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

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ABSTRACT

Most irrigation districts use GIS primarily for simple organization of spatial data. GIS is often put on a lower priority and managed by part-time personnel, which leads to datasets being out-of-date and disconnected from the water daily management. An effective use of GIS is integration with district operations as a real time decision support system.

This paper discusses the development of GIS as a real time decision support system for two irrigation districts in the region of Texas along the Mexican border. Further improvement was made in the Brownsville Irrigation District project, which started in 2009, by introducing an efficient data transfer and by managing all data through a SQL server database. The Cameron County Irrigation District No 2 project started in 2010. This project includes an on-line tool with dynamic and static maps. The dynamic maps display real time Rubicon gate data (on/off, current flow, upstream and downstream water level, and gate position) and water account status (e.g. pending orders, payment delinquents, water balances), and they are designed to assist district personnel with water scheduling and management. The static maps enable a friendlier and quicker access to the frequently used data.

Project work resulted in the identification of limits in the existing database, and recommendations for further improvement. In this paper the process of implementing the projects and the problems encountered, and their effects on the district activities will be presented. Examples of effects include changes in the water management organization, upgrades to new technology, and water and cost savings.

INTRODUCTION

Irrigation districts in Texas are aware that more is to be done in terms of efficiency and data management, and that GIS can be a useful tool. SCADA systems and online information are more being used and linked to GIS (Fipps and Leigh, 1998, Fipps and Leigh, 2003, Bonaiti and Fipps, 2010). The integration of these tools, though, is hardly achieved, and security is an issue when sensitive data are to be displayed online.

We are currently assisting several irrigation districts in the Lower Rio Grande River, which have detailed information on water accounts and flows in the canals, with the objective to improve the efficiency of daily water management. In this paper we present

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the studies of two districts that begun in 2009 and 2010. GIS was integrated to daily water accounting information and to real time water flow monitoring, and linked to the district website. This paper focuses on identifying problems and recommendations, proposing changes, and evaluating the effects of adopted changes.

PROJECTS FEATURES

The projects were carried out in two irrigation districts in the Lower Rio Grande Valley: Brownsville Irrigation District (BID) and Cameron County Irrigation District No.2 (CCID2) (Fig. 1). We describe here the improvements made to the BID project, as compared to the finding by Bonaiti and Fipps (2010), and the new CCID2 project.

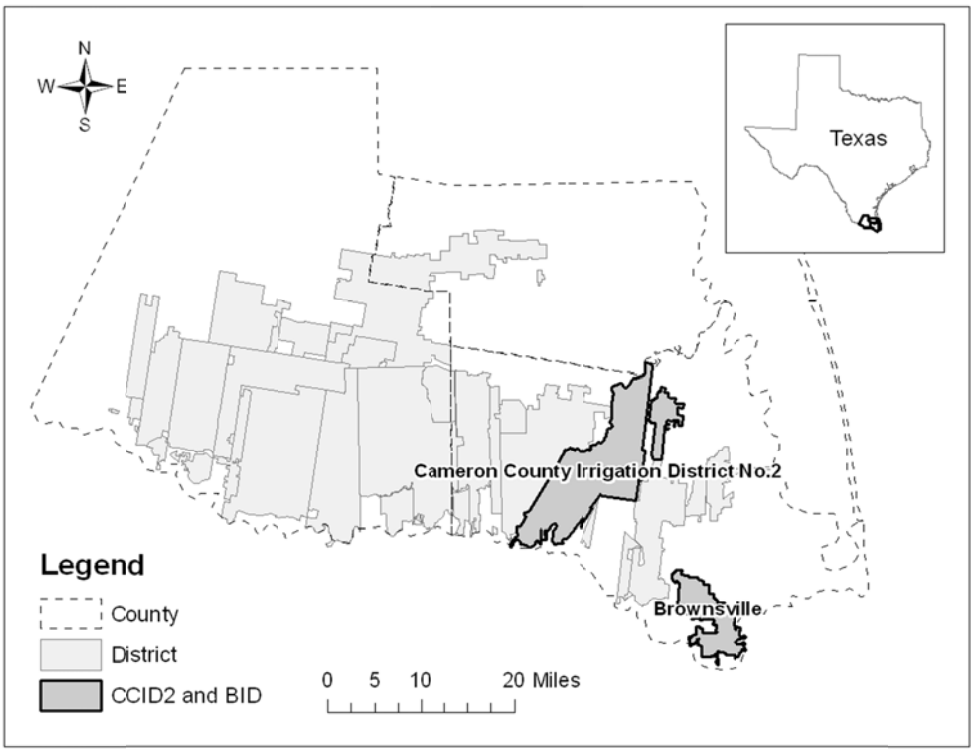

Figure 1. Cameron County Irrigation District No.2 (CCID2) and Brownsville Irrigation District (BID)

Brownsville Irrigation District (BID)

The improvements made to the BID project, which started in 2009, were an updated list of recommendations, data transfer and storage, the improved access to water account data, and the use of periodic evaluations for estimating effects of the activity. Table 1 presents an updated list of the problems and recommended changes.

Table 1. Identified problems and recommended changes for BID (2011 update)

	Problems	Suggestions
Water account database	1. Multiple databases*	1. Need one unified database
	2. Obsolete database software*	2. Move to a new open source database
	3. Output data are in a proprietary format	3. A routine had to be added that converts output in a text file format every day. Convert other database files if needed
	4. Irrigated fields (Locations) are not considered. As a result, water orders acreage do not match water account acreage*	4. Add Locations
	5. Crop management data are not available	5. Add planting date, harvest date, and irrigation method
SCADA	6. There is no communication with the internal network. Connection is needed to directly retrieve data without using Internet	6. Connect the computer to the internal network
	7. Output data are in a proprietary format. Set up is not stable*	7. A routine had to be added that converts output in a text file format every 15 minutes. Add pump on/off information in the output data
GIS	8. Multiple databases*	8. Need one unified database
	9. The information is not up to date*	9. At least yearly update is needed
	10. Irrigated fields (Locations) are not mapped*	10. Add Locations (use the same code or name used in the water account database)
	11. Turnouts are not mapped	11. Add turnouts and command areas
	12. Maps are not properly drawn*	12. Add spatial references, snap beginning and ending points of canals and pipelines, add direction of flow to canals and pipelines, edit at scale equal or larger than 1:10,000
	13. Water account number in the database includes a prefix number. This can lead to errors in data processing*	13. Split water account number and prefix in two separate columns in the database table

*Primary problems

The transfer of data is made possible through the SshSendFile.msi protocol, installed in the computers hosting the SCADA unit and the water account database. It enables transfer of all output files through the Texas A&M University (TAMU) firewall. SCADA data are sent every 15 minutes, while water account data are sent daily. All data, including spatial data, are now stored in a SQL Server database. Links to spatial data are ensured using the ArcGIS Server software, version 10.0. GIS data are manually modified every time there is an update.

A new open source database was adopted by the district to manage the water accounts. Therefore, it has been necessary to re-establish the extraction, transfer, and elaboration of data. By adopting the new database, new information became also available, which can now be retrieved from the web applications.

An evaluation form was periodically distributed to the district personnel for feedback on the effectiveness of the product and on the potential for water and cost saving. Such suggestions will help with the development of new recommendations for further improvement.

Cameron County Irrigation District (CCID2)

A new project started in 2010 with CCID2, one of the biggest districts in the Lower Rio Grande Valley. The district provides municipal water for San Benito, Rio Hondo and East Rio Hondo Water Supply Corporation (WSC), American Electric Power/Central Power and Light Company (AEP/CPL), and over 57,000 acres of irrigated farmland. The delivery network includes about 20 miles of resacas[3], 100 miles of pipelines, 200 miles of open canals (mostly unlined), one pump on the Rio Grande, 15 lift pumps , and 10 automated gates (Fig. 2). The project included the following steps:

1. analysis of the current database management
2. list of identified problems and recommended changes
3. demonstrations on proposed improvements
4. set-up of a pilot project to improve data management and availability through the Internet

Database analysis and recommendations. 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 what level of training does district personnel receive 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 pump on the Rio Grande River, and several gates (Rubicon technology) are equipped with remote terminal units (RTUs) for remote control. They are operated remotely with two SCADA units, which are installed on two separate personal computers (PC1 and PC2) disconnected from the internal network (Fig. 3). The first SCADA unit interrogates the river pump RTU for equipment status (whether pumps is on or off), flow rate, and cumulated flow. The second SCADA unit interrogates the Rubicon gates RTUs for upstream and downstream water level, gate opening, and water flow. This SCADA unit is also operated via the Internet by specialized district personnel using a laptop.

Water account information is stored and updated in the server using a Microsoft Windows Access database (Fig. 3). The district manages water orders by selling "water tickets," which specify detailed information such as date of purchase and delivery, amount of water ordered, name of landowner and grower, and crops grown. The GIS database is managed with a third PC (PC3) disconnected from the internal network.

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[3] An area of river bed that is flooded in periods of high water; an artificial reservoir (Dictionary of American Regional English, 2011. [online] URL: http://dare.wisc.edu/?q=node/144)

A list of the problems and recommended changes were compiled for the district (Table 2). The primary problems were that SCADA outputs are in a proprietary format, information on crop management and delivered volumes is not complete, and GIS is not up to date (e.g. irrigated fields are not present).

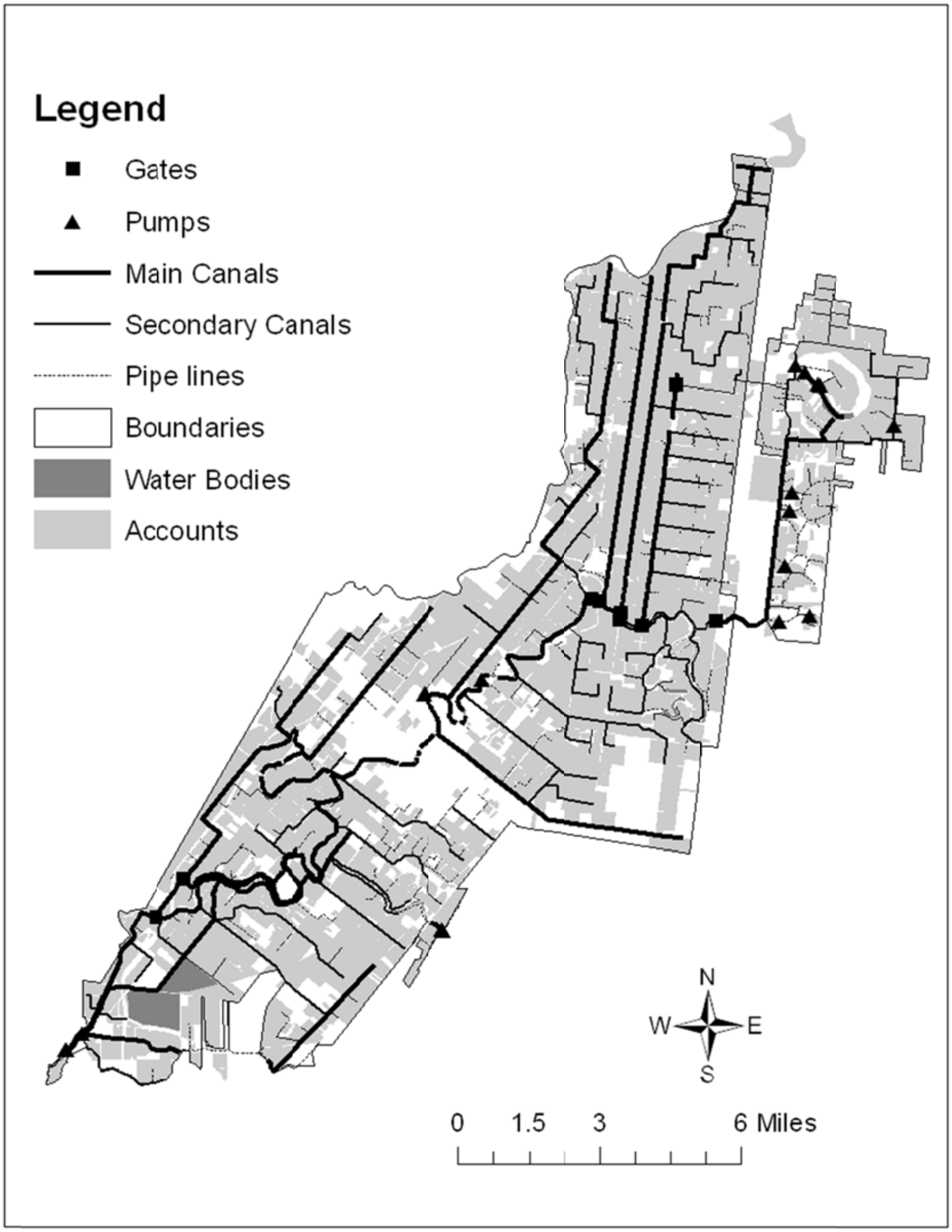


Figure 2. Delivery network and water accounts in the CCID2

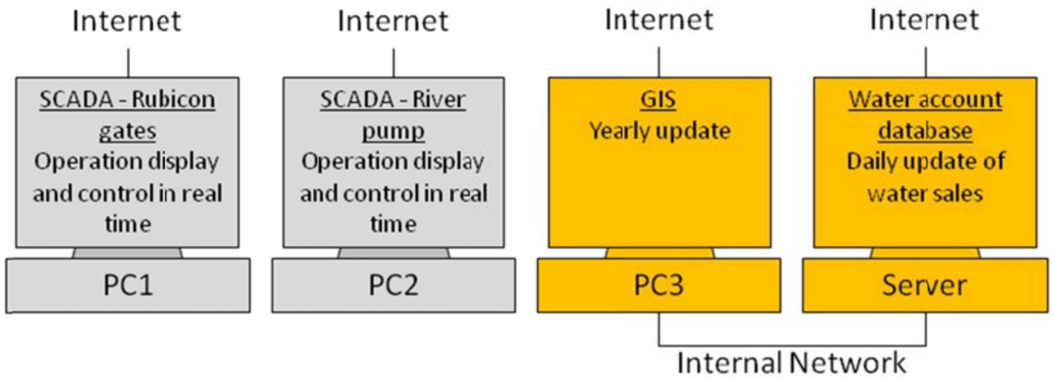


Figure 3. Schema of gates, pumps, and water orders database management
Communication with the internal network is highlighted

Table 2. Identified problems and recommended changes for CCID2

	Problems	Suggestions
Water account	1. Property ID # (PID) is not updated. As a result link to map might fail*	Update PID
	2. Some crop management data are not available	Add planting and harvest date
	3. Delivered volume is missing (only ordered)*	Measure/estimate delivered volumes
	4. Status and date wanted for PID are missing, and cannot be displayed on map*	Ask more detailed information on PID when selling water tickets
	5. Currently irrigated PID/account is not identified*	Monitor begin and end of irrigation
SCADA	6. There is no communication with the internal network. Connection is needed to directly retrieve data without using Internet	Connect the computer to the internal network
	7. Rubicon and Eagle Automation output data are in a proprietary format*	A routine had to be added that converts Rubicon output in a text file format every 15 minutes. Convert also Eagle Automation output data
	8. There is no information on currently operated canals and gates, other than at Rubicon gates (open/close, flow, etc.)	Connect other key locations for irrigation management to the SCADA system
GIS	9. The information is not up to date*	At least yearly update is needed
	10. Turnouts and command areas are not mapped*	Add turnouts and command areas
	11. Max capacity of gates and canals is not in database*	Add max capacity of gates and canals
	12. Maps are not properly drawn*	Add spatial references, snap beginning and ending points of canals and pipelines, add direction of flow to canals and pipelines, and edit at scale equal or larger than 1:10,000

*Primary problems

Web GIS Pilot Project. We set up a demonstration (Web GIS Pilot Project) to introduce the manager and district personnel to the possible use of the ESRI ArcGIS Server software (version 10.0) to integrate SCADA and water orders data, and post them online. The Web GIS Pilot Project is organized in the following steps: 1) ensuring correct data format and features, 2) transferring files in real time from the district computers to our server, 3) storing and processing received files and creating GIS projects, and 4) creating Web GIS applications for remote access.

A routine added by the Rubicon contractor in PC1 outputs and saves gates data in a CSV file format every 15 minutes. Data on PC2 have been not used due to unresolved problems with the contractor. A routine added by the IT consultant in the Server automatically extracts selected tables from the Access database as Excel spreadsheets every day. A procedure set up in collaboration with the district personnel ensures frequent updates of GIS features classes.

The SshSendFile.msi protocol, installed it on PC1, PC2, and the server, enables transfer of all output files through the TAMU firewall. Gate data are sent every 15 minutes, while water sales are sent daily.

All data, including spatial data, are stored in a SQL Server database. Links to spatial data are ensured using the ArcGIS Server software, version 10.0. GIS data are manually modified every time there is an update. Data are organized to be accessed, displayed and downloaded through the Internet according to the needs of the district manager and personnel (Fig. 4).

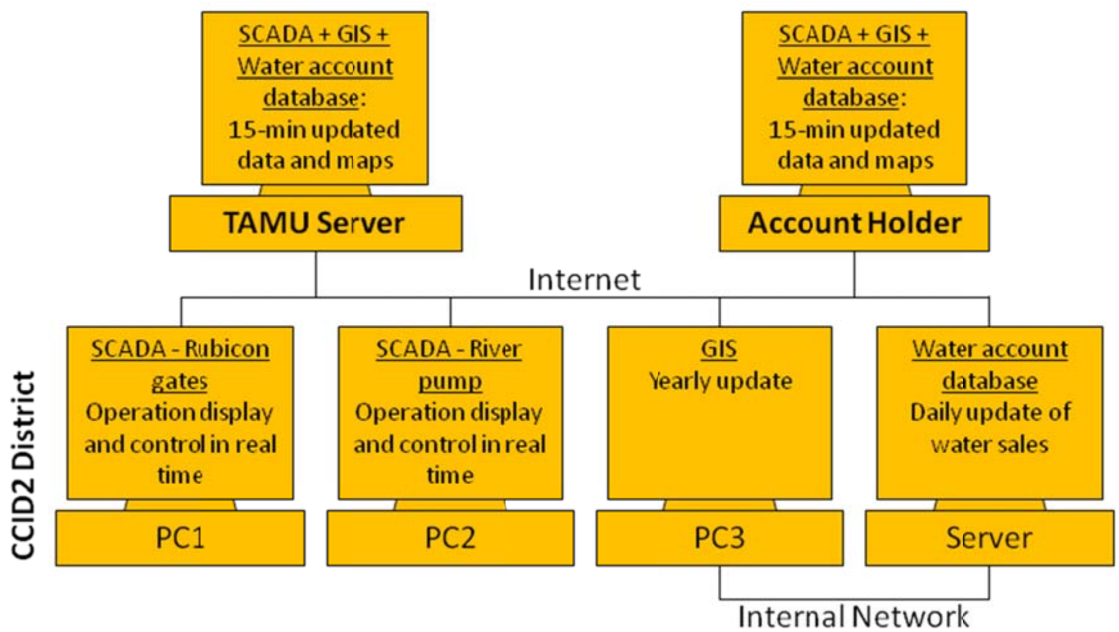


Figure 4. Database management in the Web GIS Pilot Project. Data and maps are shared through the Internet

Data access, display and download are set up differently for the growers/landowners than for district personnel, to better manage permissions and security issues. District personnel can access all data by means of a password protected web application, in which real time and historical data can be queried and downloaded as a spreadsheet and/or displayed on an interactive map. Alarms are set to alert on specific problems (e.g. water levels), and a static map is set up to show the most relevant information in real time, such as water flow, water levels, alarms, and pending water orders (Fig. 6-8). The grower and the landowner can open a dedicated interactive map (web application) on the district webpage. From the webpage, the grower/landowner can locate their fields and find related information on water tickets. Each query requires a password, which was mailed to the grower/landowner. Visualized information can also be printed. The map includes useful feature and images, such as delivery network, roads, district boundaries, and aerial photography (Fig. 9).

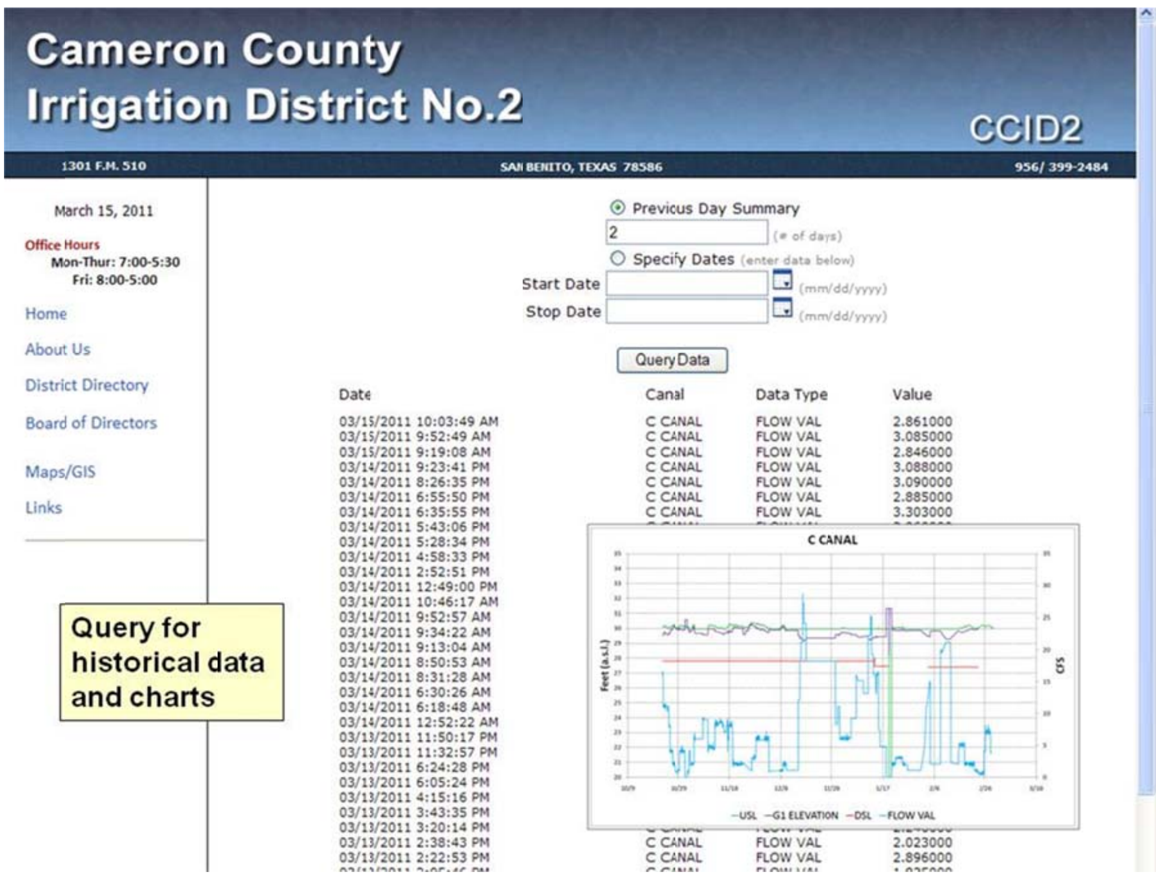


Figure 6. Historical data and charts on gates, downloaded by district personnel

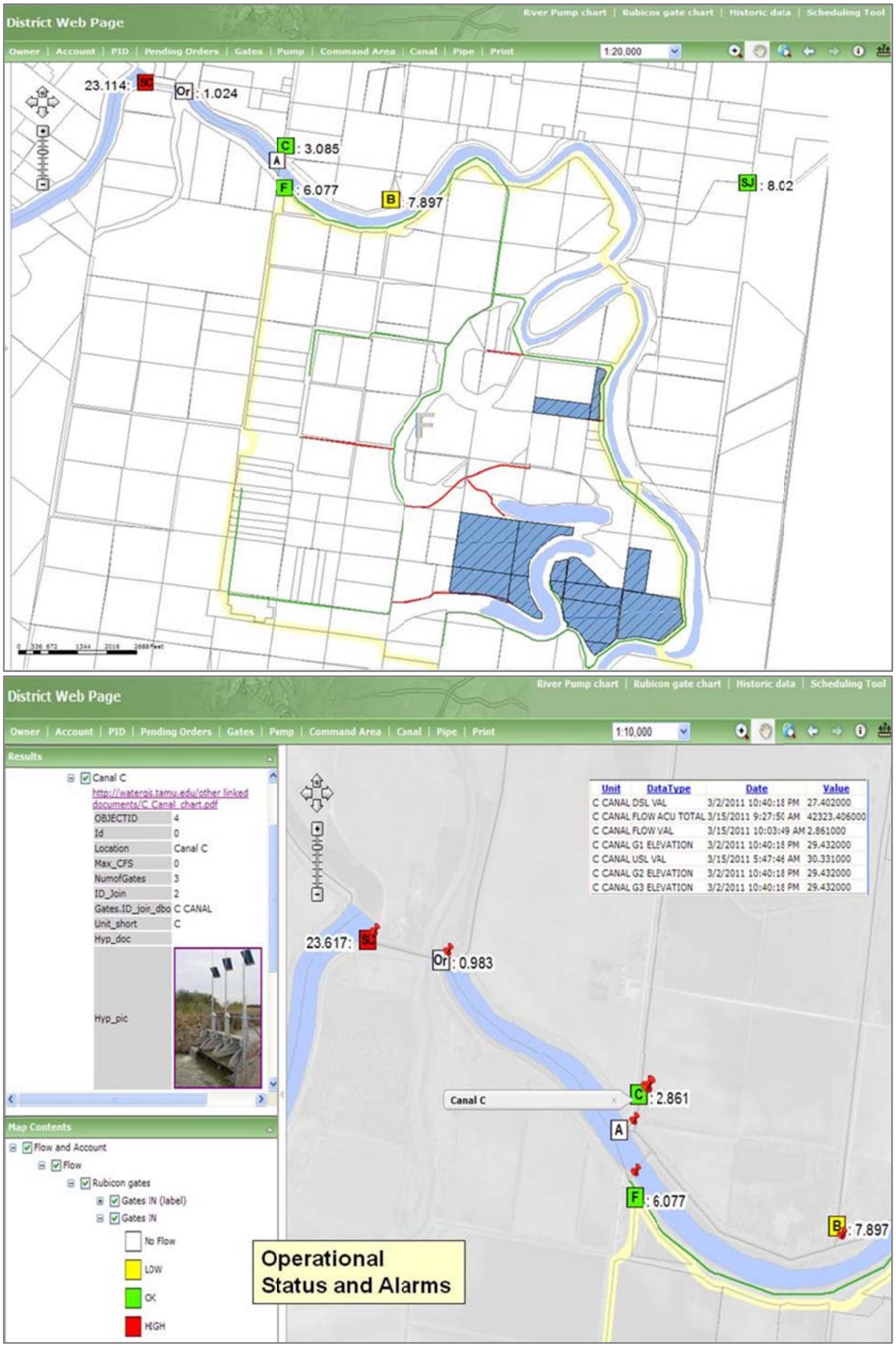


Figure 7. Interactive map accessed by district personnel. Top: Current water orders, network, gates alarms. Bottom: Detailed information on status of gates

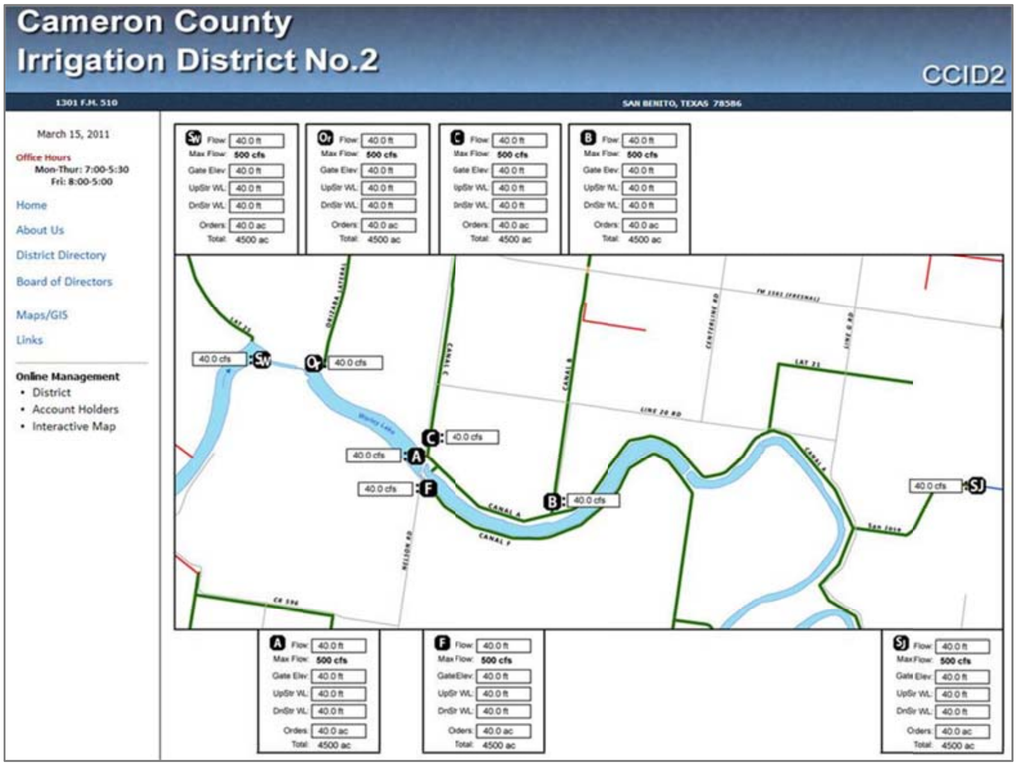


Figure 8. Static map with important information easily accessed by district personnel

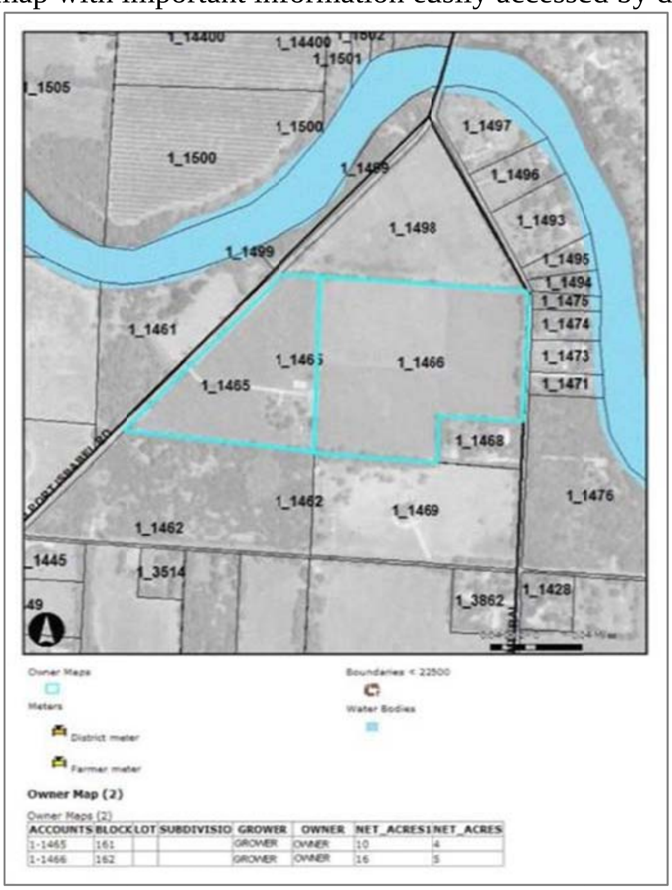


Figure 9. The grower/landowner can identify land on map and print a report

ENCOUNTERED PROBLEMS AND EFFECTS OF INTRODUCED CHANGES

Problems and Solutions

Data management. The SCADA database was in a proprietary format and required the intervention of the contractor to be converted into a format that could be used by district personnel. The polling interval and method varied according to the contractor. The set-up of a routine creating output data every 15 minutes was a feasible solution for all contractors, and acceptable for the time step required by the district personnel. Water account databases were also in a proprietary format in some cases, requiring the same solution adopted for SCADA systems. In the case of CCID2 the database was a Microsoft Access database, which is a simple database to deal with. Also in this case, though, the extraction of selected data was a process not performed on a regular basis, which required some set-up time by the IT consultant. We preferred to let the consultant deal with the processing of the database, even if the data were available in accessible format. Over all this phase required long time, but in our opinion was a successful process.

The other problems related to data management were automatically transferring them to our server, and storing and connecting them to spatial data. The issue with the firewall protecting the TAMU server was solved by writing a specific code (SshSendFile.msi protocol), while the storage and management of data was all done using a SQL server database. Also the spatial data were converted to geodatabases and stored in the SQL database, and dynamic links were managed with the “join” operation within the ArcGIS projects.

Collaboration with contractors and consultants. The involvement of the contractors was needed because most of the time they were the only ones that could manipulate the data. Often they also were the only ones that knew exactly what data were available. Contractors sometime saw us as competitors, so cooperation was lacking at times. This problem was resolved through negotiations that involved all of the people, sometimes being very time consuming. In one case we didn’t reach agreement. Except for a few times, the district encouraged us to be involved with the contractors.

As mentioned above, we always involved the consultants when managing data within the district office. This involvement was beneficial not only in terms of knowledge and future collaboration, but also in terms of minimizing any impediment to the current organization of the system. For example, minor issues needing resolution included the set up of additional users and passwords, and the choice of the best time of the day to extract and transfer files in case that the computer would be switched off at night.

Identification of district needs and best solutions. A challenging activity within the project was to identify solutions that would suit the district needs. As the district was not familiar with the proposed technology we had to design the project based on our knowledge of the district, rather than on a specific request. Among other activities, we organized some GIS classes to ensure basic skills, and workshops to demonstrate and discuss the features of the project. As a result we gained good understanding of the district activities, personnel skills, and potential for improvements.

Security. One of the recurring requests by the district was a security system that would ensure protection to sensitive data, such as landowner names, addresses, water and money balances, and meter readings. A simple password system was enough for most data, and this was possible also for the ArcGIS Web applications. In some cases, such as when enabling the user to access money and water balances, we introduced an Hypertext Transfer Protocol Secure (HTTPS) to provide encrypted communication and secure identification.

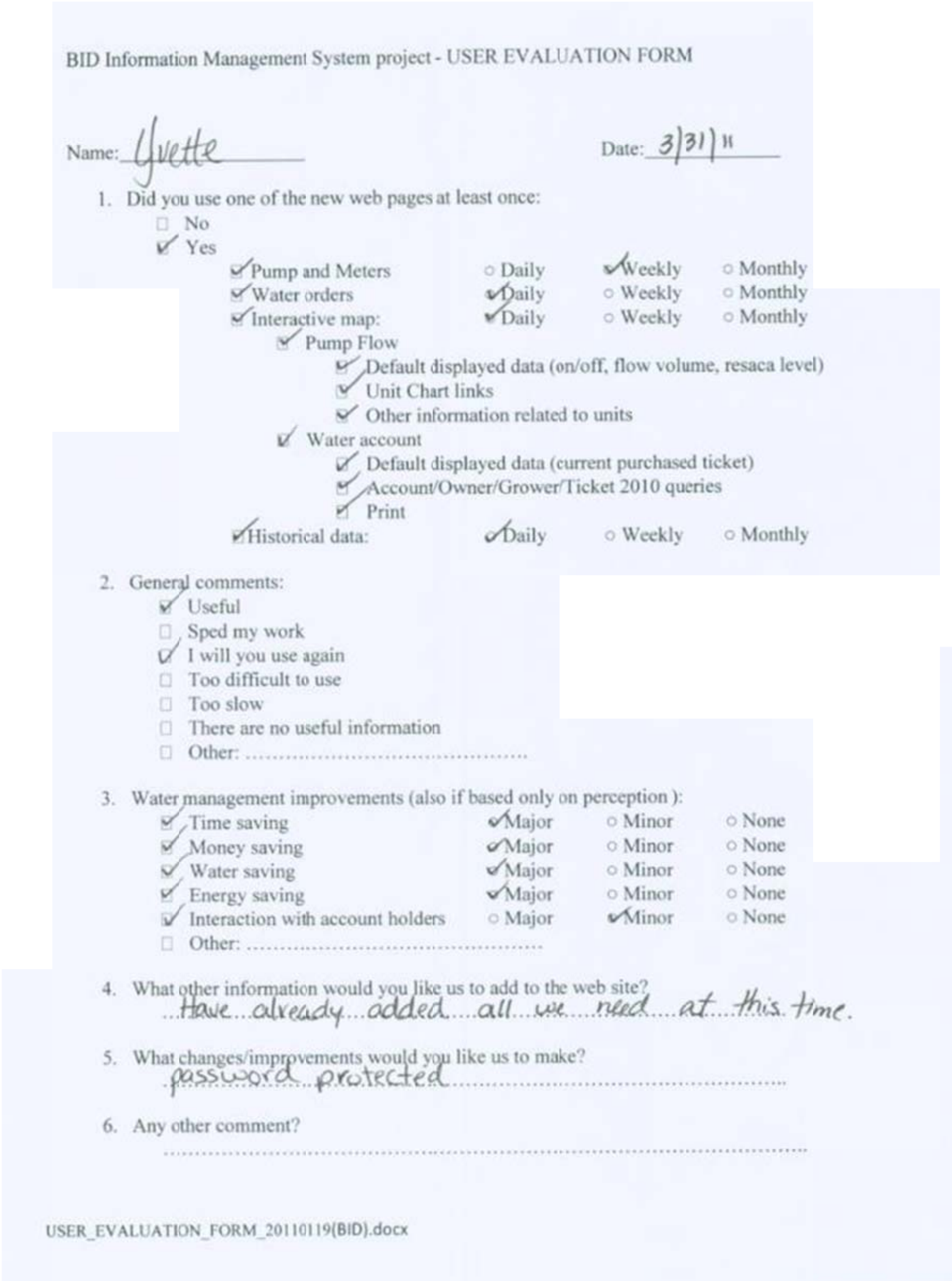
Data validation. Finally, another issue that we encountered was the management of un-validated data, still present in the database because the district typically used SCADA data only as real time source of information. Considering the importance given to the historical data in our project, we set up some simple automatic strategies to overcome most of the common errors, such as setting of routines to delete data when outside a minimum or maximum threshold.

Effects on district activity

Our activity produced some effects that looked promising for the improvement of the water management efficiency. A direct effect of the project was the district’s newly adopted work strategies. Probably one of the most interesting feature was the ability of the account holders to read their own flow meters at the beginning and at the end the irrigation. District personnel evaluated the process periodically through an evaluation form process (Fig. 10). From these initial forms there was a consistent perception that the changes introduced could save water and costs.

Another type of effect was the compliance to our recommendations for improvement, in addition to the changes required to develop the activity. For example, the district moved from an old-fashioned proprietary water account database to an open source database. Many other changes are being introduced, such as introducing other crop management data (e.g. date of planting and irrigation method), updating of water account information daily, and bringing GIS up to date. Overall, we observed an active response to our suggestions, and the development of new ideas. We therefore proposed an extended collaboration for a second phase with new goals based on such ideas.

The promising results encouraged both districts to engage in funding the second phase of the project. The results also moved other districts to seek collaboration with us in order to set up similar systems. These districts found out about the program in various ways, such as workshops, word of mouth, etc.



BID Information Management System project - USER EVALUATION FORM

Name: Yvette Date: 3/31/11

1. Did you use one of the new web pages at least once:
   - ☐ No
   - ☑ Yes
     - ☑ Pump and Meters ○ Daily ✔ Weekly ○ Monthly
     - ☑ Water orders ✔ Daily ○ Weekly ○ Monthly
     - ☑ Interactive map: ✔ Daily ○ Weekly ○ Monthly
       - ☑ Pump Flow
         - ☑ Default displayed data (on/off, flow volume, resaca level)
         - ☑ Unit Chart links
         - ☑ Other information related to units
       - ☑ Water account
         - ☑ Default displayed data (current purchased ticket)
         - ☑ Account/Owner/Grower/Ticket 2010 queries
         - ☑ Print
     - ☑ Historical data: ✔ Daily ○ Weekly ○ Monthly
2. General comments:
   - ☑ Useful
   - ☐ Sped my work
   - ☑ I will you use again
   - ☐ Too difficult to use
   - ☐ Too slow
   - ☐ There are no useful information
   - ☐ Other: ....
3. Water management improvements (also if based only on perception):
   - ☑ Time saving ✔ Major ○ Minor ○ None
   - ☑ Money saving ✔ Major ○ Minor ○ None
   - ☑ Water saving ✔ Major ○ Minor ○ None
   - ☑ Energy saving ✔ Major ○ Minor ○ None
   - ☑ Interaction with account holders ○ Major ✔ Minor ○ None
   - ☐ Other: ....
4. What other information would you like us to add to the web site?
   ...Have already added all we need at this time.
5. What changes/improvements would you like us to make?
   password protected..
6. Any other comment?
   ....

USER_EVALUATION_FORM_20110119(BID).docx

Figure 10. Evaluation form for district personnel, completed periodically

CONCLUSIONS

The project was developed in districts that were already feeling the urgency to upgrade their technologies, including GIS. Specific interests were to make best use of the large amount of available data, to adopt web applications, and to enable customers to access their data through the Internet.

Despite the efforts and will, these changes required a long time to be fully implemented due to a number of issues, such as identifying district needs, accurately designing the project, integrating the non optimal existing data, securing sensitive data, and involving contractors and consultants. Referring to contracts, they should be specific in non-propriety software in that any consultant should be able to modify in the future, and district personnel should be able to extract all data they need at any time. Nevertheless, collaboration with contractors resulted beneficial for the sound implementation of the project.

The activity produced some effects that looked promising for improved water management efficiency. The districts adopted most of the new proposed strategies, promptly complied with many recommendations, started suggesting further steps, and directly began to participate in the project implementation expenses. Finally, other districts requested our collaboration to set up similar projects.

There was an overall feeling from the districts that the adopted changes would help save water and costs, and this was assessed by means of periodical qualitative evaluations. Nevertheless, there is a need to quantitatively estimate such benefits. Water balances and reliable historical data might help to make these assessments in the future. An initial understanding of such benefits might be obtained with a description of improved services provided to growers (e.g. availability of flow meter readings on line reduces the number of calls to the canal rider).

REFERENCES

Bonaiti G., Fipps G. 2010. Use of GIS as a Real Time Decision Support System for Irrigation Districts. Proceedings of the Conference “Meeting Irrigation Demands in a Water Challenged Environment”, Fort Collins, Colorado, September 28 October 1, 2010: US Committee on Irrigation and Drainage.

Fipps G., Leigh E. 1998. GIS-Based Management System for Irrigation Districts: Implementation of a District Management System in the Lower Rio Grande Valley of Texas. Proceedings of the 14th Technical Conference, Phoenix, Arizona, June 3-6, 1998: US Committee on Irrigation and Drainage

Fipps G., Leigh E. 2003. GIS as a Tool in Irrigation Districts and Projects. Proceedings of the USCID Second International Conference, Phoenix, Arizona, May 12-15, 2003: US Committee on Irrigation and Drainage