LOW-COST, SOLAR-POWERED CANAL AUTOMATION: UTAH'S EXPERIENCE

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ABSTRACT

Much of the agricultural water distribution infrastructure in the western United States is aging and in need of upgrade. Water managers now recognize that improvements--to make systems more efficient and responsive--are necessary and are striving to find cost-effective solutions. Financial pressures on irrigation districts are increasing, making major rehabilitation prohibitively expensive. Projects throughout the State of Utah have demonstrated that even smaller districts can benefit from selective canal automation technologies.

Automated control has resulted in more efficient water management with benefits from improved crop yields, reduced operation and maintenance costs, and water conservation through reduced spillage and seepage. This paper will discuss Utah experiences with low-cost, solar-powered canal automation.

INTRODUCTION

In the United States, the Bureau of Reclamation (Reclamation), Army Corps of Engineers, National Resources Conservation Service (nee Soil Conservation Service), state and local water development agencies, and private entities have invested billions of dollars in water infrastructure. Similar activities have occurred internationally, with the encouragement of local governments, the World Bank, U.S. AID and other foreign assistance programs, and other financial incentives. Real-time monitoring and control holds an important key to intensified management on these projects thereby improving economic output, implementing measures to ensure public safety, enhancing environmental conditions, conserving water, expanding recreational opportunities, and reducing operational costs, all in a very cost-effective manner. While some of these objectives seem contradictory, they can frequently be accommodated through more intensive water management.

Although real-time systems have been available for years in the form of supervisory control and data acquisition (SCADA) systems, early systems were expensive. They were outside the cost horizon of smaller water users, those without the financial and technical resources of larger water districts [1, 2]. However, with the advent of low-cost, real-time system components, the future appears to hold almost unlimited capabilities.

Reclamation's Provo Area Office and Denver Technical Service Center, and Utah State University (USU) have been working with water managers in Utah to develop and implement low-cost, real-time monitoring and control systems [3]. For these systems to receive wide acceptance, the following elements are critical:

- low initial cost
- retrofitting on existing structures
- reliable two-way communications
- solar-powered actuators
- ease of installation and maintenance
- user friendly

STANDARDIZE EQUIPMENT

To simplify technology transfer efforts and facilitate Reclamation's and USU's support of specific applications, standardizing equipment has been important. For example, each field station regardless of its use, contains a low-cost datalogger/controller or remote terminal unit (RTU). Currently in use is Campbell Scientific, Inc. CR10X, a VHF or UHF transceiver for two-way communication to a base station, and a radio modem. Depending on the application, attached to the datalogger/controller is an appropriate collection of sensors and actuators.

Setting up the base station, which is the user's access to the real-time system requires, only a transceiver, a radio modem, and a personal computer. The base station can be either stationary (water district office) and/or mobile (ditchrider, watermaster, etc.).

For many Utah applications, the utilization of real-time technologies has been evolutionary, starting with straightforward monitoring systems and, over time, evolving into larger, more complex automation applications (see Figure 1). It is important that this process be evolutionary because as real-time technologies evolve, so does water-user interest. As interests evolve, replacing expensive equipment is not required for expansion.

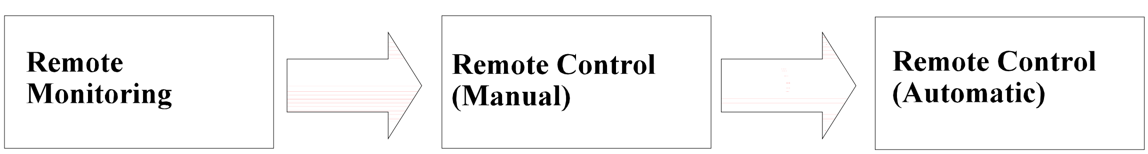


Figure 1
For many Utah applications, the utilization of real-time technologies has been evolutionary over time.

Flow Monitoring Sites

To keep abreast of canal and river conditions, a real-time monitoring station is important. If there is an existing measurement site with a stilling well, the upgrade is relatively simple. The basic costs are summarized in column 2 of Table 1 and in Figure 2. These costs are based on the assumption that communications is by line-of-sight (LOS) radio (either VHF or UHF) and that the water level in the stilling well is measured with a potentiometer connected to a float and pulley apparatus.

To stay updated on pond conditions (i.e., behind check structures, in on-farm storage ponds, or on wildlife facilities), a slightly different configuration of equipment is used. If there is no stilling well, a pressure transducer is easy to install. Photograph 1 shows a pond monitoring station at a migratory bird refuge in northern Utah.

Photograph 1
Solar-powered, real-time station monitoring pond elevation at the Bear River Migratory Bird Refuge. Sensor: pressure transducer

Most datalogger/controllers are equipped with more capabilities than are typically used at a standard monitoring site. Since adding sensors is usually uncomplicated, it is frequently worthwhile to look at secondary needs at a site. For example, at a flow monitoring site, it may be useful to also monitor water quality or weather parameters. Or, if there is a control gate nearby, selective automation may be appropriate.

TABLE 1

Cost for a Monitoring Station, plus Incremental
Costs to Upgrade to Gate Control
(with Radio Communications)

Equipment	Initial Costs (Monitoring)	Incremental Costs for Gate Automation	
		Do-It-Yourself	Commercial
Datalogger/Controller[1]	$1,090		
RF Modem[1]	295		
Transceiver and Cable[2]	275		
Antenna (directional) and	140		
Battery and Voltage	65	$ 35	$105[3]
Steel Battery Enclosure		100	100
Solar Panel and Clamp	120		240[3]
Mast	30		
Float and Pulley	400		
Fiberglass Enclosure	80		
Steel Enclosure		150	150
Ground rod, wire, and clamp	15		
Gate Actuator			4,200[5]
Miscellaneous	100	200	200
TOTAL	$2,610		$6,025
Field Installation Time	8 hours	32	8 hours

[1] Campbell Scientific, Inc., CR10X and RF95
[2] Maxon 5-watt transceiver
[3] Assumes 100 percent salvage value
[4] Intermountain Environmental, Inc.
[5] Cost is per gate

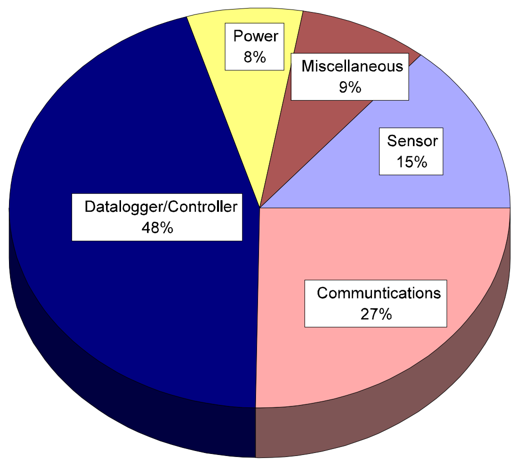


Figure 2
Cost breakdown for a low-cost flow monitor station.
Sensor: float and pulley (potentiometer)
(Total Cost = $2,610)

Gate Actuators

Frequently, canal companies and districts want to monitor flow conditions at the head of their canal, just downstream from the diversion structure. With many dataloggers, control is also possible. Thus, a monitoring site can be updated to manual remote control or automatic remote control without costly additional telemetry equipment or controllers.

In Utah, one of the principal obstacles to canal automation is the lack of gate actuators; gates are most commonly operated manually with handwheels. Thus, before any remote control can occur, a motor and sensors must be added to the gate. The two most commonly stated hurdles to adding gate actuators are: (1) the high cost of bringing commercial power to a site and (2) the high cost of gate actuators.

The Provo Area Office over the last 3 years has installed and evaluated three configurations of low-cost, solar-powered gate actuators: (1) a Do-It-Yourself unit developed for slide gates; (2) a commercial unit for slide and radial gates; and (3) a pneumatic unit for check structures.

Do-It-Yourself. After studying a low-cost AC installation made by the water users in the Delta, Utah, area [4], a prototype solar-powered gate actuator was finetuned by Reclamation [5]. The first model was installed in 1994 on three slide gates on an irrigation diversion structure in central Utah (see Photograph 2). The unit proved highly successful, and similar units have been installed at 10 additional sites throughout Utah. The basic cost for equipment is $1,400 per gate and it requires approximately 4 man-days to install (see Table 2). The incremental costs to add a

Do-It-Yourself gate actuator to a site with an existing flow monitoring system is shown in Table 1 (column 3).

Photograph 2
Do-It-Yourself gate actuators on the slide gates of the Richfield Irrigation Company diversion structure.

The Do-It-Yourself actuator is raised and lowered by a fractional horsepower 12-VDC gear motor attached to the handwheel by a chain and sprocket. A gate position sensor and limit switches are attached to gate stem. The Do-It-Yourself actuator has been installed on both frame and pedestal supports.

Commercial - Slide and Radial. Working with Great Western Valves and Automation of Salt Lake City, Utah, a 12-VDC Limitorque actuator was developed and is being tested at several locations in Utah (see Photograph 3). The cost of these units is approximately $4,200, exclusive of the power system. The incremental costs to add one of these units to an existing monitoring site is also shown in Table 1 (column 4).

An alternative design for a solar-powered gate actuator has been proposed by Mountain Controls, another small business in Salt Lake City. They propose a 110-VAC AUMA unit powered by a 12-VDC system equipped with an inverter. While this solution is less elegant than the one discussed above, it will be tested during the 1997 irrigation season.

Photograph 3
Commercially available gate actuator on a radial gate at Bear River Migratory Bird Refuge

TABLE 2
Do-It-Yourself Gate Actuator Equipment Costs

Equipment	Costs ($)
Modify Gate Bolt	$300
Gate Stem Enclosure	300
Frame for Enclosure	50
Motor	225
Sprockets and Chain	70
Relay Driver/Relays	200
Fuses and Sockets/Switches	30
Miscellaneous	225
Total	$1,400
Installation Time	32 man-

Obermeyer - Check Structure. Working with Obermeyer, Inc., Ft. Collins, Colorado, an overshot gate for use on check and similar structures is being evaluated. The Obermeyer gate is moved up and down by an air bladder [6]. A small 12-VDC air compressor is used to inflate the bladder. In 1994, an Obermeyer gate was retrofitted into a check structure of a canal in north central Utah. The gate has operated successfully for 3 years.

SELECTIVE CANAL AUTOMATION

To demonstrate the breadth of applications for real-time technologies, two specific Utah projects are discussed below.

Richfield Area

The irrigators in the Richfield area (south central Utah) are served by 11 separate canal systems, all of which divert from the Sevier River. This hodgepodge is frequently difficult to manage, as each canal operates its own distribution system. None of the canals has a full time employee; the river commissioner, canal managers, watermasters, and ditchriders are all part-time seasonal employees, who work out of their homes.

In 1993, the manager of the Richfield Irrigation Company approached Reclamation about installing a real-time monitoring station on a parshall flume located just downstream from their diversion structure on the Sevier River. This real-time monitoring task was accomplished and provided valuable information to the canal company manager during the irrigation season. The usefulness of the monitoring system and its reliability generated an interest in expanding the system to include remote control, to be able to raise or lower the 3 gates on the diversion structure from the manager's home 12 miles away.

Commercial power was not readily available and because of the high costs associated with bringing power to the site, a DC system was needed. Discussions with gate actuator vendors revealed little in the way of DC models; and those that were available were prohibitively expensive. So the first Do-It-Yourself model was designed and installed at Richfield. The gates move at a speed of 1 inch per minute. The 3-gate system is powered by 2 deep-cycle marine batteries (130 amp-hrs each), which are kept charged by a 40-watt solar panel. Precautions were taken to protect the system from vandals and to make the site safe. With the 12-VDC actuators in place, the datalogger/controller was reprogrammed to allow the gate to be remotely operated. During 1994 the system was tested and proved to be reliable.

During 1995, the Richfield diversion structure was automated. This was accomplished by installing enhanced software at the field site. Now instead of moving the gates by remote control, the water manager sets a canal flow target and the gates automatically move to maintain the required flow. The canal manager, estimates that the system has helped the company conserve approximately 12 percent of their water supply.

In addition to automating the headworks, two flow monitoring sites were added along the canal, one at the midway point and a second near the end. These two sites are improving water delivery throughout the system by allowing the manager to monitor conditions along the canal as well as at the head. Thus, the manager is able to compare how the canal should be operating with how it is operating, and make adjustments as necessary.

Because of the success of the Richfield Irrigation Company's real-time project, two additional canal companies in the Richfield area installed similar equipment during 1995. The Piute Reservoir and Irrigation Company installed five real-time flow monitoring stations along its 65-mile-long canal and the Sevier Valley Canal Company automated its diversion structure using a Do-It-Yourself gate actuator.

During 1996, the real-time monitoring and control system was expanded to include four additional canal diversions, plus three monitoring stations along the Sevier River. Additionally the feasibility of automating Piute Reservoir, a major water storage facility on the Upper Sevier River, is being studied.

With the major irrigation diversions in the Richfield area fully automated, there is the possibility of a coordinated river operating system to optimize deliveries. The principal obstacle to this appears to be organizational rather than technological: getting the 11 canal companies to mutually agree.

Developments in the Richfield area demonstrate that low-cost automation systems can evolve easily (both in the number of field sites and in the sophistication at a field site) and that this growth can be accomplished without expensive re-engineering. But, it is important to have in mind, at the onset, where a system may be headed.

Lower Duchesne River System

During the summer of 1996, in a joint effort with the water users, Reclamation staff helped design and install a real-time monitoring and control system on the lower Duchesne River in eastern Utah. The system includes 10 field sites and a base station at the river commissioner's home. It encompasses five canal systems and involves four solar-powered gate actuators, two Do-It-Yourself and two commercial models.

One innovation added to the Duchesne River system is the use of a LOS radio to a cellular telephone interface (equipped with a voice synthesizer modem) as an alarm system (see Figure 3). The interface, of which there are two that cover the entire system, call out whenever a minimum and/or maximum flow target is violated. Thus, the river commissioner is warned when the river system is not operating according to expectations. The interface also allows canal company employees and troubleshooters easy access to the system.

The Duchesne River is tributary to the Colorado River System. Because of treaty agreements with Mexico, water quality is very much an issue. The United States is committed to reducing the salt load at the border between the two counties. The lower Duchesne real-time monitoring and control system could assist the river commissioner in managing the river to reduce salt loads from the Duchesne River. This facet of the system will be explored over the next few years.

Others

In addition to the above two systems, Reclamation staff is working on systems with a variety of other Utah water users: (1) Emery Water Conservancy District; (2) Strawberry Water Users Association; (3) Uintah Water Conservancy District; (4) Ogden River Water Users' Association; (5) Bear River Migratory Bird Refuge; and (6) Twin Falls Canal Company (Idaho). Each of these real-time systems is designed and installed to meet a unique set of operating requirements. For example, the Bear River System is managed to reduce the impacts of avian botulism, and the Emery System to protect water rights.

CUSTOMER SURVEY

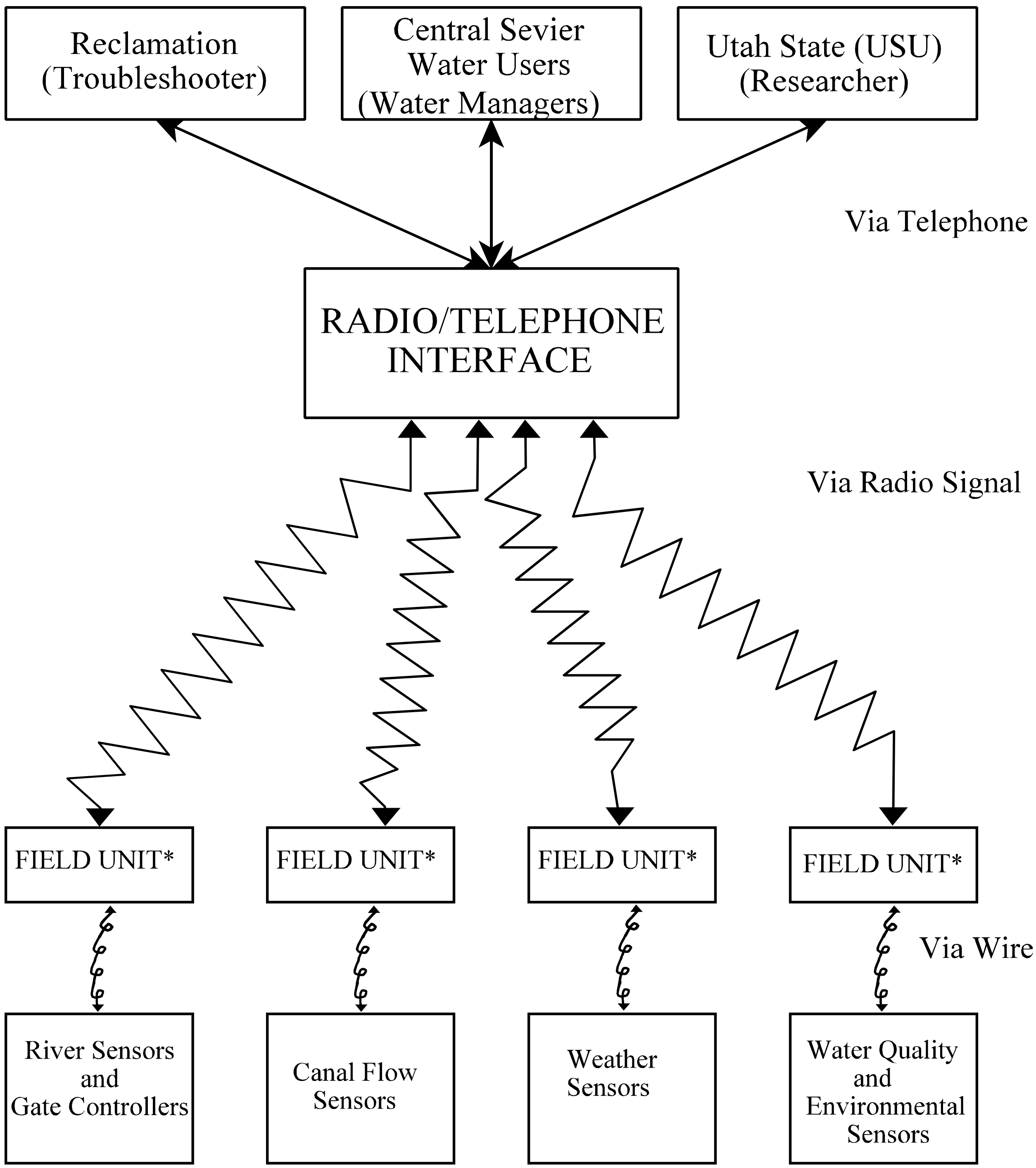
During September 1996, Reclamation staff conducted interviews with the managers of the various projects. The intent was to determine customer satisfaction and ascertain how service and products can be improved. The results of this survey are reported below.

To the question, "Has your real-time system helped you better manage your project?" the following response was typical: "Yes. To have the ability to do so much while sitting at my computer is a tremendous help. Has been useful to have all the information at my fingertips." Almost all responses were exceedingly positive. This would seem to indicate that it is very possible to transfer fairly complex technologies to smaller water user groups.

To the question, "Where do you see your automation system going in the future?" all customers are visualizing how they would like their systems expanded. The following response was typical: "I would like to expand the system and be able to monitor (and control) more of our canals and the whole river." This would seem to indicate that they all see positive benefits with their systems and that frustrations are manageable.

CONCLUSIONS

Low-cost, real-time (or near real-time) instrumentation promises a revolution in improved water management. Just as the rapid evolution in microcomputer hardware--with great memory and faster speed at lower costs--and software have expanded capabilities, so have the dynamic advances in environmental sensors, telemetry equipment, dataloggers and controllers, and solar technologies widened horizons. Today, real-time monitoring and control systems are within the cost range of almost all water user groups, including irrigators, canal companies, water districts, municipal water suppliers, and wildlife management groups.



*Each field unit has its own standardized datalogger/controller
and communication equipment.

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