early on in the project, first to recruit growers as cooperators and partners, then to share progress on development of the Flow Meter Calibration Facility (later renamed the Rio Grande Center for Ag Water Efficiency), and finally to share the research findings that can save water and benefit the agricultural community in the Lower Rio Grande Valley and beyond.

In 2010 and 2011, the Harlingen Irrigation District (the District) team produced Texas Irrigation Expos to bring agricultural water efficiency findings to two key audiences—irrigation district board members and managers, and agricultural producers and growers. Sponsors, exhibitors and speakers were solicited to expand the learning opportunities and help cover costs. Many partners participated including the Texas Water Conservation Advisory Council, the Arroyo Colorado Partnership, Texas Department of Agriculture, Texas Farm Bureau, United States Department of Agriculture/National Resources Conservation Service, International Boundary Water Commission, Texas Water Development Board, state elected officials, and even local high school students, who took part in an agricultural science contest. The Expos were well-attended and brought wide attention to the Agricultural Water Conservation Demonstration Initiative research and findings.

In 2012, the District and its partners in the Agricultural Water Conservation Demonstration Initiative project shifted focus from research to outreach and education. The Agricultural Water Conservation Demonstration Initiative project was renamed and branded as the Texas Project for Ag Water Efficiency, or Texas AWE. The logo below is featured on the project website and in publications.

AWE

TEXAS PROJECT FOR

AG WATER EFFICIENCY

From river to farm.

The narrative and lists below provide an overview of the wide variety of activities and programs undertaken to deliver research results, cost-benefit analyses, water use comparisons, and guidance on the installation and operation of water saving irrigation techniques. Education and outreach efforts took the form of developing partnerships, workshops and field days, presentations and special events, and a vast array of educational materials deployed across numerous media from factsheets to online videos.

7.1 Partnerships

In addition to the grant contractors, the District partnered with a number of individuals, universities, research centers and organizations to help with key research components, and also to leverage additional funding and outreach opportunities. (See Appendix B for more information on external grants supportive of the Agricultural Water Conservation Demonstration Initiative project.**)**

The District acknowledges and thanks the collaborative efforts of the following entities:

Arroyo Colorado Partnership
Axiom-Blair Engineering
Cameron County Extension
Citrus Producers Board
Delta Lake Irrigation District
Rio Farms, Inc.
Rio Grande Basin Initiative
Rio Grande Regional Water Authority
Rio Grande Regional Planning Group
Texas A&M AgriLife
Texas A&M University-Kingsville Citrus Center
Texas Citrus Mutual
Texas Department of Agriculture
Texas Farm Bureau
Texas State Soil and Water Conservation Board
Texas Water Resources Institute
United States Bureau of Reclamation
United States Department of Agriculture’s Natural Resources Conservation Service

The Texas Project for Ag Water Efficiency outreach efforts led to the development of a key partnership with the Rio Grande Regional Water Authority (RGRWA) to establish the Surge Valve Cooperative with funding from the United States Bureau of Reclamation (USBOR). The USBOR grant allowed RGRWA to sell the $2,000 valves for $300 to growers, and to provide training in their use. The Texas Project for Ag Water Efficiency partnered with RGRWA and AgriLife Research to provide technical and field support. A number of workshops and field days were held in 2013 and 2014 in conjunction with AgriLife and Dr. Juan Enciso. Ultimately, 28 surge valves were purchased by 14 growers. The study and grant period continues into 2015. Findings will be made public by RGRWA and on Texas Project for Ag Water Efficiency and District websites.

Why Are These Valley Growers Smiling?

They just got a handy irrigation tool at a dirt-cheap price!

WHAT'S NOT TO LIKE about getting a $2,000 water- and labor-saving device for only $300? Especially when it can deliver water savings of up to 52 percent, plus more efficiently deliver fertilizer and cut down on labor costs too.

With irrigation water in tight supply these days, smart growers are looking for cost-effective ways to make every drop count.

The Surge Valve Cooperative (SVC) can help.

SVC is an initiative of the Rio Grande Regional Water Authority (RGRWA) aimed at putting surge valves to work in the Lower Rio Grande Valley through a grant from the U.S. Bureau of Reclamation.

Field demonstrations and results from the Texas Project for Ag Water Efficiency (Texas AWE) have shown that the use of surge valves in furrow irrigation can reduce water consumption by as much as 52 percent.

Water Savings with Surge

Crop (Date)	Volume of Water Used/Acre (in acre-inches)		Savings with Surge
	Furrow	Surge	
Sugarcane (2005)	30.68	14.64	52%
Cotton (2005)	19.53	13.48	31%
Seed Corn (2007)	23.95	17.31	28%
Cotton (2010)	18	14	22%

Source: Texas Project for Ag Water Efficiency

Here's how the SV Coop works:

- Growers can receive up to two surge valves for an initial payment of $350 each;
- Growers must attend a half-day training session on how to use the equipment for maximum irrigation efficiency; and
- Growers must record water use during actual irrigation in 2014 and report results.

Cooperators who participate in a final wrap-up meeting about field experiences in the fall of 2014 will receive a $50 rebate per surge valve, bringing total valve cost down to $300 each.

Surge valve workshops and field days have been held throughout fall 2013 and will be scheduled in early 2014 at various locales in the Rio Grande Valley. Training dates, times and locations can be found on the websites below.

Registration forms for the SVC are available online at www.RGRWA.org and www.TexasAWE.org, or call Heather Stock at 956-423-7015.

The Surge Valve Coop is made possible by a grant from the U.S. Bureau of Reclamation to the Rio Grande Regional Water Authority and is supported by the Texas Project for Ag Water Efficiency.

RGRWA Rio Grande Regional Water Authority

Texas Project for Ag Water Efficiency

RECLAMATION Managing Water in the West

Promotional poster for the Surge Valve Cooperative.

Further partnerships were formed around the meter calibration capacity at the Rio Grande Center for Ag Water Efficiency when the project calibrated some 50 meters for three other irrigation districts in the region, installed and repaired meters for two additional districts, repaired meters for two growers, and verified open channel meters in an irrigation district and one municipal water district.

Auto-gate demonstration at the Rio Grande Center for Ag Water Efficiency.

Weather station at the Rio Grande Center for Ag Water Efficiency.

In support of the Crop Weather Program of the Texas A&M AgriLife Research and Extension Center at Corpus Christi, Texas Project for Ag Water Efficiency provided space for the latest weather station in the Crop Weather Program network at the Rio Grande Center for Ag Water Efficiency. The Crop Weather Program for South Texas network is a web-based decision support system designed to assist agricultural research and crop managers. Network data – available at http://cwp.tamu.edu/ – provides growers across the Lower Rio Grande Valley with a variety of information for more effectively managing irrigation, including a crop evapotranspiration calculator.

In 2009 and 2010, six Texas Project for Ag Water Efficiency demonstration sites were involved in a research project with Texas State Soil and Water Conservation Board and Texas Water Resources Institute designed to assess the best management practices on farm in order to test potential impacts on non-point source pollution into the Arroyo Colorado. While this two-year study was not funded by the Agricultural Water Conservation Demonstration Initiative project, Texas Project for Ag Water Efficiency partners and cooperators agreed for their sites to be used for data collection in support of the Arroyo Colorado Assessment project.

7.2 Workshops and field days

The Texas Project for Ag Water Efficiency education and outreach team, made of up primarily of growers and educators, understood that hands-on training for growers and farm staff would be the most effective way to transfer project results and show new irrigation tools in action. So the Texas Project for Ag Water Efficiency team utilized its staff and partners to deliver key findings through an active program of workshops and field days.

Completed in 2006, the Rio Grande Center for Ag Water Efficiency provided a much-needed regional classroom for trainings and the transfer of technical knowledge—not only for growers, but for district personnel as well. This flow meter calibration facility, the only one in Texas, is able to provide open channel and closed pipe simulations that will become increasingly important to the Texas agricultural industry as volumetric pricing becomes the accepted norm in years to come. In addition, the Rio Grande Center for Ag Water Efficiency is designed to showcase the benefits of automated canal gates and a Supervisory Control and Data Acquisition system that Texas Ag Water Efficiency has proven to be more efficient in terms of staff time and moving large volumes of water from the river to the farm. From years two through ten of the Agricultural Water Conservation Demonstration Initiative grant, field day demonstrations delivered technical know-how and new irrigation techniques straight to area growers.

Workshops and field days were promoted through project partners, District and project websites, direct email invitations, newsletters, posters, print media, radio talk shows, and of course, word of mouth shared over coffee at the local Sugar Mill.

7.2.1 List of workshops and field days

2006: Workshop: *Irrigation Management Model* by the Blacklands Research Center
Workshop: EPANET hydraulic simulation model for design of irrigation pipeline and pumping plants (Blair)
Workshop: *Water Management* (Enciso, AgriLife Extension; Santisteven, United States Department of Agriculture-National Resources Conservation Service)
Regular Meetings for Agricultural Water Conservation Demonstration Initiative managers: data collection and irrigation information database

2007: Harlingen Irrigation District hosted representatives of the Rio Grande Basin Initiative for a tour and presentation
Workshop: *Water Management/Canal Management* at Rio Grande Center for Ag Water Efficiency (Fipps, AgriLife Extension)
Workshop: Water Management, meters, soil moisture, plant water requirements (Enciso)

2008: Harlingen Irrigation District hosted tour of the demonstration sites with Texas Water Development Board personnel
Irrigation scheduling demonstrations were conducted on two Agricultural Water Conservation Demonstration Initiative sites (Enciso)
Harlingen Irrigation District hosted workshop on Texas Agricultural Technical Assistance Program

2009: Introduction to Flow Measurement for Agricultural Water Conservation, a 3-day short course taught at Rio Grande Center for Ag Water Efficiency (Blair, McCann)

2010: Soil Moisture short course at Rio Grande Center for Ag Water Efficiency
Texas Irrigation Expo 2010, Mercedes

2011: Demonstration and Research Irrigation Park for Citrus established, Kingsville Citrus Center (Nelson)
Texas Irrigation Expo 2011, McAllen

2012: Workshop: *District Technology Enhancements: Introduction to Flow Measurement for Ag Water Conservation.* Nov. 7-8, 2012; 12 attendees from area irrigation districts
Workshop: *Tools, Techniques and Technology for Producers.* Jan. 24, 2013; 25 attendees

2013: Surge Valve Cooperative workshops at Rio Grande Center for Ag Water Efficiency, Sept. 17-18
Surge valve demo at Sugar Cane Field Day, Mercedes (Enciso)
Surge Valve Cooperative Workshop at Rio Grande Center for Ag Water Efficiency, Oct
Surge Valve Cooperative Field Day Demonstration in Mercedes, Nov

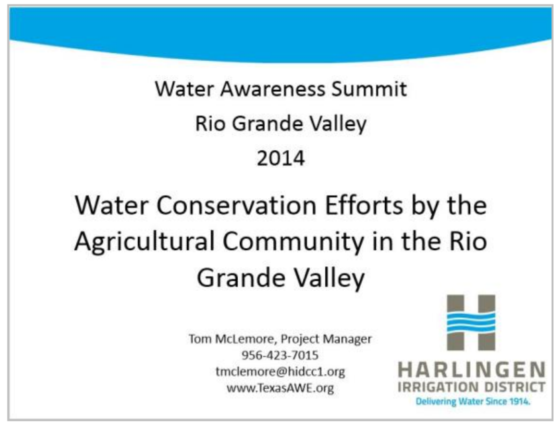
2014: Harlingen Irrigation District hosted a meter training workshop for Texas Commission on Environmental Quality (July)
Calibration demonstration with White River Irrigation District, Little Rock, Arkansas

Workshop: "Agricultural Water Issues in the Lower Rio Grande" (Enciso)

7.3 Events and presentations

From the beginning of the grant project, the Texas Project for Ag Water Efficiency team and research partners presented study results to agriculture and water industry professionals at a variety of meetings, summits and conferences in Texas, across the country, and internationally to audiences reaching into the thousands.

HID's Tom McLemore presenting at the 2011 Texas Irrigation Expo.



Powerpoint from the 2014 Rio Grande Valley Water Awareness Summit.

7.3.1 List of presentations to industry and water professionals

2005: Valley Water Summit (Halbert)
Texas Citrus Association/Texas Vegetable Association Annual Meeting (McLemore)
Environmental Quality Incentives Program information meetings (McLemore)

2006: Harlingen Irrigation District hosted Texas Water Development Board and Legislative Budget Board for tour of demo sites, updates, Rio Grande Center for Ag Water Efficiency
Harlingen Irrigation District hosted representatives of Texas Alliance for Water Conservation project
Harlingen Irrigation District hosted United States Department of Agriculture-National Resources Conservation Service Environmental Quality Incentives Program information meeting
Texas Water Conservation Association presentation (McLemore)
Booth at the 27th Annual Irrigation Show (Harlingen Irrigation District, Blair)
American Society of Agronomy-Crop Science Society of America-Soil Science Society of America 2006 International Annual Meeting, Indianapolis, IN (Nelson, Esquivel)
61st Annual Rio Grande Valley Horticultural Society (Esquivel)
Channel 6- Morning Show, Corpus Christi, TX (Nelson)

2007: Texas Agricultural Industries Association

2008: Rio Grande Valley Irrigation Conference
2008 Border Water Infrastructure Conference
11th International Citrus Congress. Wuhan, China (Nelson)

2009: Rio Grande Basin Initiative Conference, McAllen, TX (McLemore)
Texas Alliance for Water Conservation Annual meeting, Lubbock, TX (Halbert, McLemore)
Annual Consortium for Irrigation Research & Education Conference, Amarillo, TX (McLemore)
[Note: WaterPR was hired and began planning for Texas Irrigation Expo in 2010.]

2010: 2010 Texas Irrigation Expo, Mercedes, October 20-22, 230 attendees
Annual Subtropical Plant Science Society Conference, Texas A&M University-Kingsville Citrus Center

2011: 2011 Texas Irrigation Expo, McAllen, Dec. 9-10, 300+ attendees
The Economics, Finance and International Business Research Conference, Miami, FL
9th Annual Texas A&M System Pathways to the Doctorate Symposium, College Station
Annual Meeting of the American Society of Agronomy-Crop Science Society of America-Soil Science Society of America. Oct. 2011. San Antonio, TX
Annual Meeting of the American Society of Horticultural Sciences. Sept 2011
Joint American Phytopathological Society-International Plant Protection Convention meeting. Aug 2011. Honolulu, HI
North American Colleges & Teachers of Agriculture 2011 Annual Conference, June 2011, Edmonton, Alberta, Canada
65th Annual Meeting of the Subtropical Plant Science Society. Feb 9, 2011. Weslaco, TX
71st Annual Meeting of the Southern Region of the American Society for Horticultural Science. Feb 5-8, 2011. Corpus Christi, TX

2012: United States Committee on Irrigation and Drainage conference (Halbert, Blair)
Rio Grande Regional Water Authority meeting (McLemore)
Rio Grande Regional Water Planning Group meeting (McLemore)
Lower Rio Grande Water District Managers Association Meeting, Weslaco (McLemore)
Texas Water Conservation Association (Halbert, McLemore)
Amarillo Farm and Ranch Show, booth (McLemore, Jones)
Beltwide Cotton Conference (Dr. Dana Porter)
Texas Farm Bureau Young Farmers and Ranchers Leadership Conference (Halbert)
Rio Grande Valley Water Awareness Summit (McLemore)

2013: Texas Ag Water Forum, presentation and exhibit booth (Halbert, McLemore)
Rio Grande Basin Initiative, San Antonio, TX (McLemore, Nelson)
Law of the Rio Grande Santa Fe, New Mexico (Halbert)
Texas Produce Convention, San Antonio, TX (McLemore)
Texas Water Conservation Association, information booth (WaterPR)

Texas Plant Protection Conference, Bryan, TX, information booth (McLemore, WaterPR)
Irrigation Leader, 2nd Annual Operations & Management workshop, AZ (McLemore)
Texas Ag Industry Association Meeting, Kingsville, TX (Nelson)
American Society of Agronomy-Crop Science Society of America-Soil Science Society of America Annual Meeting, Tampa, FL (Nelson)
Texas Commodity Symposium, Amarillo, TX, Harlingen Irrigation District received the Blue Legacy Award for Agriculture (McLemore)

2014 AgriLife Workshop in Weslaco, TX
Rio Grande Valley Water Awareness Summit, McAllen, TX (McLemore)
Texas Water Conservation Association Fall Conference, information booth (WaterPR)
NIA presentation in Santiago, Chile – "Water conservation through surge and Narrow Border Flood" (Enciso, McLemore)

7.4 Educational materials

At the start of the grant project in 2005, a new website was created for the District that allowed publication of information regarding demonstration sites as well as weather and irrigation water usage. The site became the communication hub for project leaders, partners and cooperators. http://www.hidcc1.org.

In 2012, as the project shifted focus to a concerted education and outreach program, the Lower Rio Grande Valley's Agricultural Water Conservation Demonstration Initiative project became the **Texas Project for Ag Water Efficiency**– a memorable identity reflecting the intent of the investment being made by Texas Water Development Board. Outreach consultant WaterPR also developed collateral material to support that identity: a logo and tagline, stand-alone website (www.TexasAWE.org), brochure, customizable Powerpoint presentation with talking points and slides, a series of informational videos, a newsletter, and a library of succinct resource materials titled "AWEsome Facts." The education materials are described below.

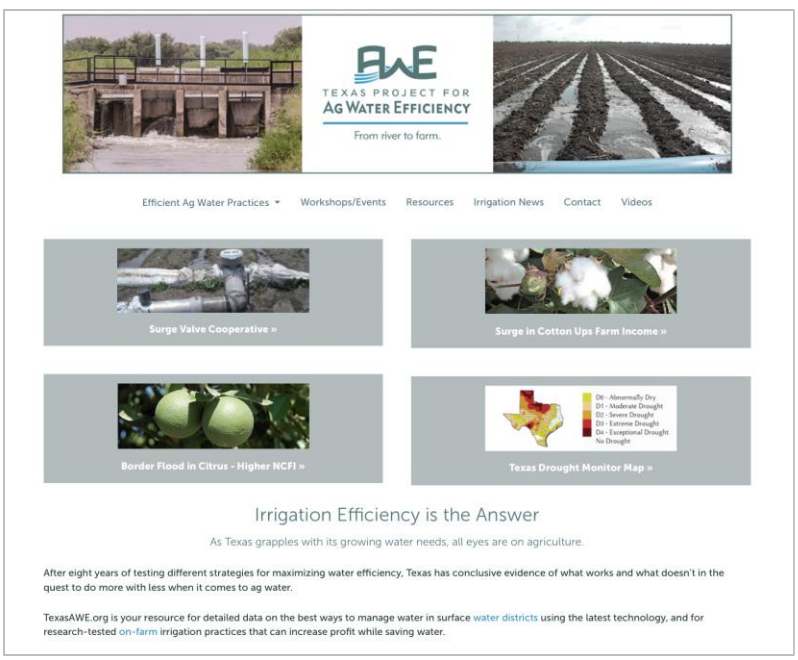
7.4.1 List of education materials

Project branding: Naming, tagline and graphic identification.

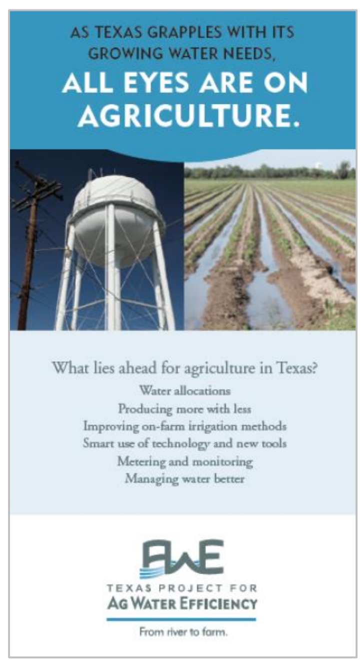
Agricultural Water Conservation Demonstration Initiative project logo.

Banner at the Rio Grande Center for Ag Water Efficiency.

TexasAWE.org: This dedicated website was launched in fiscal year 2012 and continues to be updated with current news articles, summaries of scientific studies, and information about upcoming events. Following the grant period, the unique domain name, TexasAWE.org, will continue to direct visitors to unique pages on the Harlingen Irrigation District website.



Homepage of TexasAWE.org.

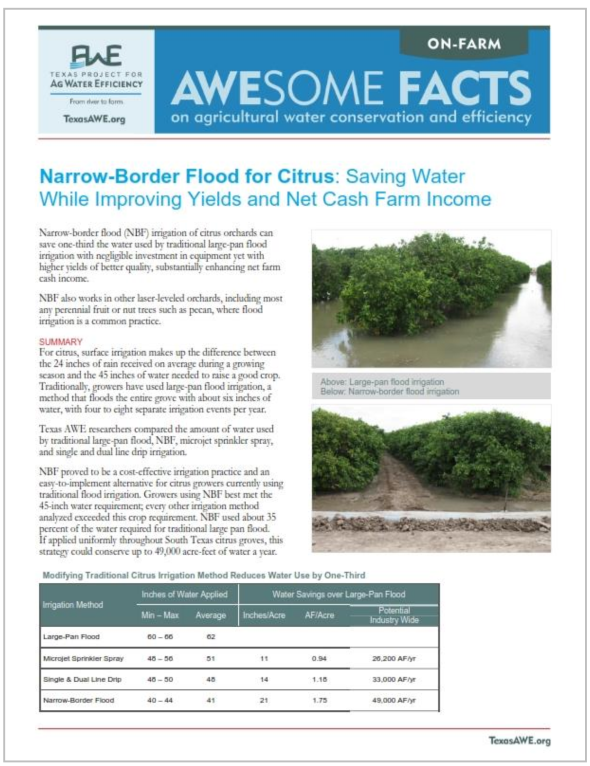


Texas Ag Water Efficiency brochure.

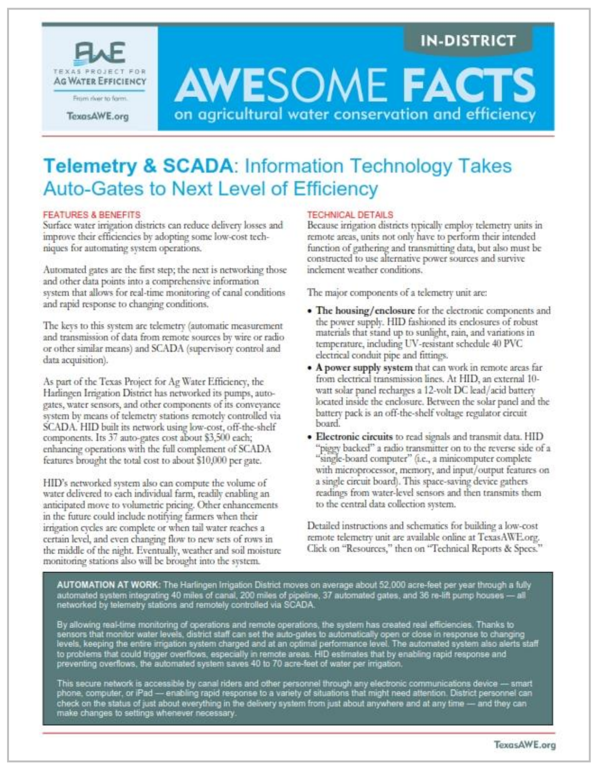
Overview brochure: The brochure was an early information tool that explained the research project, summarized the key findings, and addressed the need for farmers to do more with less in the future. The brochure included a fold-out map of the Harlingen Irrigation District conveyance and delivery system.

Texas AWE Reporter: A newsletter that launched in 2013 to provide updates on Texas Project for Ag Water Efficiency findings, promote conservation programs and events for producers, report on project news, and allow producers to share their experiences with water conservation practices. Issues were published in Summer 2013, Winter 2013/2014, and Fall 2014. These newsletters are available online and were mailed to more than 700 growers and district personnel, and distributed at a number of the conferences and events shown above.

Texas Ag Water Efficiency Reporter



Factsheet on narrow border flood for citrus.



Factsheet on telemetry and Supervisory Control and Data Acquisition.

AWEsome FACTS: A series of factsheets specific to on-farm and in-district audiences and practices. These sheets were distributed online and at events, presentations and workshops. Following are the titles in the series:

- On-Farm: *Surge Irrigation: Significant Potential for Water Savings in the Face of Increasing Scarcity*
- On-Farm: *Narrow Border Flood for Citrus: Saving Water While Improving Yields and Net Cash Farm Income*
- In-District: *Automated Irrigation Gates: Maximizing Water Delivery While Reducing Water Loss*
- In-District: *Telemetry & SCADA: Information Technology Takes Auto- Gates to Next Level of Efficiency*

Factsheets in Spanish/English, on surge valve irrigation and narrow border flood:

- On-Farm*: Inundación por bordo angosto para los cítricos: Ahorrando agua mientras se mejoran los rendimientos y el ingreso neto de la granja*
- On-Farm*: Irrigación intermitente: Ofrece un potencial significativo de ahorro de agua ante la creciente escasez*

Videos: Seven informational videos were produced to demonstrate key findings from the Texas Project for Ag Water Efficiency research, and also to explain the Agricultural Water Conservation Demonstration Initiative project and illuminate the situation farmers are facing with reduced access to Rio Grande water. The District is grateful to the partners, contractors, and Valley growers who gave their time and access to their fields for the production of these videos.

Some of the videos were presented at speaking engagements and conferences, or played on a looped video system at the Texas Project for Ag Water Efficiency exhibit booth. Additionally, the overview video (Why Texas AWE) was loaded onto branded flash drives and distributed at the Texas Water Conservation Association's annual conference in 2012.

Closed captioning was added to the entire video series, which is available online at TexasAWE.org, as well as onYouTube and Vimeo. Below are titles and running times for the video programs.

- Why Texas AWE? (running time 11:10)
- On Farm Irrigation Efficiencies (running time 4:29)
- In-District Water Management Efficiencies (running time 3:15)
- Rio Grande Center for Ag Water Efficiency (running time 2:19)
- The Future of Irrigated Agriculture in Texas (running time 3:08)
- Surge Irrigation (running time 4:36)
- Narrow Border Flood Irrigation (running time 4:29)

Powerpoint: Template, fact slides, graphics and talking points tailored for specific events and presentations.

Pop-up banner: For use at industry conferences and public events.

Flyers and posters: Promoted training events and the Surge Valve Cooperative.

Photography: With every trip to the Valley, the WaterPR team contributed to a growing library of photographic images that helps tell the story of Texas Project for Ag Water Efficiency. These photographs are used to support and enhance all education and outreach materials and have now become part of the Texas Water Development Board image library as well.

Media relations: WaterPR developed and distributed a number of press releases to Lower Rio Grande Valley media to promote the variety of workshops and field day trainings from 2012 through 2014. Additionally, awards and recognition of the project or the District were promoted to the agricultural industry and Texas media. Project leader Tom McLemore was booked on a regional talk morning radio program to discuss the project and irrigation efficiencies and to promote the Surge Valve Cooperative.

8. Honors and accolades

Harlingen Irrigation District accepting 2011 Texas Commission for Environmental Quality Environmental Excellence Award.

The Texas Project for Ag Water Efficiency and its partners have gained peer and industry recognition for successfully demonstrating easily adaptable techniques for better managing—and thus conserving—water resources in the Lower Rio Grande Valley.

The honors and accolades have included:

- The 2011 Environmental Excellence for Agriculture from the Texas Commission on Environmental Quality, awarded to the Harlingen Irrigation District (the District) for its Agriculture Demonstration Initiative achievements in promoting efficiencies in water delivery and field application to help meet future water demands in Texas while maintaining and ever increasing farm profitability.

- Recognition in January 2012 as one of nine global "good practice" projects included in a report presented to the World Economic Forum in Davos, Switzerland. The District was cited for its innovation and technological advances in the area of irrigation flow control and water usage measurement in *A Catalogue of Good Practices in Water Use Efficiency*, prepared by the Stockholm International Water Institute for the 2030 Water Resources Group. The Catalogue highlights agricultural, municipal, and industrial water efficiency and conservation projects that can be replicated elsewhere.

- The 2013 Blue Legacy Award in Agriculture was presented to the District by the Water Conservation Advisory Council for its efforts related to Texas Project for Ag Water Efficiency. The award is bestowed as a way to showcase agricultural producers as effective caretakers of water resources and to honor those groups whose practices enhance conservation of water while maintaining or improving profitability. The Council cited the District as "a leader in their community for conservation outreach," and for spreading “the news of their successful projects including presentations within the state and around the country.”

2013 Blue Legacy Award in Agriculture.

- Cover story for the June 2013 issue of the nationally circulated *Irrigation Leader* magazine, which featured long-time Harlingen Irrigation District General Manager Wayne Halbert and his work with the District and Texas Project for Ag Water Efficiency.

Wayne Halbert on the cover of Irrigation Leader.

- The 2015 Blue Legacy Award in Agriculture was presented to Dr. Shad Nelson by the Water Conservation Advisory Council. The award honors Dr. Nelson's research—much of it as part of the Texas Project for Ag Water Efficiency team—for its focus on irrigation practices that are efficient, easy to implement, cost effective. Dr. Nelson's commitment to finding workable solutions, and to putting these technologies in the hands of farmers who can use them, has earned him considerable respect in the citrus community. He leads the way in helping citrus producers adopt needed water-saving methods, while also being at the forefront of research in his field.

Dr. Shad Nelson with his 2015 Blue Legacy Award.

9. Looking Toward the Future

Texas A&M economist and project partner Mac Young predicts that the increased demand for water will likely place upward pressure on the cost and lead to greater interest in volumetric pricing. If either happens, water saving techniques such as narrow border flood and surge valve irrigation will become increasingly important tools for growers looking to save money as well as water. The library of educational materials developed though this project will continue to be available on the web and from the District office as interest in these technologies grows. Likewise, the Rio Grande Center for Ag Water Efficiency will continue to showcase water-saving technologies to other irrigation districts, and to provide meter calibration.

District personnel and other project partners are continuing to present the project findings across the state, and to further refine them as well. For instance, HID Project Manager Tom McLemore will be presenting on the District's agricultural water conservation efforts to The University of Texas School of Law 2015 Texas Water Law Institute, scheduled October 28-30 in Austin. The District also plans to continue improving the infrastructure and automation utilizing local, State and Federal funds.

Dr. Shad Nelson and the Texas A&M Citrus Center have established a Demonstration Research Irrigation Park with TWDB funding in Monte Alto, TX. The site showcases water conservation practices through field days, while allowing researchers to continue long-term assessment of alternative irrigation methods. It features drip irrigation, microjet spray, and various forms of border flood irrigation such as trench furrow flood, described in Section 6.2.1. Single vs. dual-line drip irrigation, water deficit irrigation, and partial root-zone drying are also demonstrated as possible means of conserving water while assessing their impacts on fruit yield, quality, and shape. Dr. Nelson is also testing a new planting design for citrus on raised beds, a practice that he expects will lead to lower water use, an improved soil rooting environment for trees, and a reduction in pest and disease problems currently found in conventional citrus production in South Texas. This work can be seen at the Citrus Center and also at a grower's farm in McAllen. Preliminary studies on the novel planting design is being funded by the TWDB.

Agriculture in Texas has always been and will continue to be a foundation of our state's economy. It is the biggest driver of the economy in the Rio Grande Valley—a $396 million industry heavily reliant on water. Water shortages are a growing problem in the region and will continue to increase in severity as demand grows across water user groups throughout the basin. This grant enabled regional partners to focus time and resources on identifying the water-saving practices that really work in the unique South Texas environment, and also work for the bottom line. As water supplies get squeezed and farmers are required to do more with less, these findings will serve as a road map for the agricultural industry to get the most out of every available drop.

10. References

Enciso, Juan, Sauls, Julian W., Wiedenfeld, Robert P. and Nelson, Shad. "Impacts of Irrigation on Citrus in the Rio Grande Valley." AgriLife Extension, Texas A&M System. Accessed June 8, 2015. http://oaktrust.library.tamu.edu/bitstream/handle/1969.1/87536/pdf_2574.pdf

Ribera, Luis and McCorkle, Dean. "Economic Impact Estimate of Irrigation Water Shortages on the Lower Rio Grande Agriculture." AgriLife Extension. Accessed May 28, 2015. Available at: http://www.tceq.state.tx.us/assets/public/border/economic-impact-LRGV.pdf

Young, Mac, Nelson, Shad, Klose, Steven and Enciso, Juan. "Increased Water Use Efficiency and Profitability in Citrus Production possible in the Lower Rio Grande Valley." AgriLife Extension Financial and Risk Management Assistance Focus 2013-5. December 2013.

11. Appendix A: On-farm demonstration sites

Year	Site ID	Acreage	Crop Type	Irrigation Type	Soil Type
2005	41	37.45	Cotton	Surge/Furrow	Harlingen clay
2005	46	36.38	Sugarcane	Surge/Furrow	Harlingen clay
2005	49	8	Coastal Bermuda	Flood	Harlingen clay
2005	1b	15	Valencia Oranges	Flood	Clay loam, loam
2005	23a	13.4	Oranges	Microjet	Sandy clay loam, sandy clay
2005	24a	7	Rio Red Grapefruit	Flood	Sandy clay loam, clay loam
2005	25a	56	Onions	Drip	Silt clay
2005	26a	25.7	Onions	Drip	Sandy loam, sandy clay loam
2005	27a	0.65	Onions	Drip	Sandy clay loam
2005	28a	8	Valencia Oranges	Microjet	Sandy loam
2005	28c	8	Rio Red Grapefruit	Microjet	Sandy loam
2005	28d	7	Marrs Oranges	Drip	Sandy loam
2005	29a	2.6	Cotton	Low Pressure Drip	Sandy clay loam
2005	2a	14	Henderson Grapefruit	Narrow Border Flood	Sandy clay loam, sandy clay
2005	3a	41.3	Blood Navel Orange, Rio Red Grapefruit and Tangerines	Flood	Sandy clay loam
2005	44a	38	Fall Corn	Surge/Furrow	Harlingen clay
2005	48b	80	Spring Cotton/Fall Corn	Center Pivot	Sandy loamy topsoil clay underneath
2006	1a	73	Rio Red Grapefruit	Narrow Border Flood	Sandy loam, sandy clay loam
2006	1b	15	Valencia Oranges	Narrow Border Flood	Clay loam, loam
2006	1c	85	Rio Red Grapefruit	Narrow Border Flood	Clay loam, loam
2006	1d	12	Onions White/Red	Drip	Rio Grande silt loam
2006	1e	52	Onions Yellow	Drip	Clay loam, loam
2005	2005-MA-A		Cotton	Furrow	
2005	2005-MA-B		Sorghum	Furrow	
2006	21a	3.5	Cotton	Furrow	Sandy loam
2006	21b	100	Cotton	Furrow	Sandy loam
2006	22a	3	Honeydews, Tomatoes, Peppers	Drip	Loam, silt loam
2006	23a	13.4	Oranges	Microjet	Sandy clay loam, sandy clay
2006	24a	7	Rio Red Grapefruit	Flood	Sandy clay loam, clay loam
2006	25a	56	Onions	Drip	Silt clay
2006	26a	25.7	Onions	Drip	Sandy loam, sandy clay loam
2006	27a	0.65	Onions	Drip	Sandy clay loam
2006	28a	8	Oranges	Microjet	Sandy loam
2006	28b	8	Grapefruit	Flood to Drip	Sandy loam

Year	Site ID	Acreage	Crop Type	Irrigation Type	Soil Type
2006	28c	8	Grapefruit	Microjet	Sandy loam
2006	28d	7	Oranges	Drip	Sandy loam
2006	29a	2.6	Cotton	Low Pressure Drip	Sandy clay loam
2006	2b	5	Rio Red Grapefruit	Microjet	Sandy clay loam
2006	2c	4	Ruby Red	Microjet	Sandy clay loam
2006	3a	41.3	Rio Red Grapefruit	Flood	Sandy clay loam
2006	41a	13	Cotton	Surge	Harlingen clay
2006	41b	26	Cotton	Surge	Harlingen clay
2006	42a	66	Sorghum	Surge	Harlingen clay, Laredo Silty Clay Loam, Laredo-Reynosa Complex
2006	42b	95	Cotton	Surge	Harlingen clay
2006	43a	17	Cotton	Low Pressure Drip	Harlingen clay
2006	43b	39	Cotton	Furrow	Harlingen clay
2006	44a	38	Cotton	Furrow	Harlingen clay
2006	45a	36.7	Sugarcane	Furrow	Harlingen clay
2006	47a	20	Corn	Flood	Raymondville clay loam
2006	47b	19	Corn	Surge	Raymondville clay loam
2006	4a	86	Rio Red Grapefruit, Marrs Orange, Pineapple Orange, Tangerine	Drip	Sandy clay loam, clay
2006	4b	30	Rio Red Grapefruit, Marrs Orange	Microjet	Clay loam, clay
2006	5a	22	Onions White/Yellow/Red	Drip	Sandy clay loam, clay loam
2006	6a	1.1	Rio Red Grapefruit	Drip/Microjet	Silty clay loam
2006	6b	1	Rio Red Grapefruit	Flood	Silty clay loam
2007	1a	50	Rio Red Grapefruit	Narrow Border Flood	Sandy loam, sandy clay loam
2007	1b	15	Valencia Oranges	Narrow Border Flood	Clay loam, loam
2007	1c	85	Rio Red Grapefruit	Narrow Border Flood	Clay loam, loam
2007	1e	32	Onions Yellow	Furrow	Rio Grande silt loam
2007	21c	35.5	Cotton	Furrow	Sandy loam
2007	21d	18	Rio Red Grapefruit	Narrow Border Flood	Sandy clay loam
2007	21e	3	Sorghum	Furrow	Sandy loam
2007	23a	10	Valencia Oranges	Microjet	Sandy clay loam, sandy clay
2007	24a	7	Rio Red Grapefruit	Narrow Border Flood	Sandy clay loam, clay loam
2007	24a	7	Rio Red Grapefruit	Flood	Sandy clay loam, clay loam
2007	25a	56	Onions	Drip	Silt clay
2007	26a	25.7	Onions	Drip	Sandy loam, sandy clay loam
2007	27a	0.65	Onions	Drip	Sandy clay loam
2007	28a	8	Valencia Oranges	Microjet	Sandy loam

Year	Site ID	Acreage	Crop Type	Irrigation Type	Soil Type
2007	28b	3.3	Rio Red Grapefruit	Flood to Drip	Sandy loam
2007	28c	8	Rio Red Grapefruit	Microjet	Sandy loam
2007	28d	7	Marrs Oranges Navel Oranges	Drip	Sandy loam
2007	2a	14	Henderson Grapefruit	Narrow Border Flood	Sandy clay loam, sandy clay
2007	2b	5	Rio Red Grapefruit	Microjet	Sandy clay loam
2007	2c	4	Rio Red Grapefruit	Drip	Sandy clay loam
2007	30a	30	Pasture - Bermuda grass	Center Pivot (MESA)	Sandy loam
2007	30b	30.6	Pasture - Bermuda grass	Center Pivot (MESA)	Sandy loam
2007	31a	9.4	Rio Red Grapefruit	Drip	Sandy loam
2007	31b	5	Rio Red Grapefruit	Narrow Border Flood	Sandy clay, clay
2007	31c	10	Rio Red Grapefruit	Narrow Border Flood	Sandy clay loam
2007	32a	64	Sugarcane	Furrow	Sandy clay loam
2007	33a	45.5	Sorghum	Furrow	Clay
2007	34a	9.4	Rio Red Grapefruit	Narrow Border Flood	Sandy clay loam
2007	35a	86	St. Augustine Floratan turf grass	1280 ft side roll sprinkler	Harlingen clay
2007	3a	41.3	Rio Red Grapefruit	Flood	Sandy clay loam
2007	41a	13	Seed Corn	Surge	Harlingen clay
2007	41b	26	Seed Corn	Furrow	Harlingen clay
2007	42a	66	Cotton	Furrow	Silty clay loam
2007	43a	17	Cotton	Low Pressure Drip	Harlingen clay
2007	43b	39	Cotton	Furrow	Harlingen clay
2007	44a	38	Soybeans	Furrow	Harlingen clay
2007	45a	36.7	Sugarcane	Furrow	Harlingen clay
2007	45b	72	Sugarcane	Furrow	Harlingen clay
2007	4a	16.5	Rio Red Grapefruit	Drip	Sandy clay loam, clay
2007	4b	30	Rio Red Grapefruit	Microjet	Clay loam, clay
2007	5a	22	Onions White/Yellow	Drip	Sandy clay loam, clay loam
2007	5c	74	Onions White	Drip	Sandy clay loam
2007	6a	1.1	Rio Red Grapefruit	Flood	Silty clay loam
2007	6b	1	Rio Red Grapefruit	Flood	Silty clay loam
2007	6c	7.3	Rio Red Grapefruit	Flood	Sandy clay loam
2008	1a	50	Rio Red Grapefruit	Narrow Border Flood	Clay loam, sandy clay loam
2008	1b	15	Valencia Oranges	Narrow Border Flood	Clay loam, loam

Year	Site ID	Acreage	Crop Type	Irrigation Type	Soil Type
2008	1c	85	Rio Red Grapefruit	Narrow Border Flood	Clay loam, loam
2008	1g	33	Onions	Furrow	Rio Grande silt loam, loam
2008	21d	18	Rio Red Grapefruit	Narrow Border Flood	Sandy loam, sandy clay loam
2008	24a	7	Rio Red Grapefruit	Narrow Border Flood	Sandy clay loam, clay loam
2008	28a	8	Valencia Oranges	Microjet	Sandy loam
2008	28b	3.3	Rio Red Grapefruit	Flood to Drip	Sandy loam
2008	28c	8	Rio Red Grapefruit	Microjet	Sandy loam
2008	28d	7	Marrs/Navel Oranges	Drip	Sandy loam
2008	2a	14	Henderson Grapefruit	Narrow Border Flood	Sandy clay loam, sandy clay
2008	2b	8	Rio Red Grapefruit	Microjet	Sandy clay loam
2008	2c	4	Rio Red Grapefruit	Drip	Sandy clay loam
2008	30a	30	Pasture - Bermuda grass	625 ft. Center Pivot MESA	Sandy loam
2008	30b	30.6	Pasture - Bermuda grass	625 ft. Center Pivot MESA	Sandy loam
2008	31a	9.4	Rio Red Grapefruit	Drip	Sandy loam
2008	31b	5	Rio Red Grapefruit	Narrow Border Flood	Sandy clay, clay
2008	31c	10	Rio Red Grapefruit	Narrow Border Flood	Sandy clay loam
2008	32a	64	Sugarcane	Furrow	Sandy clay loam
2008	34a	9.4	Rio Red Grapefruit	Narrow Border Flood	Sandy clay loam
2008	35a	86	St. Augustine Floratan turf	1280 ft side roll sprinkler	Harlingen clay
2008	3a	41.3	Rio Red Grapefruit	Flood	Sandy clay loam
2008	41a	13	Sorghum	Surge	Harlingen clay
2008	41b	26	Sorghum	Furrow	Harlingen clay
2008	44a	38	Seed Corn	Furrow	Harlingen clay
2008	4a	16.5	Rio Red Grapefruit	Drip	Sandy clay loam, clay
2008	4b	30	Rio Red Grapefruit	Microjet	Clay loam, clay
2008	4c	40	Rio Red Grapefruit	Flood	Clay loam, clay
2008	5a	22	Onions White	Drip	Sandy clay loam, clay loam
2008	6d	10	Rio Red Grapefruit	Flood	Fine sandy clay loam
2008	7a	7.3	Rio Red Grapefruit	Flood	Sandy clay loam
2009	1a	50	Rio Red Grapefruit	Narrow Border Flood	Clay loam, sandy clay loam
2009	1b	15	Valencia Oranges	Narrow Border Flood	Clay loam, loam
2009	1c	85	Rio Red Grapefruit	Narrow Border Flood	Clay loam, loam
2009	1d	12	Rio Red Grapefruit	Very Narrow Bordered Flood	Silty clay loam
2009	1g	33	Onions Yellow	Furrow	Rio Grande silt, loam
2009	24a	7	Rio Red Grapefruit	Narrow Border Flood	Sandy clay loam, clay loam
2009	28a	8	Valencia Oranges	Microjet	Sandy loam

Year	Site ID	Acreage	Crop Type	Irrigation Type	Soil Type
2009	28b	3.3	Rio Red Grapefruit	Flood to Drip	Sandy loam
2009	28c	8	Rio Red Grapefruit	Microjet	Sandy loam
2009	28d	7	Marrs and Navel Oranges	Drip	Sandy loam
2009	28e	8	Rio Red Grapefruit	Drip	Sandy loam
2009	2a	14	Henderson Grapefruit	Narrow Border Flood	Sandy clay loam, sandy clay
2009	2b	8	Rio Red Grapefruit	Microjet	Sandy clay loam
2009	30a	30	Pasture - Bermuda grass	625 ft. Center Pivot MESA	Sandy loam
2009	30b	30.6	Pasture - Bermuda grass	625 ft. Center Pivot MESA	Sandy loam
2009	32a	64	Sugarcane	Furrow	Sandy clay loam
2009	35a	86	St. Augustine Floratan turf	1280 ft side roll sprinkler	Harlingen clay
2009	36a	122	St. Augustine Floratan turf	1300 ft. LESA center pivot	Raymondville clay loam
2009	36b	83	St. Augustine Floratan turf	1280 ft side roll sprinkler	Raymondville clay loam
2009	3a	41.3	Rio Red Grapefruit	Flood	Sandy clay loam
2009	41a	13	Seed Corn	Surge	Harlingen clay
2009	41b	26	Seed Corn	Furrow	Harlingen clay
2009	44a	38	Sorghum	Furrow	Harlingen clay
2009	4a	16.5	Rio Red Grapefruit	Drip	Sandy clay loam, clay
2009	4b	30	Rio Red Grapefruit	Microjet	Clay loam, clay
2009	4c	40	Rio Red Grapefruit	Flood	Clay loam, clay
2009	4d	35	Rio Red Grapefruit	Single line drip	Sandy clay loam
2009	5a	22	Onions White	Drip	Sandy clay loam, clay loam
2009	6d	10	Rio Red Grapefruit	Flood	Fine sandy clay loam
2009	7a	7.3	Rio Red Grapefruit	Flood	Sandy clay loam
2010	1a	50	Rio Red Grapefruit	Narrow Border Flood	Clay loam, sandy loam
2010	1b	15	Valencia Oranges	Narrow Border Flood	Clay loam, loam
2010	1c	85	Rio Red Grapefruit	Narrow Border Flood	Clay loam, loam
2010	1d	12	Rio Red Grapefruit	Very Narrow Bordered Flood	Silty clay loam
2010	24a	7	Rio Red Grapefruit	Narrow Border Flood	Sandy clay loam, clay loam
2010	28a	8	Valencia Oranges	Microjet	Sandy loam
2010	28b	3.3	Rio Red Grapefruit	Flood to Drip	Sandy loam
2010	28c	8	Rio Red Grapefruit	Microjet	Sandy loam
2010	28d	7	Marrs and Navel Oranges	Drip	Sandy loam
2010	28e	8	Rio Red Grapefruit	Drip	Sandy loam
2010	2a	14	Henderson Grapefruit	Narrow Border Flood	Sandy clay loam, sandy clay
2010	2b	8	Rio Red Grapefruit	Microjet	Sandy clay loam
2010	32a	64	Sugarcane	Furrow	Sandy clay loam

Year	Site ID	Acreage	Crop Type	Irrigation Type	Soil Type
2010	36a	122	St. Augustine Floratan turf	1300 ft. LESA center pivot	Raymondville clay loam
2010	36b	83	St. Augustine Floratan turf	1280 ft side roll sprinkler	Raymondville clay loam
2010	3a	41.3	Rio Red Grapefruit	Flood	Sandy clay loam
2010	41a	13	Cotton	Surge	Harlingen clay
2010	41b	26	Cotton	Furrow	Harlingen clay
2010	44a	38	Seed Corn	Furrow	Harlingen clay
2010	4a	16.5	Rio Red Grapefruit	Drip	Sandy clay loam, clay
2010	4b	30	Rio Red Grapefruit	Microjet	Clay loam, clay
2010	4c	40	Rio Red Grapefruit	Flood	Clay loam, clay
2010	4d	35	Rio Red Grapefruit	Single Line Drip	Sandy clay loam
2010	6d	10	Rio Red Grapefruit	Flood	Fine sandy clay loam
2010	7a	7.3	Rio Red Grapefruit	Flood	Sandy clay loam
2011	1a	49	Rio Red Grapefruit	Narrow Border Flood	Clay loam, sandy clay loam
2011	1b	14.5	Valencia Oranges	Narrow Border Flood	Clay loam, loam
2011	1c	40	Rio Red Grapefruit	Narrow Border Flood	Clay loam, loam
2011	1d	12	Rio Red Grapefruit	Very Narrow Bordered Flood	Silty clay loam
2011	28a	8.5	Valencia Oranges	Microjet	Sandy loam
2011	28b	8.5	Rio Red Grapefruit	Flood to Drip	Sandy loam
2011	28c	8	Rio Red Grapefruit	Microjet	Sandy loam
2011	28d	8.5	Marrs and Navel Oranges	Drip	Sandy loam
2011	41a	16	Cotton	Surge	Harlingen clay
2011	41b	20	Cotton	Furrow	Harlingen clay
2011	44a	37	Sugarcane	Surge/Furrow	Harlingen clay
2011	4a	16.5	Rio Red Grapefruit	Drip	Sandy clay loam, clay
2011	4b	30	Rio Red Grapefruit	Microjet	Clay loam, clay
2011	4c	14	Rio Red Grapefruit	Flood	Clay loam, clay
2011	4d	35	Rio Red Grapefruit	Single Line Drip	Sandy clay loam
2011	6d	10	Rio Red Grapefruit	Flood	Fine sandy clay loam
2011	7a	7.3	Rio Red Grapefruit	Flood	Sandy clay loam
2012	1a	49	Rio Red Grapefruit	Narrow Border Flood	Clay loam, sandy clay loam
2012	1b	14.5	Valencia Oranges	Narrow Border Flood	Clay loam, loam
2012	1c	40	Rio Red Grapefruit	Narrow Border Flood	Clay loam, loam
2012	1d	12	Rio Red Grapefruit	Very Narrow Bordered Flood	Silty clay loam
2012	28a	8.5	Valencia Oranges	Microjet	Sandy loam
2012	28b	8.5	Rio Red Grapefruit	Flood to Drip	Sandy loam
2012	28c	8	Rio Red Grapefruit	Microjet	Sandy loam
2012	28d	8.5	Marrs and Navel Oranges	Drip	Sandy loam

Year	Site ID	Acreage	Crop Type	Irrigation Type	Soil Type
2012	44b	29.8	Sugarcane	Surge/Furrow	Clay
2012	4a	16.5	Rio Red Grapefruit	Drip	Sandy clay loam, clay
2012	4b	30	Rio Red Grapefruit	Microjet	Clay loam, clay
2012	4c	14	Rio Red Grapefruit	Flood	Clay loam, clay
2012	4d	35	Rio Red Grapefruit	Single Line Drip	Sandy clay loam
2012	6d	10	Rio Red Grapefruit	Flood	Fine sandy clay loam
2012	7a	7.3	Rio Red Grapefruit	Flood	Sandy clay loam
2013	1a	49	Rio Red Grapefruit	Narrow Border Flood	Clay loam, sandy clay loam
2013	1b	14.5	Valencia Oranges	Narrow Border Flood	Clay loam, loam
2013	1c	40	Rio Red Grapefruit	Narrow Border Flood	Clay loam, loam
2013	1d	12	Rio Red Grapefruit	Very Narrow Bordered Flood	Silty clay loam
2013	28a	8.5	Valencia Oranges	Microjet	Sandy loam
2013	28b	8.5	Rio Red Grapefruit	Flood to Drip	Sandy loam
2013	28c	8	Rio Red Grapefruit	Microjet	Sandy loam
2013	28d	8.5	Marrs and Navel Oranges	Drip	Sandy loam
2013	4a	16.5	Rio Red Grapefruit	Drip	Sandy clay loam, clay
2013	4b	30	Rio Red Grapefruit	Microjet	Clay loam, clay
2013	4c	14	Rio Red Grapefruit	Flood	Clay loam, clay
2013	4d	35	Rio Red Grapefruit	Single Line Drip	Sandy clay loam
2013	6d	10	Rio Red Grapefruit	Flood	Fine sandy clay loam
2013	7a	7.3	Rio Red Grapefruit	Flood	Sandy clay loam
2014	1a	49	Rio Red Grapefruit	Narrow Border Flood	Clay loam, sandy clay loam
2014	1b	14.5	Valencia Oranges	Narrow Border Flood	Clay loam, loam
2014	1c	40	Rio Red Grapefruit	Narrow Border Flood	Clay loam, loam
2014	1d	12	Rio Red Grapefruit	Very Narrow Bordered Flood	Silty clay loam
2014	28a	8.5	Valencia Oranges	Microjet	Sandy loam
2014	28b	8.5	Rio Red Grapefruit	Flood to Drip	Sandy loam
2014	28c	8	Rio Red Grapefruit	Microjet	Sandy loam
2014	28d	8.5	Marrs and Navel Oranges	Drip	Sandy loam
2014	4a	16.5	Rio Red Grapefruit	Drip	Sandy clay loam, clay
2014	4b	30	Rio Red Grapefruit	Microjet	Clay loam, clay
2014	4c	14	Rio Red Grapefruit	Flood	Clay loam, clay
2014	4d	35	Rio Red Grapefruit	Single Line Drip	Sandy clay loam
2014	6d	10	Rio Red Grapefruit	Flood	Fine sandy clay loam
2014	7a	7.3	Rio Red Grapefruit	Flood	Sandy clay loam

12. Appendix B: Leveraging resources

In addition to the generous Texas Water Development Board grant for the Agricultural Water Conservation Demonstration Initiative, a number of entities have contributed funds and services to the project. From 2004 to 2009, the Harlingen Irrigation District contributed $2,541,488.96 in services to support the Agricultural Water Conservation Demonstration Initiative project. This included technical management support for demonstrations, project administration and subcontracting, and capital equipment.

Another major partner was the Rio Grande Basin Initiative, which funded the on-farm demonstration sites under the direction of Dr. Juan Enciso. The Harlingen Irrigation District established a cooperative agreement with Dr. Enciso to provide Rio Grande Basin Initiative site data at no cost to the Agricultural Water Conservation Demonstration Initiative project. Dr. Enciso played a vital role in the water management workshops and technical advice for the Agricultural Water Conservation Demonstration Initiative demonstration sites.

The project partners also leveraged the Agricultural Water Conservation Demonstration Initiative grant activities to augment related research projects. In 2009 and 2010, six Texas Project for Ag Water Efficiency demonstration sites were involved in a research project with Texas State Soil and Water Conservation Board and Texas Water Resources Institute designed to assess the best management practices on farm in order to test potential impacts on non-point source pollution into the Arroyo Colorado. While this two-year study was not funded by the Agricultural Water Conservation Demonstration Initiative project, the Texas Project for Ag Water Efficiency partners and cooperators agreed for their sites to be used for data collection in support of the Arroyo Colorado Assessment project.

In fiscal year 2013, the U.S. Department of Agriculture–Natural Resources Conservation Service awarded a $232,552 grant for "Developing Irrigation Management Strategies Under Drought Conditions in Texas." The project was led by Agricultural Water Conservation Demonstration Initiative partners Dr. Juan Enciso and Dr. Shad Nelson and was designed to continue Agricultural Water Conservation Demonstration Initiative core activities related to irrigation scheduling and management. The project focused on enhancing mechanisms to guide producers in scheduling irrigations at optimum times and in precise volumes. The grant was used to develop guidelines for managing irrigation under drought conditions and computer programs for linking weather stations with irrigation scheduling.

Also in fiscal year 2013, the United States Bureau of Reclamation awarded a $155,000 WaterSMART grant to the Rio Grande Regional Water Authority for the Surge Valve Cooperative, a regional agricultural water conservation effort receiving major support from the ADI project partners. The project was a direct result of Dr. Juan Enciso's research for the Agricultural Water Conservation Demonstration Initiative project on the substantial water savings that can be achieved by using surge valves in furrow irrigation. Surge Valve Cooperative was focused on putting surge valves in Lower Rio Grande Valley fields by significantly subsidizing the cost. Participating growers paid only $300 for a valve and controller; in return, they participated in a half-day training workshop.

The following is a list of additional external grant funds that supported the Agricultural Water Conservation Demonstration Initiative project. These funds were brought to the project through the partnership with Texas A&M Kingsville.

- $296,000 - Increasing Student Learning and Career Development Through Agricultural and Natural Resources Based Research. Hispanic Serving Institutions grants. USDA/CSREES Award # 2006-38422-17008. PI: S.D. Nelson, Co-PIs: J.C. Laurenz, R.L. Stanko, T.L. McGehee. July 2006-June 2009.

- $30,000 - Effects of Water Stress on the Efficacy of Selected Pesticides in Citrus Pest Management. Texas A&M University-Kingsville Research Development Funds, University Research Grant Award. PI: M. Setamou, CoPI: S.D. Nelson. Sept. 1, 2007-Aug. 15, 2008.

- $21,000 - Effects of Water Stress on the Efficacy of Temik and Effectiveness of Selected Bayer Products. Bayer Crop Science. PI: M. Setamou, CoPI: S.D. Nelson. April 2008-March 2009.

- $30,000 - Effects of Water Deficit Irrigation on the Efficacy of Pesticides in Citrus Pest Management. USDA/CSREES Rio Grande Basin Initiative Grant. PI: S.D. Nelson, Co-PI: M. Setamou. June 2008-May 2009.

- $7,000 - Approach for a Sustainable Organic System for Organic Farming in the Lower Rio Grande Valley. Texas Citrus Producers Board. PI: S.D. Nelson, Co-PI: M. Setamou, H. Esquivel. Sept.2008-Aug 2009.

- $295,000 - Experiential Learning and Career Development in Agricultural and Natural Resources. USDA/CSREES HSI Grants. July 2009-June 2011. PD: S.D. Nelson CoPDs: R.L. Stanko, K.C.McCuistion. (Approximately 20% of total funds will pay for student labor on projects related to Agricultural Water Conservation Demonstration Initiative goals, or $60,000).

- $28,000 - On-Farm Water Savings Project in South Texas Citrus Production. USDA/CSREES RGBI. PI: S.D. Nelson, CoPI: M. Setamou. Aug 2009-July 2010. (All funds pay forgraduate student labor and water use research pertinent to Agricultural Water Conservation Demonstration Initiative goals).

- $20,000 - Effects of Water Timing on Temik Effectiveness in Citrus Pest Control. Bayer Crop Science. PI: M. Setamou, CoPI: S.D. Nelson. Mar 2009-Jan 2010. (All funds pay for graduate student labor and supplies for water use research pertinent to Agricultural Water Conservation Demonstration Initiative goals).

- $30,000 - Effects of Water Deficit Irrigation on the Efficacy of Pesticides in Citrus Pest Management. USDA/CSREES Rio Grande Basin Initiative Grant. PI: S.D. Nelson, Co-PI: M. Setamou. June 2008-May 2010. (All funds pay for graduate student labor and water use research pertinent to Agricultural Water Conservation Demonstration Initiative goals).

- $21,000 - Effects of Water Stress on the Efficacy of Temik and Effectiveness of Selected Bayer Products. Bayer Crop Science. PI: M. Setamou, CoPI: S.D. Nelson. April 2008 March 2009. (All funds pay for graduate student labor and water use research pertinent to Agricultural Water Conservation Demonstration Initiative goals).

- $7,000 - Approach for a Sustainable Organic System for Organic Farming in the Lower Rio Grande Valley. Texas Citrus Producers Board. PI: S.D. Nelson, Co-PI: M. Setamou, H. Esquivel. Sept. 2008-Aug 2009. (All funds pay for supplies and travel related to graduate projects and water use research pertinent to Agricultural Water Conservation Demonstration Initiative goals).

- $7,500 - Experimental Techniques in Animal & Wildlife Sciences, ANSC 4385. QEP 2010 Quality Enhancement Plan Grants. Texas A&M University-Kingsville. K. McCuistion, S. Nelson, and M. Garcia. Jan 2010-Dec 2010. (All funds pay for training, supplies and travel related to undergraduate research projects pertinent to Agricultural Water Conservation Demonstration Initiative goals).

- $7,500 - Experimental Techniques in Animal & Wildlife Sciences, ANSC 4385. QEP 2010 Quality Enhancement Plan Grants. Texas A&M University-Kingsville. K. McCuistion, S. Nelson, and M. Garcia. Jan 2010-Dec 2010.

- $5,000 - Impact of Saline Irrigation Water on Citrus Rootstocks in the Lower Rio Grande Valley. Texas Water Resources Institute graduate research grants. PD: C.R. Simpson, CoPD: S.D. Nelson. Mar 2010-Feb 2011. Funding provided by United States Geological Survey.

- $290,000 - Developing an Experiential Learning and Career Development Program to Foster and Mentor Students in Agricultural and Natural Resources. USDA-NIFA HSI. Jun 2010-May 2012. PD: R. Hanagriff, CoPD: R.D. Rhoades, C.R. Simpson, K.C. McCuistion, F. Hernandez, S.D. Nelson.

- $42,669 - Proposed Research Program for North African Borlaug Fellows in Irrigation Management and Water Resources. USDA-FAS. PI: S.D. Nelson, Co-PI: M. Setamou, J. daGraca, J. Enciso. Sept. 2010-Aug. 2011.

- $15,000 - Texas Citrus Producers Board. Effects of Different Sources of Compost and Biopesticides on the Management of Key Citrus Pests in Organic Production Systems. P.I. Shad Nelson, Co-PI: M. Setamou, R. Villanueva. Nov. 2010-Oct. 2011.

- $2,000 TAMUK Council for Undergraduate Research (TCUR). Texas A&M University Kingsville Oak Tree Survey and Citrus Water Management Projects. P.I. Shad Nelson, Co-PI: Juan D. Vargas. Oct 2011-Aug 2012.

- $12,500 - Texas Citrus Producers Board. Micro and Macro Nutrient Impacts at Improving Citrus Health to Combat Key Citrus Pests. P.I. Shad Nelson, Co-PI: M. Setamou, J.C. Melgar. Apr.-Aug. 2011. Project Yr 1 funding.

- $25,000 - Texas Citrus Producers Board. Micro and Macro Nutrient Impacts at Improving Citrus Health to Combat Key Citrus Pests. P.I. Shad Nelson, Co-PI: M. Seatmou, J.C. Melgar. Sept. 2011- Aug. 2012. Continued project funding support Yr 2.

- $40,000 - Title V/PPOHA Program proposal. 3D Printing for Texas A&M University Kingsville Graduate Students. PD: L. Peel, Co-PIs: S. Ozcelik, H. Zhou, H. Li, K. Jin, F. Heidari, C. Montiel, P. Mills, L. McLauchlan, S. Nelson. 2011.

- $150,000 - $600,000 Total Award. USDA-NIFA HIS Collaborative Grants. BGREEN: Building Regional Energy and Educational alliances: A Partnership to Integrate Efforts and Collaboration to Shape Tomorrow's Hispanic Sustainable Energy Leaders. PD: (UTEP) H.A. Taboada, J.F. Espirtu, W. Hargrove, S. Hernandez, J. Noveron; (TAMUK) PD: S.D. Nelson, G. Schuster, R.D. Hanagriff; (TSU-San Marcos); (NMSU) T. Jin, L. Sun, R. Richardson, D. valles, H. Sohn, N. Khandan, R. Acharya. 2011-2015. $150,000/yr x 4 yrs ($600,000 total) to Texas A&M University Kingsville (2011-2015). Total Grant Award Distributed Through UTEP: $3,200,000 (2011-2015).

- $800,000 - $3,200,000 Total Award. USDA-NIFA HIS Collaborative Grants. STEP UP to USDACareer Success: Science, Technology, and Environmental Programs for Undergraduate Preparation to USDA Career Success. PD: S.D. Nelson (TAMUK Lead), Co-PDs: E. Louzada, R. Stanko, D. Rupert; (DelMar College) J. Halcomb; (STC) Debbie Villalon; (TSTC) A. Duarte; (UTPA) M. Persans. 2011-2015. $396,000/yr x 4 yrs = $1,584,000 to TAMUK. $800K/yr x 4 yrs (2011-2015).

- $850,000 – United States Department of Agriculture- National Institute of Food and Agriculture, Hispanic Serving Institutions Collaborative Grants. STEP UP to USDA Career Success: Science, Technology and Environmental Programs for Undergraduate Preparation to USDA Career Success. PD: S.D. Nelson(TAMUK Lead), CoPDs: E. Louzada, R. Stanko, D. Ruppert; (DelMar College) J. Halcomb; (STC) Debbie Villalon; (TSTC) A. Duarte; (UTPA) M. Persans. 2012-13.

- $150,000 – United States Department of Agriculture-National Institute of Food and Agriculture, Hispanic Serving Institutions Collaborative Grants. BGREEN: BuildinG Regional Energy and Educational alliances: A Partnership to Integrate Efforts and Collaboration to Shape Tomorrow's Hispanic Sustainable Energy Leaders. PD: (UTEP) H.A. Taboada, J.F. Espirtu, W.Hargrove, S.Hernandez, J. Noveron; (TAMUK) PD: S.D. Nelson, G.Schuster, R.D. Hanagriff; (TSU-San Marcos); (NMSU)T.Jin, L.Sun, R.Richarson D.Valles, H.Sohn, N.Khandan, R.Acharya. 2012-13.

- $136,982 - Developing and Promoting Water Saving Irrigation Strategies to Increase Water Use Efficiency in Citrus. Texas Water Development Board. J.C. Melgar (PD), and S.D. Nelson (Co-PD). (2012-2014).

- $71,300 - Using Halophytes to Mitigate Salinity in Intercropping of Watermelons. Texas Department of Agriculture-Crop Specialty Grant Funds. PD: I. Volder, S. King, Co-PD: C. Simpson, J. Franco, S. Nelson. (2012-13).

- $14,960 - Texas A&M University-Kingsville. Developing Water Saving Irrigation Strategies to Increase Water Use Efficiency in Citrus. J.C. Melgar (PD), M. Setamou, S.D. Nelson and D. Ruppert (Co-PDs). (2012-13)

- $10,000 - Integrated Citrus Fertilizer Management Strategies for Calcareous Soils in South Texas. Texas Citrus Producers Board. J. Jifon (PD), M. Setamou, J.C. Melgar, J. daGraca, and S.D. Nelson.

- $7,200 - Quality Enhancement Plan grants. Texas A&M University-Kingsville. Graduate Students as Mentors of High School Students. J.C. Melgar (PD), E. Louzada, M. Setamou, G. Schuster, and S.D. Nelson.

- $3,000 - Potential Plant Bioaccumulation of Caffeine in Sandy Soils. Texas A&M University-Kingsville. 2012-13 Texas A&M University Kingsville Council for Undergraduate Research (TCUR) grants. S.D. Nelson, M. Dupnik, and C. Hagen. 2012-2013.

13. Appendix C: Related publications and presentations

13.1 Presentations at professional meetings

- Texas Irrigation Expo. Mercedes, TX. October 21, 2010. Economics of New Water Technologies in the Lower Rio Grande Valley.
- 71st Annual Meeting of the Southern Region American Society for Horticultural Science. February 5-8, 2011. Corpus Christi, TX.
    - S.D. Nelson, and M. Setamou. Engaging Underserved Undergraduate Student Populations through Experiential Learning for Careers in Horticultural Sciences. HortScience 46(9):S15. (Abstr.).
    - C.R. Simpson, S.D. Nelson, S. Cornell and M. Setamou. Evaluation of Salinity on Citrus and Watermelon Rootstock Seed Germination. (oral, 2nd place winner, PhD contest)
    - Nelson, S., Enciso, J., Peries, X., and Young, M. Water Use Efficiency and Water Savings in South Texas Grapefruit Production.
- 65th Annual Meeting of the Subtropical Plant Science Society. February 9, 2011. Weslaco, TX.
    - Esparza, M., Raygoza, J., Nelson, S.D. and Setamou, M. Effect of Soil and Foliar Calcium Sources on the Survival of Asian Citrus Psyllid. (1st place winner)
    - Peddabhoini, N.P., Setamou, M., Saldana, R. and Nelson, S.D. Testing the Efficacy of an "Attract and Kill" Strategy for the Control of Citrus Leafminer in Texas. (3rd place winner)
    - Young, M., Nelson, S., Klose, S., and Enciso, J. Impact of Irrigation Method on Rio Red Grapefruit Pack-Out Economics.
- Annual Subtropical Plant Science Society Conference at the Texas A&M University Kingsville Citrus Center. February 9, 2011. Weslaco, TX. Impact of Irrigation Methods on Rio Red Grapefruit Pack-Out Economics.
- North American Colleges & Teachers of Agriculture 2011 Annual Conference. June 2011. Edmonton, Alberta, Canada. S.D. Nelson, K. McCuistion, R. Stanko, and E. Louzada. The Power of Experiential Learning and Mentoring to Increased Underserved Minority Undergraduate Students into Graduate School. 2011 Abstracts: North American Colleges & Teachers of Agriculture Journal. Vol. 55, Suppl. 1, No. 015, p. 8-9.
- Joint Phytopathological Society American Phytopathological Society - International Plant Protection Convention meeting. August 2011. Honolulu, HI. Tanner, J.D., M. Kunta, J.V. da Graca, M. Skaria and S.D. Nelson. Evidence of a Low Rate of American Seed Transmission of Citrus Tatter Leaf Virus in Citrus.
- Annual Meeting of the American Society of Horticultural Sciences. September 2011. Waikoloa, HI. S.D. Nelson, M. Young and J. Enciso. Relating On-Farm Level Irrigation Water Use to 'Rio Red' Grapefruit Pack-Out. HortScience 46(9):S139. (Abstr.).
- Annual Meeting of the American Society of Agronomy - Crop Science Society of America - Soil Science Society of America. October 2011. San Antonio, TX

- Simpson, C.R., A. Volder, S. Nelson, G. Schuster, J.C. Melgar, J. Jifon, and S. King. Assessing the Impact of Salinity on Citrus Rootstocks in the Lower Rio Grande Valley.
    - Williams, C.F., S. Castle, S.D. Nelson, and N. Prabhaker. Linking Soil Sorption to Plant Uptake of the Systemic Insecticide Imidacloprid in Viticulture.
- 9th Annual Texas A&M System Pathways to the Doctorate Symposium. November 11, 2011. College Station, TX.
    - De Leon, V., and S. Nelson. Impact of Organic Matter on Carbon Dioxide Evolution.
    - Garcia, L., and S. Nelson. Nutrient Load Trends in Six Kleberg County Texas Streams.
    - Vargas, D., and S. Nelson. The Texas A&M University Kingsville Southern Live Oak Tree Survey.
    - Field, K., G. Schuster, S. Nelson, K. Ong, and J. Woodward. Isolation of Organisms Causing Boll Rot from Feeding Insects of South Texas.
    - Trevino, J., G. Schuster, S. Nelson, B. Bextine, and J. Munyaneza. Effects of Potato Planting Timing in Texas on Zebra Chip Incidence and Liberibacter Infection Rate in Potato Psyllids.
    - Gomez, M., C. Simpson, S. Nelson, A. Volder, S. King, J. Melgar, and G. Schuster. Salinity Impacts on Growth and Physiology of Grafted and Non-Grafted Citrus Trees.
- The Economics, Finance and International Business Research Conference. December 9, 2011. Miami, FL. S. Nelson, M. Young, R. Hanagriff and S. Klose. An Evaluation of Flood Irrigation and Compost Use in South Texas Rio Red Grapefruit Production: Are There Economic Values?
- 2012 W-2082 Annual Meeting. January 2012. Weslaco, TX. S.D. Nelson. Irrigation Management Impacts on Agricultural Chemical Movements in Soil.
- Soil & Crop Dept. Graduate Seminar. January 2012. College Station, TX. S.D. Nelson. Soil and Water Management Strategies in Citrus Production.
- Southern Agricultural Economics Association annual meeting. February 5-8, 2012. Birmingham, AL. M. Young, S.D. Nelson, S. Klose and J. Enciso. Assessing Irrigation Methods Based on Grapefruit Pack-Out in the Lower Rio Grande Valley.
- Horticulture Dept. Graduate Seminar. April 2012. College Station, TX. (Invited). S.D. Nelson. Irrigation and Nutrient Management Strategies for Preserving Citrus in the Lower Rio Grande Valley.
- Selected Paper presented at American Society of Horticultural Science Annual Conference. July 31-August 3, 2012. Miami, FL. Nelson, S., Esparza, M., Garza, D.E., Setamou, M., and Young, M. Supplemental Calcium Additions for Sustaining Citrus Production and Quality.
- Texas AWE Workshop. January 24, 2013. Los Indios, TX. Farm Assistance Staff. On-Farm Irrigation Advances for Producers. Economics and Water Management.
- Tools, Techniques & Technology for Producers 2013 Workshop Series. January 24, 2013. Harlingen, TX. S.D. Nelson. On-Farm Irrigation Advances for Producers, Soil water sensors and irrigation scheduling.
- 73nd Annual Meeting of the Southern Region American Society for Horticultural Science. February 2-5, 2013. Orlando, FL. S.D. Nelson, J. Enciso, H. Perea, L. Beniken,

M. Setamou, M. Young, and C.F. Williams. Alternative flood irrigation strategies that improve water conservation in citrus production.

- AgriLife Research Spring Seminar Series. March 4, 2013. (Invited) Corpus Christi, TX. S.D. Nelson. Crop & Water Management Strategies for Sustaining Citrus Production in South Texas.
- Texas Citrus Showcase. April 4, 2013. Welasco, TX. S.D. Nelson. Water Conservation Techniques for Citrus: Narrow Borders.
- Rio Grande Basin Initiative Meeting. April 16, 2013. San Antonio, TX. J. Enciso, S.D. Nelson, and M. Young. Irrigation Management Strategies for Water Conservation in the Lower Rio Grande Valley.
- 68th Annual Meeting of the Subtropical Agriculture & Environments Society. February 2014. Welasco, TX. B. Contreras-Barrangan, A. Kusabe, J.C. Melgar, and S.D. Nelson. Partial-Rootzone Drying an Effective Water Saving Strategy in Citrus

13.2 Referred publications

- Financial and Risk Management Assistance Focus Series 2008-5. July 2008. 1-Line Drip and Micro-Jet Spray Irrigation Illustration for Rio Red Grapefruit in the Lower Rio Grande Valley.
- Financial and Risk Management Assistance Focus Series 2008-6. July 2008. 2-Line Drip and Micro-Jet Spray Irrigation Illustration for Rio Red Grapefruit in the Lower Rio Grande Valley.
- Financial and Risk Management Assistance Focus Series 2009-6. July 2009. New Orchard Establishment: Flood and 1-Line Drip Irrigation Illustration for Rio Red Grapefruit in the Lower Rio Grande Valley.
- Young, Mac, Nelson, Shad, Klose, Steven, and Enciso, Juan. August 2010. Assessing Irrigation Methods Based on Grapefruit Pack-Out in the Lower Rio Grande Valley. AgriLife Extension, Department of Agricultural Economics, Texas A&M University.
- Young, Mac, Nelson, Shad, Klose, Steven, and Enciso, Juan. September 2010. An Evaluation of Flood Irrigation and Compost Use in South Texas Rio Red Grapefruit Production. Farm Assistance Focus Series 2010-5. AgriLife Extension, Department of Agricultural Economics, Texas A&M University.
- M. Young, S. Klose, and V. Reynolds. March 2011. Financial and Risk Management Assistance Focus Series 2011-2, Furrow vs. Surge Irrigation in Cotton Assuming Restricted Water Availability in the Lower Rio Grande Valley.
- S.D. Nelson, M. Young, and J. Enciso. Texas A&M University Kingsville Citrus Center Newsletter. March 2011. Evaluating Water Use and Yield from Various Irrigation Systems in Citrus Production. Vol. 29. No. 1. Pg 2-3.
- Nelson, S.D., L. Rock, M. Sétamou, and J. Lloyd-Reilley. June 2011. Flowering native plants able to withstand elevated abiotic salt stress. In (Eds. J.A. Pascual and F. Perez-Alfocea) Proceeding of the Fifth International Symposium on Seed, Transplant and Stand Establishment of Horticultural Crops. Acta Horticulturae. 898:103-111.
- Nelson, S.D., M. Young, J. Enciso, S.L. Klose, and M. Setamou. 2011. Impact of irrigation method on water savings and 'Rio Red' grapefruit pack-out in South Texas. Subtrop. Plant Sci. 63:14-22.

- Simpson, C.R., S.D. Nelson and H.A. Ajwa. 2011. Impact of soil texture and organic matter content on MITC volatilization from soil columns. J. Agricultural Sci. & Techn. A 1:194-198.
- Williams, C.F., and S.D. Nelson. 2011. Comparison for rhodamine-WT and bromide as a tracer for elucidating internal wetland flow dynamics. Ecological Engineering. 37:1492-1498.
- Nelson, S.D., C.R. Simpson, H.A. Ajwa, and C.F. Williams. 2011. Evaluating surface seals in soil columns to mitigate methyl isothiocyanate volatilization. In Integrated Pest Management and Pest Control. Intech-Open Access Publisher. ISBN: 978-953-307-926-4. (Book Chapter, Invited, accepted, in press).
- Nelson, Shad, Young, Mac, Hanagriff, Roger, and Klose, Steven. March 2012. An Evaluation of Flood Irrigation and Compost Use in South Texas Rio Red Grapefruit Production: Are There Economic Values? The Journal of American Academy of Business, Cambridge, 17(2):23-29.
- Nelson, Shad, et al. Fall 2012. Water Savings in Citrus Production for 2011 On-Farm Water Conservation Demonstration Sites. Texas A&M University Kingsville Citrus Center Newsletter. Vol.30, No.2, Pg. 1-2.
- S.D. Nelson. November 2012. Water Savings in Citrus Production for 2011 On-Farm Water Conservation Demonstration Sites. Texas A&M University Kingsville Citrus Center Newsletter. Vol. 30. No.2. Pgs 1-2.
- Nelson, S.D., J.M. Enciso, H. Perea, M. Setamou, M. Young, and C. Williams. Alternative flood irrigation strategies that improve water conservation in citrus production. (In Review by Coauthors).
- Enciso, J., H. Perea, J. Jifon, S. Nelson, and C. Fernandez. Performance of tensiometer and WaterMark sensors on light, medium, and heavy irrigated fields. (In Revision).
- Young, M., Nelson, S., Klose, S., Enciso, J., and McLemore, T. May 2013. Furrow vs. Surge Irrigation in Sugar Cane Under Restricted Water Availability in the Lower Rio Grande Valley. Financial and Risk Management Assistance Focus Series 2013-1. AgriLife Extension, Department of Agricultural Economics, Texas A&M University. Pp. 1-4.
- Perea, H., J. Enciso, J. Jifon, S. Nelson, and C. Fernandez. 2013. Performance of tensionmeter and granular matrix soil moisture sensors in irrigated light, medium, and heavy textured soil. Journal of the Subtropical Agriculture and Environments Society. 65:1-7.
- Perea, H., J. Enciso-Medina, V.P. Singh, D.P. Dutta and B.J. Lesikar. 2013. Statistical Analysis of Non-Pressure-Compensating and Pressure-Compensating Drip Emitters. Journal of Irrigation Drainage Engineering. American Society of Civil Engineers, 139(12), 986-994.
- Nelson, D.D., H.A. Ajwa, T. Trout, M. Stromberger, S.R. Yates and S. Sharma. 2013. Water and methyl isothiocyanate distribution in soil after drip fumigation. J. Environ. Qual. 42:1555-64.
- Young, M., Nelson, S., Klose, S., and Enciso, J. December 2013. Increased Water Use Efficiency and Profitability in Citrus Production Possible in the Lower Rio Grande Valley. Financial and Risk Management Assistance Focus Series 2013-5. AgriLife Extension, Texas A&M University. Pp. 1-3.

13.3 Posters

- Annual Meeting of the Southern Agricultural Economics Association. February 1-3, 2009. Atlanta, GA. Evaluating Alternative Irrigation Systems and Water Pricing in Rio Red Grapefruit Production in the Lower Rio Grande Valley.
- 2010 Irrigation Exposition. October 21-22, 2010. Mercedes, TX. Young, Mac, Nelson, Shad, Klose, Steven, and Enciso, Juan, Peries. Water Savings and Irrigation Use Efficiency in South Texas Grapefruit Production.
- 2010 Irrigation Exposition. Nelson, Shad, Young, Mac, Enciso, Juan, and Peries, Xavier. October 21-22, 2010. Mercedes, Texas. Evaluation of Compost Use in Rio Red Grapefruit Production.
- 71st Annual Meeting of the Southern Region American Society for Horticultural Science. February 5-8, 2011. Corpus Christi, TX.
    - M. Esparza, J. Raygoza, M. Setamou and S.D. Nelson. Impact of Plant Available Calcium to Reduce Asian Citrus Psyllid Survival in 'Rio Red' Grapefruit.
    - S.D. Nelson, M. Young, M. Setamou, X. Peries and J. Enciso. Evaluation of Compost Management in Citrus for Improved Crop Sustainability.
- 65th Annual Meeting of the Subtropical Plant Science Society. February 9, 2011. Weslaco, TX.
    - Nelson, S., Young, M., Enciso, J., and Peries, X. Evaluation of Compost Management in Citrus for Improved Crop Sustainability