Remote Telemetry:
Innovative Solutions for Managing Remote Irrigation Sites

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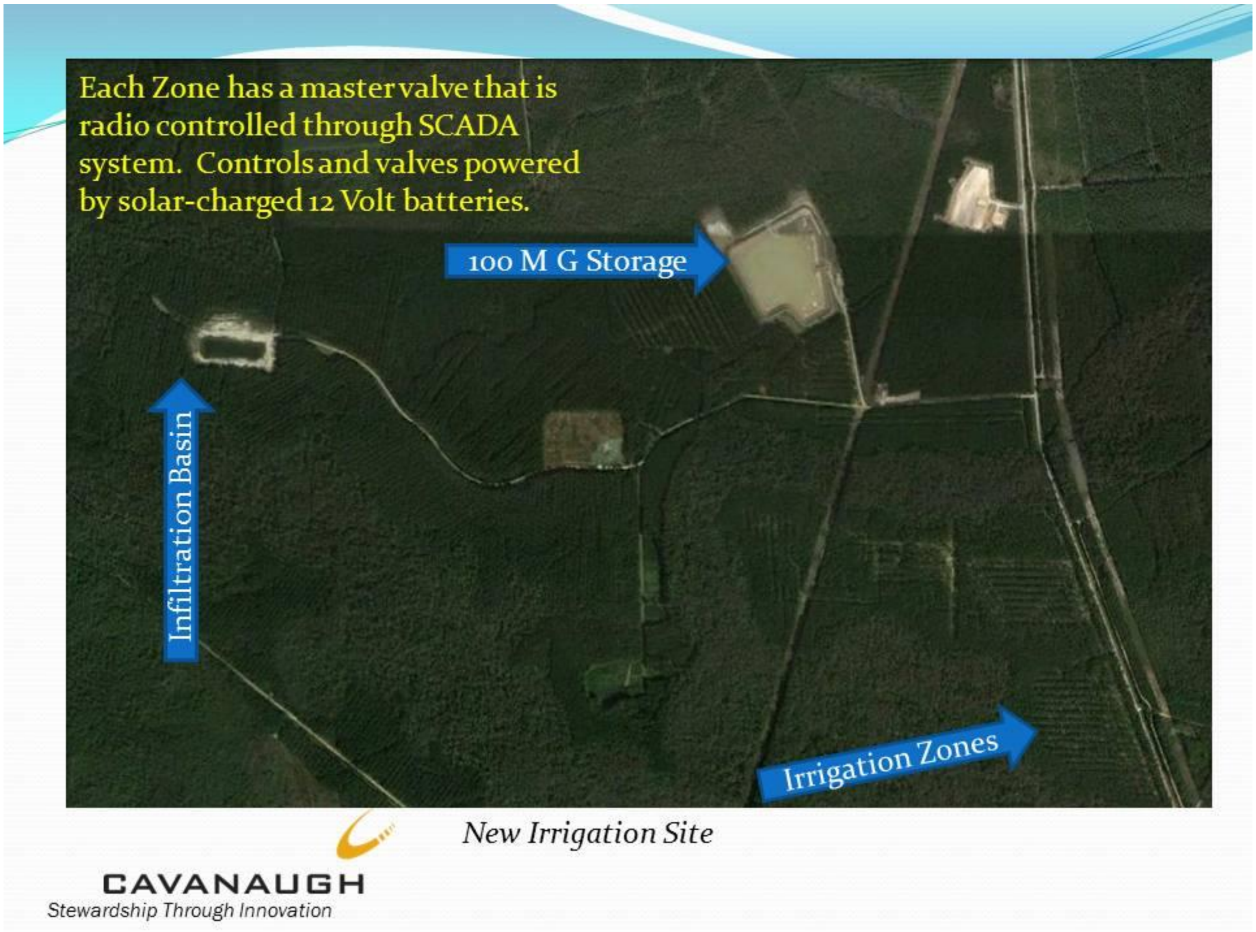
Abstract - *In 2006, the Town of Surf City, an island town located in Coastal North Carolina, began the process of expanding their wastewater facilities to meet the demands of a growing population and increasing seasonal tourism. The Town's treated wastewater is designed and permitted to meet North Carolina Reclaimed Water standards. The Town owns and operates an 88-acre sprayfield that uses small impact sprinklers to irrigate a grass receiving crop. The existing fields operate at maximum capacity, which is less than half of the Town's 10-year flow projection capacity needs. This existing sprayfield site is also bound on all sides by properties that are either unusable or unattainable by the Town for use in expansion of the non-discharge irrigation system. After an extensive search for available and usable property, the Town acquired a 2,200-acre tract under managed pine that would serve the Town's long-term needs. However, this tract of land is eight miles from the Town's wastewater facilities, in a remote, rural area. This paper describes the challenges presented in managing this remote site that has limited access and coverage by conventional telecommunications infrastructure, and the strategies implemented to overcome these challenges; including solar-powered radio controls system and custom-designed irrigation management system.*

Keywords: Solar-powered radio control systems, remote system management strategies, remote effluent utilization sites, integration of SCADA system in a remote utilization sites



Background

The beaches of coastal North Carolina have become increasingly popular, and the expanding tourism season exponentially increases the demand on wastewater facilities during the summer months. Environmental regulations and water stewardship goals require many of these areas, such as the Town of Surf City, located in coastal Pender County North Carolina, to utilize non-discharge systems for wastewater disposal. By far, the most popular form of non-discharge disposal employed by these systems is through the use of irrigation – either as a dedicated site for disposal, or through some beneficial reuse of the treated wastewater effluent ("reclaimed water") to offset an existing or proposed demand on fresh water supplies.

There were many challenges facing the Town of Surf City as they looked to expand their non-discharge wastewater system, which also required expansion of the dedicated irrigation sites (spray fields) and development of reclaimed water reuse strategies. A primary challenge was that the wastewater facilities serve a permanent population of about 2,000 people; but this served population increases to more than 20,000 in the summer as tourists and seasonal occupants arrive to spend the warm season at the beach. This vast increase in population correlates to a substantial seasonal increase in wastewater treated, which ultimately means a seasonal increase in the amount of water to be irrigated. The original 0.6 MGD wastewater plant was a simple lagoon based system circa 1990 with a spray irrigation system comprised of approximately 88 acres of small-bore impact sprinklers irrigating a Bermuda grass receiving crop. Another challenge associated with the expansion plans was that the existing wastewater plant and sprayfield were 'land locked,' or bound on all sides by properties that are either unusable or unattainable by the Town for use in expansion of the non-discharge irrigation system. Consequentially, this meant that the Town must look to acquire additional land away from the existing facilities and control system.

As you might imagine, land in this area has, historically, been actively sought for commercial and residential development to meet the increasing demands of more and more people moving to and visiting the area. Being in coastal, eastern North Carolina, the sizes of parcels of land are relatively small, and wetland areas are prevalent. Based on the foreseeable wastewater needs of the Town, it was initially determined that the Town would need to increase its wastewater system, and thus its irrigation system, five-fold (to 3.0 MGD). The existing irrigation site, as previously mentioned, is approximately 88 acres of sandy, coastal soils. Given the expansion needs, the Town began looking for a parcel, or parcels, of land that could support roughly 440 acres of irrigation – assuming similar sandy soils. It quickly became evident that none of the adjacent properties, or properties within the immediate area of the existing system, would be capable of being conjoined to satisfy this requirement.

Finally, the propensity for management problems caused by inclement weather was noted as a critical challenge for the Town. The existing system had only six days of storage capacity, which put the Town and the Operator in a very precarious situation during periods of wet weather. During the 1990's, several named storms and hurricanes dumped inches of water on the area, which resulted in localized flooding. Some of the flooded areas, unfortunately, resulted in surcharging the sewer system and creating an increased volume of treated effluent to be managed by the irrigation system; not to mention the volume of rainfall captured by the storage ponds and the wetness the rainfall created in the irrigation fields. The existing storage and irrigation system had no remote monitoring or controls system, which meant that the system had to be manned to be monitored. This is problematic not only during inclement weather, but often in the days that follow as flooding and felled trees often inhibit transportation in the area.

Given these considerations, plans were developed to expand the Town's existing wastewater treatment and irrigation system to a first phase of 1.5 MGD utilizing a sequencing batch reactor (SBR) capable of producing reclaimed water quality effluent. The Town sought to: acquire a sizable tract of land to utilize as a dedicated irrigation site – even though this required looking at parcels of land several miles away, promote the reuse of water for future customers, and implement a monitoring and controls system that provided the Operators with the ability to manage the system from a safe location during inclement weather. Cavanaugh & Associates, P.A. helped the Town of Surf City identify and acquire a 2,200 acre tract of forested land about eight miles from the Town's wastewater facilities, to serve as the irrigation site and to provide additional storage. The following describes the remote monitoring and control system developed for the Town, and the ways in which it aids in overcoming the challenges described above.

Remote Communication is the Key

It was important at the onset of the expansion planning to evaluate the current means of remote monitoring and controls utilized by the Town for other critical infrastructure and essential operations. The Town had already gone through an extensive evaluation of the challenges and benefits of differing types of remote monitoring and controls systems for other infrastructure systems, such as the Town's water distribution system and the sewer collection system. Given the likelihood of power outages and disruptions in telecommunication services, the Town quickly moved away from relying on hard-wire control systems that require conventional telephone service. The decision was reinforced to utilize a system that combined the use of internal radio communications, managed by the Town, and the internet.

The existing VHF radio communications system utilized by the Town consisted of a primary communications tower at the Town's drinking water plant, with repeaters distributed around the Town to provide signal strength. The existing drinking water distribution system and much of the sewer collection system was already connected to this supervisory control and data acquisition ("SCADA") system. The addition of the monitoring and controls of the wastewater treatment plant made perfect sense, and provided the Operators the ability to monitor and control all of this infrastructure from either the drinking water plan or the wastewater plant, providing redundancy of data and the opportunity for the Operators to control the system from either location should inclement weather prevent access to one of the sites.

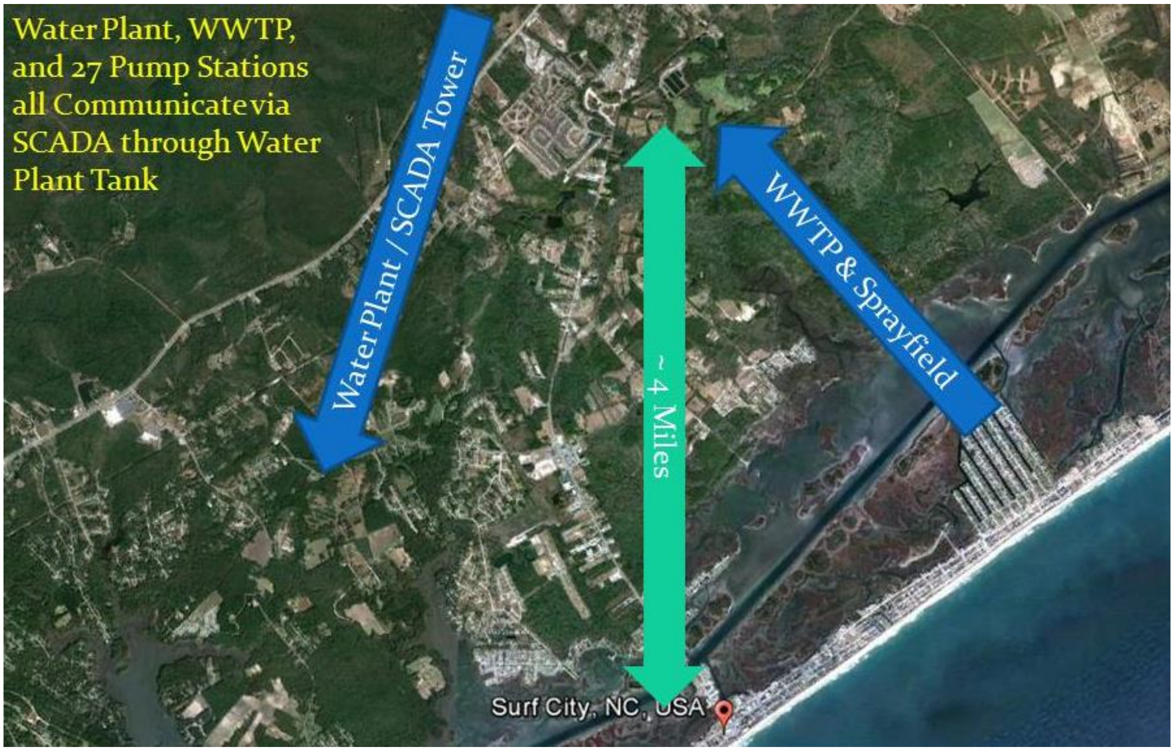


Figure 1. Existing SCADA Communications System Map

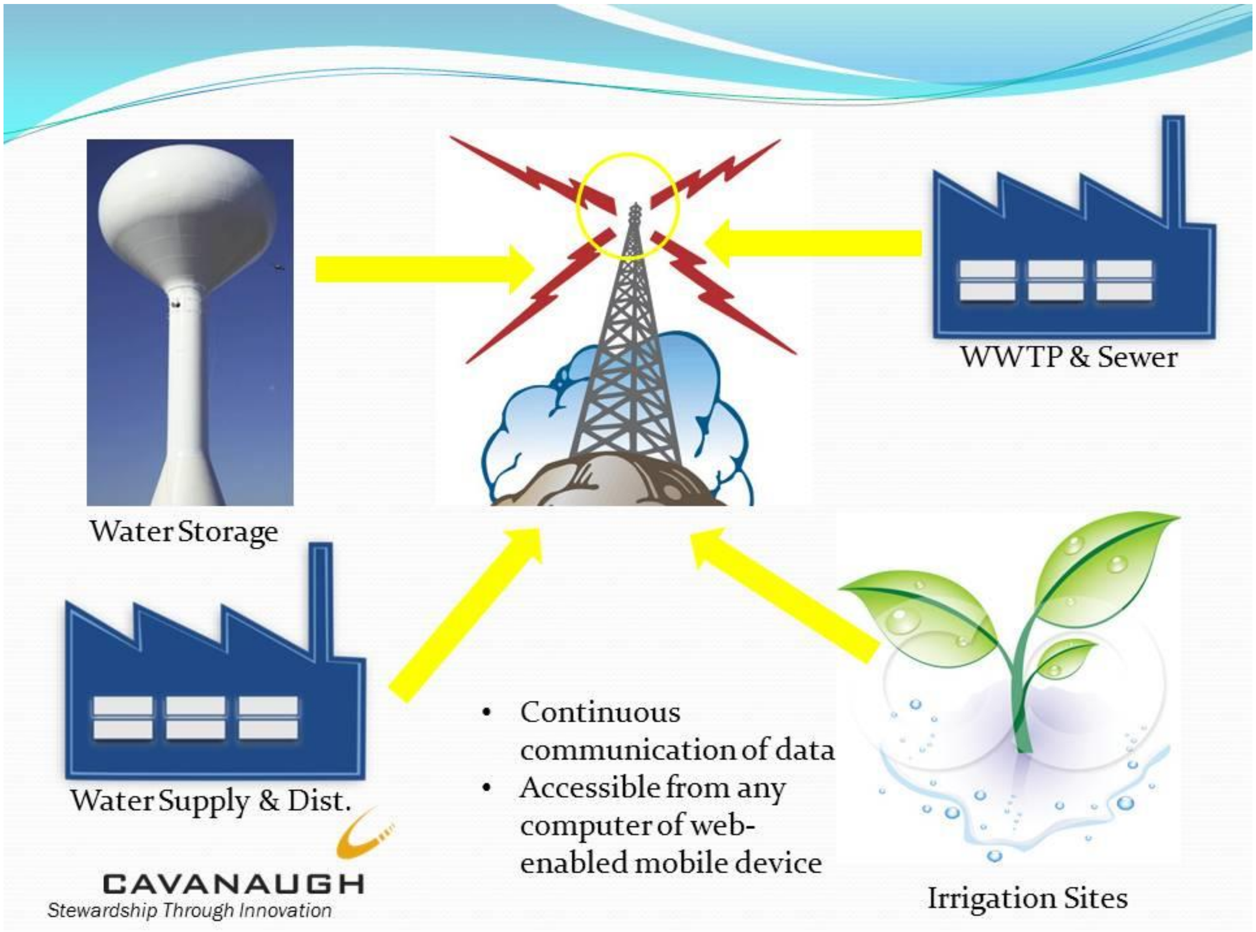


Figure 2. Town SCADA System Communications Schematic

The parcel of property acquired for the expansion of the irrigation system was over 8.5 miles away from the existing wastewater plant, and over 12 miles away from the centralized communications tower. This distance required upgrading the strength of the broadcast signal, and a decision was made to place a second broadcast antenna at the existing wastewater plant. Again, this provided redundancy for the critical operations of the Town's infrastructure, should one of the communications towers be damaged by excessive winds or flying debris.

Although the Town's operational philosophy included staffing the irrigation site during normal irrigation events to monitor for problems and errata, the ability to remotely control the site in case of emergencies, and monitor the operations of an expansive, wooded, and remote site were of utmost importance. The remote nature of the site resulted in poor cellular phone reception and inadequate unreliable phone line communications. Moreover, the area was well known and documented to suffer from multiple nearby lightning strikes annually, which can wreak havoc on wired control systems. With these factors in mind, the decision to continue the use of VHF radio communications, augmented with the ability to communicate to the Town's SCADA system via any computer connected to a secure network over the internet was clear.

Figure 3. Expansion of SCADA Communications System for New Irrigation Site

Figure 4. Communications Tower Installed at Remote Site

Access to Meaningful Data

The opportunity also existed to integrate the irrigation operations with the Town's existing SCADA system to provide the operators with a much more informative and complete set of data regarding the Town's water cycle. Rather than purchasing an off-the-shelf irrigation control system, the Town decided to build in the control functionality and monitoring typically provided through commercial irrigation control applications into their existing SCADA program. Using the existing SCADA software for irrigation program control afforded several advantages:

- The software used by the Town is an 'open source' application; meaning future additions and modifications to the programs could be accomplished by any of a large number of SCADA system integrators and programmers. This allowed the Town with the greatest flexibility in managing the costs and customer service experience.
- As technology improves over time (new sensors, meters, gauges, etc.), these devices can be added without purchasing an upgrade or entire new software module.
- The "irrigation controls software" would be tied to the other pertinent data available for managing the water cycle of the system, including:
  - Drinking water supply consumption
  - Available storage capacity
  - Influent flow at waste water plant (compared to drinking water flow, points to consumption as well as inflow, infiltration, or unmetered source flows)
  - Weather data (temperature, precipitation, humidity, etc.)
  - Sewer collection system status (pump status, equipment failures that impact effluent quality, etc.)
  - Wastewater plant data (pump status, equipment failures that impact effluent quality, real-time constituent monitoring such as disinfection system efficacy, etc.)

Not only would the operators receive information about storage capacity and application events of the irrigation system, but also receive information about rainfall across the Town, tidal influx, and water usage. Flow meters on all major pump stations also provide the operators with information regarding the influent flow patterns and predictions on flow to the wastewater storage system over a short period of time. Wastewater plant data can provide the operator with real-time and current data on the effluent constituents, including nutrient concentrations and pathogen information. All of this information allows the operators to develop long-term trends for daily and seasonal flows to the irrigation system for more accurate and predictable irrigation budgeting, as well as better manage the performance of the irrigation system and safety of the workers. Total integration with SCADA allows the operator to control the entire water resources system.

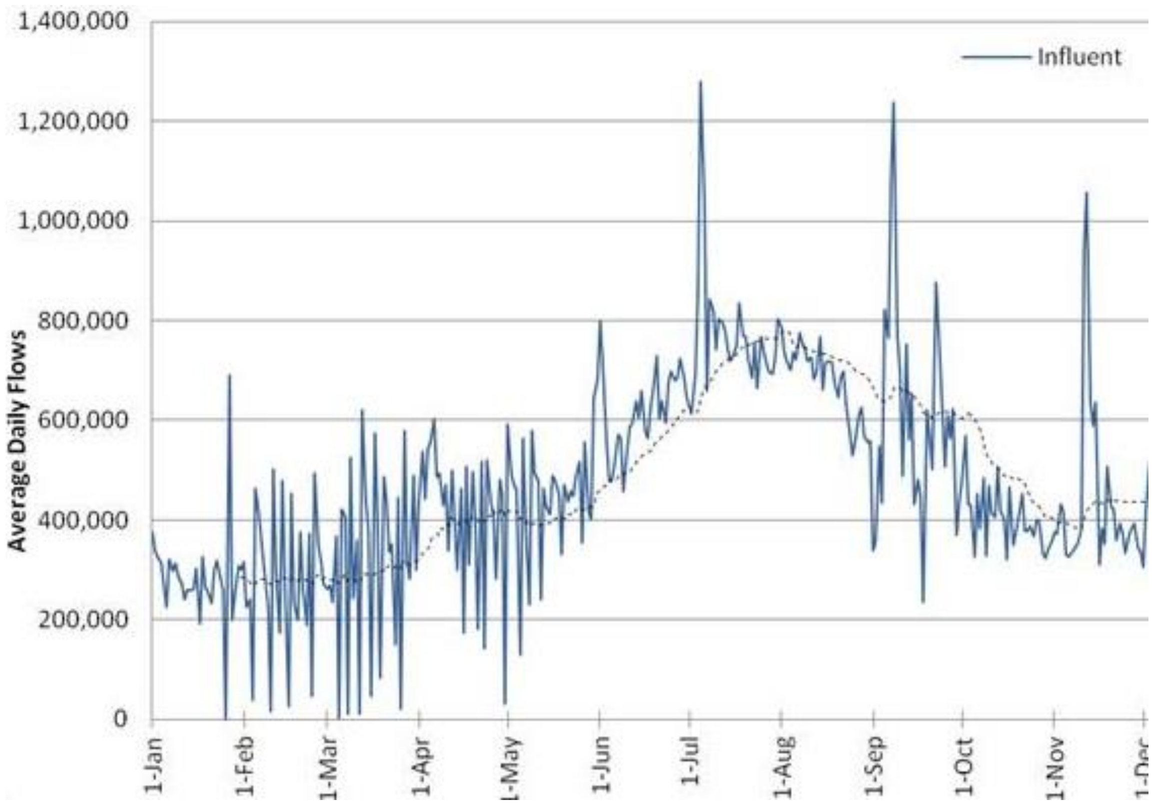


Figure 5. Example Influent Flow Trend Graph from SCADA System

Irrigation Control System for Remote Site

The remote irrigation control system is comprised not only of a wireless connection to the primary control facilities, but also a wireless zone control system to further overcome the challenges discussed above associated with typical hard-wired zone control systems. A combination of manual zone valves and automated zone valves were installed to control the sprinklers, which communicate to the centralized server at the irrigation pump station. Each zone has a master diaphragm valve that is actuated by a small, electric solenoid valve. The solenoid valves operate on DC current supplied by 12-volt deep cell batteries located in the zone control panels at each zone. The solenoid valves are controlled by a small programmable logic controller (PLC) in each zone control panel, also powered by the 12-volt batteries. When the SCADA system sends a signal for any zone control valve to open, the solenoid valve opens creating a pressure differential on the diaphragm (irrigation system must be pressurized by irrigation pumps for pressure differential to be created). This pressure differential operates the diaphragm, thus opening and closing the valves, as desired. Using this configuration, a simple, inexpensive ¼” solenoid valve is able to open and close 8” to 18” zone control valves.

The 12-volt batteries powering the zone control panel and solenoid valves are connected to solar panels mounted on the communications tower at each zone. The solar panels were sized to provide sufficient charging capabilities to maintain functional power for a 5-day period; ensuring “cloudy days” do not limit the functionality of the system. Power efficiency is further managed by having the PLC “sleep” a majority of the time, which consumes far less power than staying “on” continuously. The PLC “wakes up” for 30 seconds every 5 minutes to listen for a control signal. In this fashion, the PLC is only fully powered approximately 10% of the time.

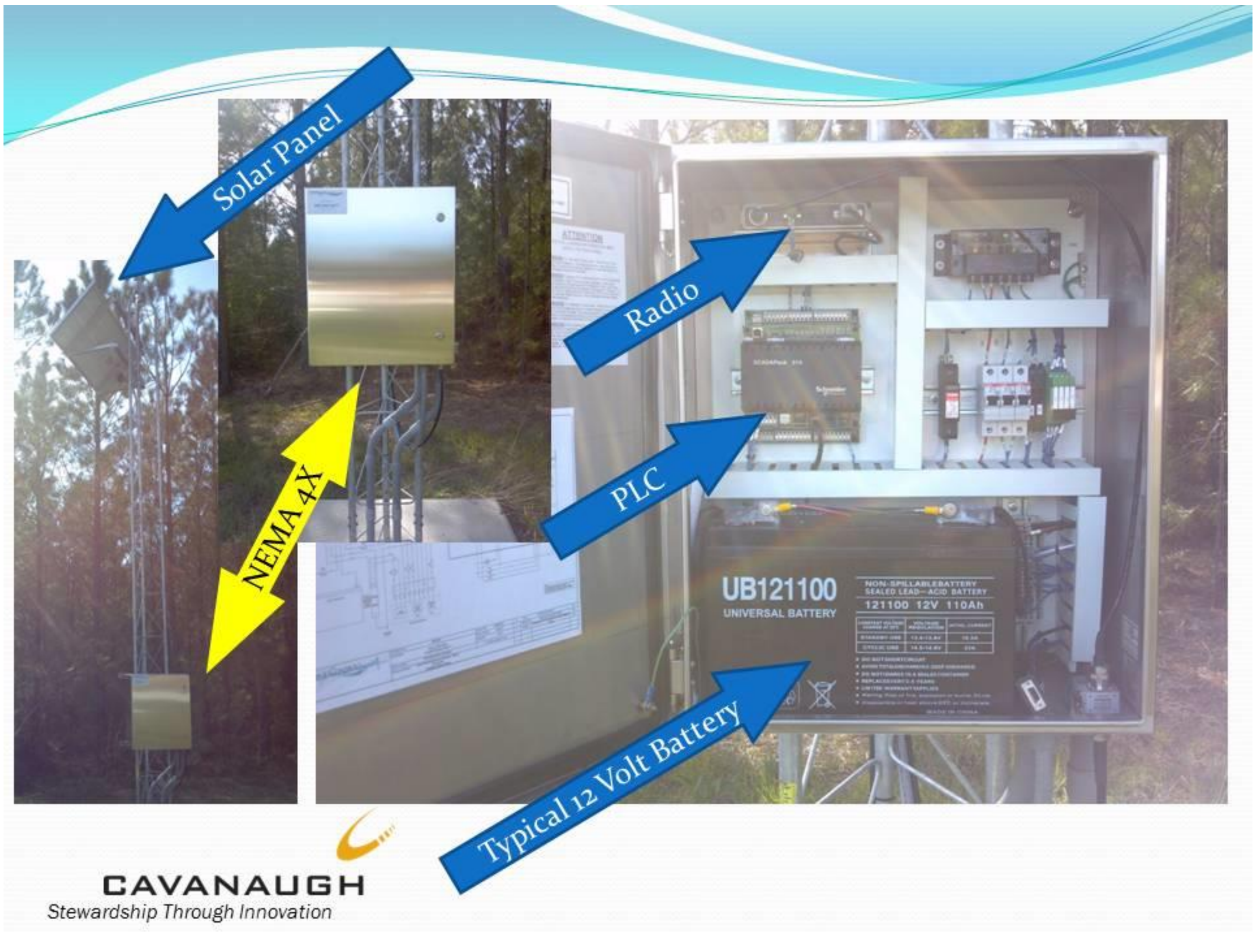


Figure 6. Typical Remote Irrigation Control System Installation

There are two main control valves that direct effluent flow to either of two available storage basins to provide the operator with maximum flexibility. It was determined to keep these two valves in continuous operation to provide the operator instant control over flow direction (flow direction was considered to be a critical function requiring “instantaneous” changes in the event of system malfunction to prevent spills or create safe conditions). As such, multiple 12-volt batteries were provided for these control panels, and larger solar panels provided.

The SCADA system, also serving as the irrigation program control package, controls the frequency and duration of each irrigation event for each zone. The SCADA software was developed to include 48 customizable programs (expandable to a near infinite number of programs) that allow for multiple irrigation events of zones within a single program. This flexibility of programming allows the operator to perform multiple zone doses during a single program to provide specific dosing of each irrigation zone. There are 32 valve calls per program, and no set pattern. The irrigation pumps are controlled by variable frequency drives (VFD's) that allow for pump speed control. Pumps ramp up when each program is initiated to provide system pressure for control valve manipulation, and ramp down between programs to prevent over pressurization and water hammer as valves close. Each irrigation zone has an adjustable pressure set point, and the VFD-driven pumps adjust speed during irrigation events to maintain desired zone pressure. Additional, programmable safeguards were added to allow the operator to program alarm conditions for pressure and flow. For example, if zone flow (at the pressure set point) exceeds a set percentage (1-100%), the pumps shut down. This is an important monitoring feature of the system to indicate to the Operator that a sprinkler riser may be broken or that a supply line may be broken. Automatic pump shut-down for this alarm condition minimizes, and virtually eliminates, runoff due to breakage. If this were a case of clean water irrigation rather than treated wastewater effluent, the same capability will prevent unnecessary water waste; or nutrient/pesticide waste in the case of fertigation. Similarly, low- and high-pressure alarm set points may indicate valve failure, and similarly result in pump shut-down. All of these set-points are adjustable by the Operator, affording flexibility as the system changes or expands over time.

Conclusions

Implementation of remote irrigation management systems, as described for this project, provides real-time data and control of critical irrigation infrastructure by the Operators. Further integration of total water cycle data, such as source flows, weather data, and storage availability provide for better irrigation scheduling, water budgeting, and decision making. This data may also be used by the Operators to better predict storage needs, application rates, and other operational considerations as time moves forward and more data is kept for trend analysis. Integrating irrigation management software applications with other existing supervisory control and data acquisition (SCADA) system applications affords the Operators and system owners with the greatest amount of control and flexibility – able to not only shut-off critical irrigation system components in case of emergency or inclement weather, but also by managing (even shutting down) source flow contributors, such as upstream pump stations. The ability to remotely control critical pumps and valves by both internal VHF radio system and by internet-capable devices provides the Operators, in this case, a means of monitoring and controlling the system from safe locations in the event of inclement weather, such as hurricanes. This ability will enable the Operators to control and manipulate storage and flows, preventing spills and overflows from the wastewater system.

The use of radio control systems affords the opportunity to avoid the expense and challenges associated with the installation and operation of typical hardwire control systems. Using battery-powered zone control systems and zone control valves, recharged by solar panels, also eliminates the hazards of installing electrical lines in a wet service location, and the expense of installing miles of high-voltage power lines. Installations, such as the remote irrigation control system employed by the Town of Surf City, demonstrate the improved management techniques that continue to be availed to irrigation system operators as radio communications, internet-enabled mobile devices, and solar-powered control systems become more affordable and accessible.

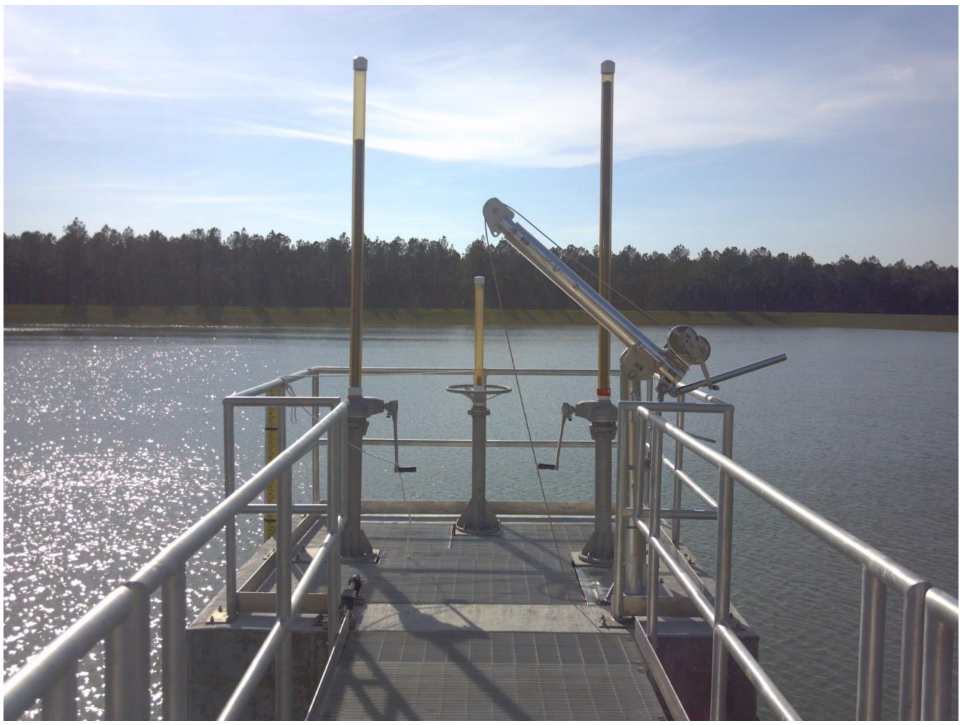


Figure 7. Inlet Control Structure at 32-acre Storage Pond Serving Surf City Irrigation System

About the Author:

William G. “Gus” Simmons, Jr., P.E. served as Engineer in Responsible Charge and Lead Designer for the Town of Surf City Irrigation System Expansion. Gus has designed and operated thousands of acres of sprinkler irrigation for the purposes of wastewater effluent utilization and beneficial reuse for agricultural, industrial, and municipal installations across the United States. Gus continues to work with the Town of Surf City and the irrigation system Operators in analyzing the data associated with the Town’s total water balance, and planning for efficient use and expansion of the Town’s irrigation system infrastructure. For more information, please visit **www.cavanaughsolutions.com**.