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Technical Memorandum

To: Jon Haukaas, City of Blaine
From: Sheldon Sorensen, Zach Nesler, Barr Engineering Co.
Subject: City of Blaine SCADA Assistance – Project Recommendations
Date: February 14, 2018
Project: 23021056.00
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1.0 Background

This memorandum provides recommendations to the City of Blaine for continuing improvements to the City's supervisory control and data acquisition (SCADA) system.

Barr's April 13, 2017 memorandum provided a series of recommendations to the City, summarized in two groups as follows:

- ✓ **Group 1 - Short-term improvements:**
  - ✓ Expanded after-hours monitoring of the system by operations staff until interim improvements are made to increase the reliability and redundancy of the system.
  - ✓ Install water tower backup alarm systems at each tower as an independent alarm to operations that water tower levels are low in the event of an emergency.
  - ✓ Instead of having a single master control panel, distribute the automation to each of the three WTPs so that each plant can back up the system and run independently of a master control system in the event of an emergency.

The short-term improvements were implemented by the City in 2017.

- **Group 2 - Long-term improvements:**
  - The City should utilize a single reliable primary communication network to all areas of the City.
  - The City should conduct field investigations of critical panels or equipment that are missing documentation, and maintain up to date record drawings as equipment is upgraded.
  - Panels should be replaced or upgraded once they are obsolete or have reached their useful life. As panels are upgraded and/or replaced, a standard design methodology should be employed.

- The existing software should be cleaned up, alarm functions should be verified and tested, and new equipment installations or control revisions should be revised per City SCADA standards by a software integrator.

The remainder of this memorandum provides Barr's observations and recommendations regarding the long-term recommendations.

2.0 Communication Network

The existing Blaine SCADA system primarily communicates over three different networks:

- 450 MHz licensed radio network, owned by the City.
- Motorola "Canopy" Ethernet radio network.
- Fiber optic lines extended to two of the Water Treatment Plants, owned by Anoka County and leased by the City.

Each of the three networks have limitations that preclude the use of any one network to reliably serve all of Blaine's SCADA sites. The City needs to utilize a reliable primary communication network to all areas of the City.

In addition to the above networks, the City of Blaine owns fiber optic segments between some of the SCADA sites. These fiber optic segments have provided reliable communication.

2.1 Existing Conditions

2.1.1 450 MHz Licensed Radio Network

This system uses a licensed radio frequency to transmit and receive data between each site in the network. The 450 MHz system is reliable, but is based on "Modbus RTU" protocol at a very low communication speed of 300 baud. This is a holdover from the original 1990s SCADA network, which is an out of date technology. The low baud rate makes it impractical to use this network for remote monitoring or control due to long delays in data updates.

The 450 MHz system has a single master antenna located at Tower 1 in the southwest portion of Blaine. The signal is not strong enough at some sites in northern and eastern portions of the City to receive and transmit data.

A review of the City's existing FCC license indicates that the system is not currently operated in strict compliance with the FCC license. The existing license limits antennas to 20-foot height (some sites exceed this height), and remote radios are limited to 2 watts output power (some radios are currently operating at 5 watts).

2.1.2 Motorola "Canopy" Ethernet Radio Network

The Motorola canopy network uses Ethernet protocol to communicate data across the network. The City has experienced reliability problems with the Canopy network. The reliability is not sufficient for operating and monitoring the City's water and wastewater infrastructure as a primary communication channel.

The Canopy network serves other City functions, including networks for monitoring of video cameras at some remote sites and water meter data. For water system reliability and security, it is recommended that the water and wastewater SCADA networks operate separately from all other City networks.

2.1.3 Fiber Optic Network

Fiber optic communication can provide excellent speed and reliability. However, installation of the system is expensive. Two of the Water Treatment Plants are currently served, and the installation of a new complete fiber network by the City without other partners or projects already in progress would be cost and schedule prohibitive. The fiber optic network is also less-desirable when operated by another party, since the City does not have direct control over system operation, repairs, etc.

The City owns shorter fiber optic segments that are used for communication between the following sites:

- Water Treatment Plant 1 to Water Tower 1
- Water Treatment Plant 2 to Well 17
- Water Treatment Plant 3 to Well 11
- Water Tower 4 to Well 18
- Water Tower 4 to Well 19

The fiber optic segments listed above have provided reliable communication, and should remain in service

2.2 Recommendations

At Barr's recommendation, the City contracted with Larson Data Communications of Sioux Falls, South Dakota for a complete analysis of the City's SCADA radio needs. The analysis included development of proposed new radio infrastructure, field signal strength measurements at each site, and recommendations for system hardware and antenna installations.

Larson Data provided a lengthy report, included as Appendix 8.3 to this memorandum.

The Larson Data recommendations were reviewed with the City, Barr Engineering, and In Control, Inc. (the City's current software integrator). The recommended system will provide Ethernet connectivity to each site, providing for SCADA communication, as well as the possible future addition of other Ethernet-based applications. The system will include three 450MHz radio sub-networks, centered around Water Towers 1, 3 and 4, as shown in Figure 1.

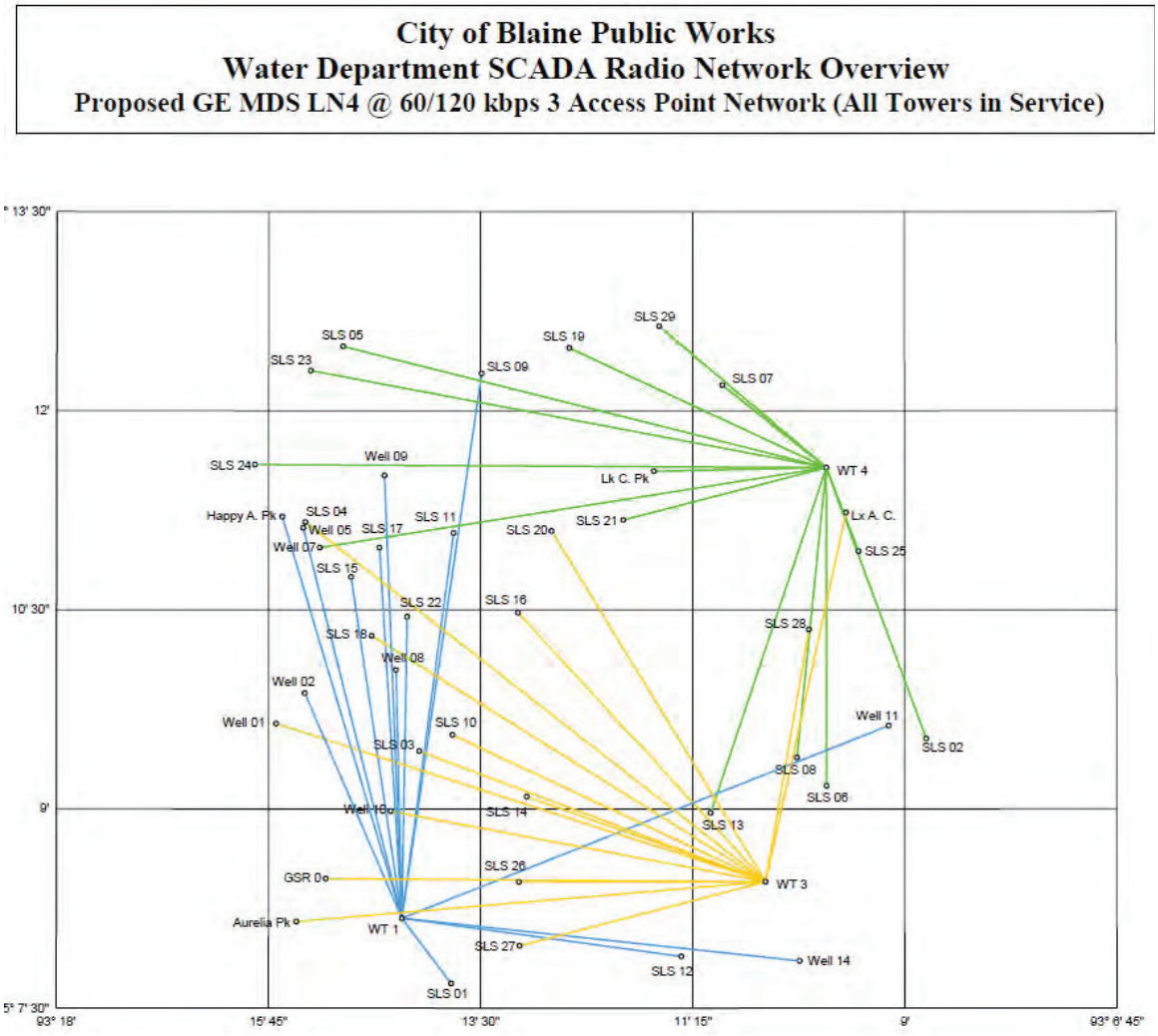

Figure 1- Proposed Radio Sub-Networks

The three 450MHz radio sub-networks will communicate with one another, and with Water Treatment Plants 2 and 3 using a high-speed microwave radio backbone as shown in Figure 2. Water Treatment Plant 1 currently has fiber optic communication to Water Tower 1, which will remain in service. Similarly, the planned future Water Treatment Plant 4 will have fiber optic communication to Water Tower 4.

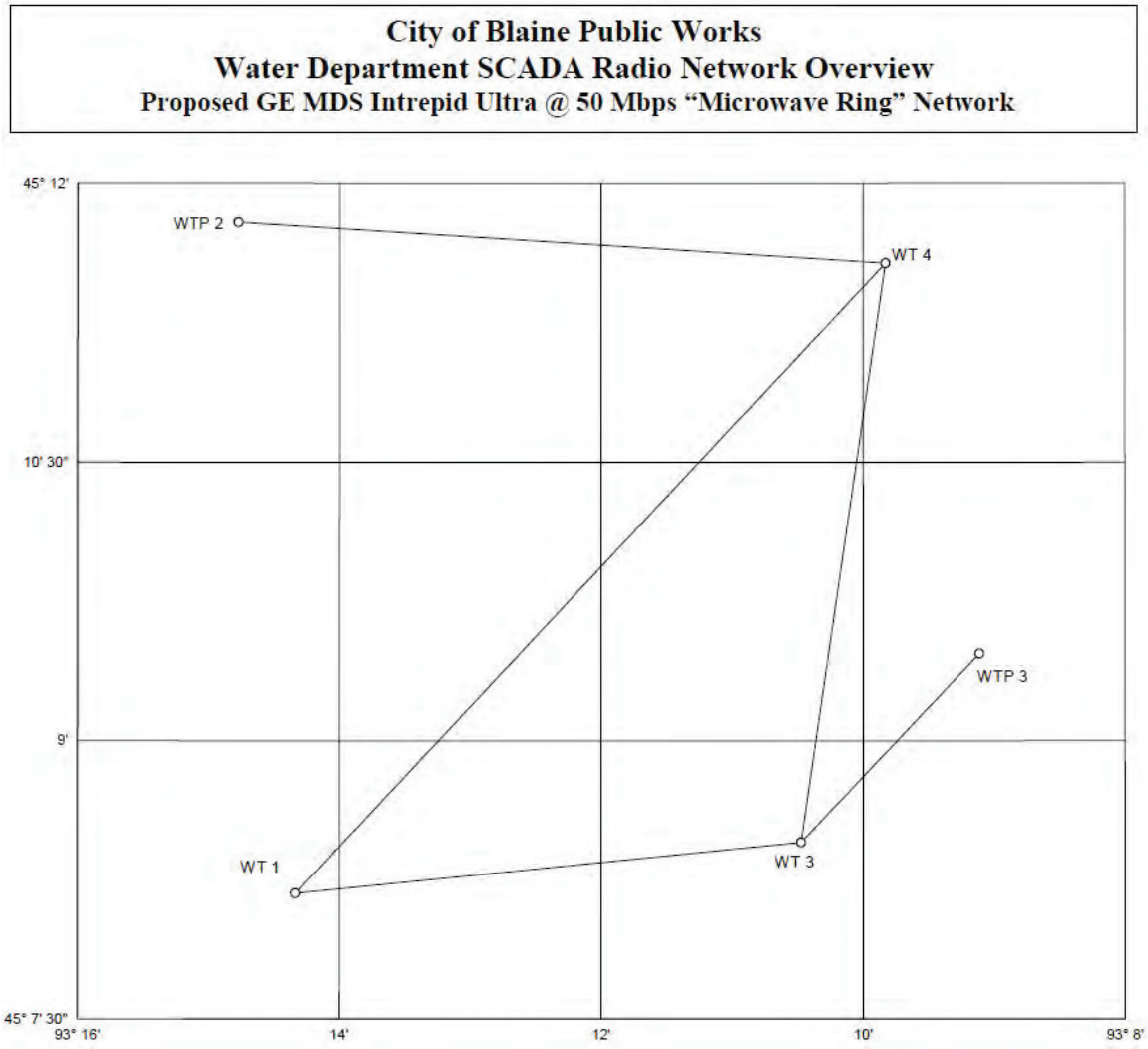

Figure 2 - Proposed Microwave Backbone

The Larson Data report includes recommendations for antenna types, heights and aiming. The Larson Data recommendations should be included as part of an overall SCADA improvements project.

It should be noted that the conversion to an Ethernet communication platform will require updates at many sites where the existing control equipment does not currently have Ethernet capability. Therefore, the recommended radio system upgrades need to occur as part of a coordinated project that also includes replacement and/or upgrades to other field equipment and panels, as described later in this memorandum.

3.0 Site Audits to Determine Hardware Upgrades at Each Site

3.1 Existing Conditions

Barr conducted a field review of each of 48 existing SCADA sites. The review was intended to inspect the general condition of equipment and panels, document the control hardware that is currently in place, and assess the feasibility and cost-effectiveness of modifying or replacing equipment at each site.

Water system panels (water treatment plants, wells, water towers) and wastewater lift station control panels vary in age and condition and design standard. The control panel equipment is generally of good quality. However, the issue is with the age and the technology of the installed equipment. The older panels get, the more their technology is out of date and they are hard to service. The oldest panels date back to 1994. New panels have been included on many infrastructure projects over the 23 years that followed, and the City is continuing to expand the system as the City's infrastructure grows.

The panels include a variety of programmable logic controllers (PLCs). The PLCs provide the system automation, and serve as the device for SCADA communication. Several sites have older PLCs that do not support newer communication protocols (Ethernet), and are obsolete.

Many of the panels include an uninterruptible power supply (UPS) system having battery backup for short-term communication during power loss. The UPS units provide the advantage of operation during power loss, but they can also fail, leaving a station inoperative. Current design practice is to monitor the UPS units for alarm conditions, and to automatically bypass the UPS in the event of UPS failure. These features do not exist within some of the panels in Blaine, and should be included.

For lift station control panels, it is common practice to include a separate redundant system to control the pumps using float switches, in the event of failure of the primary level control system. The Blaine lift station control panels have a variety of schemes for level control and backup level control. A standardized system should be used at each site for uniform operation and ease of troubleshooting.

3.2 Recommendations

Barr has prepared a summary sheet with specific recommendations for each of the sites. The summary sheets are included in Appendix 8.1. The following paragraphs provide an overview of Barr's general recommendations:

3.2.1 Sanitary Lift Stations

Many of the older panels (circa 2006 and earlier) will require replacement of the PLC, radio and operator interface unit with new Ethernet devices. The existing enclosures are in aging condition, or are not large enough to receive the new equipment. Additionally, the cost to replace these components in the field will rival the cost and complexity of complete panel replacement. Therefore, Barr is recommending complete replacement of 14 of the 29 existing panels. The City has proceeded with a separate lift station

improvement project that includes three of these 14 panels. Barr is recommending field modifications to the other 15 panels that will remain in place.

Allen-Bradley "MicroLogix 1400" PLCs are recommended at all sanitary lift stations for standardized programming, service and parts. Eleven (11) of the newer lift station panels already have this model, which preserves the City's investment in newer stations.

3.2.2 Water Towers

A new SCADA panel was recently installed at Water Tower 1. This panel should remain in service.

Water Tower 2 does not have a dedicated SCADA panel. The tower level is sensed at nearby Wellhouse 9.

At Water Towers 3 and 4, the existing panels will require PLC, radio and operator interface unit replacement for Ethernet compatibility. The existing enclosures are not large enough to house the new equipment, so new panels are recommended for these two sites.

Allen-Bradley "CompactLogix" PLCs are recommended as a standard platform for all water sites.

3.2.3 Seasonal Wellhouses

The panels at seasonal wellhouses are generally older, and many of the sites have controls mounted in an aging motor control center compartment. The City is planning on reconstruction of these wellhouses, which will result in significant controls modifications at these sites. As a result, new SCADA panels are recommended for all of the seasonal wellhouses.

Allen-Bradley "CompactLogix" PLCs are recommended at the wellhouses, to achieve the standard platform recommended for all water sites.

3.2.4 Water Treatment Plants

Water Treatment Plants WTP1, WTP2 and WTP3 have similar PLC-based control systems. Each of the plants includes two separate PLC-based control panels; one panel for the Filtronics filter process, and one panel for the "rest-of-plant" processes. The panels include Allen-Bradley "SLC" PLCs that are still available and supportable, but no longer receiving design upgrades from the manufacturer. For long-term reliability and supportability, Barr recommends the following:

- Replace the existing SLC PLCs with new "CompactLogix" product for longer service and support life.
- Simplify the installation to include one PLC processor at each Water Treatment Plant. The single processor will contain a combined program that monitors and controls all of the plant processes.

4.0 Software Programming

In Control, Inc. provided comments on the existing PLC programs. The general observations were included in Barr's April 13, 2017 memorandum, including:

- All programs should be reviewed, corrected, and tested to confirm that communication failure is alarmed for each site.
- PLC programming code should be reviewed and cleaned up to eliminate unused code, and correct points that are wired to the PLC but not used in the PLC program.
- Review existing code at all sites and modify for software standardization to the maximum practical extent.
- Review and confirm alarm points and alarm handling system

The software component of a major SCADA upgrade is equally or more important and complex than the hardware component. Software documentation, standardization and training are key components to the project success. As the City of Blaine considers a major system improvement, the project provides a rare opportunity to streamline, optimize and document the SCADA software. Barr recommends selecting a "software integrator" that will take on the software design and implementation role. The software integrator should be a key team participant in the project design and implementation. Because of the importance of the software design role, we recommend selection of the software integrator based on professional qualifications, project experience and staff capabilities.

5.0 Project Implementation

This memorandum provides Barr's findings and recommendations for moving forward with needed improvements to the City's SCADA system. To continue forward, the following steps are recommended:

5.1 Project Design – Hardware and Contractor Installation Work

Prepare final design of the SCADA hardware improvements. The design should be led by an electrical engineer and include panel work, components, wiring, installation, and field wiring for each of the SCADA sites. The hardware contract would also include construction of the new radio systems as recommended in the Larson Data report. The SCADA hardware improvements project can be implemented using a traditional design/bid/build contracting method.

The design effort will require coordination with City staff, as the City is currently implementing or considering other infrastructure projects that could affect the SCADA project scope.

5.2 Software Integration Services

As recommended above, the City should engage a qualified software integration firm to provide software programming services. The software work will include programming of PLCs, operator interface units and computers for the entire SCADA project. The software integration firm will need to work in close cooperation with the hardware contractor, City and Barr Engineering in order to meet project timelines and cutover dates. Barr has used this method successfully on other large SCADA projects.

A selection process should be undertaken to evaluate and select the software integration firm.

6.0 Project Schedule

In Barr's April 13, 2017 memorandum, an 18-month period was planned for design and construction of the long-range SCADA improvements. Since April, 2017, other infrastructure projects have been introduced (wellhouse reconstruction, lift station replacements, Water Treatment Plant No. 4, etc.) which may potentially impact the timing and progress of SCADA improvements. Because of the linear nature of a control system upgrade, and the need to limit outages to only one or two sites at a time, it appears that an overall design/construction schedule of 24 months or more may be prudent. The final project schedule should be developed in conjunction with City staff during the final design process.

7.0 Project Costs

Appendix 8.2 provides a detailed breakdown of Barr's preliminary project cost estimate. Project scope and details will be refined during the final design process. At this pre-design point, the estimate should be considered +/-20%.

8.0 Appendices

8.1 Barr Site Audit Summary Sheets (51 Pages)

8.2 Project Cost Estimate

8.3 Larson Data Communications Report (649 Pages)