Implementing Early Warning of Toxic Chemical Intrusion into a WWTP by Using Remote Toxic Chemical Sensors Communicating Over Cellular Wireless Telemetry into a Central SCADA System with Advanced Alarming and Voice Notification.

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ABSTRACT

Problem:
The District of Columbia Water and Sewer Authority (DCWASA) has experienced in the past sudden influx of high concentrations of organic chemicals into their main pumping station and the Blue Plains Wastewater Treatment Plant. Many DCWASA staff members were affected by the presence of the toxic gas in the main pump station. There was no early warning system in place to warn the staff of the pending intrusion.

The environmental impact of a major system disruption could be extreme. Flooding has proven to cause major local community and regional impacts. Introduction of toxic substances into the system will impact all facilities along the path to the treatment plant.

Solution:
DCWASA has installed an MSA remote toxic chemical sensor upstream of the main pumping station to provide an early warning of the pending threat. It is currently monitoring volatile organic compounds (VOCs). The VOC sensor had to be installed in an underground location in a public area with high pedestrian use in a park setting. The use of antenna masts for communications was not feasible. Cellular communications with a low profile hidden antenna was the selected as the method of transmitting data to a central SCADA system. An Allen-Bradley CompactLogix PLC was connected to the VOC detector at the remote site. The PLC monitored the status of the VOC detector plus also performed other functions such as communications logic and also provides unauthorized intrusion logic. A Rockwell RSView SE SCADA system provides monitoring and alarming to a touch screen located in the main control room. Since the operators are not always in the control room, a voice annunciation system was also installed. In the event of an alarm, a pre-recorded voice (WAVE file) is sent to speakers in the control room and outdoor bullhorn type speakers outside the control room.

KEYWORDS

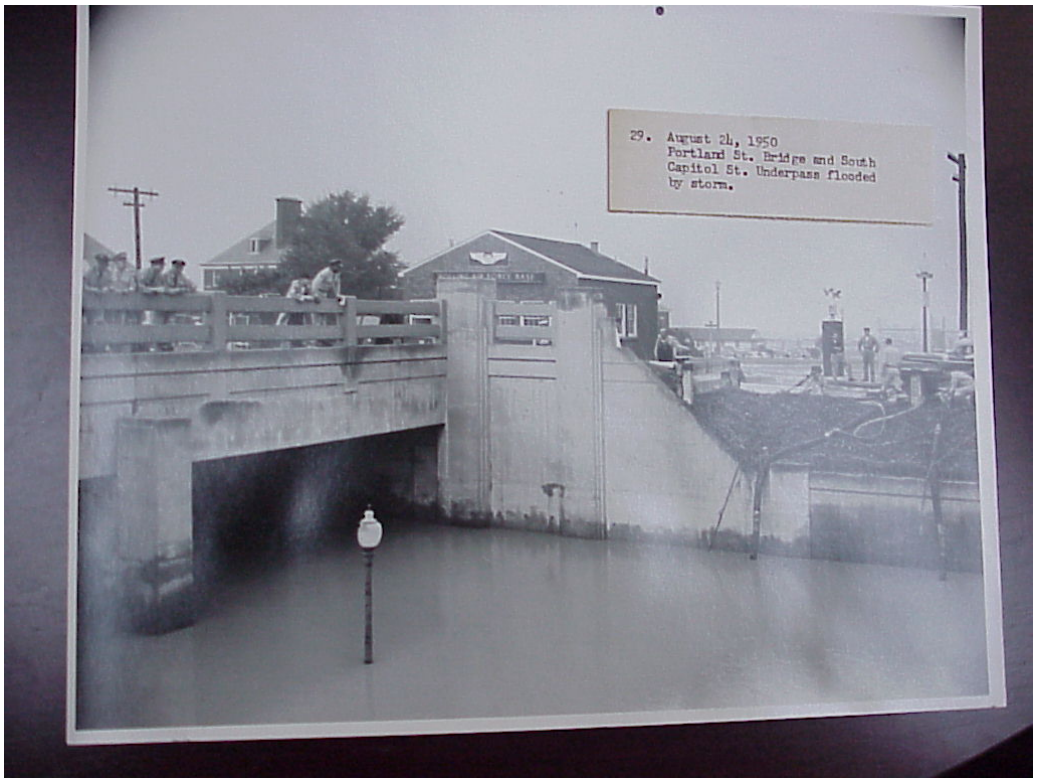
Toxic chemical warning, cellular communications, SCADA, wireless, VOC monitoring, PLC, voice annunciation, MSA, Rockwell, volatile organic compounds, WASA

INTRODUCTION

The District of Columbia Water and Sewer Authority (WASA) is a regional utility serving the needs of several jurisdictions. WASA provides drinking water and wastewater collection and treatment to a population of more than 500,000 in the District through a base of 130,000 residential, commercial, and governmental customers. WASA also collects and treats wastewater for a population of 1.6 million in Maryland and Virginia. At the end of FY 05, WASA had net assets of 880.7 million and operating revenues of 272.7 million.

To collect wastewater, WASA operates and maintains, on behalf of the District of Columbia, 1,800 miles of sanitary and combined sewers, 12 Fabridams and Swirl Facilities, 60 CSO Outfalls and 95 CSO Structures, 22 flow-metering stations, nine off-site wastewater pumping stations and 15 stormwater pumping stations within the District. Separate sanitary and stormwater sewers serve two –thirds of the city. In the remaining part of the city, primarily in the downtown area, combined sewers are in service.

Where there is no early warning in place to alert the staff of sudden influx of flow or potential flooding; the impact of a major storm disruption could be extreme. Local overflows have proven to cause major local community, regional and financial impacts from lack of system access and possible flooding. Hurricane Isabel of June 2003 and storm of August 1950 are good examples of major storms, as results of these storm events and lack of early warning at storm stations, power failure at several storm stations caused significant stations, roads and highway flooding.



New System Provide Protection against toxic substances**.**

The District of Columbia Water and Sewer Authority (DCWASA) has experienced in the past sudden influx of high concentrations of organic chemicals into their main pumping station and the Blue Plains Wastewater Treatment Plant. Many of United States Department of Treasury (US Treasury Department) located at 15th Street and Pennsylvania Avenue NW; and DCWASA staff members located at 125 O Street (main pumping station) was affected by the presence of the toxic gas in the main sewer. As a result, US Treasury Building and DCWASA main pumping station were evacuated. There was no early warning system in place to warn the staff of the pending intrusion at the main pumping station.

Installation Restrictions

The location of the toxic chemical sensor was in the main interceptor located in a very high public use park area and subject to the following restrictions:

- No telephone leased line
- No radio tower or mast
- Hidden antenna
- No radio repeater stations
- Sensor located underground
- Vandal proof installation
- Low maintenance
- Remote VPN access for programming and maintenance

It was because of these restrictions, that cellular communications were selected with a hidden low profile, vandal proof antenna located in the park. All communication and hardware was located in an existing underground pump station that was hidden from public view and access. (See Figure 1)

The AirLink Raven EVDO industrial radio was selected to provide wireless communications to the Verizon cellular towers. AirLink was selected due to the following features:

- Always-on, Always-aware intelligent connections
- EVDO Rev A with Automatic fallback feature
- Dual antenna inputs (800 MHz & 1900 MHz)
- 140 degree Fahrenheit temperature rating
- Hazardous location rating (Class 1 Division 2)
- Intrinsically safe
- Remote Configuration and Maintenance
- Low power consumption
- Ethernet connectivity

Figure 1: Cellular Antenna

Hardware/Software Architecture

The hardware and software architecture required a full featured SCADA system that was to be initially standalone, but could be easily converted to a distributed system with the ability to communicate with other systems in the future. The following is a list of hardware that was used in this system:

- MSA ChemGard Infrared Gas Monitor
- Allen-Bradley CompactLogix PLC – Remote stations
- Allen-Bradley ControlLogix PLC – Central Station
- Allen-Bradley VersaView Integrated Touch Screen
- AirLink Raven EVDO Cellular Radio
- RuggedCom RX 1000 Routers
- Cisco 2800 Router

The security of a wireless communication system was insured with the use of secure VPN tunnels to the remote sites. This was achieved by installing a RuggedCom RX1000 router at each remote site and placed between the local PLC and the AirLink wireless radio. In addition, the cellular carrier assigned a static IP address that was located on a private network for each wireless radio. This provided an encrypted VPN connection

between the remote site and a Cisco router located at the cellular termination point in the DCWASA LAN.
As an added feature, only specific ports were opened for communications between each remote station and the central station. In essence, the SCADA communications were locked down tightly to prevent unauthorized intrusion from the outside. In addition, the SCADA computer was also prevented from any internet/web features such as web browsing, e-mail, downloading, Instant Messaging, etc. In essence, the SCADA system could only communicate with the remote stations. Refer to Figure 2 for the overall system architecture.

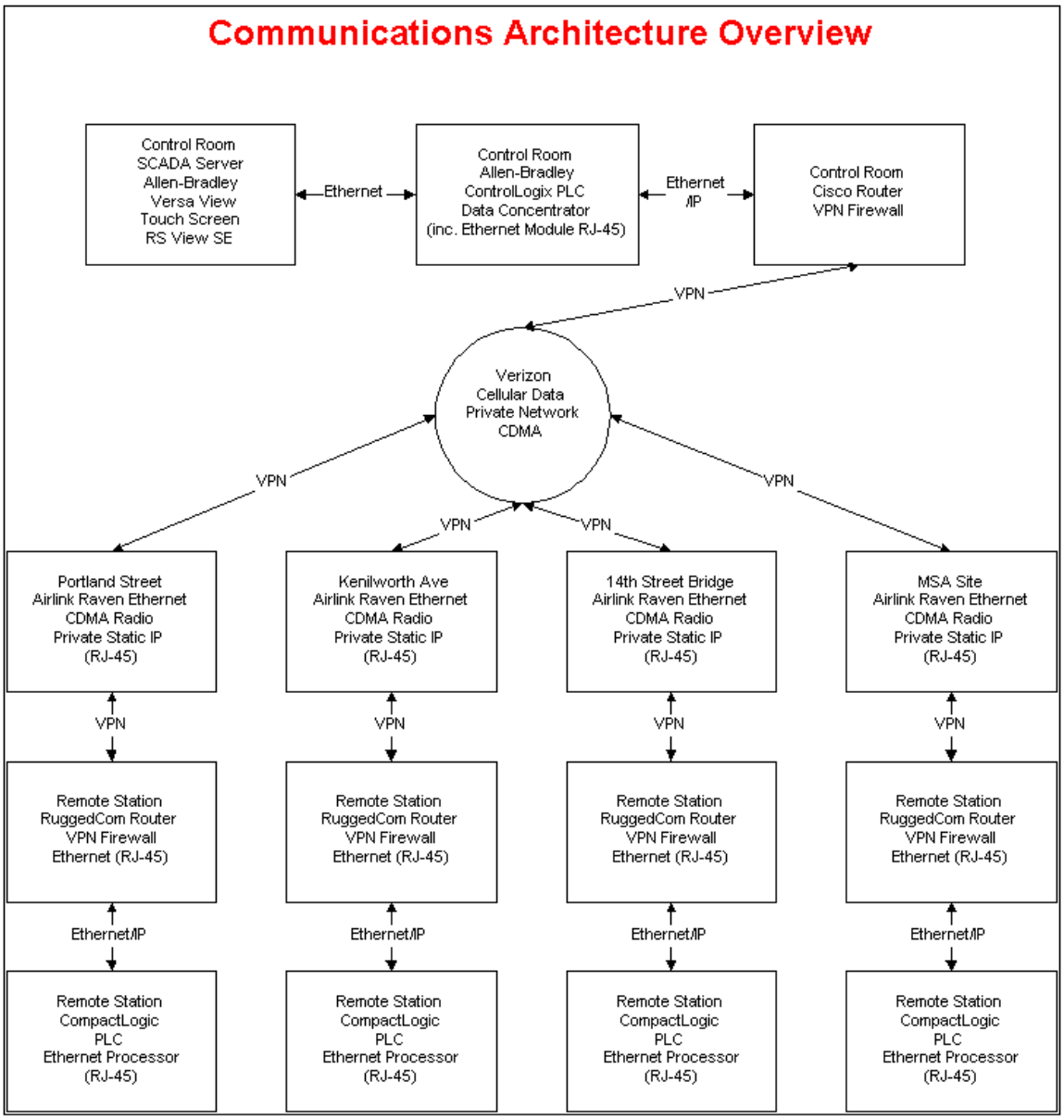


Figure 2: Communications Architecture Overview

The visual equivalent of Figure 2 for each remote station is displayed in Figure 3. It displays the individual component architecture starting at the remote VOC detector through communications and ending on the SCADA display in the central control room.

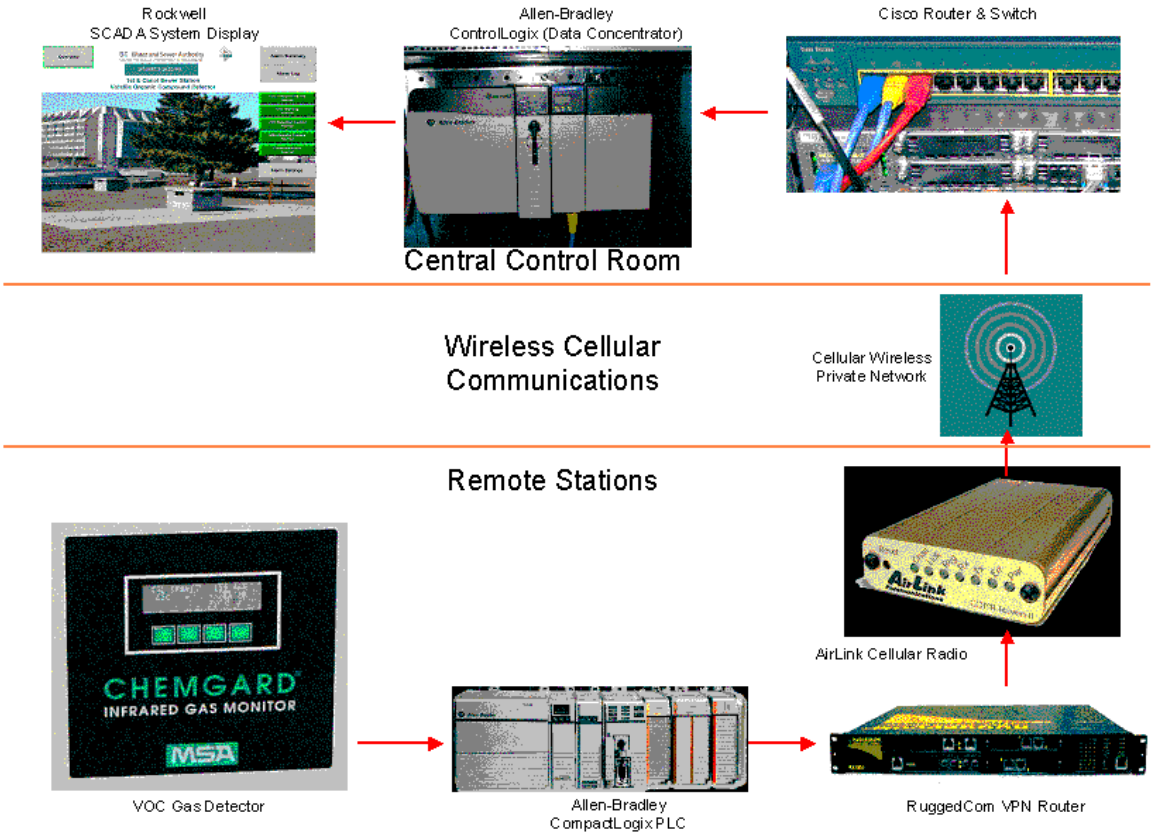


Figure 3: Component Architecture

Monitored VOCs:

The Volatile Organic Compounds (VOCs) that are currently monitored are mostly related to organic compounds. The MSA ChemGard detector was setup to provide four levels of alarms:

- Trouble
- Caution - 400 ppm
- Warning - 600 ppm
- Severe - 800 ppm

Propane is used as the calibration gas. Other gases monitored are 1, 2 Dichloroethane, Toluene, Methane, Ethyl Benzene and other gasses that could cause burning, tearing and coughing. Figure 4 displays the MSA ChemGard installation.

Figure 4: MSA ChemGard installation

The ChemGard VOC detector continually samples the adjacent interceptor via a remote sampling tube. Technicians can easily maintain and calibrate the system from the built-in touch screen on the ChemGard unit.

PLC Communications:

An Allen-Bradley CompactLogix PLC was connected to the VOC detector at each remote site. The PLC monitored the status of the VOC detector plus also performed other functions such as communications logic and also provides unauthorized intrusion logic. All of the data from the PLC was transmitted over the cellular wireless connection using encapsulated Ethernet IP addressing.

One of the main goals of this installation was to minimize the amount of data transmitted and thus resulting in a low monthly data use fee from the wireless cellular carrier - Verizon. In order to achieve this, an unsolicited data transmission scheme was adopted combined with a regular one-hour heartbeat. An Allen-Bradley ControlLogix PLC acted as a data concentrator and was located in the central control room. The function of the data concentrator PLC was to “listen” for unsolicited messages from each PLC at the remote stations. In addition, the data concentrator PLC sent out a “heart beat” request to

each remote station on a regular basis to confirm that the communications to each station was working properly.

The type of unsolicited data that is transmitted from each remote site varies depending upon the type and quantity of Input and Output (I/O) devices. An intrusion alarm system was installed at each station to provide a local alarm warning plus alarming at the central control room. The types of I/O monitored are as follows:

- VOC trouble
- VOC alarm levels
- Wet Well Level (feet)
- High Wet Well Level Alarm
- Pump 1, 2 or 3 Running
- Power Failure Alarm
- Station Flood Alarm
- Station Door
- Intrusion Alarm
- Communication Error

Since Ethernet was used as the communication protocol, all remote CompactLogix PLCs could be programmed and maintained from the central control room. The high-speed wireless connectivity from the AirLink Raven EVDO radios provided a fast connection for easy and quick troubleshooting. RSLogix 5000 programming software is loaded on the central SCADA computer in the control room. Direct connections to all the remote stations are made from this central location. This is an extremely valuable tool for the maintenance staff at DC-WASA. Refer to Figure 5 that displays all of the hardware located in the central control room (excluding the VersaView touch screen computer).

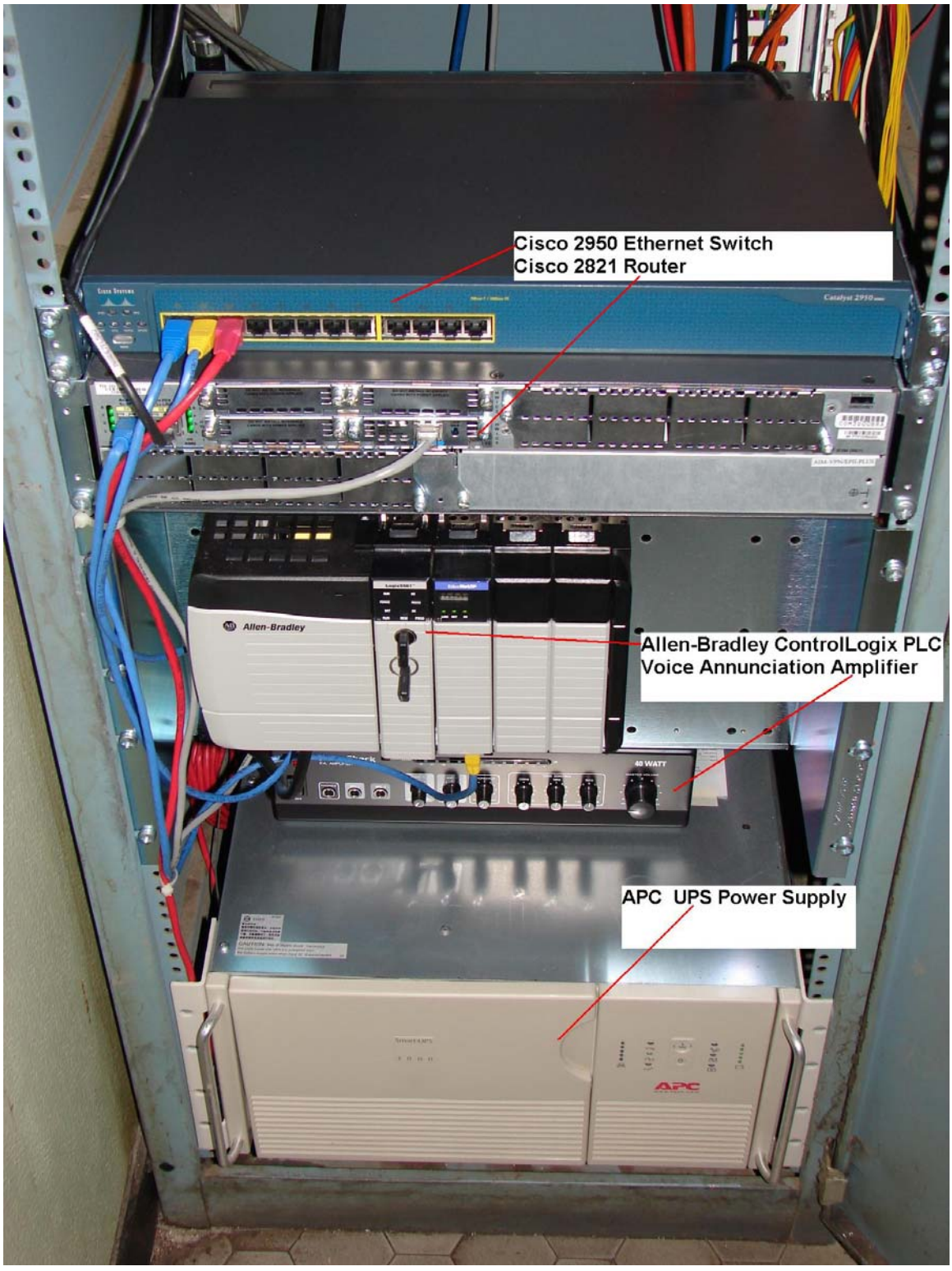


Figure 5: Control Room Hardware Components

The control room data concentrator PLC serves data to the Rockwell RS Factory Talk View central SCADA system. The system is monitored and alarms acknowledged from a touch screen located in the main control room. The SCADA system provides real-time process information to the operators in the control. The maximum time delay from process value change to display on the SCADA screen is less than 2 seconds. Refer to Figure 6 for a typical remote station display.

- Real-time process information
- Graphical alarm display
- Alarm logging
- Alarm summary
- Alarm Suppression
- Historical Collection
- Historical Display (charts)

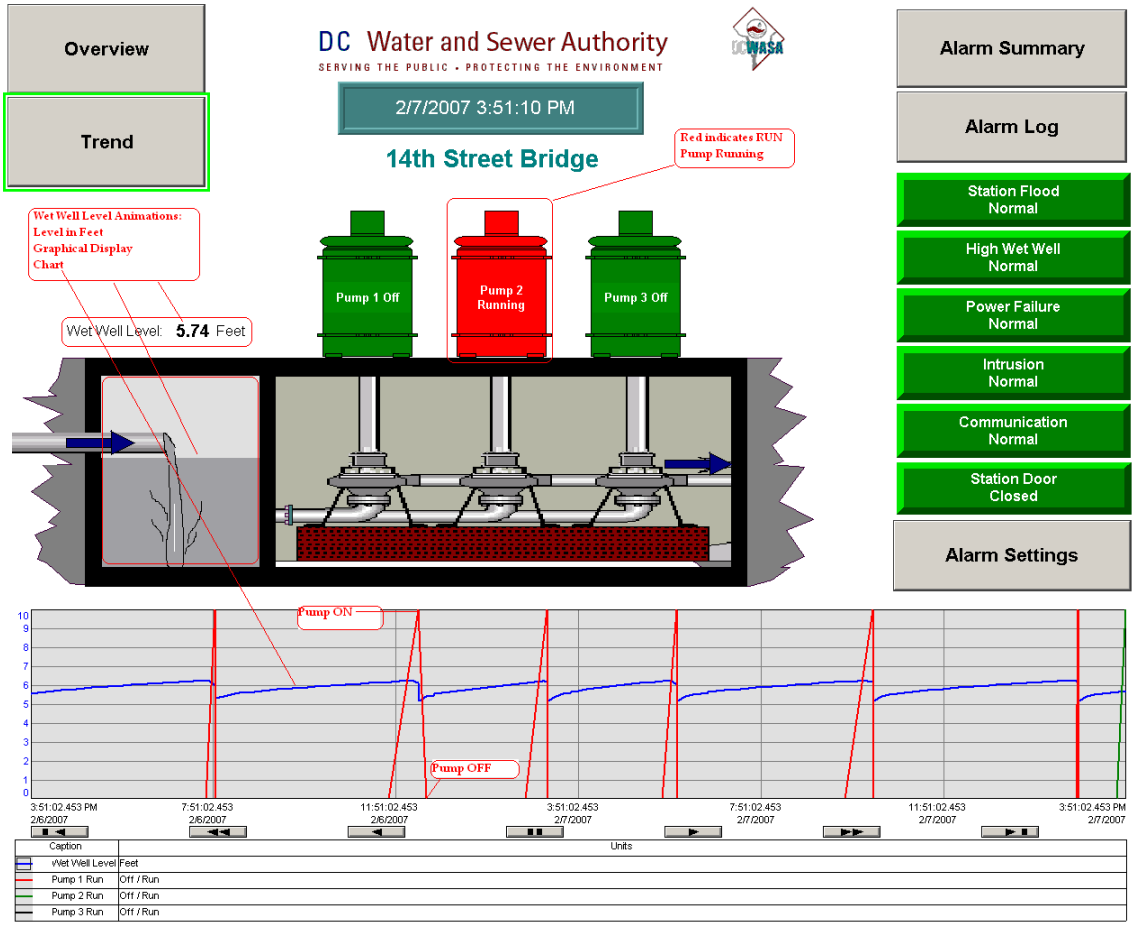


Figure 6: Typical SCADA display of remote station

Since the operators are not always in the control room, a voice annunciation system was also installed. In the event of an alarm, a pre-recorded voice (WAVE file) is sent to speakers in the control room and outdoor bullhorn type speakers outside the control room. The voice alarms repeat every 2 minutes until acknowledged by the operator. The alarm settings feature allows voice annunciation to be suppressed for individual alarms. This is useful for devices that are out of service or undergoing maintenance. Sound tests can also be performed from the alarm settings display. Refer to Figure 7 to see a typical alarm settings display.

Figure 7: Alarm settings

CONCLUSION

DC-WASA is currently operating a wireless cellular SCADA system that includes continuous monitoring for Volatile Organic Compounds. The rapid response time of all alarms will allow DC-WASA operators and staff to effectively respond to impending emergencies and provides additional life safety measures for protection of the general public.