LOW-COST AUTOMATION AND SCADA: A PACIFIC RIM PERSPECTIVE

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Abstract

Automating water projects makes economic sense in the western United States. But is it justified in other parts of the world? The authors feel strongly that it is. This paper discusses the experiences of the U.S. Bureau of Reclamation and others in developing, installing, and evaluating low-cost automation systems in the western United States. It also briefly discusses similar low-cost automation projects in P.R. (People's Republic of) China and Malaysia.

Introduction

Several developments in recent years have made real-time monitoring and control cost-effective for even smaller irrigation systems. The convergence of the following technologies has made low-cost automation a viable reality: (1) low-cost data loggers/controllers; (2) a growing variety of inexpensive sensors; (3) expanding use of solar-energy systems; (4) innovations in communication equipment; (5) rapid advancements in the PC industry; and (6) the phenomenal growth of the Internet. The latter is exemplified by what is occurring in South Korea. More than a third of the country's 47 million people are logging onto the Internet: one of the highest per-capita ratios of web access in the world[1].

This paper will discuss low-cost automation and SCADA (supervisory control and data acquisition) projects in the USA, P.R. China, and Malaysia. Staff from the U.S. Bureau of Reclamation (Reclamation) is a primary or secondary participant in all projects. General information on each automation project is shown in Table 1 and the location of each is shown in Fig. 1.

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Table 1
General Information on Automation/SCADA Projects

Irrigation Project	Location	Automation Type*	Sponsor
Sevier River Basin	Western USA	C	Sevier River Water Users Association (SRWUA)
Jingtai Irrigation Scheme	North-West P.R. China	D	China Institute of Water Resources and Hydropower Research (IHWR)
Kerian Irrigation Scheme	North Peninsular Malaysia	D	Malaysia Department of Irrigation and Drainage (JPS)
Kerian Irrigation Scheme	North Peninsular Malaysia	C	Malaysia Department of Irrigation and Drainage (JPS)

*C=Complete System
D=Demonstration Project

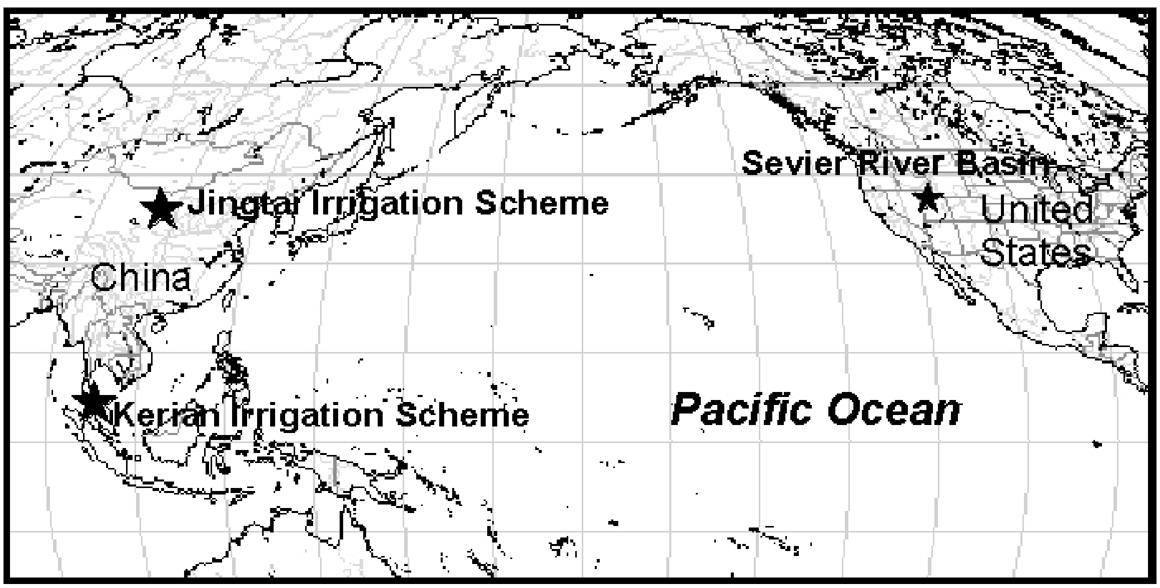

Fig. 1
General Location of Low-Cost Automation/SCADA Projects

Sevier River Basin, USA

The Sevier River Basin (Basin) in south-central Utah is one of the state=s major drainages. A closed river basin, it encompasses 12.5 percent of the state=s total area. From the headwaters, 400 kilometers south of Salt Lake City, the river flows north and then west 300 river kilometers before reaching Sevier Lake. Since the turn of the century, irrigation has depleted the river and the only flows that reach the terminal lake are occasional floods, like those in 1983 and 1984, and some return flow.

Automation System

The Sevier River Basin is instrumented with low-cost automation equipment and a low-cost SCADA system which uses the Internet (www.sevierriver.org) and web browser as a delivery vehicle for real-time data display[2]. The automation system includes 3 large reservoirs, 3 smaller re-regulating reservoirs, and 15 diversion structures. Additionally, there are 10 river monitoring sites, 15 canal monitoring sites, plus four weather stations (and counting). Most of the field sites (including those with control) are solar powered. A typical field installation is described in this paper's companion piece[3]. The general characteristics of the automation system are shown in Table 2.

Table 2
Automation Project Comparison

Irrigation Project	Automation Type	Gate Actuators	Communication	Datalogger	Base Station Software	Internet Integration
Sevier River Basin	C	Commercial and "Do-It-Yourself"	VHF Cellular Land-line Phone (limited) Satellite (limited)	CR10X Datalogger	Internet	Nearly Total
Jungtai Irrigation Scheme	D	Commercial and "Do-It-Yourself"	Land-line Phone	CR10X Datalogger	Datalogger	None
Kerian Irrigation Scheme	D	Commercial	Cellular Phone (GSM)	MC-1000 Datalogger	Datalogger	None
Kerian Irrigation Scheme	C	Commercial	UHF SHF Satellite (limited)	Unknown	Off-the-Shelf SCADA	Partial
C=Complete System D=Demonstration Site(s)						

With the installation of the low-cost monitoring and control system, the Association is not only in the business of water distribution, but is advancing into the information distribution business also. The concept is that better and more timely information leads to better decision-making and enhanced water management.

Website

The various monitoring and automation systems in the Sevier River Basin generate substantial amounts of data, but initially it was unavailable to all but a few water managers. This was a constant source of frustration to a number of excluded water managers who needed the data to improve their operations. Meanwhile, the rapid rise in the development and use of the Internet meant that many of the water managers were either getting "on-line" or considering it. It became apparent that getting the real-time data onto the Internet might be a good way to distribute the information to a wide audience without requiring the water users to purchase specialized equipment.

In 1997, StoneFly Technology, Inc. approached the water users with a proposal to connect their real-time database to the Internet. This proposal was accepted and Reclamation agreed to assist with the project. That fall, a preliminary web site was tested and well received. The site was enhanced for the 1999 irrigation season and the graphic displays were expanded. By the end of 2000, the web site presented an accurate real-time representation of conditions throughout the Basin. Any water manager or interested individual was able to sit down at a computer and survey hydrologic and weather conditions throughout the Basin.

The web site created by StoneFly Technology is designed to serve a variety of users with a variety of displays. The log-in page gives the user several options. A variety of time series information is available. One popular display is of hourly flow data for the previous 7 days (see Fig. 2) Current river and canal flow information is displayed in spatial diagrams (see Fig. 3). Another popular display shows the real-time status of all major reservoirs throughout the Basin (see Fig. 4).

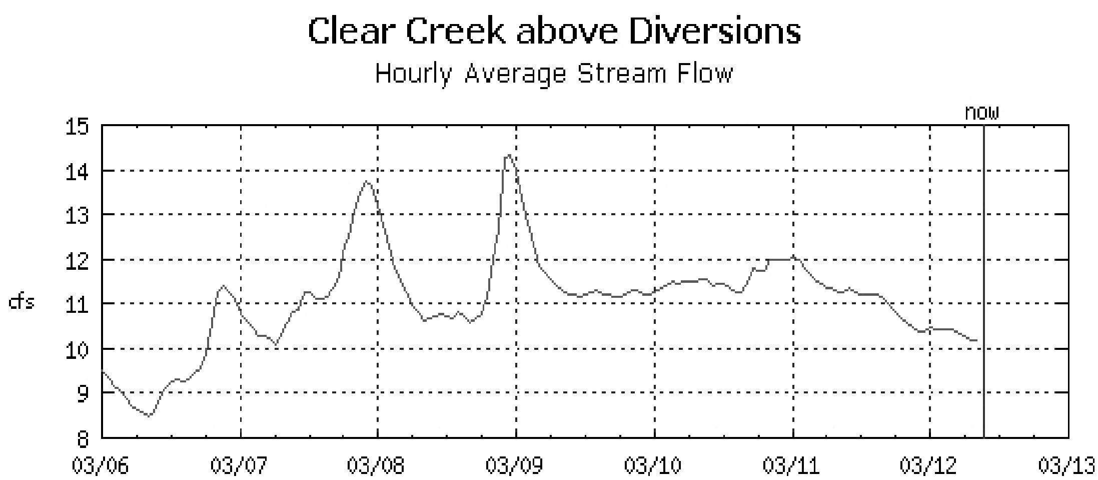

Fig. 2
This time-series plot displays hourly flows at a river gaging site for the previous 7 days.

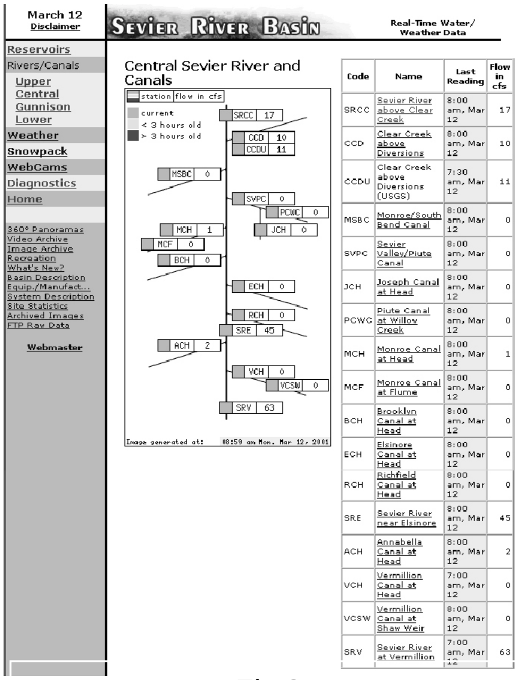

Fig. 3
Spatial diagram displaying real-time information for a stretch of the Sevier River

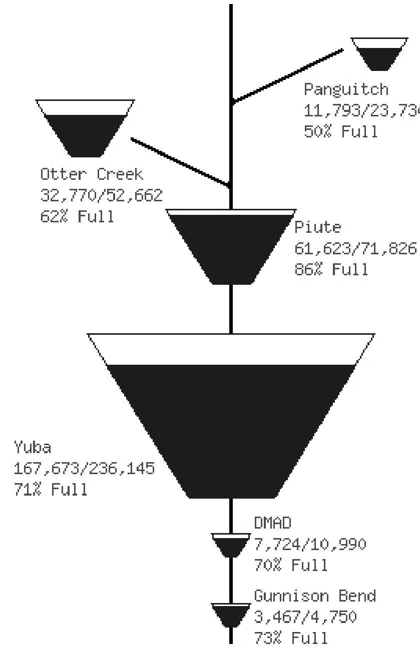

Fig. 4
Real-time status of all major water storage reservoirs in the Sevier River Basin.

During the summer of 1998, StoneFly Technology, under contract to the Sevier River Water Users Association, designed and installed a prototype Internet camera system at the head of the Richfield Canal in the Upper Basin. This camera takes high-quality color images of the headgates every 10 minutes and makes them immediately available worldwide via the Internet (see Fig. 5).

Fig. 5
Real-time image of the fully automated gates on the

Richfield Canal diversion structure as displayed on web site.

The real-time images have several benefits. The canal company manager is now able to visually verify the gate settings on the automation system. (The camera serves as a redundant gate position sensor.) The image is also used to check for the trash build-up on the river side of the gates, and for deterring vandalism.

Jingtai Irrigation Scheme, P.R. China

In north-west China, the Jingtai Irrigation SchemeBa large-scale irrigation project which pumps water from the Yellow River to irrigate grain and other cropsBis divided into 2 phases, with Phase I complete in 1974 and Phase II complete in 1994. The design flow capacity is 28.6 cubic meters per second with an irrigated acreage approaching 66,700 hectares. The project encompasses an impressive group of pumping plants, aqueducts, lined canals, tunnels, etc.

The project has significant social and environmental benefits. Up to 1998, the project area had produced 2,030 million kg of grain and 661 million kg of oil seed with a total value of $32 million. With the project nearing completion, 400,000 people from surrounding mountainous areas have relocated to the project=s service area. Because of these secondary benefits, the national government pays a high percentage of the electrical costs of pumping the irrigation water.

Due to the complicated canal systems, project management is very difficult by conventional methods. It was noticed that the farmers at the head of canal had enough, even surplus water, but the farmers at the tail of the canal did not have enough water. The water using efficiency is low. It was proposed to test the low-cost automation technology at the key sites on the canal system to improve water management. In conjunction with the China Institute of Water Resources and Hydropower Research (IWHR) and the irrigation district, Reclamation staff has been consulting on two low-cost automation installations: (1) a 12-VDC (volts direct current) unit located on a major lateral, and (2) a trifurcation structure on a major canal. The equipment costs for both projects are shown in Table 3.

The 12-VDC demonstration site is installed on the head works for a major lateral. A lead-acid battery is used to power the gate actuator, telemetry equipment, and gate controller (CR10X datalogger). The gate actuator consists of a fractional horsepower 12-VDC gear motor attached to the gate=s gear box with chain and sprocket. A device to measure gate position and provide limit switches was also attached.

Table 3
Equipment Costs: Jungtai Irrigation Scheme
Automation Demonstration Project

Equipment	Costs ($ US)	
	Lateral	Trifurcation
Datalogger/Controller	$1,100	$1,100
Telephone modem (w/voice)	700	700
Water-level sensor(s)	1,000	2,200
Gate-position sensor(s)	600	1,800
Gate-actuator(s)	800	*18,000
Miscellaneous (enclosures, control panel, conduits, etc.)	300	4,200
Total	$3,500	$28,000

*This site did not have the gearboxes and hoists installed on the radial gates; to make to costs comparable, the above table does not include these costs.

The trifurcation structure is located at the terminus for a major canal. Here, the water is split to go three separate directions. The first split goes to a relift pumping plant, the second to a distant desert area that the irrigation district is currently developing, and the third directs water to adjacent irrigated lands. Because of the critical nature of the site, it was felt that automation was a necessity. Commercial gate actuators (Limitorque) were installed on the three radial gates. At this site, all the equipment (gate actuators, telemetry, and controllers) is powered by commercial power.

Communications for both demonstration sites are by land-line telephone. Low-cost dataloggers/controllers are used to monitor the state of the water delivery system and control the gates. The gate control software consists of a modified-PI algorithm. The water district has a choice of two control options: manual remote control or automatic remote control. With the first option they make gate movements, and with the second they set flow targets. The base station software being used is the software provided by the datalogger/controller manufacturer. The general configuration is shown in Table 2.

Kerian Irrigation Scheme, Malaysia

The Kerian Irrigation Scheme, which covers about 23,400 hectares of land on the coastal alluvial plain in northern peninsular Malaysia, provides water for paddy rice. It is the oldest and third largest granary area in the country. The primary source of irrigation supply for the Kerian Irrigation Scheme is from the Bukit Merah Reservoir having a total storage area of approximately 75 million cubic meters of water. The Bogak Pumping Plant supplements the irrigation supply.

The agricultural policy of Malaysia, as described in the National Agricultural Policy (NAP3), is to attain 5.5 tons/hectare and 65 percent self-sufficiency in rice production by 2010. The basic strategic plan for achieving the goals of NAP3 are recommended in the "The Study on Modernization of Irrigation Water Management System in the Granary Areas of the Peninsular Malaysia, 1998"[4]. One recommendation was the introduction of telemetry/telecontrol and computerized systems to modernize the water management systems.

Because of a need for better water management and higher crop production, and concerns about possible future labor shortages, the Malaysian Department of Irrigation and Drainage (JPS) is automating the principal water control structures on the Kerian Irrigation Scheme. The consulting firm of Ranhill Bersekutu is currently in the design stage, but by September 2001 will be well into the project.

In advance of the bigger project, an automation demonstration system was installed on the existing slide gates at the head of Selinsing Canal (see Fig. 6) at Bukit Merah Dam. The first step in this process was to install and test commercial actuators on the two control gates.

Fig. 6
The slide gate in the foreground was automated
as part of Kerian Irrigation
Scheme (Malaysia) automation demonstration project.

Once the gate actuators were fully tested, the remainder of the automation equipment was installed including: datalogger/controller, communication system, water-level sensors, and digital camera and server. The general configuration of the demonstration project is shown in Table 2. The costs for the equipment is $22,200 (see Table 4).

Communication is by cellular telephone (GSM). A low-cost remote terminal unit (an MC-1000 datalogger) is used to monitor the state of the facility and control the gates. The base station uses the software provided by the manufacturer.

Table 4
Equipment Costs: Kerian Irrigation Scheme
Automation Demonstration Project

Equipment	Cost ($ US)
Datalogger/Controller	$2,300
Cellular telephone module w/antenna	600
Water-level sensors (2 @ $550 ea.)	1,100
UPS	600
Gate actuators (2 @ $6,000 ea.)	12,000
Digital camera and server	1,600
Miscellaneous (enclosures, control panel, conduits, etc.)	4,000
Total	$22,200

The complete Kerian automation system will have several important differences from the system installed at the demonstration site. The overall communication system will be a combination of UHF, SHF high-speed wireless, and INMARSAT satellite links. Additionally, the base station software will be an off-the-shelf SCADA package. The general configuration of the complete system is shown in Table 2.

System Evolution

The nature of the above technological interventions bears discussion. Water projects typically have a beginning and an end. For example, Reclamation constructs a dam and then turns it over to the water users to repay and operate. In the case of automation and Internet technologies, there is a continually evolving product. The technologies get more sophisticated and less costly with each passing day. And as the technologies get more complex, so do the needs of the water users. With real-time technologies, you are promoting a process more than a specific product.

Traditionally, Reclamation has had a fairly rigid product development process. This approach was taken in the development and installation of large SCADA systems. The problems with this process for small-scale automation systems are numerous: (1) it is too costly; (2) it takes too long; (3) hardware and software are frequently proprietary; (4) the customer does not always get what he needs; and (5) it is difficult for the product to evolve.

Recommendations and Conclusion

Is small-scale automation sustainable? We think so, but only time will tell. Important keys to the survivability of the innovations include: (1) active participation by the end user's staff with design, installation, and maintenance, and (2) the end users providing a consistent level of funding. It is critical that the end users be involved at all levels. This will necessitate redefining jobs. For example, a river commissioner will need to evolve from a gate turner/strip-chart reader to a telecommunication/computer specialist. This transition will not always be easy.

From experiences in the western United States, P.R. China, and Malaysia, the following observations can be made: (1) it is difficult to operate a project 24/7 (24 hours/day; 7 days/week) in manual mode; (2) many river systems, watersheds, and irrigation systems around the Pacific Rim are over allocated; and (3) on many projects, automation can substantially reduce operating expenses and enhance water management.

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