CHAPTER 13 – SCADA & CONTROL ASSESSMENT

13.1 Introduction

The primary purpose of the Supervisory Control & Data Acquisition (SCADA) system is to provide unattended status and alarm monitoring of the GWA water and wastewater facilities. The system also offers a valuable management tool in providing historical operational and trending data and, when integrated into a preventive maintenance program, aids in improving resource allocation. This assessment focuses on the existing and recommended SCADA technology and controls to assist GWA in accomplishing its goal "…to plan, design, build, operate, maintain and manage GWA's systems and facilities in a manner that provides long-term value while meeting Guam's vision for growth and development in a sustainable manner and complies with all Federal and local environmental and safety regulations."

The existing SCADA system was installed in the mid-1990s but became nonfunctional after a few years, primarily as a result of storm damage and personnel vandalism of the central base unit. This system was designed to operate on the Government of Guam's Trunked Radio System (800 MHz). This same system is also used by the Guam Police, Fire and Emergency Services. It is imperative that this vital communication system operate during an emergency condition.

Based on observations of approximately 75% of the water stations and 55% of the wastewater stations and despite the non-use of the existing system, a portion of it is either operational or, in the case of the newer stations, unwired or wired but non-operational. It is estimated that approximately 25% of the existing system could quickly become operational with minimal effort. Completion of SCADA applications at critical stations should be the short-term priority.

Implementation of the SCADA plan would proceed in several phases, as discussed below:

Phase 1: The existing Motorola SCADA system would be revived by the addition of a base station at the GWA Dispatch Center. The existing units would be assessed by Motorola and the salvageable parts would be reused to create operational units for the critical stations. The field wiring and instrumentation for the existing system would be checked made operational.

Phase 2: The system would be expanded to include the installation of new Remote Terminal Units (RTUs) at GWA selected Priority One and Two sites. These sites generally will require new wiring as the RTUs are relocated to the building interior. Additional monitoring points would be installed at each of the RTUs.

Phase 3: The system would be expanded through the GWA local area network (LAN) to allow key personnel to access information and data for report generation and analysis.

Phase 4: A maintenance management system would be incorporated to integrate operational data and accounting information for life cycle and asset valuation determination.

This recommended plan to implement the recommended courses of action in a timely fashion will yield a substantial return in terms of GWA resource utilization.

13.2 Existing SCADA & Control System Description

Motorola installed the initial SCADA system in the early to mid-1990s at all water and wastewater treatment plants and pump stations, reservoirs and related facilities. More recent projects in the past five years have incorporated later Motorola designs; however, these installations were never made operational.

The original system was the Motorola Intrac RTU series consisting of a power supply, Basic Module, Status Input Module (SI-8), Analog Input Module (AI-8), Control Output Module (CO-8) and a Maxtrac radio unit. Several units were also equipped with Line Isolation Modules to isolate the higher input voltages from the RTU. These units were equipped with a set of rechargeable batteries for continued operation during a power outage. Although the Intrac series is no longer manufactured by Motorola, parts are available through aftermarket suppliers.

The latest installed RTU systems are of the Motorola MOSCAD-L series design. These units have removable circuit boards and include a central processor, status input modules, analog input module, output module, a handheld transceiver radio and battery backup.

The output power of the older Maxtrac model radio is estimated to be 30 watts while the new models are estimated at 2.5 watts. As a comparison, the power output of cellular phone transmitters is less than 0.5 watt.

The radio frequencies used are within the Government of Guam's trunked system (800 MHz band) through four repeater sites that provide coverage throughout the island. This is the same system that is used by the Guam Police, Fire and Emergency Services. The Guam Police Department manages the user database and assigns the talk group and identification of each unit on the system.

The four repeater sites are secured and backed by uninterruptible power supplies (UPS), a standby generator and radio redundancies. Several sites are shared with the Guam Telephone Authority (GTA). The repeaters are linked by GTA's fiber communications link. Future plans include backing up this link with microwave communications owned by the Government of Guam, as well as adding repeater sites to provide better coverage.

The SCADA system relies on input information from process instrumentation in the field, including such basic items as power failure, high water pressure, pump and generator operation, flow pulsing, wet well level and alarms. The SCADA output at the water pump stations is designed to provide pump starting and stopping capability in response to high-level condition at a tank or reservoir. Locations without commercial power were originally equipped with photovoltaic panels to charge the batteries.

13.3 Methodology

The methodology used to conduct this assessment consisted of site surveys and observations of the existing SCADA and control equipment, review of digital photographs, field voltage checks and communications testing (where possible). The survey covered the one-year period from June 2004 to May 2005.

The results were tabulated using the rating scale presented in Table 13-1.

Table 13-1 – Assessment Rating Scale

System Rating	Description of Equipment State
0	Required equipment is missing or not present. Equipment is not operating or repairable. New equipment is required.
1	Equipment is present but in poor condition. Equipment is not operating but may be repairable. If repaired, it probably has a short remaining life.
2	Equipment is present and in fair condition. Equipment may be operational but require other elements of the system to be functional. Equipment requires maintenance and repairs.
3	Equipment is present and in moderate condition. Equipment is operational. Routine maintenance being performed.
4	Equipment is present and in like new condition. Equipment is operational and newly installed.

Each station was divided into separate subsystems, to which a weighted value was assigned. The total was then added to arrive at a station assessment value. The maximum value for any station would be 4. Only whole integers were used to compile the assessment, whereas the weighted average value was computed to the nearest decimal ten. The final value for each station was rounded to the nearest tenth.

The detailed assessment sheets and tabulation were prepared as a template using Microsoft Excel spreadsheet software and are located in Appendix 1L of this report. A summary and an explanation of the ratings for each of the stations are presented in the following subsections. These ratings can be used as a comparative reference in future assessments.

13.3.1 Assessment Weighting Factors

Weighting factors for each area of the station or system were assigned based on their importance from a control standpoint. Factors that affect the operation of the station were given higher consideration while those that provide a supporting role, although important to the end product, were given lesser consideration.

The presence and condition of the elements needed to form a complete control system were also a factor in the evaluation process. Equipment that was intact (i.e., sealed from the environmental elements) and likely to be easily repaired was rated higher.

The percentage weight assigned to a subsystem is shown in parenthesis. This is the value assigned to that portion in comparison to the whole.

13.3.2 Water Systems Assessment Explanation

At the well and booster water pump stations, the pump controls, chlorination system controls, pump bypass controls and SCADA RTU were assessed. A value of zero through four was assigned and weighted as follows:

13.3.2.1 **Pump Controls** – 50% of Station Value

- Automatic Pump Controls (30%) – This value is based on the ability of the control system to operate automatically through an external system such as the SCADA system. The rating is higher if all elements of the system are intact and operational.

- Manual Pump Controls (15%) – This value is based on the ability of the control system to operate in a manual mode through a local control switch. This rating is higher if the local control or mechanical bypass means are available and can be safely operated by non-electrical personnel.
- Motor Protection Controls (five percent) – This value is based on the application of motor protective devices at the station, such as Class 10 overload protection, phase monitor, motor protective devices, surge protection and motor thermal switches. The rating is higher when a higher degree of protection is provided, without any protective device being bypassed or removed.

13.3.2.2 Chlorination System Controls – 25% of Station Value

- Automatic Pump Controls (10%) – This value is based on the ability of the control system to operate automatically. The controlling items are the field instrumentation of flow switches and being interlocked with the main pump starter.
- Manual Pump Controls (10%) – This value is based on the value of the control system to operate safely through a local control device. The rating is higher if this local device is protected and interlocked with the main pump controller.
- Chlorination Control Valves (five percent) – This value is based on the ability of the chlorination system to shut off any chlorine flow when the system is shut down. A valve or other device to prevent such flow will improve the rating.

13.3.2.3 Pump Bypass Controls – 10% of Station Value

- Valve Controls (five percent) – This value is based on the bypass system having the essential elements for operation from the electrical controls to the solenoid valve, limit switch and control piping. Having all the elements improves the rating.
- Automatic Valve Actuator (five percent) – This value is based on the presence and condition of the valve actuator. Lack of corrosion and the degree of maintenance improve this rating.

13.3.2.4 SCADA RTU – 15% of Station Value

- SCADA RTU (five percent) – This value is based on the presence and condition of the Motorola RTU unit. The essential elements of the power supply, control module, input and output modules and wiring affect the rating.
- SCADA Antenna and Cabling (2.5 percent) – This value is based on the presence and condition of the RTU antenna and communication cabling.

- Enclosure (2.5 percent) - This value is based on the condition and location of the RTU enclosure. Installations within the generator building or under the eave score higher. Those located on the building exterior or exposed to the elements are rated lower because of the heavy corrosion on the protective enclosure.
- Flow meter and Sensor (2.5 percent) – This value is based on the condition of the flow transmitter and receiver. The value is higher when the unit is operational and lower when one element is missing. Stations where the newer flow meters with signal output capability were installed, but are not yet operational, were rated lower.
- Pressure Transducer and Alarm (2.5 percent) – This value is based on the presence and condition of the pressure transducer and pressure switch and their integration into the SCADA system. A higher rating was given to those stations where the transducer is located downstream of the wellhead rather than at the wellhead. The presence of a pressure transducer with intact wiring also improved the rating.

13.3.3 Wastewater Pump Station Assessment Overview

The evaluation format used at the wastewater pump stations was similar to that used for the water pump stations. The pump controls, sump pump and SCADA RTU elements were considered and assessed as follows:

13.3.3.1 **Pump Controls** – 70% of Station Value

- Automatic Pump Controls (40%) – This value is based on the station's use of an operational level control system for pump control. The condition of the wiring, motor starter, control relays and control cabinet affect the rating. A higher value was given to those stations where all elements of a newly installed pump control cabinet were operational. A lower value was assigned to stations with cabinets that contained modified wiring or control equipment.
- Manual Pump Controls (20%) – This value is based on the ability of the control system to operate safely through a manual selector at a local control device. This function requires operator intervention to maintain the wet well level.
- Motor Protection Controls (10%) – This value is based on the application of motor protective devices at the station, such as thermal overload protection, phase monitor, surge protection and motor winding thermal switches. The rating is higher when a higher degree of protection is implemented, without any protective device being bypassed or removed.

13.3.3.2 **Sump Pump** – 10% of Station Value

- Control Cabinet (five percent) – The operational condition and location of the control cabinet affect this rating. Locating the control cabinet in the drywell decreases this rating.

- Level Control (five percent) – The presence of a float or other level control device is essential for automatic operation. Stations where a sump pump was manually operated were rated lower.

13.3.3.3 SCADA RTU – 20% of Station Value

- SCADA RTU (10%) – This rating is based on the presence and condition of the essential elements of the Motorola SCADA RTU. Items such as the power supply, control and input/output modules and wiring affect this rating.
- SCADA Antenna and Cabling (five percent) – This value is based on the presence and condition of the SCADA antenna and cabling.
- Enclosure (five percent) – This value is based on the condition and location of the RTU equipment enclosure. Units installed within a building or under the building eave were scored higher than those located on the windward side of the building or completely exposed to the environment.

13.3.4 Wastewater Treatment Plants Assessment Explanation

Refer to Appendix 1L – Tables 1 through 9 for the wastewater treatment plants detailed ratings. Table 5 is a summary of the detailed assessments of the wastewater treatment plants.

13.4 SCADA & Control System Site Observations

Site visits were made to approximately 75% of the water wells and booster pump stations and to 55% of the wastewater pump stations. The observations noted during these visits are discussed below.

13.4.1 SCADA Observations

13.4.1.1 SCADA General Observations

During the field observations of the existing Motorola SCADA system, the following items were observed:

- Several stations appeared to be operational in the sense that radio transmissions were heard through the radio speaker. When the RTU cabinet door was opened (intrusion alarm), the radio transmitted a signal with the status input card indicating actuation of the toggle switch.
- At a few stations, the radio unit was operational but the RTU status input card had no indication that it was operational, even in the test mode.
- At a few stations, the RTU status input card displayed an indication, but the radio was not operational.
- At several stations, there was no electrical power at the RTU cabinet.
- Those RTU cabinets that were installed in the exterior environment and adjacent to the water well or equipment sites showed visible signs of corrosion. Several cabinets that were located near the ocean were badly corroded. For those units with RTU cabinets that were not heavily

corroded and were sealed, the equipment on the interior appeared to be in fairly good condition.

- The RTU cabinets installed on the building exterior but under the roof eave appeared to be in fairly good condition.
- At several stations, the wiring appeared to be incomplete. In some cases, wiring was installed in the cabinets but not terminated. A few conductors were identified; however, many were not. The masking tape that was used to identify wiring and equipment had deteriorated.
- At the newer stations, the field and power wiring was installed but was not terminated.
- No evidence of the central base station units was located. These would have consisted of at least two personal computers (PCs), field interface units and software. These devices are likely to be obsolete now (likely a 386- or 486-type computer).
- The directional Yagi-Uda antennas were basically intact at most stations, although a few were redirected or damaged as a result of typhoons.
- Based on information gathered, the initial SCADA system was installed during a time when only the wellheads or the chlorination sheds existed. The generator buildings were constructed at a later date.
- Most of the stations had 120 volt AC power present at the RTU cabinet. In many cases, the RTU Power Supply Module provided 120 volts at the input terminals, but no 24-volt DC output voltage was observed at the radio or RTU modules.
- The antennas and cabling were intact at most stations.
- The RTU cabinets that were installed in a building or under a covered eave exhibited less corrosion than those directly exposed to the weather.

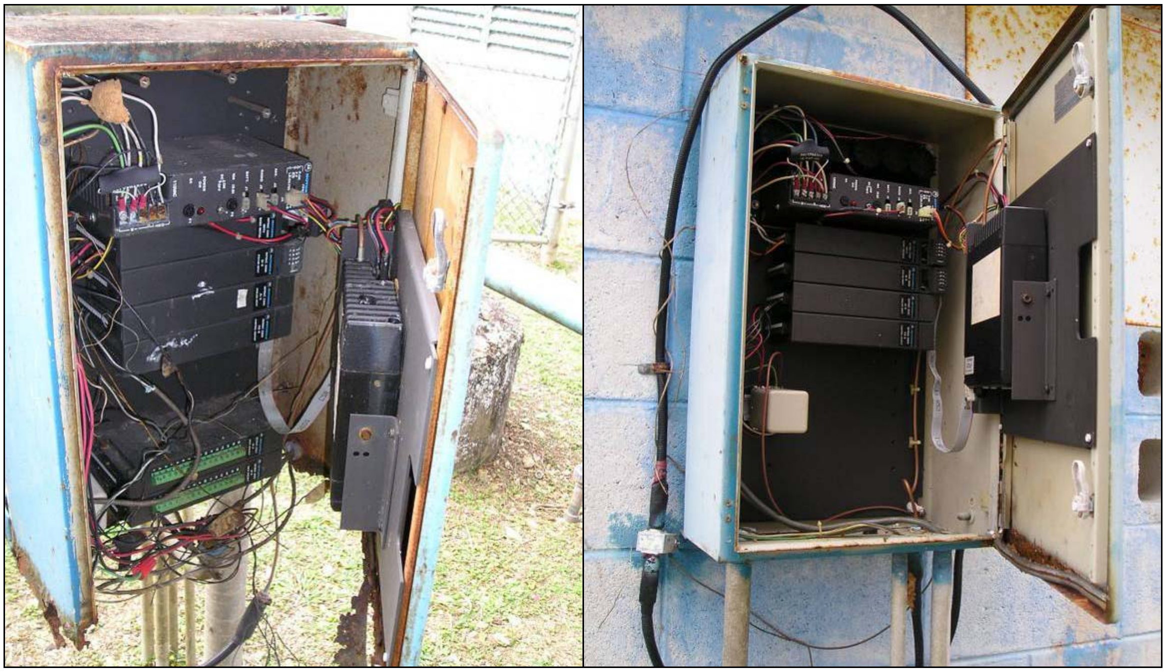
13.4.1.2 Water Pump Stations

The following is a summary of existing SCADA system observations relating to the Motorola system in place at the water pump stations. These were primarily located in the Northern and Central Districts.

- A minimum of nine stations (F-1, F-13, F-15, F-16, F-17, F-18, D-22, M-20A and F-21) had operational radio units. These units were able to transmit or receive status information. The analog input signals (flow and pressure) were wired to the analog input module. Discrete status input points (e.g., pump run, generator run, power fail and chlorine detection) were not wired at most stations although wiring was present at the RTU.
- At four stations (Y-16, Y-17, Y-21A and Y-23), the newer Motorola MOSCAD-L units were installed; however, they were not powered or wired. These units can be programmed to work with the newer SCADA technology.

- A majority of the water well sites were originally installed without a means of sheltering the RTU from the elements. This resulted in the RTUs being installed adjacent to the well or water line or being mounted on the chlorine storage building. In both cases, the equipment was exposed to the environmental elements. (See Figure 13-1.)

Figure 13-1 – Corroded SCADA Cabinet at A-21 (left) / SCADA unit in Good Condition at F-10 (right)



- At several locations, the generator building was constructed at a later date and the RTU units were never relocated. As a result, the enclosure cabinets exhibit varying signs of corrosion and, as a general rule, are not suitable for relocation or re-use for the long term.
- Most of these stations either did not have 120 volt AC power or were not operational.
- At most of the sites, the well pressure transducer was still present; however; the pressure switch had deteriorated. It is estimated at that at least 50% of these transducers could be placed back into operation.
- The field wiring and raceways were still intact at many well location sites.
- The chlorination and pump system leak detection was not monitored by the SCADA system at any of the observed locations.

13.4.1.3 Water Booster Stations

The water booster pump stations generally serve to transfer water from one reservoir or area to a higher reservoir or tank. The following observations relate to the water booster pumps:

- The booster pump stations were located in areas where the gravity tanks could not provide the needed line pressure.

- Several booster stations were used to pressurize a line serving a housing area. In those cases, the pump operated continuously without a pressure switch to shut it down.
- The pump motors were either horizontal or vertical, air cooled-type construction pumps.
- At most stations, generator backup power was provided.

13.4.2 Control System Observations

13.4.2.1 Water Pump Stations

Most of the deep well water pump stations are currently operating in manual control mode and do not utilize inputs from the instrumentation.

Pump Bypass Valve

The original piping and pump control system incorporates a process for the automatic divergence of the initial pump output to a bypass line. There was evidence that this automatic start procedure was operational or could be made operational at the newer well stations. Without such an automatic process in place, injection of mud and debris or chlorine slugs will be injected into the potable water system. Figure 13-2 shows the operational bypass valve installed at Station Y-12A.

Figure 13-2 – Operational Bypass Valve at Station Y-21A

The control system is designed so that the bypass control valve will be in the normally open position when the pump is not operational. When the pump becomes operational, the valve actuator solenoid is energized by the pump control system, thereby allowing pump flow to be directed to the closing diaphragm of the valve. The initial pump output is diverted to the bypass line. The duration of this bypass flow is set by the timing valve. When the bypass valve is closed, the pump output is forced into the line through the check valve.

The opposite is true when the pump is turned off. In that case, the flow is diverted to the bypass line, allowing the check valve to gently close to reduce the effect of water hammer on the system. When the bypass valve is partially opened to actuate the limit switch on the valve, the motor is turned off.

At Station Y-21A, the vent line for the bypass valve solenoid was found to be plugged. The line was cleared and the timing valves adjusted so that the bypass line operated to divert the initial flow. The closing sequence did not operate as planned because the limit switch adjustment was not correctly calibrated. During the period that the pump is not operational, the bypass valve is in the open position. This leaves a direct line to the well from the exterior for vermin to enter. It is highly recommended that this line be screened.

Most of the bypass valves at the older pump stations, however, did not have the diaphragm valve or the control solenoids or limit switches in place, as indicated in Figure 13-3.

Figure 13-3 – Non-Functioning Bypass Valve and SCADA Cabinet at Station A-03

Pump Controls

The well pump control system is designed for external control through the SCADA system while in the automatic mode of operation. This setup provides input from the associated tank level controller programmed to the SCADA computer or through remote operator intervention. Since the SCADA system is not operational, the wells have been functioning in manual mode.

Chlorination Controls

The chlorination of the well water relies on manual monitoring and setting of the chlorine injection control valve. A chlorination pump is used to inject a chlorine mixture (gas and water liquid mixture) into the well discharge line that is based on the well flow rate.

In automatic mode, the chlorine pump controls were found to be interlocked to be dependent on the well pump operation controls; however, the operation of the well pump is independent of the chlorination pump. At one of the stations, the chlorination pump operated when in HAND control mode, without the well in operation. This feature needs to be reconfigured with a spring return operator to allow for temporary operation to check for motor rotation and testing; otherwise, chlorination liquid could be injected into the line or the pump will attempt to pump "dry".

Pump Instrumentation

Lack of monitoring water pressure also reduces system effectiveness and efficiency. Since there are no control communications in place between the reservoirs and their respective pump stations, it is impossible for the pump stations to cycle at the proper times to maintain a desired reservoir level.

The following is a list of instrumentation and related devices that should be operational at all deep well water pump station to in order to operate the system properly, safely and efficiently.

- Wellhead pressure monitoring: Used to protect the pump from excessive pressures resulting from valve failure or blockage and also to confirm that the pump is operating within design pressure range.
- Water flow meter: Used to meter total water produced which becomes a part of the calculation to determine system water losses.
- Bypass valve solenoid: Used to operate the bypass valve to purge the system at the start of the pump cycle.
- Water flow switch: Used to confirm water flow and initiate the operation of the chlorination control logic.
- Water pump starter: Used to start and stop the deep well pump motor and protect it from overloads and also to monitor pumps status (overload trip, on and off conditions).
- Pump motor protector: Used to provide added protection for voltage and current unbalance, over and under current, phase loss or reversal and motor over-temperature with adjustable time delays.
- Chlorination pump starter: Used to start and stop the chlorination injection pump motor and protect it from overloads.
- Chlorine supply line solenoid: Used to protect the system from accidental injection of chlorine when pump is off.
- Chlorine gas leak detector: Used to provide local and SCADA alarm if chlorine gas is detected.

Note: The system will work properly only if the associated mechanical equipment is also operational. Most of the diaphragm-actuated bypass valves require maintenance or replacement. (The assessment of the condition of mechanical equipment is not under the scope of this section.)

Generator

The majority of the deep well water pump stations are linked to an emergency generator. In the event of a power failure, the automatic transfer switch control panel should automatically start the generator after a pre-determined delay period. The transfer switch automatically transfers the station power to the generator source. Upon power restoration, the control panel monitors for voltage stability, transfers the station back to utility power and allows the generator to go through a cool-down cycle.

The following are a list of recommended input points for monitoring the generator to enhance the system operation:

- Generator run/standby
- Generator fault
- Voltage unbalance
- Power fail
- Battery voltage
- Fuel tank level
- Day tank level
- Transfer switch position

Note: While there are other generator and transfer switch input points that can be monitored, the list above represents the minimum necessary for effective remote monitoring by a SCADA system.

13.4.2.2 Booster Pump Stations

Most of the water booster pump stations are currently operating in manual mode and do not incorporate the benefits of the instrumentation and automatic control. Figure 13-4 shows a booster pump station operating in manual mode.

Figure 13-4 – Interior View of Brigade Booster Pump Station

Pump Instrumentation

Monitoring of system pressures and flow is essential to efficient operation. Also, alternation of pump operation evens out the mechanical wear on the equipment. In addition, two or more pumps could be called into service in the event of high demand or low pressure, depending on the design and capacity of the water distribution system.

The following is a list of instrumentation and related devices that should be operational at every potable water booster pump station in order for the station to operate properly, safely and efficiently:

- Inlet pressure transmitter: Used to monitor pump suction pressure to avoid cavitation and initiate an alarm condition.
- Outlet pressure transmitter: Used to monitor head pressure for control logic and alarm initiation.
- Water flow meter: Used to quantify volume of water pumped and to calculate water losses.
- Water flow switch: Used to confirm water flow and for control system interlocks and alarm initiation.
- Water pump starters: Used to start and stop the booster pump motors and protect them from overloads and also to monitor pump motor status (overload trip, on and off conditions).
- Pump motor protector: Used to provide additional protection for conditions of over and under voltage and phase loss or reversal.

Control interlocks between the reservoir levels and the operation of the deep well pumps and booster pump stations were not evident. Lack of process controls and instrumentation results in the following situations:

- Low or high (overflow) reservoir level
- Low or no system pressure (line breakage)
- High system pressure

Generator

The comments regarding the generator controls included in Section 13.4.2.1 also apply to the water booster pump stations. Earlier comments regarding mechanical equipment condition also apply.

13.4.2.3 Water Treatment Plant

The Ugum WTP is the only water treatment facility operated by GWA. At the time of the onsite evaluation, most of the plant was being operated manually, with the exception of a bubbler system that controlled the pump of water from the finished water wet well to the reservoir. A chlorine leak detection and a few minor systems and interlocks were also found to be operational. However, the operators indicated that most of the plant was being operated manually.

Plant Instrumentation

The plant has a main control room that contains four control consoles manufactured by Leopold as shown in Figure 13-5 – Control Console and six programmable logic controllers (PLCs). There are also remote control stations located throughout the facility that are used for local control (e.g., operation of motorized valves). None of these systems were in service at the time of the site visit.

Figure 13-5 – Unused Control Console at Ugum WTP

This assessment is not intended to review each individual input/output (I/O) device in the water treatment plant. The detailed equipment assessment resulted in an overall process control rating of 1.86. This rating implies that most of the process control system is out of service. Even though the plant is currently being operated manually, it is a challenge to operate the plant in such a manner at peak efficiency over a long period of time while consistently producing high-quality potable water.

Major systems that should be automated in order to achieve peak plant performance are listed below.

- Finished water pump control system
- Chemical mixing and feed system
- Flocculation and coagulation control system
- Sedimentation and filtration control system
- Backwash control system
- Blower control system
- Booster pump station control system
- Sludge removal system
- Chlorination system
- Finished water quality monitoring
- Reservoir water level
- Historical collection system for:

- Plant optimization
- Troubleshooting
- Trending and reporting
- Alarm annunciation and reporting

In general, the local controls for the Ugum WTP should be designed to operate independently (i.e., without any external inputs). However, the operation of the plant should be coordinated with the Ugum River raw water pump station and other booster pump stations and reservoir levels, which will require external communications.

Generator

The comments regarding the generator controls detailed in Section 13.4.2.1 also apply to the Ugum WTP. Comments regarding mechanical equipment condition also apply.

13.4.2.4 Wastewater Pump Stations

Most of the wastewater pump stations had a Motorola SCADA RTU installed; however, a few of the newer stations, such as Chaot (New), Chalan Pago 3 and 5 and Machanao were not equipped.

A few of the stations were observed to have operational radio and/or RTU modules, such as at Agana Main, Asan and Piti.

Most of the RTU cabinets were installed indoors or under a building's roof eave. The cabinets under the eave were observed to be in fair condition. Those located in the building's interior fared much better.

The field wiring was installed to the cabinets; however, most of the conductors were not terminated and need to be traced. Masking tape was used for wire identification and much of the tape has since become brittle and fallen off the conductor.

Pump Operation

Two types of pump station designs used at the GWA pump stations are wet wells with one or more submersible pumps or wet wells with multiple centrifugal pumps located in an adjacent dry well.

Stations with submersible pumps generally had their controls modified to simple controls system consisting of wet well level detection and a pump alternator. The larger wastewater pump stations have submersible pumps located in the dry wells. In those stations, it is important to have a fully functional sump pump and high dry well level float switch to provide an alarm initiation in the event of a flood condition.

The minimum I/O process controls for wastewater pump stations with multiple pumps are as follows:

- High dry well level float switch
- High wet well level float switch
- Wet well level sensor

- Power failure
- Pump starters
- Generator run/standby status
- Redundant pump start/stop controls
- Chlorine gas detection and control (where applicable)

The following additional I/O process devices would enhance the operation, maintenance and alarm capabilities of all types of wastewater pump stations.

- Communicator control monitoring (where applicable)
- Wet well low level indication
- Station flow metering
- Motor moisture and winding thermal detector
- Motor load and condition
- Motor overload status
- Phase monitoring
- Pump variable speed controller (where applicable)
- Accurate wet well level transmitter (example: level probe)
- Generator fuel level
- Generator fuel leak detector

Most of the wastewater pump stations use a bubbler system that provides wet well level input (dry contact) to a simple pump alternator manufactured by Time Mark (model 471 multi-stage alternator). Other level detection systems include level detection rods, ultrasonic level detectors and ball and float level switches.

A bubbler system requires an air compressor to provide a reliable source of instrument air. GWA maintenance staff is trained to regularly drain the condensate moisture from the air compressor tank. The second most common type of pump control was the use of float switches located in the wet well.

A bubbler system is recommended to provide wet well level input to the pump control system for most of the wastewater pump stations because it is fairly simple in design and easy to maintain. Wet well level indication can also be determined with the installation of a level gauge used in conjunction with a pressure transducer to provide an analog level indication to the SCADA system.

It is also recommended that double air compressors with an air reserve tank be installed, as well as a high level float switch in every wet well. If the bubbler system fails, the high-level float switch will not only signal an alarm condition but will also initiate a timed pump-down cycle.

Generator

Most of the wastewater pump stations were equipped with an emergency generator. The operation of the wastewater generators is similar to that covered in the discussion of generators for water pump stations in Section 13.4.2.1.

The following is a list of recommended additional input points for monitoring the generator:

- Generator run/standby
- Generator fail
- Voltage unbalance
- Battery voltage
- Fuel tank level
- Day tank level
- Transfer switch position

Note: While there are many more generator and transfer switch input points that can be monitored, the list above represents the minimum necessary for effective remote monitoring by a SCADA system.

13.4.2.5 Wastewater Treatment Plants

The control systems were assessed at all of the wastewater treatment plants. In general, most of the plants' operational functions were being operated manually with the exception of the wet well level control and associated motor alternation and control.

Even though the plants can be, or are currently being, operated manually, it is a challenge to operate them at peak efficiency. Automated systems enable plants to operate at peak performance with minimal manpower.

Plant Controls

The major unit process areas that require properly operating automation systems in order to achieve peak plant performance are listed below.

- Headworks
- Clarifiers
- Pump gallery (e.g., sludge, recirculation, scum pumps)
- Centrifuges
- Blowers
- Digesters
- Odor control systems
- Chlorination
- Effluent pumps
- Plant generator

Not all of the systems listed above apply to all wastewater treatment plants.

In general, the control systems for the wastewater treatment plants should be designed to operate independently (i.e., without any external inputs). However the operation of the plants must be monitored from a central SCADA system since none of the wastewater treatment plants have a 24-hour staff. A communication system linking the treatment plants to a central SCADA system is necessary to accomplish this monitoring. In addition, it is advantageous to have each treatment plant monitor the status of all pump stations associated with that plant.

Figure 13-6 is an example of a control panel for the centrifuge feed pumps that are not operational at the Hagatna STP. Other controls for the sludge pumps were also noted to be non-functional. It is unknown if these were operational even when the equipment were functional.

Figure 13-6 - Unused Control Panel at Hagatna STP

Generator

The comments regarding the generator controls presented in Section 13.4.2.1 – Water Pump Stations, Generator also apply to the wastewater treatment plants. Comments regarding mechanical equipment condition also apply.

13.4.3 Assessment Summary

Tables 13-2 and 13-3 summarize the findings and ratings for the water and wastewater pump systems, respectively. This evaluation is based solely on the condition of the equipment in place at the GWA facilities when the assessment was made.

At that time, most of the equipment was running in manual operation, thereby bypassing the automatic process controls. The predominant automatic controls found to be operational at most locations were those of the pump level control system at the wastewater pump stations. Most of the other systems were operating in manual mode. In general the condition of most of the process controls was rated between “1” and “2” on the assessment scale (see Table 13-1).

Table 13-2 – Water Pump Stations SCADA Assessment Totals

Station Name	Pump Controls	Chlorination System	Pump Bypass	SCADA RTU	Assessment Total
A-01	0.90	0.50	0.10	0.18	1.7
A-02	0.90	0.50	0.00	0.23	1.6
A-03	0.90	0.50	0.00	0.13	1.5
A-04	0.00	0.00	0.10	0.15	0.3
A-05	0.80	0.50	0.00	0.18	1.5
A-06	0.85	0.50	0.10	0.20	1.7
A-07	0.00	0.00	0.10	0.23	0.3
A-08	0.85	0.50	0.00	0.25	1.6
A-09	0.90	0.40	0.05	0.18	1.5
A-10	0.90	0.40	0.05	0.18	1.5
A-12	0.00	0.00	0.00	0.23	0.2
A-13	0.00	0.00	0.00	0.18	0.2
A-14	1.20	0.50	0.10	0.08	1.9
A-15	1.20	0.40	0.10	0.18	1.9
A-17	0.00	0.00	0.10	0.18	0.3
A-18	1.20	0.50	0.00	0.20	1.9
A-19	0.00	0.00	0.00	0.18	0.2
A-21	1.20	0.50	0.10	0.13	1.9
A-28	1.15	0.50	0.10	0.18	1.9
A-29	1.15	0.50	0.10	0.25	2.0
A-30	0.60	0.50	0.10	0.25	1.5
A-31	1.20	0.50	0.00	0.23	1.9
A-32	0.00	0.00	0.20	0.20	0.4
AG-2A	1.20	0.50	0.20	0.25	2.2
D-04	1.20	0.50	0.00	0.20	1.9
D-07	1.20	0.50	0.00	0.15	1.9
D-08	1.15	0.50	0.05	0.20	1.9
D-10	1.20	0.50	0.05	0.18	1.9
D-11	1.15	0.50	0.05	0.18	1.9
D-12	1.15	0.50	0.00	0.20	1.9
D-13	1.15	0.50	0.00	0.18	1.8
D-14	0.95	0.40	0.05	0.18	1.6
D-15	1.00	0.00	0.05	0.15	1.2
D-16	1.20	0.40	0.20	0.20	2.0
D-19	1.20	0.40	0.20	0.20	2.0
D1-D2	1.20	0.50	0.00	0.18	1.9

Table 13-2 – Water Pump Stations SCADA Assessment Totals (continued)

Station Name	Pump Controls	Chlorination System	Pump Bypass	SCADA RTU	Assessment Total
D-20	1.15	0.40	0.20	0.15	1.9
D-21	1.20	0.50	0.10	0.18	2.0
D-22	1.15	0.50	0.20	0.43	2.3
EX-11	1.15	0.50	0.20	0.18	2.0
F-01	0.95	0.50	0.10	0.18	1.7
F-02	1.20	0.50	0.05	0.13	1.9
F-03	1.20	0.50	0.00	0.15	1.9
F-06	1.15	0.50	0.15	0.18	2.0
F-07	1.20	0.50	0.10	0.15	2.0
F-09	1.15	0.50	0.20	0.18	2.0
F-10	1.15	0.50	0.20	0.20	2.1
F-11	1.20	0.50	0.20	0.20	2.1
F-12	1.20	0.50	0.20	0.18	2.1
F-13	1.20	0.50	0.15	0.40	2.3
F-15	1.20	0.50	0.20	0.45	2.4
F-16	1.20	0.50	0.20	0.45	2.4
F-17	1.20	0.50	0.20	0.45	2.4
F-18	1.20	0.50	0.20	0.45	2.4
HCG2	1.20	0.00	0.20	0.20	1.6
M-01	0.00	0.00	0.10	0.18	0.3
M-02	1.20	0.00	0.10	0.18	1.5
M-03	1.20	0.00	0.10	0.18	1.5
M-04	1.05	0.50	0.10	0.18	1.8
M-06	1.15	0.50	0.10	0.18	1.9
M-07	1.20	0.00	0.10	0.23	1.5
M-09	1.20	0.50	0.10	0.20	2.0
M-15	1.15	0.50	0.10	0.18	1.9
M-17-A	0.00	0.00	0.00	0.15	0.2
M-17-B	1.20	0.50	0.20	0.18	2.1
M-18	1.20	0.50	0.20	0.28	2.2
M-20-A	1.00	0.50	0.20	0.30	2.0
M-21	0.00	0.00	0.00	0.45	0.5
M-23	1.20	0.50	0.20	0.35	2.3
Y-01	1.15	0.50	0.00	0.18	1.8
Y-02	1.15	0.50	0.10	0.13	1.9
Y-05	1.15	0.50	0.20	0.15	2.0
Y-06	1.20	0.50	0.20	0.18	2.1

Table 13-2 – Water Pump Stations SCADA Assessment Totals (continued)

Station Name	Pump Controls	Chlorination System	Pump Bypass	SCADA RTU	Assessment Total
Y-07	0.00	0.00	0.00	0.18	0.2
Y-09	1.20	0.50	0.20	0.18	2.1
Y-10	1.00	0.50	0.20	0.28	2.0
Y-15	1.05	0.50	0.15	0.35	2.1
Y-16	1.20	0.50	0.20	0.45	2.4
Y-17	1.20	0.50	0.20	0.38	2.3
Y-21-A	1.25	0.50	0.30	0.38	2.4
Y-23	1.05	0.65	0.25	0.43	2.4
Total Average Assessment	1.12	0.49	0.14	0.22	1.7

Table 13-3 summarizes an inventory of the existing SCADA equipment at the wastewater pump stations that were visited. A "1" indicates the presence of that piece of equipment while a "0" indicate the absence. A "U" indicates information that was not verified and the equipment could be present. (This coding system applies to the wastewater stations also).

Table 13-3 – Wastewater Pump Stations SCADA Assessment Aggregated Totals

Station Name	Pump Controls	Sump Pump	SCADA RTU	Total
AGANA MAIN	2.10	0.20	0.60	2.9
ALUPANG COVE	1.50	0.00	0.00	1.5
ASAN	2.10	0.00	0.50	2.6
ASTUMBO 1	1.40	0.00	0.00	1.4
ASTUMBO 2	1.40	0.00	0.00	1.4
BARRIGADA	2.10	0.20	0.70	3.0
BAYSIDE EJECTOR	1.50	0.00	0.20	1.7
CABRAS	1.40	0.30	0.05	1.8
CHALIGAN	2.10	0.20	0.00	2.3
COMMERCIAL PORT	1.50	0.25	0.15	1.9
DAIRY ROAD	1.50	0.00	0.30	1.8
DOUBLE TROUBLE	2.10	0.10	0.40	2.6
FEMA 96	1.50	0.00	0.00	1.5
FUJITA (TUMON)	1.50	0.20	0.30	2.0
HAFI ADAI	1.40	0.00	0.00	1.4
HARMON	1.40	0.00	0.20	1.6
HUEGON 5	2.10	0.00	0.00	2.1
INARAJAN MAIN	1.50	0.00	0.30	1.8
LATTE PLANTATION	1.40	0.00	0.00	1.4
MACHANANAO	1.40	0.20	0.00	1.6
MACHECHE	1.40	0.00	0.15	1.6

Table 13-3 – Wastewater Pump Stations SCADA Assessment Aggregated Totals (continued)

Station Name	Pump Controls	Sump Pump	SCADA RTU	Total
MAITE	1.40	0.00	0.25	1.7
MAMAJANAO	2.10	0.20	0.25	2.6
MANGILAO	2.10	0.20	0.40	2.7
NEW CHAOT	2.10	0.30	0.00	2.4
OLD CHAOT	1.50	0.25	0.35	2.1
ORDOT	2.10	0.00	0.00	2.1
PACIFIC LATTE	1.40	0.00	0.00	1.4
PAGA CHAO	2.00	0.00	0.30	2.3
PAGO DOUBLE SHAFT	2.10	0.20	0.35	2.7
PASEO DE ORD	1.40	0.00	0.00	1.4
PGD	2.00	0.00	0.00	2.0
PITI	2.10	0.20	0.40	2.7
PS-12	1.40	0.00	0.30	1.7
PS-15	0.00	0.00	0.00	0.0
PS-17	1.40	0.00	0.30	1.7
ROUTE 16	2.10	0.25	0.30	2.7
SANTA ANA SUBDIVISION	1.40	0.00	0.00	1.4
SANTA CRUZ 3	2.10	0.00	0.00	2.1
SINAJANA	2.10	0.25	0.35	2.7
SOUTHERN LINK	1.40	0.20	0.80	2.4
SUBMARINE	2.10	0.00	0.00	2.1
SUNSET VILLA	1.30	0.00	0.20	1.5
TAI MANGILAO	2.10	0.20	0.00	2.3
TALOFOFO	1.40	0.10	0.00	1.5
YIGO	1.40	0.20	0.35	2.0
YPAO	1.40	0.20	0.30	1.9
YPAOYPAO	1.40	0.00	0.35	1.8
Average Assessment	1.66	0.21	0.20	1.9

13.5 SCADA & Control Implementation Activities

The process control system is a critical component in achieving GWA goals for operational efficiency. Therefore, the recommendations in this report include technologies that comply with the following criteria:

- Adoption of standards for hardware installations
- Open standards for software programming languages
- Leveraging existing communication infrastructures
- Integration of current Information Technology (IT) systems

The adoption of equipment installation standards and procedures will assist GWA employees to become more familiar and proficient with specific types of hardware. In turn, this will reduce maintenance costs associated with decreased inventory and maintenance labor (e.g., lower repair and troubleshooting time).

Also, the adoption of "open" standards for programming languages will enable the maintenance and IT staff to become proficient in standardized programming languages in lieu of learning multiple proprietary languages. This development of a highly trained workforce that can skillfully respond to software maintenance and troubleshooting issues will in turn decrease system downtime.

Leveraging Guam's existing communication infrastructures and equipment will relieve GWA's burden of operation and maintenance of the communication infrastructure, thus reducing downtime.

Finally, the integration of the current IT architectures will enhance the ease of distributing the process control system information to a broad variety of staff. This information includes real-time process control information, alarm information distribution, historical reporting and analysis and maintenance management system interface, plus automated report generation for federal and local agencies.

These four components will significantly assist in meeting GWA's vision for growth and development in a sustainable manner and enhance its ability to comply with all federal and local environmental and safety regulations.

To achieve the objectives of improved efficiency and reduced operational costs, the following implementation phases are recommended:

Phase 1 – Activation of Existing SCADA System

Based on the site observations and preliminary testing, resurrecting and updating the existing Motorola SCADA system is recommended for the following reasons:

- Approximately 10 to 20% of the RTUs are operational or can be made so with relatively minor testing.
- Components of the RTUs that are not functional or repairable can either be used for parts or discarded. A number of these spare units will become available for use elsewhere.
- Replace all back-up supply batteries.
- One of the existing MOSCAD-L units could be converted to a field interface unit for the entire SCADA system.
- A PC with SCADA software could be used as the base station to monitor the status of the water and wastewater systems.
- Off-the-shelf software, such as that manufactured by Wonderware or Intellution, could be used in the PC rather than customized software.
- GWA could use the communication system as that currently being used by the Fire, Police and other emergency agencies, which is already owned and operated by the Guam government.

Phase 2 – SCADA System Integration

During the second phase of the SCADA installation, the revised SCADA system would be modified to accommodate the use of multiple users on a system wide LAN network. This work is projected to take place in the next five years as the SCADA system is expanded.

13.5.1 Local Process Control Improvement Recommendations

This section includes general process control equipment recommendations including design standards.

Standardization of Automation Devices and Design

A wide variety of equipment and equipment manufacturers, performing nearly identical functions, currently exists in the various types of GWA installations. This has developed naturally over several years of operation and maintenance. Unfortunately, because of such an extensive variety of designs and manufacturers, it is costly for GWA to maintain and troubleshoot an adequate reserve supply of replacement parts. Therefore, it is recommended that GWA select a standard device or family of devices for each process control component, as well as standardize the design schematic and wiring diagrams.

Simple design – Although complex systems are available in the market today, they may not be the best solution for GWA. It was observed that many of the electronic devices and wiring methods had failed and these systems were bypassed or replaced with more simple systems. An electronic level sensor is the most common example that is replaced with a simple bubbler or float system. Some devices will include electronics; however, they should be industrial-rated and suitable for use in a harsh environment.

Manufacturer selection criteria – The manufacturer of the automation device should be a recognized vendor with local representation of products and a large installed base with parts readily available in stock. The manufacturer should demonstrate a track record of support and supply of replacement stock over a long period of time. Unfortunately, these criteria may eliminate some of the newer companies with new products. GWA will have to weigh the advantages of their products against the risk of losing of long-term support.

13.5.2 Local Process Control Requirements

Many of the sites had magnetic relays, timers, pump alternators and other hard-wired components that composed the local process control functions. While these systems operate effectively, they usually only control the "core" function of the site. However, the complexity of the hard-wired systems increases dramatically when additional functions are added to the control systems. Consequently, a critical threshold is reached whereby it is no longer feasible to operate a site using traditional hard-wired components. As the number of inputs and outputs at a site increase, the complexity of the wiring increases dramatically. Troubleshooting the wiring becomes a difficult and complex task.

PLCs and RTUs are designed to replace complex hard-wired control systems. In addition, most are capable of a direct connection to a telemetry system or have a telemetry system built into their architecture.

Both PLCs and RTUs perform process logic electronically. RTUs tend to be designed to perform specialized functions and have limited process logic capabilities and therefore they are proprietary in nature. RTUs also offer additional capabilities, such as built-in communication systems, radio and modem equipment. RTUs are usually more economical than PLCs.

In contrast, PLCs tend to be more complex and expensive yet offer versatility and expandability. PLCs usually do not have built-in communication systems and generally require an external radio or modem. A good example of RTU use RTU would be in remote pump stations, whereas PLCs would be used in a treatment plant. Recently, however, many PLC manufacturers have reduced the size and price of some of their PLC family members to compete with RTU manufacturers. At the same time, the PLC manufacturers have been able to retain many of the capabilities of their traditional PLCs.

The PLC/RTU offers a high I/O density so that the unit does not have a large footprint. The typical I/O density per I/O module is as follows:

- Digital Inputs – 16 (non-isolated)
- Digital Input – 8 inputs (isolated)
- Analog Input – 4 inputs
- Relay Output – 8 outputs (isolated and non-isolated)
- Analog Output – 2 outputs

The PLC/RTU should have the capability to add additional inputs and outputs without having to replace the entire unit. The hardware should have the ability to be expanded to accept up to 16 I/O modules.

The PLC/RTU should support remote access for remote configuration, programming and troubleshooting. This support should include full function capabilities using various communication methods.

The PLC/RTU should support an open logic programming software product. This will enable GWA to train its staff on the use of one programming package that has the ability to program the processors located in remote pump stations as well as those located in the treatment plants.

13.5.3 Operations and Maintenance Implementation

A detailed training program should be initiated. The content will vary, depending on the job responsibility of each staff member. In general, there are four training classifications:

- Operators
- Maintenance
- Information Technology
- Management

Operator training includes the basic operation of the device, hardware, or software if the operator's normal job functions require direct interaction with the product. For example, an operator should understand the process functions whenever a PLC logic program is activated. However, the operator is not required to know how to program the PLC. The training should include hands-on work with the process and equipment. Testing is also a necessary portion of the training program in order to determine the level of operator competence. Regular refresher training courses and testing ensures that the operators maintain their understanding of the systems and are able to continue operating the systems properly.

Maintenance training includes all the topics presented to the operators, plus a more in-depth training on the actual installation – wiring, terminations, processors, modules, power supplies, calibration and testing. It also includes detailed training on PLC programming, troubleshooting and monitoring. All training should be hands-on in the classroom and at actual field installations. In general, the GWA maintenance staff should be thoroughly trained so that they can troubleshoot, replace hardware and load PLC/RTU logic without requiring outside assistance. Testing is also necessary to determine the level of individual competence. Regular refresher training courses and testing ensures that GWA maintenance staff members retain a high level of competence in keeping the systems operating properly.

IT staff training includes all of the topics for operators and some of the general topics provided to the maintenance staff. (Detailed PLC programming is not necessarily a job responsibility required by the IT staff.) In addition, the IT staff should be thoroughly trained in the network infrastructure, hardware (servers and workstations) and all software programs running as part of the process control system. The IT staff should be trained in performing backup and restoration of the programs and in communications troubleshooting. The IT staff should also be trained on report generation.

The GWA management staff should be trained on the overall concept of the SCADA and control systems, as well as thoroughly educated on the function and capabilities of each hardware and software component. Detailed management training should be provided in all aspects of historical trending, analysis, report generation, monitored alarm sequencing and performance monitoring, together with all other types of administrative capabilities of the SCADA system.

13.5.4 GWA Maintenance Equipment Requirements

GWA maintenance staff should be equipped with the proper tools for calibrating the instrumentation. In addition, the staff should have a minimum of two ruggedized notebooks loaded with the PLC/RTU programming software as well as a copy of all PLC programs.

GWA should maintain an adequate supply of replacement parts in stock.

13.5.5 Site Security and Intrusion Detection Security Monitoring System

GWA's remote stations have been affected by considerable vandalism and unauthorized intrusion. Intrusion detection devices, such as motion detectors, magnetic door detectors and infrared light beams, among others, should be installed at each remote location for monitoring purposes. Any intrusion will be displayed as an alarm.

13.5.6 SCADA System Communication Improvement Implementation

SCADA systems require communications between the SCADA system and the remote PLCs or RTUs. Two main categories of communication are currently in use today: hard-wired and wireless.

13.5.6.1 Hard-Wired Technologies

Hard-wired technologies include the following types of installations.

Private Communication Systems

A private communication system would require GWA to install wiring between each of the sites and connect them to the main administration building. Since this approach is extremely expensive, it will not be considered as an option.

Public Communication Systems

The GTA provides a hard-wired public communication system that serves the island. Traditionally, the copper telephone systems were somewhat unreliable and provided a low data connection speed. Recently, however, GTA has installed four fiber optic rings on Guam: Northern ring, Central ring, Tumon ring and Southern ring. Each ring provides high-speed access for data transmission. At the time of this assessment report, approximately 99% of GTA's telephone system is installed underground. Telephone terminal boxes were observed near many of the water and wastewater pump station locations.

13.5.6.2 Current Wireless Technologies

This assessment includes the radio communication system as part of the definition of the SCADA system. Therefore, the types of radio or wireless systems available today are discussed.

Four main wireless technologies commonly used with current SCADA systems are as follows:

- Licensed radio (800 Mhz, UHF and VHF)
- Unlicensed radio (Spread Spectrum)
- Cellular communications
- Satellite communications

Although other wireless communication systems are available, such as microwave, they are too expensive, too specialized, or not widely used in today's SCADA applications. The characteristics for each type of communication system are listed below:

Licensed Radios

- Low data throughput: 1.2 kilobytes per second (kbps) to 9.6 kbps
- Federal Communications Commission (FCC) license required – Government of Guam
- Existing Government of Guam Trunked Radio System
- Minimal operation cost

Unlicensed Radios

- High data throughput: 2 to 3 megabytes per second or higher
- Line of sight required
- High susceptibility to interference (Example: wireless residential phones)
- Subject to signal loss during rain

- Antennas usually mounted on towers
- Owner maintains equipment and infrastructure
- High initial installation cost
- Minimal operation cost

Cellular Communications

- Medium data throughput: 153 to 384 kbps (depending on selected technology)
- Line of sight not required
- Monthly service fee per site required
- Service provider maintains infrastructure
- Owner maintains radio
- Moderate initial installation cost

Satellite Communications

- Low data throughput
- Usually only transmits data using the "Report on Exception" methodology
- Subject to loss of signal (rain fade)
- Service provider maintains infrastructure
- Owner maintains radio
- Moderate initial installation cost
- High service provider cost

While all four technologies are currently used with SCADA systems, this assessment report recommends using the Government of Guam Trunked Radio System during the initial phases, for the following reasons:

- Makes use of existing infrastructure (does not require GWA to build infrastructure)
- Low initial cost of installation
- Low cost of ownership since the Government of Guam owns and operates the infrastructure
- High reliability, especially when used for emergency services
- Acceptable signal strengths
- Two-way communication within the GWA Talk Group
- Key personnel can interface with Police and Fire Departments for coordination

13.5.7 SCADA System Improvement Implementation

One of the key functions of a SCADA system is alarm annunciation. If alarm conditions are detected early, then the maintenance or operation staff can be dispatched to make repairs and avoid more serious damage to equipment. A SCADA alarm system could also assist in avoiding wastewater spills and loss of potable water supply to consumers. There are many other benefits that result from the alarm function of a SCADA system.

At the present time, local alarm annunciation is installed at various facilities, such as the Ugum WTP (Figure 13-7). These are alarm points wired for a specific purpose. Physical space and information limitations are the constraints of using this type of system. A computer based SCADA system can provide added information for the operator to make intelligent decisions.

Figure 13-7 – Annunciator Panel at Ugum WTP

13.5.7.1 SCADA Supervisory Function

A SCADA system Supervisory Function is designed to operate only in a supervisory capacity. That is, it is not designed for continuous process logic, which is a function of the PLC or RTU. The SCADA system communicates continually with the PLC/RTU processors and the process logic in the PLC/RTU should continue to operate normally in the event that the SCADA system computer ceases communication with the PLC/RTU. For example, the SCADA system would not contain logic that would continually coordinate booster pumps. This task would be the responsibility of the PLC.

13.5.7.2 SCADA Data Acquisition Function

A SCADA system Data Acquisition Function is designed to acquire data from the remote PLCs and RTUs. The data is then electronically transferred into a real-time database. The database is used to provide data to the following software applications:

- Graphical objects on the display screen
- Real-time trending
- Historical collection applications
- Real-time reporting applications
- Voice, e-mail and telephone alarm annunciation
- Other databases via ODBC (Open Data Base Connectivity) connections
- OPC (an open protocol used in process control) connections to other applications

13.5.7.3 SCADA Clients

A SCADA client is defined as a remote display terminal that allows the viewing and operation of the SCADA system screens. The location of and access to the SCADA clients will be based on the job responsibilities of the GWA employee. A SCADA client can be located on the existing GWA network, as part of a plant network, or as a wireless connection. The following is a list of suggested SCADA client locations:

- GWA dispatch office
- Water division supervisor office
- Wastewater division supervisor office
- IT manager office
- GWA general manager office
- GWA compliance manager office
- GWA operations manager office
- Ugum WTP control room
- Hagatna STP control room
- Northern STP control room

13.5.7.4 Central Command Location

In addition to the SCADA client locations listed above, it is recommended that at least two SCADA clients be located at a secure site that would serve as a Central Command post during storms or other emergencies. Preferably, this Central Command center would be co-located inside or adjacent to the IT department that contains the core hardware and software. The Central Command location can also serve as a central control room during normal operations if desired. It should be noted, however, that the recommended SCADA architecture is based on a distributed workforce and therefore a continually manned control center is not an absolute necessity. The Central Command hardware will be supplied with power from UPS units and also backed up by an emergency generator.

13.5.7.5 SCADA Maintenance & Development Location

The Central Command post will also serve a dual purpose as the SCADA maintenance location by the GWA staff. It will be also used by the SCADA installation contractors for software installation, testing, training and final acceptance.

13.5.7.6 SCADA Security

The SCADA system serves as the monitoring and communication backbone for a utility and it must be secured from unauthorized access at all times. Security can be achieved by implementing one or more of the following security features as deemed necessary to protect GWA operations at all times.

- Hardware firewall with virus signature analysis
- Anti-virus protection
- Windows security
- Network encryption
- Virtual Private Network (VPN) wireless connections
- Dynamic Internet Protocol (IP) addressing
- Dynamic Welch codes (a data compression coding algorithmn)
- Secure site connections
- Lock and key

13.5.8 Information Management System Improvements

13.5.8.1 GWA IT Department Requirements

It is recommended that the core hardware and software components of GWA's SCADA system reside in the IT Department facility. The term "core hardware and software" refers to a central location that serves as a central repository of SCADA information and has the ability to monitor all installations, generate alarms, provide trending information, collect historical data, generate administrative reports and provide facility operational metrics. The core components communicate with other SCADA servers, such as those in the water and wastewater treatment plants and monitor their operations. Finally, the core hardware and software will perform general system duties such as adjusting and monitoring the reservoir level setpoints and associated alarm points.

The assessment team visited the GWA IT manager and discussed the SCADA requirements as presented in this section.

13.5.8.2 Data Highway

The main wireless connection will tie into the SCADA system from the IT department's switches. The data could arrive via any one or more of the following data highways:

- GTA
- Cellular radio

- Internet T-1
- Internet DSL (Symmetric (SDSL) or Assymmetrical (ASDL) Digital Subscribere Lines)
- Microwave

All data should pass through a hardware firewall that supports virus signature scanning and provides front line security protection to all computers behind the firewall. The data should then pass through a router to isolate SCADA traffic from GWA administration traffic.

13.5.8.3 Hardware Location

All SCADA hardware should be located in two dedicated 19-inch enclosed racks. The racks should be located in a temperature- and humidity-controlled room and be provided with uninterruptible power and a backup generator.

13.5.8.4 Thin SCADA Clients

The SCADA clients will be located on the existing GWA LAN and operate as single board thin client (limited processing computers that depend on a central server) computers that have terminal server sessions on the terminal server computer. The SCADA thin clients do not require any added software or maintenance because all software applications and licenses are loaded and maintained on the terminal server. This significantly reduces any maintenance requirements of client PCs. Thin client single board computers do not have any moving parts and therefore have a significantly longer hardware life span. In addition, thin clients require very little IT personnel maintenance since all maintenance is performed in the server rack located in the IT Department.

13.5.8.5 Printers

Network printers will be installed on the existing GWA network. Reports will be printed from the SCADA reporting software.

13.5.8.6 IT Staff Responsibilities

GWA staff will be responsible for maintaining all the equipment located in the two SCADA racks. In addition, the IT staff is responsible for backup of data and applications on a regular basis. High-density backup tape drives will be specified as part of the hardware server requirements.

In addition, the IT staff will be highly trained on all applications loaded on the SCADA servers, with the exception of PLC programming. At least one person in the IT staff should be trained on the SCADA software and communication drivers.

13.6 Conclusions

- A SCADA monitoring system which was installed in the 1990s was never functional
- Water pumping and booster station automatic controls are currently operating only in a manual mode
- Site visits revealed that many complex electrical instrumentation and controls systems were not operational

- During field visits to facilities it was evident that there is a lack of skilled personnel to operate and maintain control system
- Effective information transfer would be enhanced by providing two-way radio communication between operations, maintenance, and administrative personnel

13.7 Recommendations

- Activate or install a operational SCADA system
- Repair or replace control instrumentation at all stations and plants
- Continuously train personnel, using both internal skilled personnel to provide information technology as well as external assistance from on-island educational resources and off-island experts
- To the extent possible, standardize on equipment manufacturers
- Implement the use of two way radio communication on the Government of Guam Radio System

13.8 CIP Impacts

The 20 year CIP Projects presentation in Volume 1, Chapter 15 – CIP Program shows expenditures over the period of 2007 – 2011 for implementation of a functioning SCADA system based on discussions and recommendations in this chapter. The system is recommended to be implemented in four phases identified in the CIP list.

- Phase 1 - 2007
- Phase 2 - 2008
- Phase 3 - 2009
- Phase 4 - 2010

Specific facility information is given for water projects in Volume 2, Chapter 9 – Recommended Water CIP and for wastewater in Volume 3, Chapter 9 – Recommended Wastewater CIP.