USE OF GIS AS A REAL TIME DECISION SUPPORT SYSTEM FOR IRRIGATION DISTRICTS

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ABSTRACT

GIS technology has been utilized in the past years by drainage and irrigation districts mostly for organization of spatial data, and as decision support system. However in some cases, GIS has not reached its full potential due to such factors as lack of interest after initial set up, effort required for and the high costs of keeping the system updated, and a disconnect with daily management.

This paper discusses the development of a real time GIS decision support system for the Brownsville Irrigation District of Texas (District). The objectives were to provide the District with a simple tool that would improve the management of water orders, allow access of data by landowners through the internet, and to improve the availability of pump flow data from the existing SCADA system. An important component of the project was to interact and train District personnel. The final product of the project is a website, where water orders and pump operations information are displayed in real-time, along with links to related historical data, and other information.

The activity resulted in an expanded interest on the use of GIS as a real time decision support system by District personnel, the identification of solutions for limits in the existing database, and recommendations for further improvement. In this paper, we present the steps that were taken with District personnel to set up the system, the website features, and the initial benefits that have been identified by District personnel and the manager.

INTRODUCTION

Water conservation in the irrigation districts of the Lower Rio Grande Valley of Texas has been a key challenge for more than a decade. Hence, new technologies and water management strategies have been implemented. GIS is one of the technologies that have been introduced in irrigation districts, and has been used primarily for mapping and planning purposes (Fipps and Leigh, 1998, Fipps and Leigh, 2003, Leigh et al, 2009). GIS has not reached its full potential, due to such factors as lack of interest after initial set up, high costs of upgrades and keeping the system updated, and a disconnect with daily management.

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A demonstration project started in June 2009 by the Irrigation District Engineering and Assistance (IDEA) program of the Irrigation Technology Center, in collaboration with the Brownsville Irrigation District (District). The general objective was to improve the use of GIS in managing pump operation data, which are monitored with a Supervisory Control And Data Acquisition (SCADA) technology, and water account data.

The District is one of the smaller of 28 irrigation districts in the Lower Rio Grande Valley (Figure 1). The irrigated land is about 4,200 acres, typically using the flood irrigation method, and the most common irrigated crops are corn, soybean, sugarcane, and orchards. Water is pumped from the Rio Grande River, and delivered to the fields by means of re-lift pumps and a network of pipelines under low pressure. Pump operation data are continuously measured and remotely monitored with a SCADA system. Water sales are recorded daily in a water account database, with the support of manual meter readings. The GIS is mainly used to create maps representing total yearly water sales, and distribution network features.

Objectives

The objectives of the project were to:

- Improve access to existing pump operation and water account data, both from District office and via the internet
- Enable landowners and growers to access their data directly
- Use GIS to link different sources of data and to serve as interactive display tool
- Interact and train District personnel

We carried out three main activities:

- Analysis of pumps operation and water orders management
- Education and GIS training program
- Establishment of a Web GIS Pilot Project

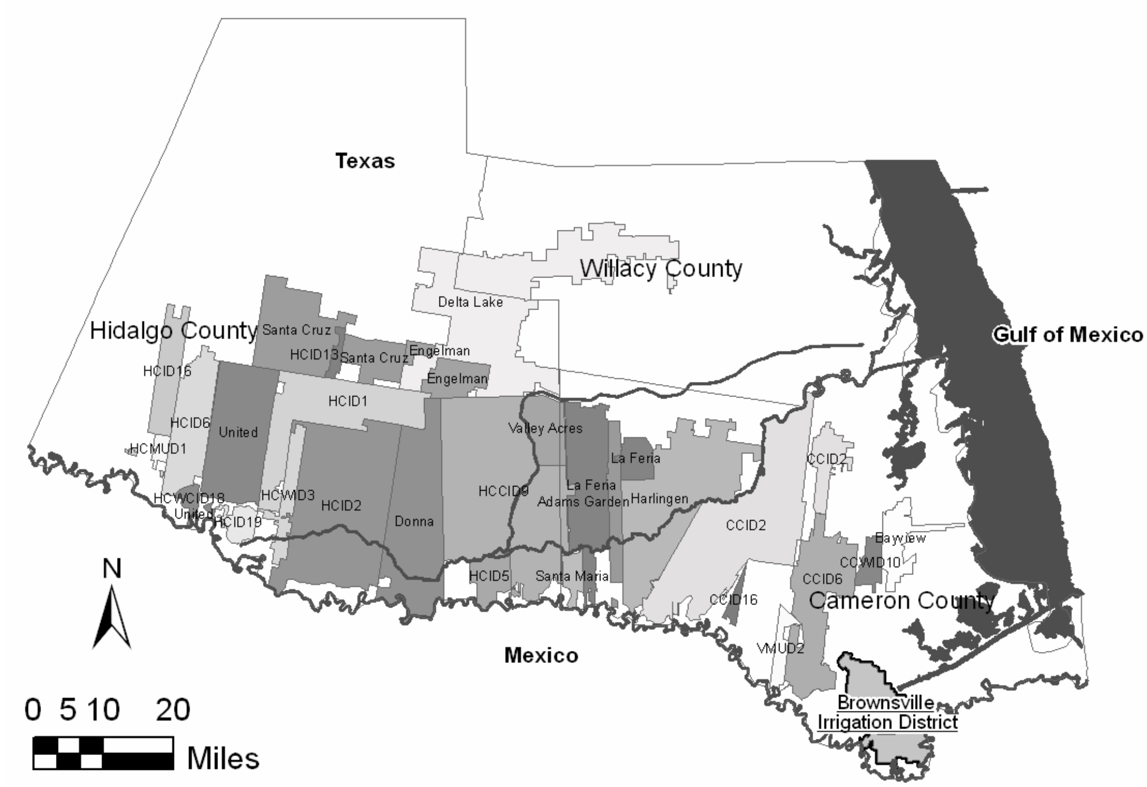


Figure 1. Service areas of the irrigation districts in the Lower Rio Grande Valley of Texas.

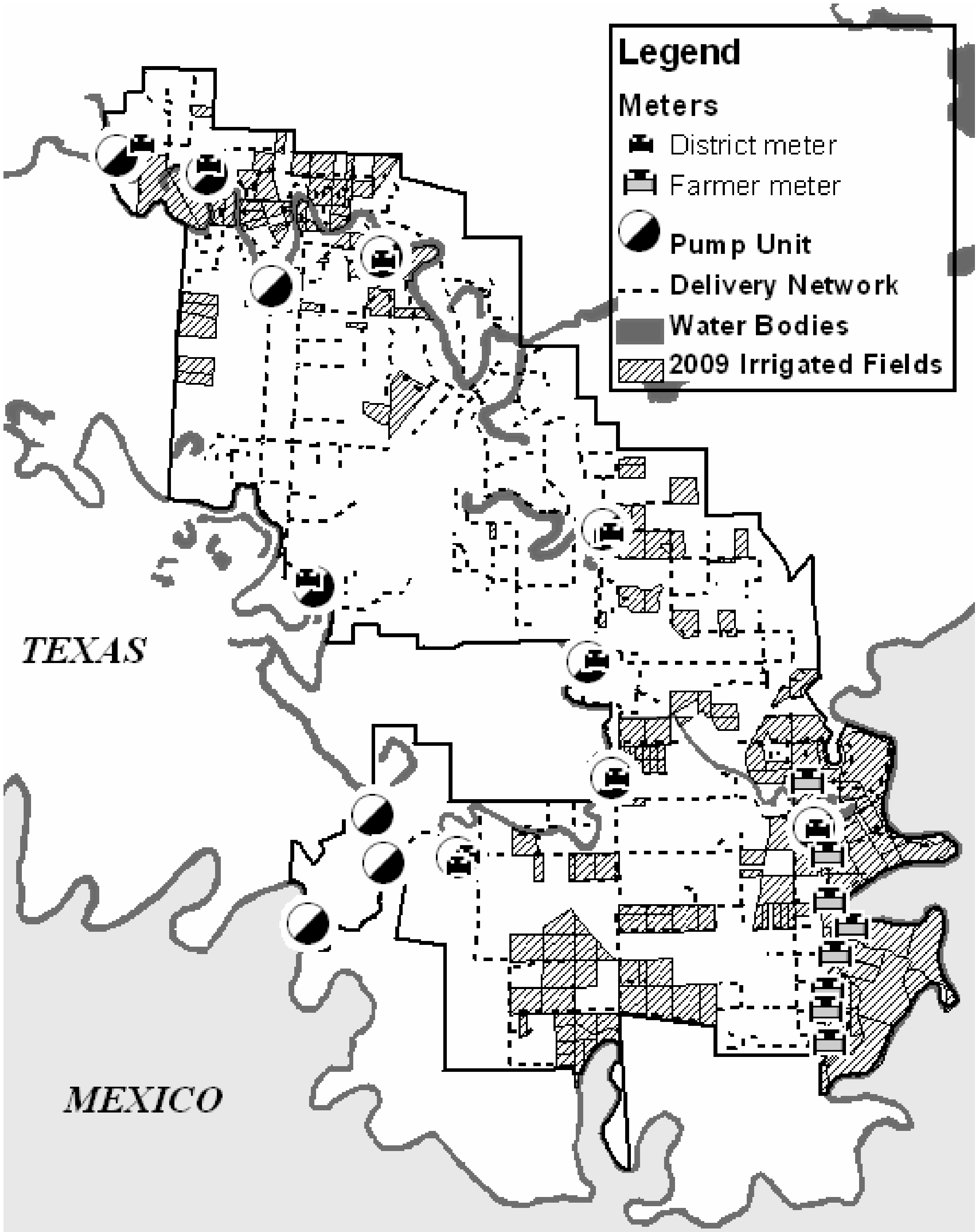


Figure 2. Pump stations and delivery network in the Brownsville Irrigation District.

ANALYSIS OF PUMPS OPERATION AND WATER ORDERS MANAGEMENT

District's Internal Computer Network

We examined the District's internal computer network to ascertain if and how computers are interconnected, how data is stored, what software is used for data acquisition and management, and the level of training of District personnel on the use of computer systems and associated software. Data recorded at the District office were identified, along with storage and use details. We also determined what type of information District personnel considered the most useful and what improvements were desirable.

The District's pumps are equipped with remote terminal units (RTUs) for remote control. The pumps are operated remotely with SCADA software, which is installed on a personal computer (PC1) disconnected from the internal network (Figure 3). The SCADA unit polls the RTUs for water data of the canals from where water is pumped, equipment status (whether pumps are on and off), flow rate, and cumulated flow.

Water account information is stored in the server, and is updated daily from a personal computer (PC2) with the database management software FilePRO (Figure 3). The District manages water orders by selling "water tickets," which specify detailed information such as date of purchase and delivery, amount of water sold and delivered, name of land owner and grower, crop. The water accounts database is frequently not updated in a timely manner with water ticket information, particularly the dates of order and delivery. However, water ticket information for a few of the largest farms is kept more current on a third computer (PC3). GIS database is also managed and stored on PC2.

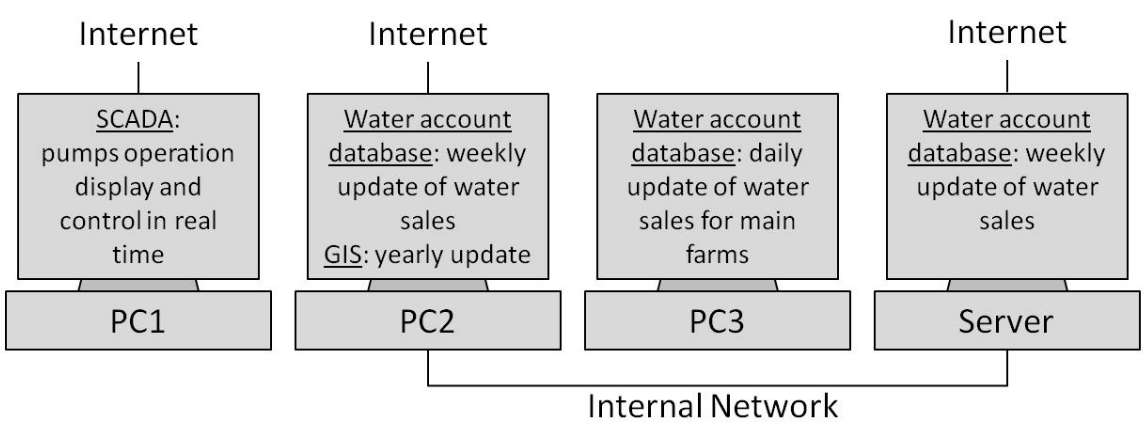


Figure 3. Schema of pump and water orders database management. Communication is missing between some sources of data.

Identified Problems and Recommended Changes

The most evident problem was a missing communication link between different sources of data. Internet access was, nevertheless, ensured to three out of four computers. Some modifications to database settings (e.g. output data formatting) can only be done by contractors, which leads to a strong dependency on the contractor and ties the hands of the District staff.

A list of the problems and recommended changes were compiled (Table 1) for the District, some of which were addressed during the Web GIS Pilot Project.

Table 1. A sample of the identified problems and recommended changes.

	Problems	Recommended changes
Water account database	• Output data are in an encrypted format	• Add routine that converts output in a text file format, or converts to a different database product
	• Update of water tickets is done weekly	• Update water tickets information daily
	• Irrigated fields (“locations”) are missing in the water account database	• Add “location,” ensuring the use of the same code as in the GIS database.
	• Daily updates of water sales are recorded in a standalone computer (no connection to the internal network)	• Record data in the water account computer (PC2)
	• Information on planting date, harvest date, and irrigation method are missing	• Require the canal rider to record this information and update them daily in the database
SCADA	• District personnel do not know how to access stored data	• Convert output into a text file format with the desired frequency
	• No communication with the internal network	• Connect to the internal network
GIS	• Current shape files are not usable with available alphanumeric information and other IDEA Team shape files	• Re-project to common spatial references; add fields to host new information; edit at scale equal or larger than 1:10,000; snap network and update it
	• Water orders area differ from water account area (sub areas, mistakes on drawing, over selling, confusion of order between accounts, etc.)	• Frequently update maps with information on location, turnouts, and cultivated parcels, encourage the identification of irrigated fields with grower
	• “Locations” recorded by canal rider differ from water account boundaries	• If the location is larger, use this name to identify the account; if it is smaller, use it to split account
	• Daily updates of water sales are recorded in a standalone computer (codes in the spread sheet not compatible with GIS)	• Modify files to meet GIS requirements, or record data in the water account computer (PC2)

EDUCATION AND GIS TRAINING PROGRAM

The education and GIS training program was designed to help District personnel and contractors to better use available tools, and to learn new ones. Meetings, GIS classes, demonstration sessions, and field tours were the activities carried out as face-to-face sessions (Table 2). Correspondences by regular mail and email, and phone calls, are not reported in the table, but were used extensively.

Table 2. Face to face education and GIS training program.

	Meetings	Demonstrations	Classes	Field tours
NUMBER OF EVENTS	9	6	2	3
PEOPLE (counted for each event):				
District manager and personnel	11	8	2	1
Water account database contractor	1			
SCADA contractor	1	2		
TOTAL	13	10	2	1
HOURS (hours x people)	28	10.5	5	7

Meetings

Meetings were organized to foster discussions with the manager and District personnel, and to identify expected outcomes. Those discussions focused on improvement need for database organization and access.

To obtain useful results, we met frequently and spent a considerable amount of time discussing the current organization, proposed tools, and specific aspect to be developed. This allowed for both, District and IDEA Team personnel, to understand each other vision, and to carefully evaluate proposed changes.

GIS Classes

The project required that District personnel learn two key skills in GIS database management. Therefore we organized two classes to teach staff how to use basic and some advanced tools available in the ArcGIS ArcView software, and to set up procedures for the Web GIS Pilot Project.

Demonstrations

During the first session, we introduced the manager and District personnel to ArcGIS Server web applications, and demonstrated how the Districts data could be managed with this extension of ArcGIS. In the following session, we designed and taught a tool that could effectively help the District manage pump operation and water orders through ArcGIS Server web applications. The features of this tool are described below.
Sessions were also organized for the SCADA contractor upon his request. We introduced him to the ArcGIS Server web applications, and to the ongoing Web GIS Pilot Project at

the District. After the demonstrations, the contractor expressed his intention to continue GIS education, in an effort to improve further technical assistance.

Field Visits

Several field visits were conducted by the canal rider in order to bring the IDEA Team up to speed on the distribution network system. The visits were useful for understanding the type of field activities carried out, and gave the canal rider the opportunity to explain in detail his work methods.

WEB GIS PILOT PROJECT

The Web GIS Pilot Project was organized in the following steps:

- Ensuring correct data format and features
- Transfer of files in real time from District computers to the IDEA Team server
- Storing and processing of received files
- Creation of GIS projects to synthesize data
- Creation of Web GIS projects for remote access

Data Format and Features

Some changes had to be made to the database structures in order to use them in the Web GIS Pilot Project. A routine was added by the SCADA contractor in PC1 to output and save data in a CSV file format every 15 minutes. Data older than a week are overwritten; in this way the size of the file is kept limited for faster transfer.

In the same way, the FilePRO daily output was set up to be automatically converted to CSV format. The size of this file is not an issue since transfer is only needed once a day.

For PC3, minor changes were made in the spread sheet files to limit errors in the data entry process (e.g. introduction of drop down lists) and to facilitate the exchange of files (e.g. limiting of number of new workbooks).

Finally, spatial references were added to the feature classes in the GIS database, together with identification codes enabling joining with other databases. This allowed for water account detailed boundaries to be added (Figure 4). A procedure was set up in collaboration with the District personnel for ensuring frequent updates of class features.

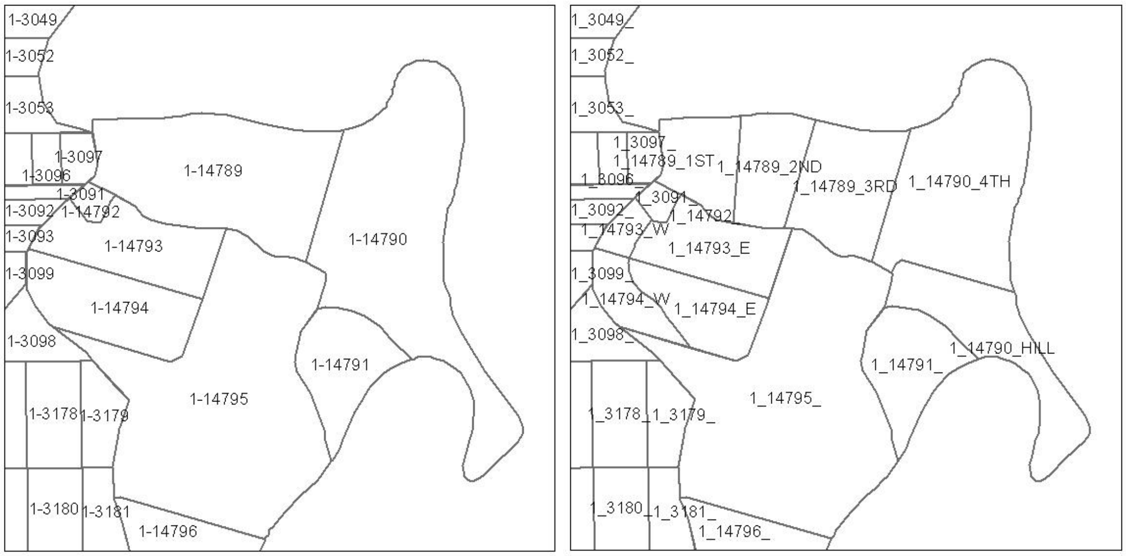


Figure 4. Water accounts were split to display orders in the specific fields. Canal rider can check if water is allocated correctly.

Transfer of Data

Internet access was added to PC3. Then Secure Shell Protocol (SSP) was installed on each computer containing needed files and set up to automatically transfer files from the District computers to the IDEA Team server. Pump operation data were set to be transferred every 15 minutes, while water sales and GIS data were transferred daily.

Processing of Data

A set of automatic routines were set up on the IDEA Team server to process received data. The objective was to create a new, simplified database, and to create queries to extract the most useful information (e.g. current flow rate, last water ticket order, pending water tickets, cumulated ordered water for each field for a selected year, historic database). This data is stored in a SQL Server database. ArcGIS feature classes were converted to geodatabases using ArcGIS ArcInfo, and are manually modified every time there is an update.

Centralized GIS

ArcGIS is used to retrieve all spatial data received and all related information from the database. New maps are created using the feature classes sent by the District combined with those possessed by the IDEA team (roads, soil properties, cities, etc.). Maps are set to automatically update when new attribute data is received.

Web GIS Access

Data is organized to be accessed, displayed and downloaded through the Internet according to the needs of the District manager and personnel. This was done by publishing the new maps as "services" and "web applications," using the ArcGIS Server software, and by linking historical data. Meter readings and District personnel web pages are password protected. Data access, display and download are set up differently for the growers/landowners than for District personnel, to better manage permissions and security issues. Pump operation and water account management in the Web GIS Pilot Project is shown in Figure 5.

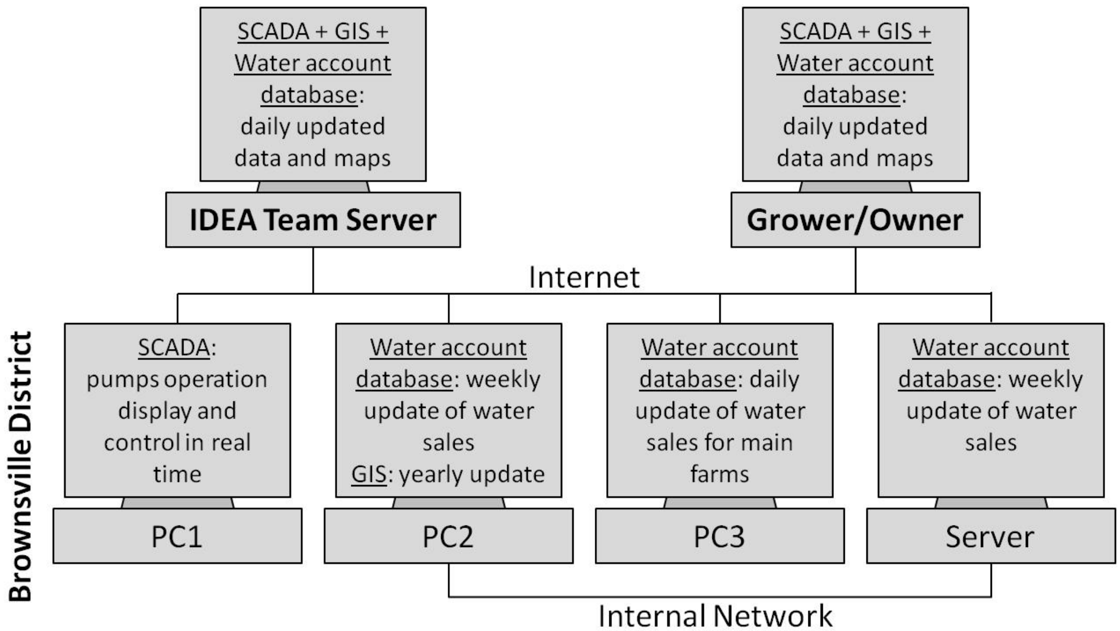


Figure 5. Database management in the Web GIS Pilot Project. Data and maps are shared through the Internet.

<u>Grower/Landowner</u> The grower and the landowner can open a dedicated interactive map (web application) on the District webpage (Figure 6). From the webpage, the grower/landowner can query the flow meter on their land and check the latest readings, which are updated every 15 minutes, without having to call the canal rider. With a different query, they can locate their fields, and find related information on water tickets. Each query requires a password, which was mailed to the grower/owner. Visualized information can also be printed. The map includes useful feature and images, such as delivery network, roads, District boundaries, and aerial photograph (Figure 7).

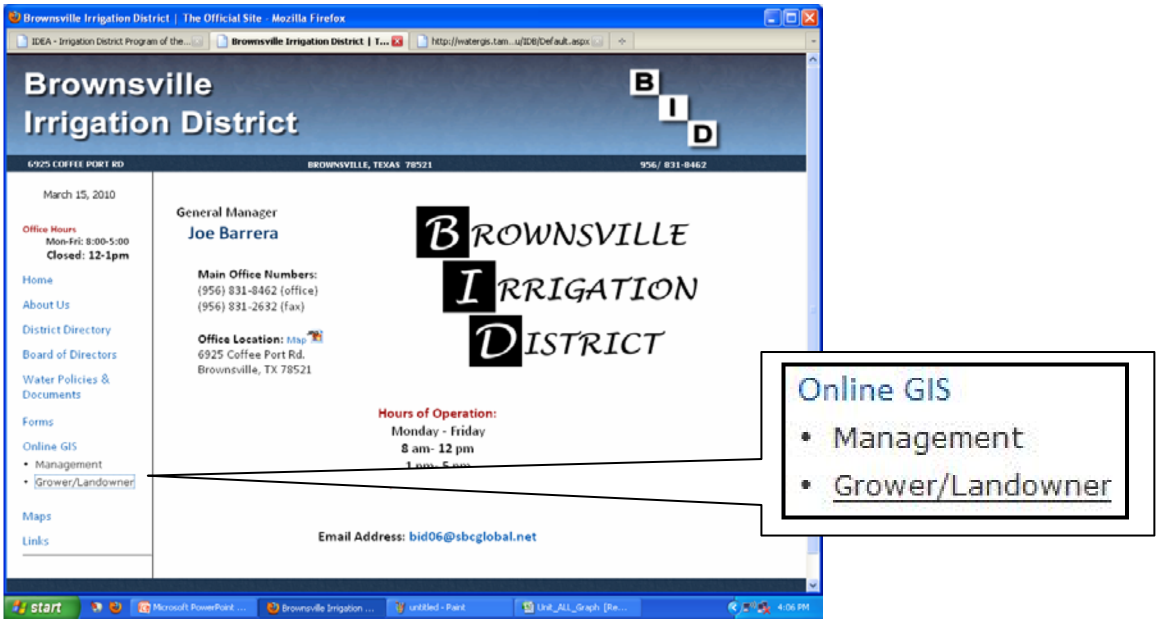


Figure 6. The Grower/Landowner can open a dedicated web application from the District Web page.

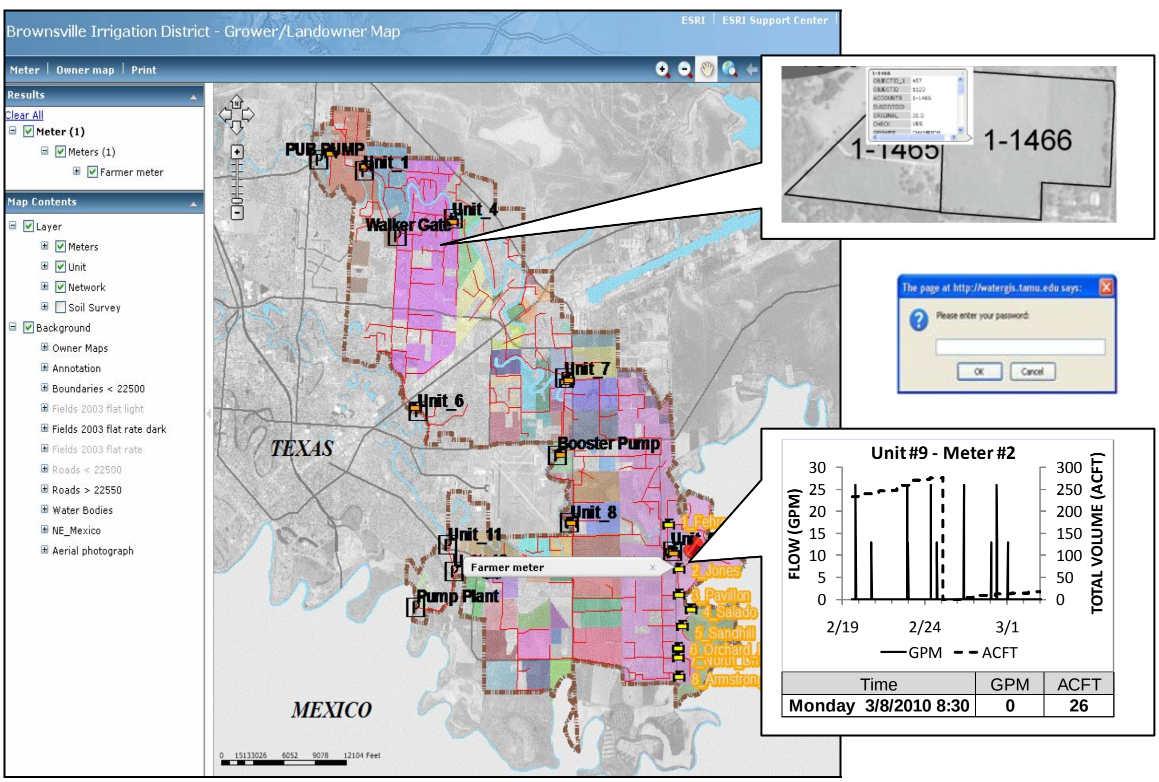


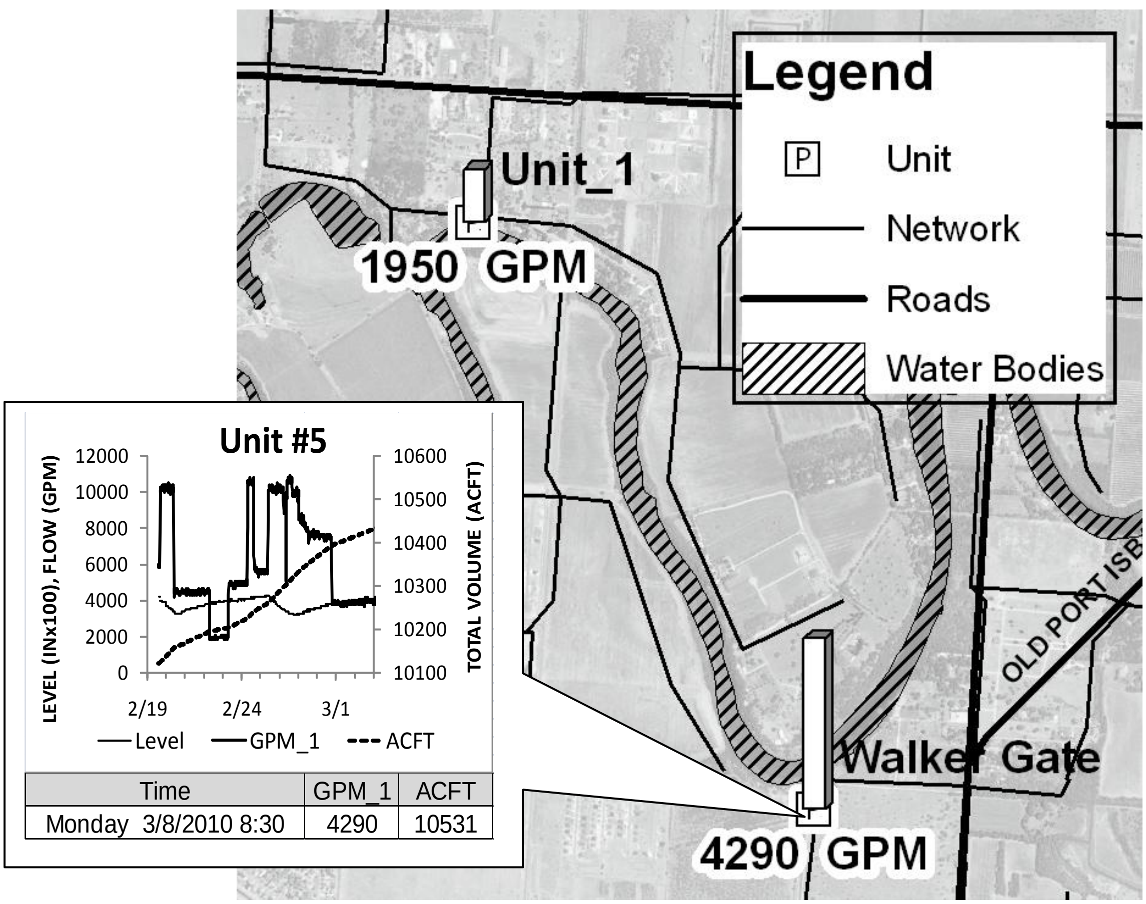
Figure 7. Personal information is retrieved from the Grower/Landowner web application.

District Personnel From the District webpage, District personnel are redirected to another webpage, where they can choose to access real time or historical data. The access to this page is password protected.

The web page shows current operating pumps, related flow and water body levels, along with a link to the data from the last week of operation. The map includes information on other useful features and images, such as delivery network, roads, District boundaries, and aerial photograph (Figure 8).

Real time water sales are displayed in the same web application, and queries are set to find the desired field in the map. Options for queries include searching by water account number, owner name, or grower name (Figure 9).

Finally, all historical data regarding pump operation and water orders can be accessed from a different webpage. Data is in a spreadsheet format, and may contain further elaboration as requested by the District personnel (Figure 10).



Time	GPM_1	ACFT
Monday 3/8/2010 8:30	4290	10531

Figure 8. Pump operation real time and historical data accessed by District personnel.

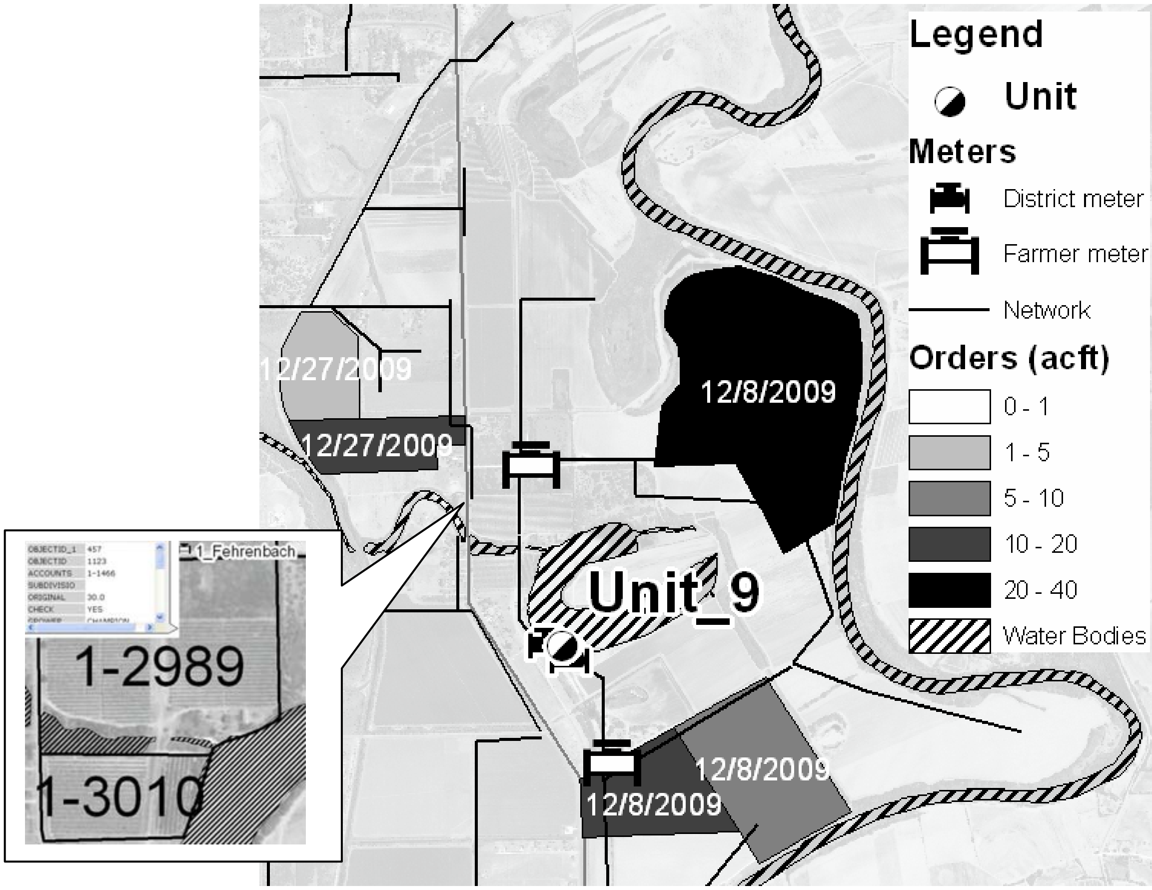
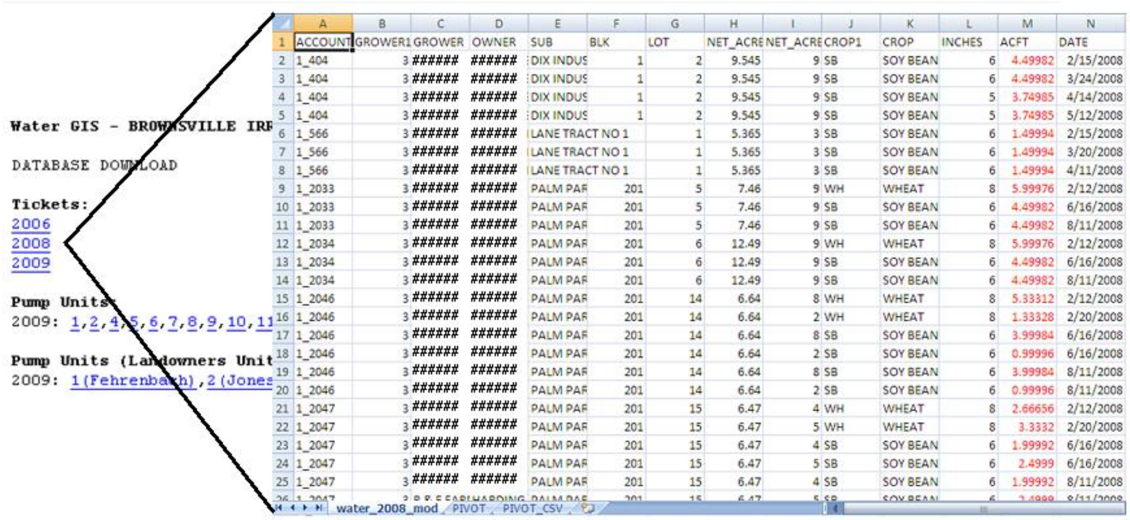


Figure 9. Water ticket sales and water account database accessed by District personnel.



	A	B	C	D	E	F	G	H	I	J	K	L	M	N
1	ACCOUNT	GROWER1	GROWER	OWNER	SUB	BLK	LOT	NET_ACRE	NET_ACRE	CROP1	CROP	INCHES	ACFT	DATE
2	1_404	3	######	######	DIX INDUS	1	2	9.545	9	SB	SOY BEAN	6	4.49982	2/15/2008
3	1_404	3	######	######	DIX INDUS	1	2	9.545	9	SB	SOY BEAN	6	4.49982	3/24/2008
4	1_404	3	######	######	DIX INDUS	1	2	9.545	9	SB	SOY BEAN	5	3.74985	4/14/2008
5	1_404	3	######	######	DIX INDUS	1	2	9.545	9	SB	SOY BEAN	5	3.74985	5/12/2008
6	1_566	3	######	######	LANE TRACT NO 1		1	5.365	3	SB	SOY BEAN	6	1.49994	2/15/2008
7	1_566	3	######	######	LANE TRACT NO 1		1	5.365	3	SB	SOY BEAN	6	1.49994	3/20/2008
8	1_566	3	######	######	LANE TRACT NO 1		1	5.365	3	SB	SOY BEAN	6	1.49994	4/11/2008
9	1_2033	3	######	######	PALM PAR	201	5	7.46	9	WH	WHEAT	8	5.99976	2/12/2008
10	1_2033	3	######	######	PALM PAR	201	5	7.46	9	SB	SOY BEAN	6	4.49982	6/16/2008
11	1_2033	3	######	######	PALM PAR	201	5	7.46	9	SB	SOY BEAN	6	4.49982	8/11/2008
12	1_2034	3	######	######	PALM PAR	201	6	12.49	9	WH	WHEAT	8	5.99976	2/12/2008
13	1_2034	3	######	######	PALM PAR	201	6	12.49	9	SB	SOY BEAN	6	4.49982	6/16/2008
14	1_2034	3	######	######	PALM PAR	201	6	12.49	9	SB	SOY BEAN	6	4.49982	8/11/2008
15	1_2046	3	######	######	PALM PAR	201	14	6.64	8	WH	WHEAT	8	5.33312	2/12/2008
16	1_2046	3	######	######	PALM PAR	201	14	6.64	2	WH	WHEAT	8	1.33328	2/20/2008
17	1_2046	3	######	######	PALM PAR	201	14	6.64	8	SB	SOY BEAN	6	3.99984	6/16/2008
18	1_2046	3	######	######	PALM PAR	201	14	6.64	2	SB	SOY BEAN	6	0.99996	6/16/2008
19	1_2046	3	######	######	PALM PAR	201	14	6.64	8	SB	SOY BEAN	6	3.99984	8/11/2008
20	1_2046	3	######	######	PALM PAR	201	14	6.64	2	SB	SOY BEAN	6	0.99996	8/11/2008
21	1_2047	3	######	######	PALM PAR	201	15	6.47	4	WH	WHEAT	8	2.66656	2/12/2008
22	1_2047	3	######	######	PALM PAR	201	15	6.47	5	WH	WHEAT	8	3.3332	2/20/2008
23	1_2047	3	######	######	PALM PAR	201	15	6.47	4	SB	SOY BEAN	6	1.99992	6/16/2008
24	1_2047	3	######	######	PALM PAR	201	15	6.47	5	SB	SOY BEAN	6	2.4999	6/16/2008
25	1_2047	3	######	######	PALM PAR	201	15	6.47	4	SB	SOY BEAN	6	1.99992	8/11/2008

Figure 10. Historical data can be downloaded by District personnel as spreadsheets.

CONCLUSIONS

In collaboration with the Brownsville Irrigation District, an education and demonstration project was implemented to use GIS in managing pump operation, and water account data.

Problems and recommended changes in managing data were identified. The most relevant problems were an incomplete connection link between computers, a formatting of output data not suitable for GIS applications, and a missing relation between irrigation water orders and irrigated fields.

A Web GIS Pilot Project was established which also addresses some of the identified problems. GIS training sessions were organized to ensure effectiveness of introduced changes. As a result of the Project, real time and historical data can be retrieved from GIS applications through the internet and owners and growers can access their personal water account and meter reading information, reducing need for help from District personnel.

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