IMPLEMENTATION AND USE OF SCADA FOR THE SOUTHERN WATER SUPPLY PROJECT

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ABSTRACT

The Northern Colorado Water Conservancy District (NCWCD) provides approximately 210,000 acre-ft of raw water to much of Northeastern Colorado via the United States Bureau of Reclamation Colorado – Big Thompson Project (C-BT). Deliveries through C-BT began in the 1950's and were predominately for irrigation. However, over time as the Colorado front range has developed, the portion of water delivered to the municipal and industrial (M&I) sector has increased substantially. As this shift from agricultural deliveries to M&I has occurred, pipelines have been added by NCWCD to the original canal system to provide for more flexible and reliable year-round deliveries.

In the mid-1990's, NCWCD began the construction of the Southern Water Supply Project (SWSP). The SWSP consists of 110 miles of pipeline connecting numerous municipal water providers in the southern and eastern portions of NCWCD to the St. Vrain Canal at Carter Lake Reservoir. In addition to the pipelines, three booster pump stations have been added to the system to increase the system delivery capacity. In total, the SWSP has the delivery capability of 110 cubic feet per second.

The implementation of the SWSP necessitated the installation of a Supervisory Control and Data Acquisition (SCADA) system throughout the new system. The delivery system contains seven flow control structures, three pump stations, and several intermediate valve and metering structures along with the operation of the Carter Lake Reservoir outlet works. This highly reliable system utilizes a distributed control system. Local control functions such as delivery control are made via programmable logic controllers (PLCs) at each individual site. These sites communicate via radio system to NCWCD where overall system control and water orders are made. This system acts to primarily make desired water deliveries. However, fail-safe features area also integrated to provide integrity to the pipeline in the event of system outages or pipeline failure.

This paper will provide information on the planning and implementation of the SCADA system as well as lessons that have been learned through both the implementation and continued operation of the system.

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SOUTHERN WATER SUPPLY PROJECT

The Southern Water Supply Pipeline (SWSP) conveys water from the Windy Gap and Colorado-Big Thompson projects to various Front Range cities within the Northern Colorado Water Conservancy District (District) and the Municipal Subdistrict of the Northern Colorado Water Conservancy District (Subdistrict) boundaries. A map of the project is shown in Figure 1. The project consists of 110 miles of steel pipe ranging in diameter from 45 inches to 16 inches. The total project cost was $65,000,000.

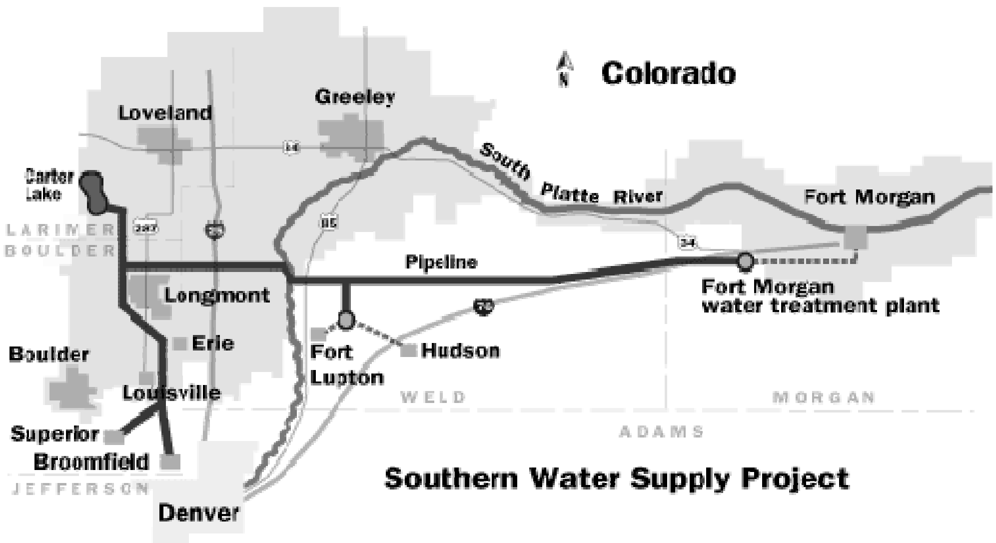
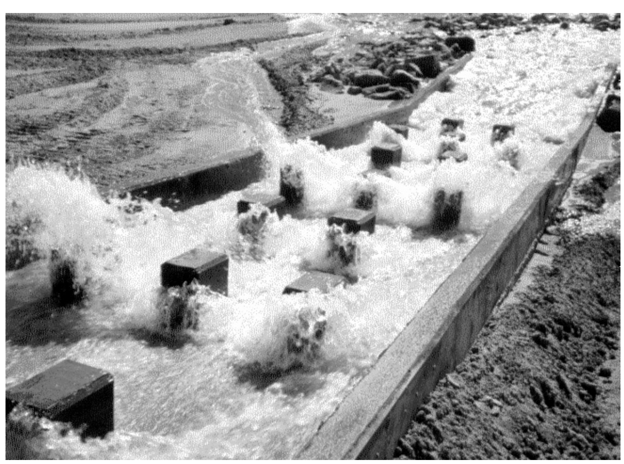


Figure 1. Conceptual Map of the SWSP System

Construction on the first phase of the pipeline, from Carter Lake to Broomfield, began in November 1993. The second, from Platteville to Fort Lupton and Hudson, was completed in July 1996. Construction on the last 41-mile section, from Platteville to Morgan County, was completed in August 1999.



First Filling of Fort Morgan's Reservoir

The Northern Colorado Water Conservancy District (District) owns the pipeline. Participants in the project own the contractual rights to the water. Participants include the cities of Fort Morgan, Fort Lupton, Broomfield, Hudson, Berthoud, Longmont, Erie, Louisville, the Morgan County Quality Water District, the Little Thompson Water District, Central Weld Conservancy Water District and the Superior Metropolitan District. Each paid its share of the design and construction costs.

The total capacity flow capacity of the original pipeline system was 62 cubic feet per second (cfs). Beginning in 2002, a series of booster pump stations were added to the system to boost the overall capacity of 110 cfs, an eighty percent addition. Thus far, two of the three pump stations have been installed, with one site remaining for construction. The estimated cost to add this capacity is approximately $10,000,000.

SWSP OPERATIONS

The SWSP system was designed to operate with minimal flow disruption and minimal labor. Water flows through the outlet works at Carter Lake, through a half-mile of covered canal, then into the pipeline. The flow is regulated at each participant's flow control structure. All of the system is operated via a SCADA system that can be controlled from the District's east slope office or from the operation center at the Farr Pump Plant on the Western Slope. This section describes the operations of the system and includes a description of the SCADA system that is used.

General Operations

Outlet Works: The Carter Lake outlet was historically used only during the irrigation season from approximately April 1 through October 31 of each year. The addition of the SWSP necessitated the need for year-round operations. The operations of the outlet works are now divided into summer and winter operations. In each case, a canal order is received from the SCADA system, and the gates are adjusted based upon a feed-back loop with the downstream parshall flume. During winter operations, when there is no flow down the St. Vrain Supply Canal, an overshot gate is raised into an *up* position and the canal gates are set to the SWSP order. Since there are inherent inaccuracies between the Parshall flume flow measurement and the SWSP measurements, a pool is maintained within a prescribed maximum and minimum level. If the pool falls outside of these limits, a correction of up to 10 percent is made to the SWSP flows using the canal gates. If that correction fails to compensate, then a correction is made at the gatehouse. All of this is designed to minimize the number of times the Carter Lake gates must be operated. A schematic of this system is shown on Figure 2.

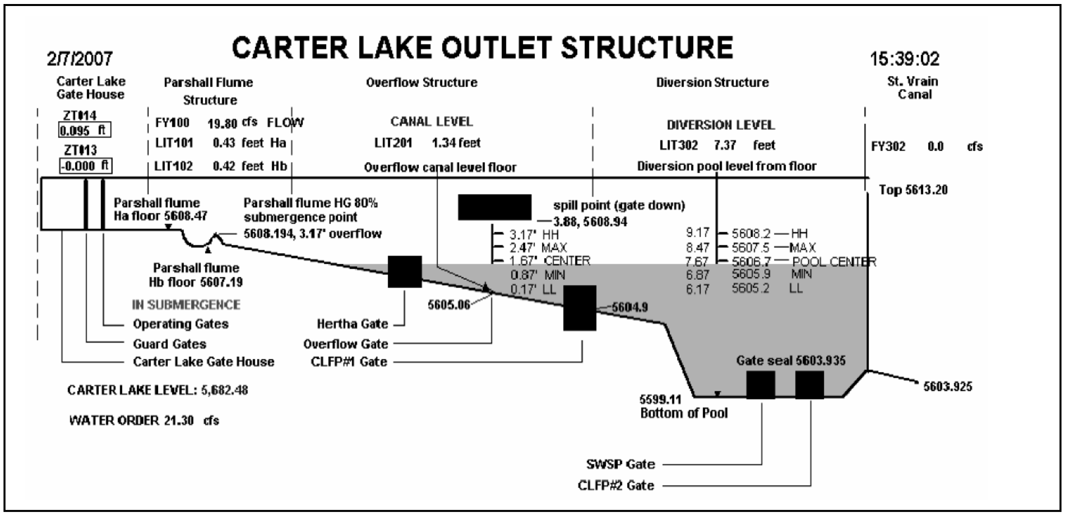


Figure 2. Schematic of St. Vrain Canal Pool Operation

During the summer operations, when there is a canal order, the overshot gate is lowered to the *down* position and the SWSP project flows are simply included into the canal water orders. During the "shoulder" periods between full summer and winter operations when canal orders are below 50 cfs, the overshot gate is put into an intermediate position in order to maintain a pool above the SWSP intake.

Pipeline Operations**:** Except for the Louisville/Superior pipeline, the SWSP operates under gravity flow. The flow control stations utilize CMB Industries Bailey Polyjet 305 valves. These valves are specially designed to control flow and dissipate energy without causing cavitation damage. The valves are controlled using the hydraulic pressure of the pipeline and are opened or closed using 24-volt solenoids attached to the SCADA system. The Louisville/Superior Pump Station operates in a way similar to the flow control stations except that instead of valves regulating flow, variable speed pumps are used to regulate flow.

Mainline valves are provided throughout the pipeline project. In general, the valves are located approximately between 8- and 10-mile spacing. The Broomfield Pipeline has two mainline valve vaults, one on the north side of Longmont at the Fort Lupton/Hudson Pipeline turnout and one on the south side of Longmont. The north mainline valve is connected to the SCADA system and can be automatically shut off. The remaining mainline valves in the system are buried high performance butterfly valves with manual operators. The manual operators were selected since the pipeline is generally only brought down for maintenance once a year.

Booster Pump Station Operations: The booster pump station addition to the SWSP allows the system to flow at a higher rate by making up for the additional pressure loss in the pipelines due to higher flow. The pumps are all equipped

West Longmont Pump Station with 4-500 hp pumps

with variable frequency drives (VFDs). The VFDs allow the pump speed to range from 50% to 100% of the rated pump speed. The desired flow and/or pressure can then be adjusted. The startup and shutdown of these stations needs to be closely integrated with the downstream flow control facilities so the system stays in "sync." When the booster stations are turned on or off, this represents a change in state for the entire pipeline system from "Gravity Mode" to "Pump Mode."

Emergency Shutdown: In the event of a pipe rupture the entire SWSP is shut down. The system compares the flow at the Master Meter to the sum of the meters downstream. If the Master meter is greater than the sum of the meters, the SWSP valves are closed and the Carter Lake gates are adjusted to the accordingly. This is likewise true for the Fort Lupton/Hudson Pipeline and the Morgan pipeline, both of which have a meter at the beginning of each pipeline. A tolerance of approximately 5 cfs is allowed to take into consideration differences in metering error or travel time in flow changes from downstream to upstream. In addition to all automated valves being shut on the pipeline, the outlet works flow is also reduced by the amount of pipeline flow order.

SCADA Operations

The SCADA system operation is based upon water orders from the various participants. Participants are allowed to place up to different three water orders each day by phone to the District. The District staff in turn place the orders into the system through a water order screen. The desired flow rate is then sent to individual sites for execution.

Each flow control site acts autonomously from the remainder of the system. When a new water order is executed, the local PLC looks at the flow rate and adjusts the valve position or pump speed until the desired water order is achieved. Since the pipeline system is dynamic – a change in flow at one site may change the pressure at another site – a constant feedback loop at the local PLC is employed. This feedback loop continually monitors required flow or pressure and makes adjustments to the valve position or pump speed as necessary.

In addition to the adjustment of flow, the local PLCs monitor various data and report the information back to the District every few seconds. Such data includes flow, pressure, valve position, pump speed and temperature, intrusion, and high water. Based upon this information, various alarms will signal at the District PC if parameters are outside set tolerances. Additionally, all information is logged into a database for troubleshooting and in the case of flow, water accounting.

SYSTEM DESIGN AND IMPLEMENTATION

The planning for the SWSP SCADA system began well before the first joint of pipeline was laid. Critical to the overall planning was integration of the Operations and Maintenance (O&M) department's ideas and concerns since ultimately the operation and maintenance of the pipeline would fall under their control.

The District contracted with Leedshill-Herkenhoff, Inc. of Albuquerque to provide for the basic design of the system. The primary consideration was to keep the majority of the system operational even if an individual site went down. Hence, a *distributed control* system was selected as the overall structure. Leedshill-Herkenhoff assisted District staff in the selection of the equipment and overall system logic.

A general specification and system outline was then given to Ener-Tech of Albuquerque for implementation. Ener-Tech was required to provide a successful bench test of the entire system prior to installation. This step proved invaluable since several tries were required before the system operation was successful. Had this step been attempted in the field, the time required to implement the process would have been greatly increased and the O&M staff's confidence in the system greatly decreased.

Following successful testing, the system was installed with a combination of District staff and Ener-Tech staff. Testing of the system was then made and the SCADA system became operational. As additional sites have been added to the system, all installation and programming has been done by District staff.

In all cases the pipeline and pump station contractors were required to install all instrumentation and bring all the wiring to a terminal box. The District then installed the connection to the PLC cabinet.

SCADA EQUIPMENT AND OPERATIONS

SCADA Equipment

The District uses a PC-based SCADA system that can control the SWSP either from the District's headquarters on the east slope or from the west slope operation center at the Farr Pump Plant. Since the Farr Pump Plant is manned 24 hours a day, the default operations are made from that plant.

Figure 3 shows conceptually how the SCADA system operates. The system uses distributed control - the actual control of valves is made at the individual sites - and the computers at the District only send out water order commands. The two PC controllers are connected via the District's east slope-west slope fiber optic/microwave communication system. All of the sites in the system report via radio to the Bald Mountain microwave site, located west of Loveland. At that point, the information going in and out is connected to the east slope-west slope communication system.

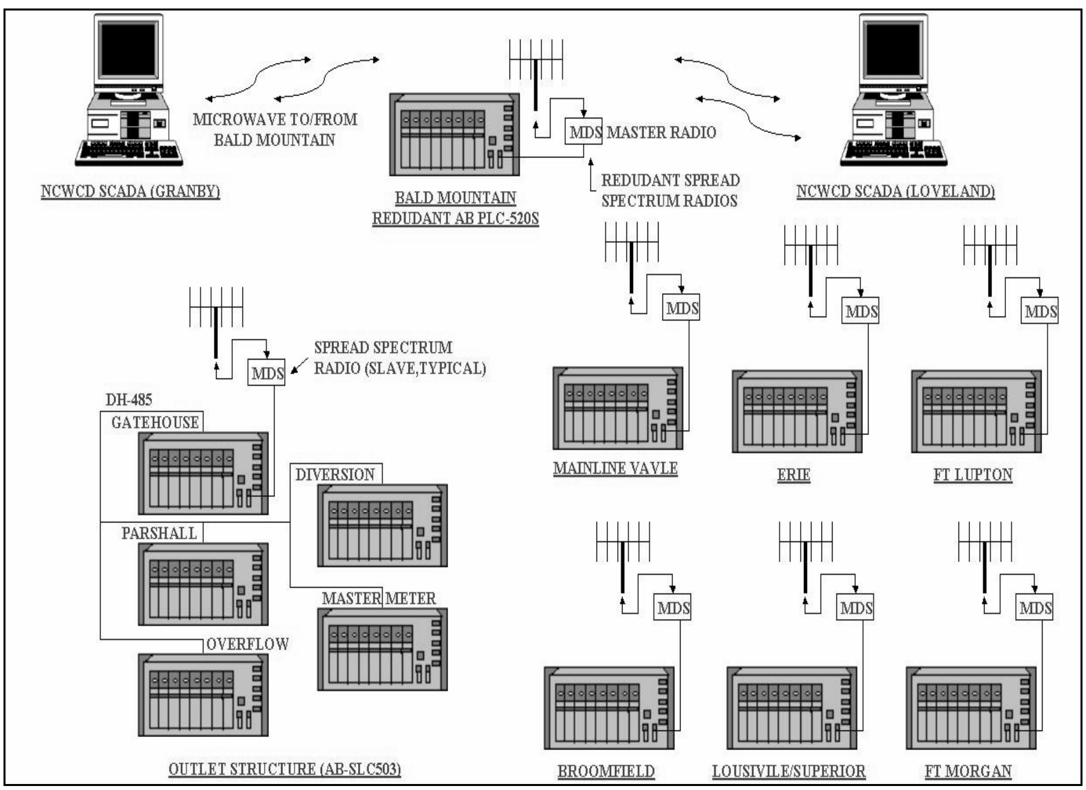


Figure 3. Original SWSP SCADA Layout

The controls performed in the field are made via Allen-Bradley "Slick 500" Programmable Logic Controllers (PLCs). The PLCs take in miscellaneous data in either digital or analog format. Programming is achieved using "ladder logic." Such data includes pressure sensors, flow sensors, valve position, intruder alarms, and high water alarms for a typical flow control station. This data is constantly radioed back to the District. When a water order is sent to a PLC, the PLC compares the water meter flow value to the new value and adjusts the valve accordingly. In the case of the Louisville/Superior pump station, the same type of logic is used to adjust the speed of the pumps.

Communication between the sites and Bald Mountain are made via a 900 Mhz spread spectrum radio signal. The radios are Microwave Data Systems 1-watt radios with a range of nearly 60 miles. This type of communication was chosen over other communication medium such as telephone and fiber optic because of its relatively low cost and high reliability. The spread spectrum signal is unlicensed which may produce signal conflicts in the future. The approach was chosen as opposed to a licensed 900-Mhz system only because there are currently no channels in that frequency bands available from the FCC.

The interface between the radio signals and the District's data network is made at Bald Mountain. An Allen Bradley PLC 5 acts as the interface between the distributed network and the District data system.

The overall control is performed using a PC-based SCADA interface. The system was designed using Intellution's FIXDMACs software (now GE). This software provides a graphical operator-system interface for data display and system control. A sample display of showing the system overview is shown on Figure 4. The system is also used to report alarm conditions and archive data.

LESSONS LEARNED

After twelve years of operation, there are several important lessons learned from the SWSP SCADA system.

1) The SCADA system is reliable. Since the SWSP is the major or sole source of water for the Participants, extended downtime is unacceptable. Fortunately, the SWSP SCADA system has proven to be exceptionally reliable. Even with the occasional lightning strike or communications failure, the nature of the distributed control allows the system to stay functional when one particular site has a problem. The equipment selected however has proven to be durable and long lasting.

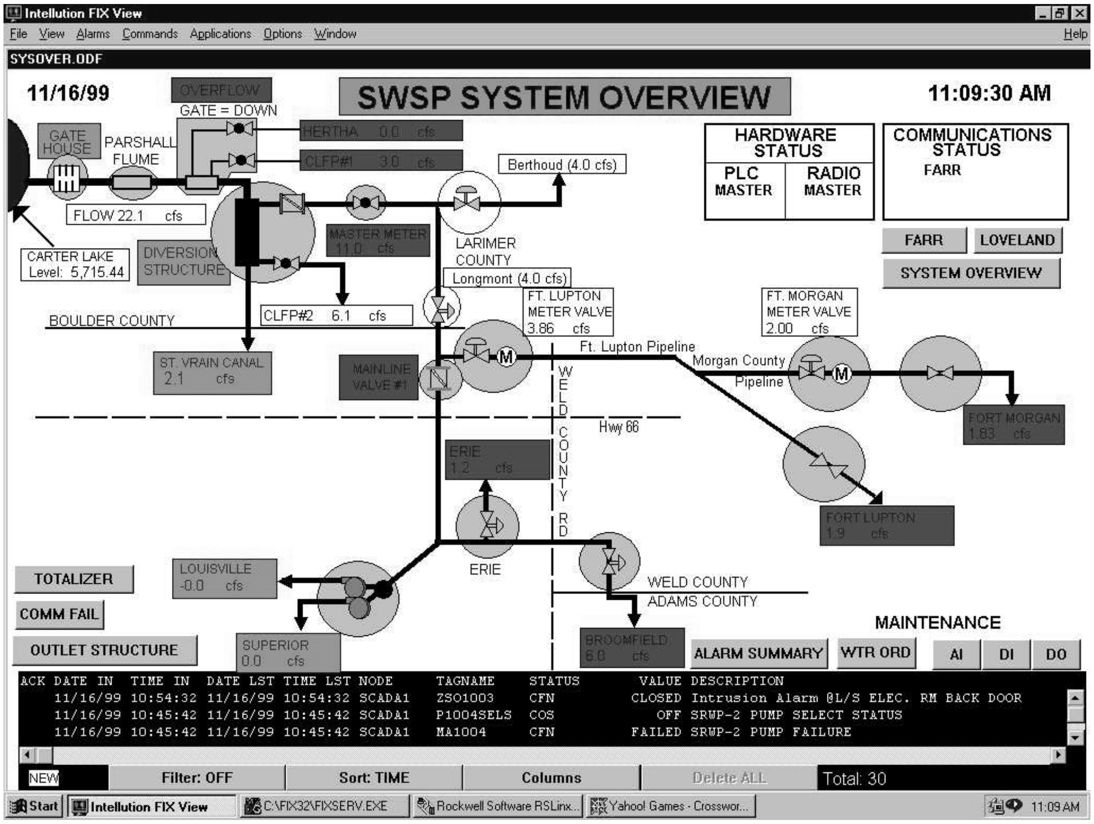


Figure 4. SWSP System Overview Screen

2) SCADA can improve system operations. The SWSP SCADA system has enhanced the overall operation of the delivery system. Firstly, the operation of Carter Lake Reservoir outlet is now run automatically based upon water orders versus the previous manual operation. Hence, operations personnel no longer are required to attend to the outlet when flow changes are made. More importantly, the quantity and quality of the information obtained throughout the system allows for rapid troubleshooting should operational problems arise.

3) SCADA is not maintenance free. SCADA is not something that once installed, can be left alone. The District has two employees who are dedicated to the maintenance of the District's SCADA system which includes the SWSP and other facilities throughout the collection and distribution system. Since the operation of the system is only as strong as the weakest piece of equipment, upkeep and calibration of the instruments and SCADA equipment is imperative. While the SCADA PLC and radio systems provide the communication conduit and commands, the actual instruments – flow measurement, pressure measurement, valve position, etc. – are the backbone of the operation.

4) SCADA systems are adaptable and expandable. The SWSP implementation was staged over 12 years. The first part of the system – the Carter Outlet Modification and the Broomfield pipeline – served as the initial backbone of the project. Initially the system started with the canal outlet area, two automated mainline valve stations, and two flow control structures. Over time, two additional mainline valve stations, five additional flow control stations, and three pump stations have been added. Additional structures are planned in the future. With the expertise of the two District SCADA and instrumentation staff members, the expansion of this system by nearly 200 percent has been straightforward and cost effective. System logic has been modified, and in certain instances, equipment has been upgraded.

5) SCADA as is cost effective. Of the original $67,000,000 project cost before the pump station additions, SCADA represented about $1,000,000 of the cost or about 1.5%. Considering the cost of manual operation – at least two to three full time people operating the SWSP system – the cost of the system has been money well spent.