SCADA'S ROLE IN GETTING DRINKING WATER STANDARDS THERE!

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ABSTRACT

The purpose of the Drinking Water Standards for New Zealand (DWSNZ) is to ensure that all drinking water supplied in New Zealand is safe and wholesome. Although these standards seem to be straightforward, implementing a system which reliably monitors and provide early warning on the water infrastructure apparatus is not.

This paper will examine SCADA's role in complying with the drinking-water standards, and the methods of processing associated samples and measurements (Plant->Instrumentation->Remote Terminal->Communication->Processing->Data Storage->Reporting).

The paper will also present some of the real-world issues that the responsible organisations face, and offer a number of solutions and practical examples of how these issues could be resolved. For example:

- Collected data validity
- Sampling rates
- Hand-dressing of data
- Instrumentation accuracy
- Dealing with and preventing missing data
- Traceability – being able to pin-point what went wrong, and where.

Abbey Systems has been working closely with a number of the organisations concerned with the provision of safe and wholesome drinking-water to communities in New Zealand on both local and regional levels.

KEYWORDS

SCADA, Control systems, Telemetry systems, Plant Control, Disaster management, Drinking Water Standards

1 INTRODUCTION

1.1 WHAT IS THE PURPOSE OF THE DRINKING-WATER STANDARDS?

The Health (Drinking Water) Amendment Act 2007 amended the Health Act 1956.

The Drinking-water Standards for New Zealand 2005 resulted from the Expert Committee on Drinking-water Quality that was set up to advise the Ministry of Health (Ministry of Health 2005a).

Commonly referred to as *DWSNZ*, the Drinking-water Standards for New Zealand 2005 (revised 2008) is the result of further submissions from water suppliers and the consideration of the Guidelines for Drinking-water Quality 2004 (WHO GDWQ), Drinking-water Standards for New Zealand 1984, 1995, 2000 and 2005 as well as the National Primary Drinking Water Regulations: Long Term 2 Enhanced Surface Water Treatment Rule: Final Rule (USEPA 2006a).

The DWSNZ is a comprehensive guide which defines the minimum water quality standards that all drinking-water suppliers must adhere to. It defines the criteria for monitoring drinking-water quality and how to demonstrate compliance. The Standards also provides supporting information to assist in the general management of public and private drinking-water supplies in terms of the maximum amounts of organisms, residues and other contaminants that are allowed while still ensuring that all drinking-water supplied in New Zealand is always safe and wholesome.

1.2 WHAT IS THE PURPOSE OF A SCADA SYSTEM?

SCADA (Supervisory Control and Data Acquisition) refers to systems that measure, acquire information and control over a distance. These type of systems are all broadly classed as *telemetry systems*. The word telemetry comes from the Greek root words:

- *tele* – over a distance, and
- *metry* – to measure.

Supervisory Control can be in the form of digital outputs (controls) turning a pump ON or OFF, or analogue outputs setting motor speed.

Data Acquisition can be in the form of digital inputs (statuses) such as an indication for PUMP ON or PUMP OFF, or analogue inputs (measurements) indicating temperatures and water levels.

Distance can range from 1 meter to 12,000+ kilometres.

The purpose of SCADA (or telemetry systems) falls into five categories:

1.2.1 ALARMS

Alarms is the mechanism that alerts users that something is out of normal range with what is being monitored. The Alarm Annunciation is the mechanism of communicating the alarm condition using methods such as SMS (Short Message Service), email or visually on an HMI (Human Machine Interface), to responsible parties who can implement corrective action without delay if needed. For example, disinfection residual, turbidity or dosage found to be outside the MAV (Maximum Allowed Values) specified.

1.2.2 CONTROL

Control is an on-site or off-site event that triggers a change of state in a control element, with the understanding that automated control takes place independently from SCADA, meaning that the control should not stop when the SCADA is turned off e.g. the automated processes associated with plant operation.

Supervisory control refers to supervisor-initiated overriding control, or remote control of controllable elements.

1.2.3 SYSTEM OVERVIEW

System overview is having system-wide health and performance as well as operational visibility on elements and equipment that makes up the complete SCADA / Telemetry system, which are not necessarily nearby.

1.2.4 DATA MANAGEMENT

Data Management is the ability to retrieve, store and protect the integrity of the raw measurement data.

1.2.5 REPORTING

Reporting is the process, applicable tools and formatting that will enable the manipulation and presentation of raw data to make sense of it.

1.3 SCOPE OF PAPER

The practical implementation of the DWSNZ requires an in-depth understanding of all the continuous monitoring requirements associated with the standards as well as an in-depth technical knowledge on how to integrate multiple differing technologies, each with its own specific limitations and associated challenges. It is because of the large number of technologies, protocols and interfaces between the different process groups, that resilient SCADA solutions are complex to design and implement.

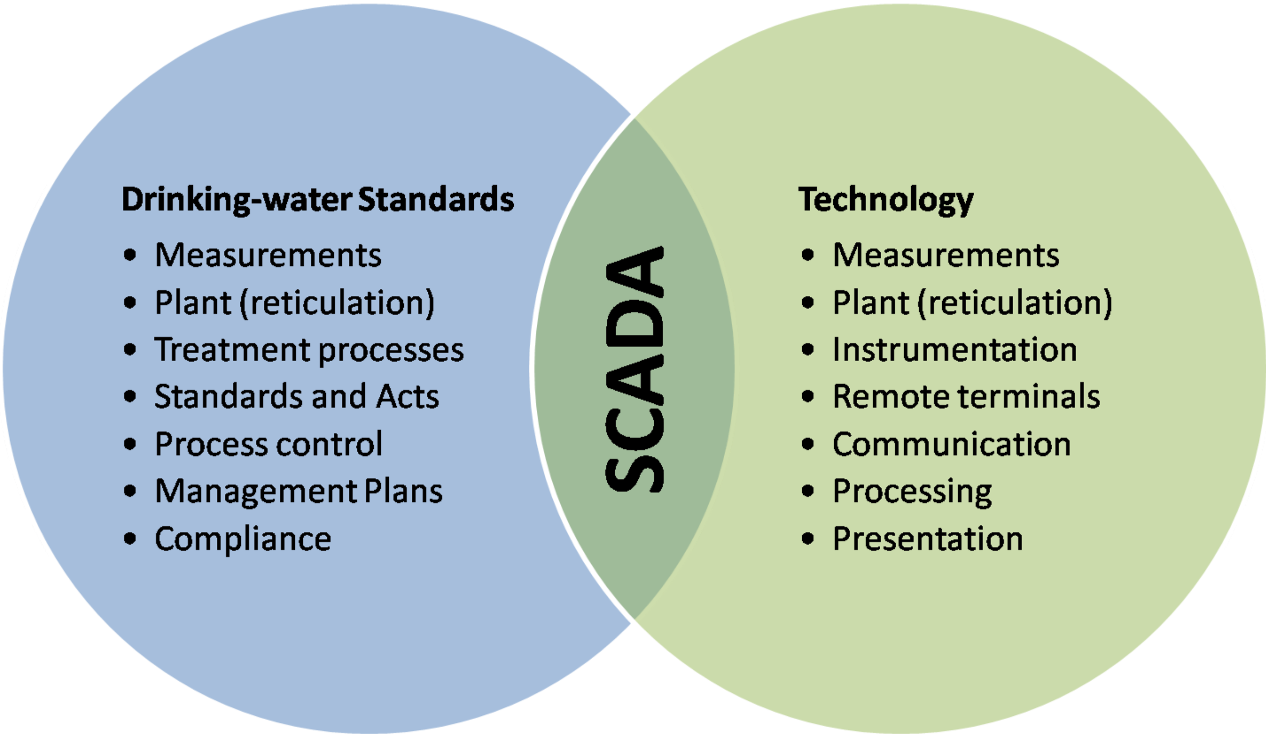

Figure 1: SCADA's role as translator between DWSNZ and the technology used to monitor compliance

This paper will present SCADA's challenging role to translate the *raw engineering measurement* language into *drinking-water compliance* language, and highlight possible pitfalls if there is not a clear understanding of the intent and requirements of both these domains.

2 A TYPICAL SCADA SYSTEM

SCADA systems may vary greatly in size, function, technology and complexity but they can all be identified as having the basic components of plant, instrumentation, remote terminal, communication, processing, data storage and reporting.

2.1 PLANT

Plant covers specific infrastructure that requires management through monitoring and controlling. This could, for example, be the reticulation system, reservoir or a pump station. Examples of the types of information of interest are turbidity, flow, chlorine concentration, water level and temperature.

2.2 INSTRUMENTATION

Instrumentation is the specialised electro-mechanical devices that will translate measurements into either analogue or digital signals. For example, a pressure transducer generates an analogue 4-20 mA signal as a result of the pressure imposed on it.

2.3 REMOTE TERMINAL

A Remote Terminal can be either an RTU (Remote Terminal Unit) or a PLC (programmable logic controller)

An RTU is a microprocessor-controlled electronic device that interfaces directly with instrumentation or indirectly via a standard protocol such as DNP3 or Modbus. The RTU will translate signals received into a system protocol that can be transported via a communication medium to a Master Station for processing. Standard RTUs always require a connection to a Master Station and do not have the ability to be programmed or make logic-based decisions. However, modern and specialised RTUs are programmable, can locally process logic and offer onboard data logging capacity to overcome communication outages without the loss of raw data.

RTUs are typically designed for SCADA/Telemetry applications where information may come from other sources at sporadic intervals.

PLCs are similar to RTUs but are typically designed for process control systems with higher I/O counts, which makes them popular for the control of machinery and assembly lines. PLCs are more likely to be connected to a local high-speed IP communications network and are designed to operate autonomously.

2.4 COMMUNICATION

Remote Terminals, both RTUs and PLCs, make use of a communication medium to transport the translated signals received from instrumentation to a Master Station. Examples of popular communication mediums deployed in SCADA networks are Wi-Fi, microwave, analogue radio (UHF and VHF), digital radio (UHF and VHF), cellular (CSD, GPRS, EDGE, SMS), 2 or 4 wire interfaces and optic fibre.

2.5 PROCESSING

The processing of the raw data received from Remote Terminals is performed in the Master Station or SCADA Base Station. The term Master Station refers to a combination of hardware and software components that is responsible for gathering, storing and ensuring the transmission of data via SCADA Gateways, which provide support for the various communication mediums deployed in a specific system.

For redundancy purposes a Master Station might also have duplicated components that are equivalent to the primary elements, but not active. These duplicated components can take over as the primary device should there be any component failures.

Modern industry trends are to move processing functionality associated with Masters Stations into the cloud (virtualising the Master Stations), which gives more flexibility, but also has its share of risks and security concerns that must be carefully considered.

2.6 USERS

Users are generally more interested in actual plant information (such as turbidity, flow, chlorine concentration or temperature), and less interested in the technologies and intermediate disciplines such as instrumentation, Remote Terminals, communication or processing.

Data is commonly viewed on virtual control panels with simulated pushbuttons, lamps and gauges together with other operational and reported information in the form of graphs and statistics on touch screens, smart phones and laptops.

3 KEY FACTORS IN USING SCADA TO GET THE DWSNZ THERE

Before investment in a specific solution or kicking off configuration changes to an existing SCADA system, a detailed analysis should be performed of what parameters will be needed from the SCADA system to assess compliance with the DWSNZ.

3.1 KNOW WHAT YOU NEED

3.1.1 MEASUREMENTS

Which operational requirement values will be used to measure compliance? If MAVs cannot be used, which surrogate criteria will be used, and where will the surrogate measurements be taken?

Avoid unnecessary measurements, data logging and monitoring as it overloads the system's collection and processing resources which drastically increases the risk of data loss, and results in additional costs for data storage.

3.1.2 ACCURATE TIMING

Know the applicable separation between data records (one, five or fifteen minutes). How will accuracy in time measurement for the recordings be achieved in order to ensure that even short-term transgressions are recorded?

If a Remote Terminal is not connected to a high-speed communications network (which in most cases it is not), it will have to time-stamp data as it is recorded.

3.1.3 ACCURATE DATA

The collected data records may be compressed but only if the accuracy of the original (raw data measurement) is preserved.

The SCADA system must maintain the integrity of the raw data for audit and traceability purposes.

3.1.4 ALARMS

With the DWSNZ the approach changed from quality control to one of quality assurance. What are the respective applicable control limits and how and when should the SCADA system react to measurements that approach control limits?

The SCADA system should provide effective alarming to allow site visits or other corrective action before an instance of non-compliance occurs.

3.1.5 MONITORING FAILURES

In the case of a monitoring failure, when to carry out manual monitoring?

Determine which components in the SCADA system will be monitored to give an indication when continuous monitoring has failed and manual monitoring should commence.

3.1.6 REQUIREMENTS

All sampling, standardising, testing and reporting procedures must meet the requirements of the DWSNZ.

Where the DWSNZ do not specify the calibration of instrumentation, the calibration should be performed by a qualified person according to the instrument manufacturer's specified procedures and frequency, or at least every three months – whichever is more frequent.

4 WHERE CAN IT GO WRONG?

4.1 COLLECTED DATA VALIDITY

There is the risk that the collected data records may have lost their initial accuracy if the SCADA system is not directly connected to the instrument that is taking the measurement - garbage in equals garbage out. For the purposes of Resource Consent and DWSNZ reporting, the instrument-generated signal should be split so that it can be fed into multiple Remote Terminals simultaneously.

4.2 SAMPLING RATES

Remote Terminals not designed for compliance monitoring may not have the capabilities to perform sampling with the correct separation between data records, or to accurately timestamp data as it is recorded and store data records locally until they can be transferred to the Master Station.

Modern Remote Terminals designed for compliance monitoring will continue operating even if the connection to the Master Station is lost. The DWSNZ requires that some determinants do not exceed a certain value for more than three, five or fifteen minutes which implies that Remote Terminals should have the capability to provide effective local alarming in conjunction with generating alarms messages that are sent to the Master Station.

4.3 HAND-DRESSING OF DATA

A clear distinction should be made between *reporting of data* and *hand-dressing of data*.

Reporting of data involves specific calculations based on original measurements and the formatting thereof to show compliance. For example, reporting data as a percentage of time (or duration) by which the value was exceeded (or met) during the compliance monitoring period.

Hand-dressing of data is the modification of data that will result in the non-preservation of original measurements or their accuracy. The DWSNZ makes provision for avoiding a false record of non-compliance when the water is not being supplied for drinking. This could for example be during plant-specific routines when back-washing filters might create a temporary exceeding of certain maximum allowed values. It does not however, imply any modification of original measurements, but rather that compliance monitoring results are not reported for the period in question.

4.4 INSTRUMENTATION ACCURACY

Not all instrumentation is created equal. Apart from varying quality and reliability, applying the correct instrumentation for the job and understanding the behaviour of the substance being measured is critical. For example, using ultra-sonic level measurements in a well where the measured liquid has the tendency to foam up will give misleading level readings and incorrect derived flow rates that could result in faulty dosaging in subsequent processing.

Lack of maintenance and not performing regular calibration will lead to instrumentation drift over time. The quality assurance procedures associated with the calibration of instrumentation has to be approved by the Drinking Water Assessor (DWA).

4.5 DEALING WITH AND PREVENTING MISSING DATA

The SCADA system should always have clear indications of the current status of any specific device making up the solution, either in the form of an accurately time-stamped system log file or device-specific log files that can be cross-referenced with compliance measurements.

During day-to-day operations there can be many possible failures, each of which could cause data to be missing or lost.

Communication failures are the most common problem and could be caused by marginal coverage, weather conditions, equipment failures, network or services issues. Implementing redundant communication mechanisms on critical paths will make a significant improvement, but there is still the risk of power, computer or instrumentation failures and major emergencies (earthquakes, tsunamis, hurricanes and volcanic eruptions to name a few), where implementing redundancy by duplication or alternative paths will make the SCADA system implementation economically less viable.

Logging data on the Remote Terminal and maintaining the data in a circular buffer locally in the device provides an option to recover missing data. Keeping copies of the raw measured data and archiving the data at the Master Station while also exporting data to an external geographically separated or cloud-based database results in the most cost-effective and technically efficient data-resilience strategy.

4.6 COLLECTED DATA VALIDITY

As described above in 2.2 Instrumentation is the specialised electro-mechanical devices that will translate measurements into either analogue or digital signals. The instrumentation could give a 0-20 mA, 4-20 mA, 0-5V or just a pulse as a function of the measured parameter.

Data validity refers to the correct definition of these instrument functions in the SCADA system, since the SCADA system will not necessarily have sufficient intelligence on its own to uncover this type of configuration error.

Specifications and system solution descriptions are rarely sufficiently detailed, and the actual implementation of instrumentation in the field is contracted out in many cases. But the integration and definition of the instrumentation function in the SCADA system is usually performed in-house.

For example, instrumentation generating an analogue representation of 4-20 mA will deliver a 20% error, if in fact the sensor operates over a 0-20 mA range. Where the function generated is in pulses, the difference of one pulse for every litre/min vs. m^3/min could have disastrous results.

4.7 TRACEABILITY

Traceability gives the ability to pin-point what went wrong and to take the necessary corrective action to avoid a similar situation from happening again.

The system log files in a SCADA system is in many cases an under-utilised resource that, when cross-referenced with accurately time stamped measurements, can provide a step-by-step insight into the actions leading up to or following a specific event of interest.

5 CONCLUSIONS

5.1 SYSTEM DESIGN

The most effective method of SCADA system design is one that follows a “Bottom Up” approach. Involve your SCADA supplier at the earliest planning stages, before specifying and purchasing significant plant. They might be able to help minimise the effort required, offer alternatives not previously considered and limit costly overruns.

One pit-fall that should be avoided at all costs is “gold plating”, the development of a requirement beyond what is required operationally or by the DWSNZ, where the cost of the additional data being logging and monitored is not worth the value it adds.

5.2 RESILIENCE

The most resilient SCADA networks are the ones with the ability to store data (or in this case DWSNZ raw measurement data) at various points in the network for later recovery, and where a balance is struck between duplication of equipment and simplicity.

5.3 TRANSPARENCY

Incomplete automation is the biggest threat to transparency in a SCADA system.

If the SCADA system "thinks" it is monitoring and logging data, but manually controlled valves in the system are operated, invalid data measurements and a certain amount of unaccounted product will result.

5.4 ACTIVE COMPLIANCE MONITORING

A well-engineered SCADA system with the necessary resilience and transparency will be able to predict well in advance when transgressions and non-compliance will take place, thus allowing the appropriate remedial action to be taken.

5.5 GOVERNANCE

A SCADA system consists of rules, best practices and the necessary logic to track and manage processes. As a tool for water suppliers and compliance assessors it should be set up and used to provide a framework for system governance, and not for just its ability to log data, also ensuring its own integrity is maintained at all times so that all drinking water supplied to any community in New Zealand is safe and wholesome.

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ABBREVIATIONS

CSD	Circuit switched data
DNP3	Distributed network protocol
DWSNZ	Drinking-water Standards for New Zealand 2005 (Revised 2008)
EDGE	Enhanced data rates for GSM evolution
GDWQ	Guidelines for drinking-water quality
GPRS	General packet radio service
HMI	Human machine interface
mA	milli Ampere
MAV	Maximum allowed values
PLC	Programmable logic controller
RTU	Remote Terminal unit
SCADA	Supervisory control and data acquisition
SMS	Short message service
UHF	Ultra high frequency
USEPA	US environmental protection agency
VHF	Very high frequency
WHO	World health organization