SOUTH PLATTE DITCH COMPANY ─ DEMONSTRATION FLOW MONITORING AND DATA COLLECTION PROJECT

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ABSTRACT

The Prior Appropriation Doctrine formulated in early-day Colorado as a means of appropriating water used primarily by the mining industry became the framework of water law for most states of the western United States. Colorado has also been a front-runner in establishing legal recognition of the hydraulic connection between surface streams and the tributary aquifers in within stream basins. Colorado's Water Right Determination and Administration Act of 1969 was passed to integrate administration of groundwater pumped from tributary aquifers with the administration of diversions from surface streams. The impact of the 1969 act on well users was magnified by a 2001 Colorado Supreme Court ruling, (Empire Lodge Homeowner's Association vs. Moyer), subsequent to which eastern Colorado water users that depend at least in part on groundwater wells have faced a dramatic increase in requirements for measuring and recording water flows.

A case-study is presented documenting an effort spearheaded by the South Platte Ditch Company (SPDC) in northeastern Colorado with objectives of improving flow measurement capabilities and of simplifying data collection and data management tasks. After an initial season with two field sites, representing SPDC's first experience with electronic flow monitoring equipment, the district quickly recognized that integration of electronic technologies represented a steep learning curve, and saw evidence that significant mutual benefits could be realized if multiple small districts like themselves (along with individual irrigators) could jointly establish and utilize a wireless data collection network.

A grant to fund a broader scale demonstration project was awarded to SPDC by the Colorado Water Conservation Board (CWCB) in late 2005. The key objective of the project is to enable water users to make water management decisions – including augmentation of stream flows to offset depletions due to past well pumping – based on real-time data. In the aftermath of the 2001 Empire Lodge ruling, well augmentation requirements are being quantified based on "worse-case" projections using data whose availability is typically lagged a month or more. Cooperating partners in the demonstration project include the South Platte Ditch Co.; shareholders of the Johnson and Edwards Ditch Co.; the Lower South Platte Water Conservancy District; the Colorado Division of Water Resources; US Bureau of Reclamation; Control Design Inc. along with limited support of other water entities and equipment manufacturers.

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BACKGROUND

Colorado's Water Right Determination and Administration Act of 1969 (1969 Act) brought operation of wells pumping from tributary aquifers under the Prior Appropriation Doctrine that is the basis for Colorado water laws governing diversion of water from surface streams. The 1969 Act was passed in recognition of the hydraulic connectivity between surface streams and alluvial aquifers in a stream basin whereby pumping of wells with junior water rights creates injuries to senior surface water rights holders on a time delayed basis. The 1969 Act called for well owners to secure water supplies that could be used to augment surface flows to repair injuries "in time and in place" that would otherwise be inflicted on senior water rights as a result of well pumping.

As a potential augmentation supply, the idea of developing groundwater recharge systems emerged. At times when available stream flow exceeded calls by established water right holders, flows could be diverted from the surface stream and routed to a point it could be allowed to percolate through the soil profile and "recharge" the alluvial aquifer. This would have the effect of augmenting surface flow on a delayed basis in the inverse manner in which well pumping depletes surface flow on a delayed basis.

The South Platte Ditch Company (SPDC) was a cooperative partner in a demonstration pilot groundwater recharge project initiated in 1972. Other participants in the project included the now defunct Groundwater Appropriators of the South Platte River Basin Inc. (GASP), Colorado State University (CSU), and the Colorado Division of Water Resources, (CDWR). In a continuation of the pilot project, SPDC eventually secured one of the most senior recharge diversion rights along the South Platte River with a priority date of 1974. During the early years of operation, return flows from the SPDC recharge project that were projected to augment surface flow at times when surface flow was insufficient to meet demands were leased to the GASP organization on an annual basis. SPDC irrigators who also operated wells enrolled their wells in GASP to administer augmentation needs. During this period, flows in the SPDC recharge project were documented using paper-chart flow recorders.

A 2001 Colorado Supreme Court Ruling, Empire Lodge Homeowner's Association vs. Moyer, (Empire Lodge Ruling) dramatically shifted how the 1969 Act would be administered by the State Engineer's Office within the CDWR. Accounting for well usage and the projected delayed injury to surface flows, along with the monitoring of stream augmentation to repair well pumping injuries has subsequently been held to a higher degree of precision both in terms of timing and location. A culture of accounting for flows on a monthly or even seasonal basis lacked the type of data availability needed to adjust rapidly to new operational constraints.

Wells that were able to remain in operation have done so for the large part by furnishing augmentation supplies to meet "worse-case" scenarios by which – even in an unusually dry year when greater than normal pumping might be required and when less than normal recharge accretions and/or other augmentation sources might be available – the well owner could demonstrate the capability of offsetting any stream flow injury with sufficient augmentation supplies.

Flow meters on wells are required to be recorded daily, but are reported monthly to the Office of the State Engineer. Paper chart recorders are being replaced with electronic data loggers that record flow information in 15 minute intervals, but most of these units require periodic on-site data downloads. The steep increase in data management tasks for the State Engineer's office bears little resemblance to modest staffing increases. As a result there is a time lag on the order of months between the point in time at which a piece of flow information is recorded and the time at which processed information from the State Engineer is in the hands of the decision maker seeking to ensure his well is appropriately augmented. Under this operating scenario, well depletions are typically over augmented using projections generated from the most recent available – but a month or more old – data. Progressive irrigation managers have recognized access to real-time flow data as potentially a key aspect for long-term economic viability of irrigated operations along the Colorado South Platte Basin.

PROJECT STARTUP

During the spring of 2005 an SPDC board member contacted an engineer at Reclamation's Hydraulics Investigations and Laboratory Services Group (HILS) in Denver seeking information on electronic flow measurement data collection equipment. As a demonstration project, HILS agreed to install a low cost system that had been developed in-house for an application at the East Bench Irrigation District in Montana. The device which HILS staff called the Continuous Flow Meter (CFM) was assembled using a programmable logic controller with integral display module that was marketed as a hobby robot controller.

An analog signal from any of a range of readily available electronic level sensors could be linked to the controller and calibrated to measure water level. A simple program written in a BASIC programming language would first apply calibrated slope and offset constants to an equation to calculate water level. This level value was then input into a power equation with calibration constants appropriate for the flow measurement structure at which the unit was installed. A desired measurement time interval (i.e. 15 minutes) input into the CFM program would trigger a measurement cycle. Once a flow rate had been calculated, a volume increment was determined based on the measured flow and the elapsed time from the previous reading. This volume increment would be added to a previous running total value. With each reading cycle, the most recently measured flow depth, flow rate, and total volume would be displayed on the CFM.

CFM units were installed at two locations on the SPCD recharge system to operate in parallel with existing Stevens paper chart recorders. A key shortcoming of the CFM for this application was the limited on-board memory which was insufficient for storing data logged values. The State Engineer's requirement of logging flow values at 15 minute intervals could not be met with this equipment. Approximately a month after installation both CFM units were removed.

DATA LOGGING AND TELEMETRY

During the same time frame the SPDC demonstration project was being initiated, HILS engineers came in contact with Control Design Inc. (CDI) of Placitas NM. CDI produces units that consist of a programmable logic controller coupled with a proprietary communications modem plus a communications radio operating on UHF frequency. Upon learning of the SPDC demonstration project, CDI offered use of equipment for two field sites plus two office base units for the 2005 season.

The CDI programmable controllers are designed around radio communications operation. All available on-board memory, including memory available for data logged values, is configured as Modbus registers. CDI worked with HILS engineers to develop a flow monitoring program for the demonstration project. A software program provided by CDI named Project 3 was installed on a Windows-based computer at a SPDC office site as well as at the Lower South Platte Water Conservancy District (LSPW CD) in Sterling CO. Project 3 can be configured to direct CDI base units to periodically poll field sites and download accumulated logged data values. Retrieved data is then stored on the computer hard drive in an Excel compatible .csv data file.

CDI units were installed on the SPDC recharge system at the two sites where the CFM units had previously been. Figure 1 shows the installation at the original G2 flume. This site marks the beginning of the reach of the Sandhill ditch for which SPDC receives recharge credit for canal seepage losses. Figure 2 shows the Sandhill pond installation.

Figure 1. 2005 Photo of the SPDC G2 Flume

Figure 2. 2005 Installation at the SPDC Sandhill Pond Entrance

During 2005 operations, the CDI equipment provided a promising level of performance with regard to performing on-site functions and in reliably performing data transmission tasks. Performance of third-party level sensors on the other hand was somewhat sporadic. The ultrasonic "down-looker" level sensors that were being used at both sites repeatedly lost accuracy at temperatures approaching freezing.

Another system "snag" encountered during 2005 was related to attempting to collect data at two office locations. The Project 3 software which is available for download from CDI's web site was developed for systems with a single data-collection node. As field sites were polled by an office base unit, Project 3 would reset the field units to write the next data in the initial Modbus register of register field designated for data logging. Unless a second base attempting to retrieve the same data did so before the subsequent 15 minute data cycle, or else some data registers would be overwritten. It was deemed important for the CDWR or an entity acting on CDWR's behalf (i.e. LSPWCD) to receive direct transmission of recharge project field data. At the same time, it was important for SPCD to also have real-time access to the field data to ensure that all fields sites are functioning properly at any point in time.

Overall, SPDC recognized significant value in benefits it could realize from electronic flow monitoring coupled with a reliable wireless data telemetry system. The limited-scope of the 2005 demonstration project left SPDC interested in seeking a means of extending the demonstration to develop a framework for a network that could potentially be beneficial for multiple water using entities in the area.

EXPANDED DEMONSTRATION PROJECT

Following the 2005 irrigation season, SPDC board members that had worked closely with the demonstration project approached two neighboring districts to see whether there might be support for a multi-district effort to seek funding support from the Colorado Water Conservation Board (CWCB). After receiving an affirmative response from the boards of both neighboring districts, a funding proposal was submitted to the CWCB. During the CWCB November 2005 board meeting, $100,000 in grant funding was awarded to the project over a three year period.

Shortly after grant funding was approved the project encountered controversy. One of the neighboring districts notified SPDC that they had decided not to participate in the demonstration project. Issues linked to the ramifications of the Empire Lodge ruling and the subsequent demise of GASP represented a strain on resources of the district and of individual shareholders. The other partnering district notified SPDC that some of their shareholders had entered into an option agreement for sale of ditch company shares. Those shareholders whom had entered the option agreement did not want wireless monitoring equipment installed at sites owned by them or on district owned sites.

Following these developments, an agreement was negotiated with CWCB whereby the scope of the CWCB-funded project would include monitoring locations within the SPDC system, plus key control structures that SPDC planned to look at automated or remote manual operating capabilities. In addition, willing shareholders in the Johnson & Edwards Ditch Company (J & E) agreed to install radio/control equipment on wells designated through water court as Alternate Points of Diversion to J & E surface rights, and at recharge facilities owned by participating J & E shareholders.

Ironing out these controversies consumed considerable time. A contract for the grant funding was finally issued by CWCB in April 2007. At that point in time, CDI notified project participants that the company was developing an upgraded product line that would be specifically geared toward low energy consumption for solar charged applications. In addition, the new product would be developed entirely “in-house” to eliminate quality control issues CDI had been experiencing with circuit boards developed for CDI by a contracting electronic design firm. New CDI units would not be available till late 2007.

After weighing factors including comparative product affordability, the high level of technical support that had been provided, and the “fit” of CDI product capabilities with project operational needs led SPDC and J & E participants in the demonstration project decide to delay start-up of installations with CWCB assisted funding until the new CDI product line was in production. The first new units were installed in the fall of 2007 at the SPDC main flume, and at the SPDC G2 and Sandhill Pond recharge sites.

A project task funded by SPDC was replacement of the G2 flume. The previous flume was a trapezoidal flume constructed of sheet metal. The trapezoidal flume lacked lateral support members and over time the sides had been pushed in to the point where calibrations for the "as-fabricated" cross sectional geometry were no longer valid. Additionally, backwater effects on the trapezoidal flume resulted in it operating under excess submergence at flow rates commonly encountered at the site. A new ramp-type long throated flume was constructed at G2 in September of 2007. Figure 3 shows the completed installation at the new G2 flume.

Figure 3. New Ramp-Type Long-Throated Flume at the SPDC G2 Site

During 2008, radio/control equipment was installed at additional recharge sites on the SPDC recharge system, and at one site on the J & E recharge system. A new base unit was installed at the Lower South Platte Water Conservancy District (LSPWCD) office in Sterling CO. CDI radio/control units were also installed on four J & E alternate point of diversion wells. At all recharge sites, redundant recording devices are in place.

At the SPDC main flume and the J & E recharge site, Sutron Stage & Discharge Recorder (SDR) units are installed. At the remaining SPDC recharge sites, Stevens type F chart recorders are installed. Both the Sutron SDR units and the Stevens type F recorders utilize float and pulley type level sensors. In an effort to minimize variability between recording technologies, multi-turn potentiometers were installed on the Sutron and Stevens equipment to serve as level sensors for the CDI radio/control units.

Each of the J & E alternate point of diversion wells was already equipped with McCrometer propeller meters. In order to provide electronic input signal for the CDI radio/control units, pulse output modules were installed on the McCrometer meters. Translation of pusles into flow rate was calibrated by starting with a McCrometer-supplied "K" factor then comparing the electronic totalized flow with the totalized value on the mechanical McCrometer over extended run time. The K factors have adjusted in an effort to achieve outputs as nearly synchronized as possible.

Level measurement accuracies are a point of focus. With the open channel sites, it is a straight-forward task to identify slope and offset values for the electronic sensors (multi-turn potentiometers linked to a float & pulley apparatus). With these calibrated constants, the radio/control equipment is able to make an accurate a determination of water level, and in turn of flow within the accuracy limits of the flow measurement structure. There is greater uncertainty in the monitored pump flow. Propeller meter measurement accuracy is difficult to verify without installation of an independent flow meter of known accuracy in series with the propeller meter. Thus the system being employed on the J & E alternate point of diversion wells is presently limited to the unknown accuracy of installed propeller meters.

A potentiometer installed on a Stevens type F recorder is shown in Figure 4. A kit available from Stevens enables a multi-turn potentiometer to be installed in the gear mechanism of the type F recorder. Others who have utilized this kit report that they typically needed to reset the offset on the potentiometer every time a new paper chart is loaded, as it is common practice to loosen the thumb screw that tightens the pulley to the shaft it rotates to adjust the chart to the existing flow level. For this project it was reasoned that by attaching directly to the pulley, the relationship between float elevation and potentiometer rotation would remain constant despite these chart-setting adjustments.

Figure 4. A Potentiometer Mounted to a Stevens type F Recorder Pulley

After installing the pulley-mounted potentiometers, it became apparent that not only do chart installers loosen the thumb screw for adjustments, lifting the beaded float cable off the pulley is another commonly employed practice. SPDC has encountered repeated instances of the potentiometer offset getting off a distance equal to one or multiple times the distance between bead notches in the pulley after CDWR staff had installed new paper charts. Presumably this will be a problem that goes away as CDWR develops a confidence level in the radio/control monitoring and telemetry system and agrees to discontinue the redundant datalogging using paper charts.

Figure 5 shows a McCrometer meter with pulse output module installed on a well discharge pipe. The pulse output generator is installed at the base of the mechanical meter. Installing this module requires a shaft extension for the mechanical meter as well as longer screws to secure the mechanical meter to the meter base.

Figure 5. A Pulse Output Module Installed on a McCrometer Meter at a J & E Well

Despite the availability of on-site electrical power, all radio/control installations in the project are powered using solar charged systems. This was done to eliminate the potential of damaging surge voltage coming in through power supply lines. The CDI radio/control units feature an on-board charge controller to maintain battery voltage within an appropriate range.

In addition to the flow monitoring and logging functions the radio/control units are currently performing, they may be programmed to perform expanded functions in the future. The capability exists to perform tasks such as monitoring of pump panel fuses, panel or motor temperature, timed startup and/or stoppage of the wells, remotely controlled well startup or stoppage, etc. Figure 6 shows the radio/control unit installation at a J&E well site.

Figure 6. A CDI Radio/Control Unit Installed in the Pump House Shown in Figure 5

FLOW CONTROL

During 2009, the first gate automation site was added to the SPDC demonstration project. A lateral that serves approximately one-third of SPDC acreage, referred to as the "Company Lateral", branches off near mid reach of the main SPDC canal. Flow entering the Company Lateral is controlled by a vertical slide gate. Lateral flow is measured at a flume located approximately 70 yards below the gate. The gate is automated to maintain a target flow rate. CDI radio/control units were installed at both the gate and flume sites. The flume unit reads the water level and calculates a flow rate every 60 seconds. The gate unit calls the flume site to obtain current data and determines whether or not a gate adjustment is called for at 3 minute intervals.

The gate was previously operated by turning a hand-wheel about a threaded rod attached to the gate leaf. A chain drive system was installed to motorize the gate. The rim of a 50 tooth sprocket sized for #50 roller chain is attached to the underside of the gate hand wheel. A 20 rpm gear drive 12 volt DC motor with a 12 tooth sprocket is mounted to the top of the gate frame. Gate position is monitored using a multi-turn potentiometer linked to a gear that engages in the gate stem threads. Limit switches are installed to interrupt the motor circuit as a redundant safety limit to software limits programmed into the control unit. Figure 7 shows the Company Lateral Gate with motorization equipment installed.

Figure 7. Gate Automation Equipment at SPDC Company Lateral Headgate

SPDC may adjust the gate by multiple means. A new target value may be entered at the District office using a PC linked to the base radio unit. SPDC also has a mobile radio/control unit marketed by CDI as the "Ditch Rider Unit". Following on-screen prompts and providing inputs using the six button keypad, the ditch rider can check current conditions and/or enter a new target value from his pickup. While on-site, a new target may be input following on-screen prompts and using keypad inputs on the field CDI unit at the gate site. On-site toggle switches also allow changing control from auto to manual. In manual an on-off-on toggle is labeled for raise-off-lower positions. And finally, should there be a power or motor failure, by removing a safety guard over the gate wheel and disconnecting the roller chain, the site may be reverted to hand operation in minutes.

In 2010, a new motorized overshot gate was installed in a previously stop-log controlled bay at a spill structure just upstream the SPDC main flume. SPDC plans to automate the overshot gate to maintain a target canal bay water level. A three-bay check structure immediately downstream from the spill gates currently features three hand-wheel operated vertical slide gates. SPDC plans to motorize one of these gates and install gate position sensors on all three. Once this is completed, a CDI radio/control unit will control automation of the overshot gate to maintain a target upstream water level and calculate gate-measured spill discharge. The same CDI unit will control the motorized gate in the adjacent check to maintain a target flow rate at the SPDC main flume. Figure 8 is a photo of the overshot gate in the SPDC spill structure.

Figure 8. Newly Installed Overshot Gate at the SPDC Spill Structure

FIELD DAYS

SPDC and the participating J&E shareholders have hosted annual field days open to all interested parties in 2008 and 2009. A September date is currently being targeted for a 2010 field day. Figure 9 is a photo of the 2008 field day field tour.

Figure 9. 2008 Field Day Tour Stop at the SPDC Main Flume

LONG-DISTANCE NETWORK BACKBONE

During 2009, a component was added to the demonstration phase of the project to look at potential benefits of a system extending beyond the SPDC and participating J & E shareholders. A task to demonstrate the transmission range that can be provided by the CDI equipment was carried out by establishing a series of repeater stations. Key additions were repeater units on towers owned by KCI, a local internet provider based on Sterling CO.

A CDI radio/control unit was installed on a KCI tower on the west edge of Fort Morgan. From this site, it is possible to communicate with the SPDC office to the east, and with a CDI repeater station that the Northern Colorado Water Conservancy District (NCWCD) has established approximately 20 miles east of its office complex at Berthoud CO.

A second repeater was installed at what KCI calls its Peetz tower approximately 30 miles northeast of Sterling. From this site, it is possible to communicate to the west with the SPDC office. This site was also be contacted to the east from Julesburg during a radio check using a mobile "ditch rider" unit.

Installation of repeaters at the two KCI towers provides the capability to transmit information from Julesburg to the NCWCD office via repeats at the Peetz KCI tower, the SPDC base, the Fort Morgan KCI tower, and the NCWCD repeater. Remote sites that have been linked to this extended network include a recharge measurement site on the Morgan Ditch system, and a recharge well owned by Roth Brothers near Goodrich. Figure 10 is a map showing nodes of this communication path.

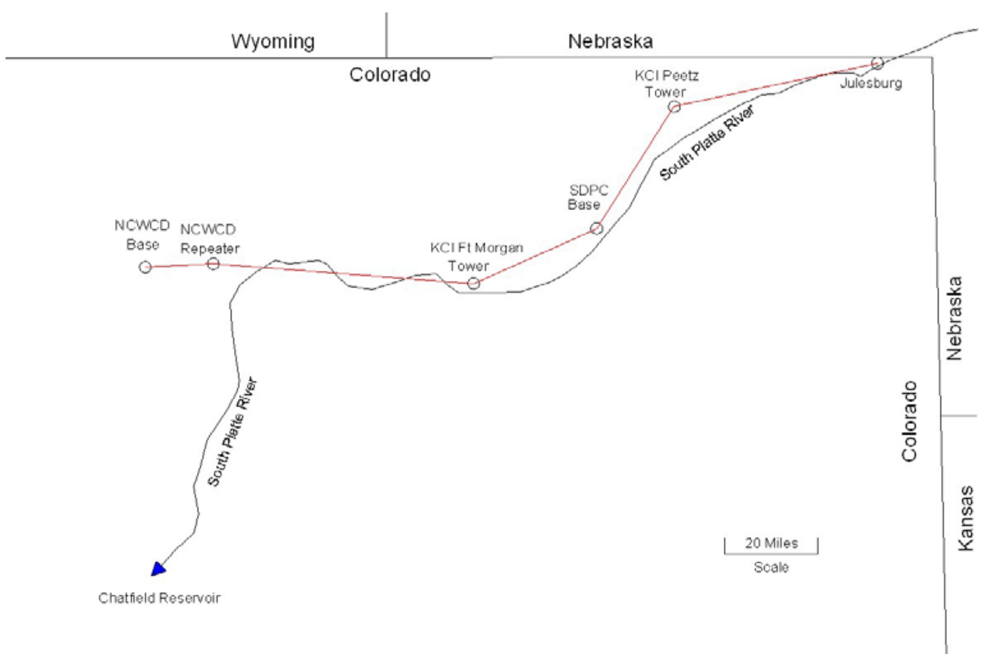

Figure 10. Extended Communications Network Radio Pathway

CURRENT PROJECT STATUS AND FUTURE PLANS

The three year project term defined in the CWCB grant contract ran through April, 2010. As of January 2010, approximately half the funding made available by CWCB had not been spent. As per agreements made at the project outset, there has been some modification of project tasks by mutual agreement of project participants and CWCB staff. The large remaining portion of unspent funds is due in part to some lower than budgeted equipment costs, along with utilization of surplus solar charging equipment made available by Reclamation. In addition, the project has fallen behind schedule on various tasks, as labor requirements that represent in-kind contributions by participants have exceeded estimated time needed.

In early 2010 CWCB granted the project a two year extension. Among remaining tasks is installation of a CDI radio/control unit at the SPDC river diversion. This unit would be linked to a pneumatically operated overshot gate on the river dam and to a similar gate in the canal mouth. SPDC plans to use gate-measured flow passing the spill structure as feedback for automated or remotely operated adjustments of the river diversion structure. Other installations planned include additional SPDC recharge monitoring sites, additional J&E alternate point of diversion wells, monitoring of an SPDC ditch pump and monitoring flow of an SPDC well utilizing pressure differential at a pipe diameter reduction.

In addition to remaining planned field installations, project participants are developing a plan to revise the data collection/data management aspect of the project. Attempts to enable polling of field units by multiple entities have come up against multiple constraints. Present plans are to set up an internet server at the SPDC base site and handle data collection exclusively through the SPDC base unit. Retrieve data would be logged and stored on-site in addition to being posted on the internet server.

For control functions and daily operational monitoring tasks, a second radio frequency will be employed along with a second radio/control unit to be installed at the SPDC base. The data collection base radio/control unit will control all direct communications with field sites. The most recently acquired data from field units along with a field-site generated time stamp will be passed to the secondary (or control and daily operations) radio/control base. Remotely entered control set point adjustments will either be entered directly into the secondary base, or radio transmitted to the secondary base from the mobile ditch rider unit, then passed from the secondary base to the primary base for transmission to field sites.

Similarly, alarm conditions detected by field units will read as part of the data polling process by the primary base. Alarms will then be passed to the secondary base. As alarm conditions are detected, the secondary unit can directly pass alarm information to mobile ditch rider units. A third-party alarm system linked to digital output ports of the secondary base unit will also be able to send out alarm messages by phone or by voice or pager radio systems.

SUMMARY

SPDC and participating partners have been able to develop a framework for a system that can significantly improve capabilities to manage and more efficiently use irrigation water supplies. The CWCB grant has enabled participants to develop a system that addresses issues unique to their needs and the regulatory environment in which eastern Colorado irrigation districts operate.

One aspect that may have been less than fully appreciated by project participants at the outset is the amount of time that a project of this nature might require. Some of this can be attributed to the versatility of the radio/control devices being utilized. As CDI founder Jim Conley has jokingly stated to project participants on multiple occasions, “Unfortunately, there isn’t very much you can’t make this equipment do.” As the equipment capabilities become more fully appreciated, it is difficult to resist trying to incorporate additional tasks. Much time gets tied up developing and field testing programs that will “do more things”. As the programs being developed become more complex, the debugging process seems to become exponentially more time consuming.

At present the SPDC demonstration projects includes numerous loose ends. At the same time, equipment configurations and programming that have been developed as part of this project will be readily transferable to other projects. To wit, flow monitoring and gate control algorithms utilized on this project are being utilized by Reclamation and others on irrigation systems distributed over several western US states. The loose ends aspect is likely to persist as long as creative minds are looking for better ways to do things. Each accomplishment seems to open up a myriad of previously unconsidered possibilities.