Drinking Water Contamination Warning Systems – Design and Implementation of an Online Water Quality Monitoring System for Military Water Systems

Technical Information Paper #31-008-0609

PURPOSE

To provide military facilities and installations with information and guidance on designing and implementing an online water quality monitoring system for the detection of intentional contamination of drinking water distribution systems.

REFERENCES

Appendix A contains a list of references.

INTRODUCTION

Intentional Contamination of Drinking Water Distribution Systems

The most vulnerable component of a drinking water system to an intentional contamination event is the distribution system (references 1-3). A drinking water system's distribution infrastructure is ubiquitous in the environment. It is present in the form of hydrants on a roadside, elevated and aboveground storage tanks in remote areas, and faucets and taps in homes and offices. Drinking water distribution systems are vulnerable to intentional contamination because of the large number of potential access points, the relative ease of access, and the lack of any additional treatment barriers beyond a disinfectant residual. Contamination of a drinking water distribution system can have tremendous adverse effects – loss of life, extensive contamination of infrastructure and environment, and fiscal strains from recovery and remediation efforts. Therefore, the need exists to develop an effective contamination warning system (CWS) to reduce the vulnerability of a drinking water distribution system to intentional contamination. This Technical Information Paper (TIP) provides guidance to military facilities considering investing in online water quality monitoring systems for use primarily as a tool for detecting intentional contamination of drinking water distribution systems.

Contamination Warning System Development

Military facilities should consider online water quality monitoring systems as one of several tools or components to use for the detection of intentional distribution system contamination events. The U.S. Environmental Protection Agency (EPA) is at the forefront in developing a CWS.

Homeland Security Presidential Directive 9 directs the EPA to "develop robust, comprehensive, and fully coordinated surveillance and monitoring systems, including international information, for … water quality that provides early detection and awareness of disease, pest, or poisonous agents" (reference 4). In response to this Presidential Directive, the EPA introduced the Water Security Initiative in an effort to develop a CWS for distribution system security. A CWS collects and analyzes data from multiple sources of information, or components, to detect an intentional or unintentional contamination event early enough to minimize or reduce potentially devastating consequences. The components of a CWS include (reference 1):

Online Water Quality Monitoring System

Online water quality monitoring systems consist of a platform of various online water quality parameter monitors [e.g., disinfectant residual, total organic carbon (TOC), and pH] located at pre-determined sites within the distribution system. Accompanying software analyzes data for abnormalities of the water quality to detect contamination events. Many contaminants affect various water quality parameters allowing the software to recognize abnormal water qualities.

Public Health Surveillance

Public health surveillance is the collection and analysis of various public health data to identify potential drinking water contamination events. Over-the-counter drug sales, 911 calls, and infectious disease surveillance systems are sources of public health data. This surveillance involves close coordination and involvement with public health personnel.

Consumer Complaint Surveillance

A centralized, consumer complaint surveillance procedure can help identify potential contamination events. Consumers will report unusual taste, odor, and appearance of water to their Department of Public Works (DPW) work-order desk or directly to water system personnel.

Enhanced Security

Providing additional security countermeasures for distribution system components (e.g., storage tanks, pump houses, and valve pits) can help identify potential contamination events through detection or discovery of evidence of intruders. Operational security countermeasures such as adding a distribution system component to the facility's Mission Essential Vulnerable Area list, and physical security countermeasures such as an intrusion detection system (IDS) are examples of enhanced security.

Sampling and Analysis

Increased routine distribution system sampling and analysis, and sampling and analysis as a response from other CWS components is used to help identify or confirm potential contamination events. Sampling and analysis can be conducted for groups of contaminants (e.g., pesticides) or specific microbial, chemical, or radiological contaminants.

The CWS components are used for monitoring and surveillance of a distribution system in order to detect potential contamination. When one or more components indicate a potential contamination event has occurred, the water system personnel must act on this information. The final part of the CWS is providing guidance on how to act when CWS components indicate a potential contamination event; this is called consequence management. The overall CWS operational plan is illustrated in Figure 1.

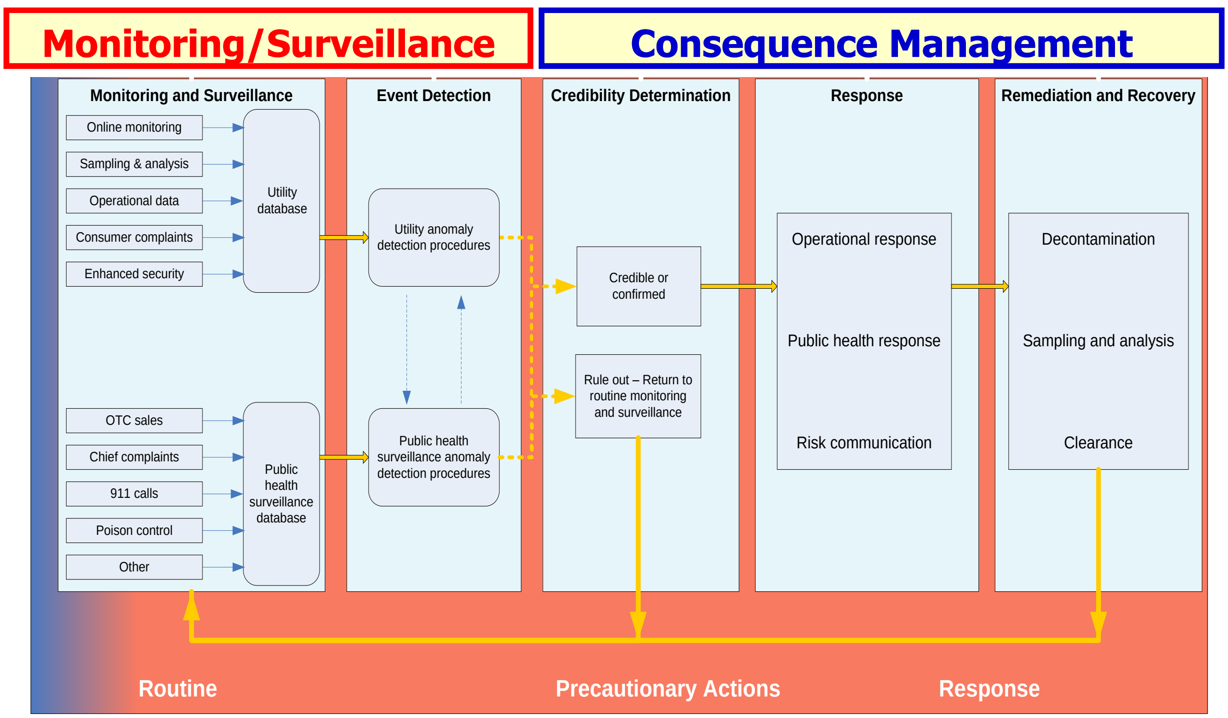

Figure 1. CWS Operational Plan (reference 1).

To have a useful CWS, a military facility does not necessarily need to implement all the CWS monitoring and surveillance components. However, implementing as many CWS components as possible will result in quicker detection of contamination events, and ultimately lead to fewer or less severe adverse consequences. More information on the EPA's Water Security Initiative and CWS can be found at http://cfpub.epa.gov/safewater/watersecurity/initiative.cfm.

U.S. Army Corps of Engineers Construction Engineering Research Laboratory (USACERL) Initiative

The USACERL is working on a project to develop a more seamless and effective online water quality monitoring system. The USACERL's enhanced online water quality monitoring system improves upon EPA's online water quality monitoring system concept in two ways: 1) forms a more seamless integration into a water system's existing Supervisory Control and Data Acquisition (SCADA) system and distribution system water quality model; and 2) develops an improved water quality database that allows more accurate contaminant fate and transport modeling of drinking water distribution systems. The USACERL online water quality monitoring system will provide data in near real-time to a SCADA network. Data from the SCADA network is then entered into a highly calibrated and accurate distribution system water quality model containing the improved water quality fate and transport database for analysis. When a contamination event is detected and a specific contaminant is initially identified by the online water quality monitoring system, the water quality model can immediately run scenarios to determine extent, location, and concentrations of contaminants throughout the distribution system at various times. This information will allow a water system operator to more quickly conduct initial response actions (such as isolation or taking storage tanks off-line). As part of this project, the USACERL is currently operating three online water quality monitoring systems at a continental United States military facility.

OVERVIEW OF ONLINE WATER QUALITY MONITORING SYSTEMS

The basic elements of an online water quality monitoring system are the online water quality monitoring equipment and software that analyzes the data produced by the monitoring equipment to see if abnormal water quality conditions are present that may indicate contamination. For a water system, an online water quality monitoring system would consist of a single set or platform of online water quality monitoring equipment (e.g., pH and disinfectant residual) and associated analyzing software or multiple sets of monitoring equipment and analyzing software located at pre-determined locations throughout a distribution system. For the purpose of this TIP, a platform of online water quality monitoring equipment and associated analyzing software is referred to as a sensor. An online water quality monitoring system consists of single or multiple sensors located throughout a distribution system. The sensors provide data and analysis to a centralized location [e.g., the water treatment plant (WTP)] via a SCADA network. Figure 2 shows a sensor installed at a military facility. As implied by the description of an online water quality monitoring system, it does not monitor for specific contaminants. Monitoring for many different specific contaminants is currently not feasible (reference 5). Instead, research shows that many contaminants affect one or more water quality parameters such as chlorine residual, TOC, pH, conductivity, and turbidity (references 5-7). Research also shows that online water quality monitoring systems have a high potential to detect many groups or classes of contaminants (Table 1) (references 1 and 2). Military facilities should consider additional components of EPA's CWS (e.g., public health surveillance and consumer complaint surveillance) to detect other groups or classes of contaminants. The software that analyzes data from the online water quality monitoring equipment is referred to as an Event Detection System (EDS). The function of the EDS is to identify and alarm when changes in water quality indicate a potential contamination event (reference 8). The EDS must be able to recognize and learn typical water quality as well as routine and known nonroutine events that cause changes in water quality (such as seasonal changes in source water or pipe breaks).

Figure 2. Online Water Quality Monitoring System Sensor.

Table 1. Contaminant Groups Detected by Online Water Quality Monitoring Systems.

Petroleum products	Pesticides (with odor or taste)
Inorganic compounds	Pesticides (odorless)
Bacterial toxins	Plant toxins
Pathogens causing diseases with unique symptoms	Persistent chlorinated organic compounds
Pathogens causing diseases with common symptoms	

Military facilities considering investing in an online water quality monitoring system must carefully evaluate the potential benefits of such a system against available resources and develop a plan of action for implementing the system. An effective online water quality monitoring system requires a significant long-term commitment. Capital costs are high and routine operational costs must be included in future budgets. Such a system requires a long-term commitment by facility personnel who are responsible for operating and maintaining it. In many situations, this results in additional duties for personnel already assuming more duties from a down-sized staff. The following sections provide information to help personnel determine how to successfully design and implement an online water quality monitoring system at their facility.

DESIGN OF AN ONLINE WATER QUALITY MONITORING SYSTEM

Objectives of an Online Water Quality Monitoring System

Main Objective

The goal of an online water quality monitoring system is to detect intentional contamination events. There must be a main objective decided upon to achieve this goal. Therefore, the first step in the design of an online water quality monitoring system is to determine the main objective. The main objective could be:

- Increasing protection of public health (Soldiers, civilians);
- Reducing extent of water system contamination;
- Reducing amount of contaminated water; and
- Increasing protection of mission-critical facilities.

These main objectives may or may not result in the same online water quality monitoring system design. Careful consideration to each objective and its trade-offs must be given on a facility-specific basis to determine the main objective of your online water quality monitoring system. A military facility with no housing or barracks and a significant number of mission-critical facilities may want to consider protection of mission-critical facilities as its main objective. Choosing this objective may also increase protection of public health if the majority of personnel are present and working at the mission-critical facilities.

Secondary Objectives

Significant resources are necessary to implement an effective online water quality monitoring system. Most facilities will choose not to use an online water quality monitoring system if it can only meet a single objective. Therefore, an online water quality monitoring system must meet additional objectives or provide multiple benefits. Other benefits an online water quality monitoring system can provide are:

- Gain a better understanding of water quality throughout a facility’s distribution system. Online water quality monitoring systems can either replace or, better yet, supplement existing distribution system monitoring conducted by water system personnel.

- Improve distributed water quality by identifying treatment and other routine operational procedures that degrade water quality. At the military facility where USACERL is testing an online water quality monitoring system, the water system operator was able to identify a routine procedure at the supplier’s WTP that degraded water quality after reviewing water quality data generated by the system. Routine operations such as turning pumps on and off and using different water sources can also change distributed water quality. Identifying and subsequently modifying routine treatment and operation practices will improve distributed water quality.

- Identify nonroutine events such as disruptions in treatment and distribution (e.g., treatment process breakdown or pipe break). At the facility where the USACERL online water quality monitoring system is operating, the water system operator was able to identify a pipe break in the supplier’s distribution system due to changes in water quality.

Components of an Online Water Quality Monitoring System

Online Water Quality Monitoring Equipment

A key aspect of an online water quality monitoring system is choosing the water quality parameters to monitor and the associated monitoring equipment. As discussed earlier, certain water quality parameters are affected by various classes or groups of contaminants (see Overview of Online Water Quality Monitoring Systems). The best approach is to consider as many water quality parameters as necessary to cover a majority of potential contaminant classes (Table 1) and pilot test online equipment from various vendors. Research shows that TOC, free available chlorine (FAC), and conductivity are affected most by the majority of potential contaminant classes (references 5-7). Priority consideration should be given to monitoring these parameters. Various other water quality parameters (while shown not to be as sensitive or reliable) should also be considered. These include pH, oxidation reduction potential (ORP), chloride, and turbidity. Finally, consideration may also be given to surrogate parameters that could replace other water quality parameters as a cost-effective measure. For example, ultraviolet absorbance at 254 nanometers (UV_{254}) can be a suitable alternative to TOC (reference 9). Ultimately, choice of water quality parameters is facility-specific and depends upon existing water quality and treatment. There are several manufacturers and vendors of online water quality monitoring equipment. Table 2 provides a non-inclusive listing. Facility personnel should consider local or regional vendors since they will provide the best service. Typical costs for most online water quality monitoring equipment (pH, ORP, FAC, conductivity, and turbidity) range from $2,000-$6,000. An online TOC analyzer costs considerably more, $15,000-$30,000.

Table 2. Manufacturers of Online Water Quality Monitoring Equipment (reference 5).

Manufacturer
Dascore, Inc., (Jacksonville, Florida)
Hach Company, (Loveland, Colorado)
ManTech Associates, Inc., (Ontario, Canada)
Rosemount Analytical, Inc., (Irvine, California)
YSI, Inc.,(Yellow Springs, Ohio)
Applied Microsystems Ltd., (Sidney, BC, Canada)
Analytical Technology, Inc., (Collegeville, Pennsylvania)
Isco, Inc., (Lincoln, Nebraska)
Clarion Systems, Inc., (Indianapolis, Indiana)
GE/Sievers Ionics, Inc., (Boulder, Colorado)
Wallace and Tiernan Products, (Vineland, New Jersey)

When deciding on online water quality equipment, facility personnel should evaluate parameters based on distributed water quality and current water treatment. Historical water quality monitoring and water system operator experience and knowledge are helpful in determining which water quality parameters to monitor. As a guide, facilities should pilot test online monitoring equipment from various vendors for at least TOC (or UV_{254}), FAC, and conductivity. Although the majority of military water systems use FAC as a residual disinfectant in distribution systems, some may use chloramines. In those cases total chlorine, instead of FAC, should be a parameter for consideration. The use of third-party testing and validation information will help facility personnel narrow the list of vendors to choose from. The EPA's Environmental Technology Verification (ETV) program and Technology Testing and Evaluation Program (TTEP) conduct third-party verifications of online monitoring equipment for drinking water (references 10 and 11). Two manufacturers, HACH and Clarion Sensing Systems, provide packaged systems containing both online monitoring equipment and EDS software – the HACH Guardian Blue™ and Clarion Sentinel™ 500. Both packaged systems have been verified through the ETV program (references 12 and 13). The Guardian Blue consists of a platform of monitoring equipment analyzing for five parameters – TOC, turbidity, conductivity, FAC, and pH – and event detection software. Similarly, the Clarion Sentinel 500 monitors pH, conductivity, FAC, ORP, and temperature and has EDS software. The HACH Guardian Blue costs about $60,000-$80,000. The Clarion Sentinel 500 costs about $10,000-$30,000. (Guardian Blue™ is a trademark of HACH Company, Loveland, Colorado. Sentinel™ is a trademark of Clarion Sensing Systems, Inc., a division of ECSI, Clifton, New York.)

Event Detection Systems

Monitoring and producing water quality data alone will not help identify contamination events quicker. The data produced by the online monitoring equipment must be analyzed and interpreted. This is the function of the EDS. In addition to online monitoring equipment an EDS is necessary to analyze data and identify potential contamination events. EDS' use algorithms to analyze the data generated by the online monitoring equipment to filter out variations in water quality that typically occur and identify contamination events (reference 8). Figure 3 shows example output of an EDS (reference 14). Currently, there are only three commercially available EDS' specifically developed for drinking water applications. They are the HACH event monitor, the Clarion Sensing Systems Sentinel, and the Frontier Technology H20 Sentinel™. The HACH event monitor and Clarion Sensing Systems Sentinel are part of packaged systems containing both online monitoring equipment and EDS software, the HACH Guardian Blue and the Clarion Sentinel 500, respectively. The Frontier Technology H20 Sentinel is a stand-alone EDS that is compatible with any online water quality monitoring equipment. There are other EDS' not specifically developed for drinking water applications, but have been used in other applications and have the potential to be used for an online water quality monitoring system (reference 8). In addition to commercially available EDS', EPA and Sandia National Laboratories developed the CANARY EDS; a public domain EDS (reference 15). The EPA hopes that vendors will use CANARY to develop future EDS' specific for online water quality monitoring systems. When choosing an EDS, facility personnel must ensure its compatibility with online monitoring equipment, existing SCADA system and communications architecture. (H20 Sentinel™ is a trademark of Frontier Technology, Inc., Goleta, California.)

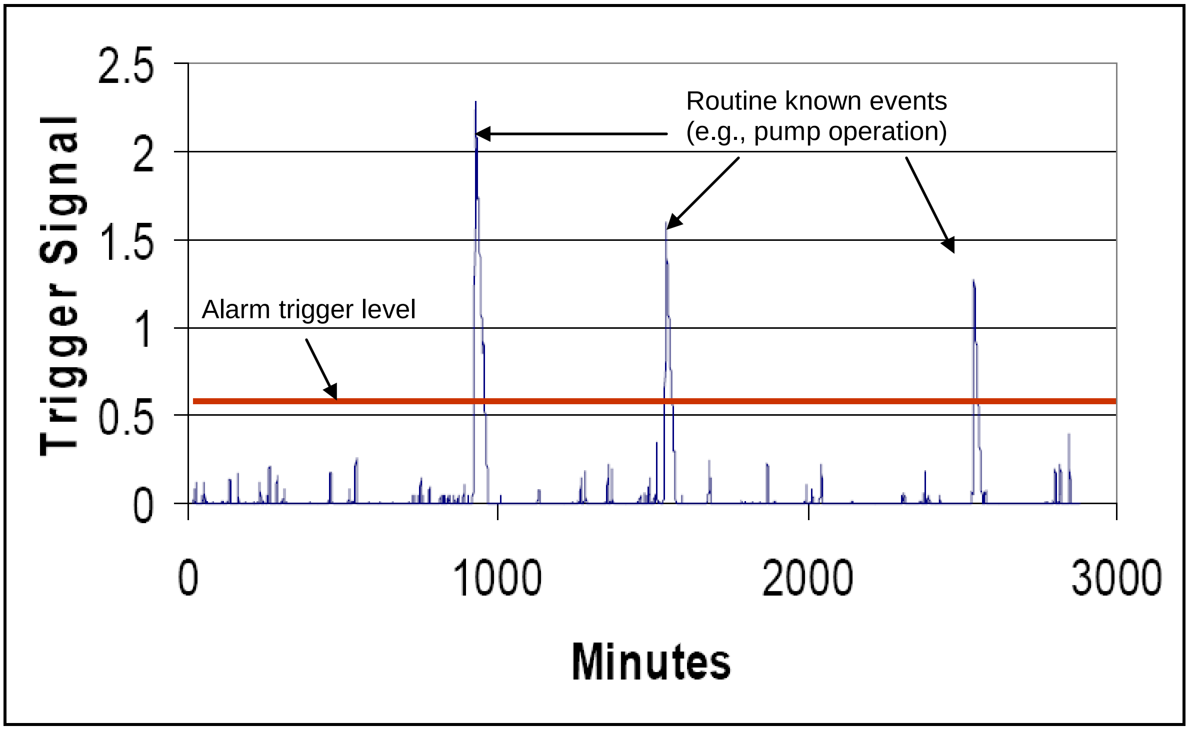

Figure 3. Example EDS Output (reference 15).

Locations and Number of Sensors in an Online Water Quality Monitoring System

Determining the number of sensors and their locations in the distribution system is a critical process in meeting the main objective of an online water quality system and maximizing cost-effectiveness. It has been demonstrated that using a calibrated, accurate water quality model with optimization software for locating and determining the number of sensors is the best approach (references 2, 9, 16, and 17). The use of a model and optimization software is strongly recommended because of the significant resources that an online water quality monitoring system requires. If your facility's water system does not have a hydraulic or water quality model of the distribution system, make plans to develop one before moving forward with an online water quality monitoring system. See Implementation of an Online Water Quality Monitoring System – Distribution System Water Quality Model for a discussion on distribution system water quality models. Currently, there are two readily available software tools for optimizing locations - the Threat Ensemble Vulnerability Assessment and Sensor Placement Optimization Tool (TEVA-SPOT) and PipelineNet (references 15 and 18). Both are public domain software. Using the distribution system model and sensor placement software, numerous contamination scenarios are analyzed to determine optimum locations to place sensors. Also, information on the most cost-effective number of sensors is provided. Figure 4 shows an example of effectiveness in meeting the main objective of a water quality monitoring system (e.g., increased protection of public health) based on the number of sensors placed at distribution system locations identified by sensor placement software. The example in Figure 4 is based on results from real-world case studies. In the figure, four to seven sensors located at specific locations throughout a distribution system are 65-80% effective in meeting the main objective. More than 10 sensors result in only a marginal increase in meeting the main objective (85-90%). Based on this example, facility personnel should consider four to seven sensors to meet the main objective and maximize cost-effectiveness. The locations identified by the sensor placement software should be further ranked by facility personnel to determine final sensor locations. Ease of operator access, access to sewer, water, electrical, and communications all need to be considered when choosing locations. Consideration should also be given to locating sensors at or near an existing monitoring site (e.g., Total Coliform Rule monitoring site). Locating sensors at existing monitoring sites reduces the burden on operators by not adding an additional site to routinely visit.

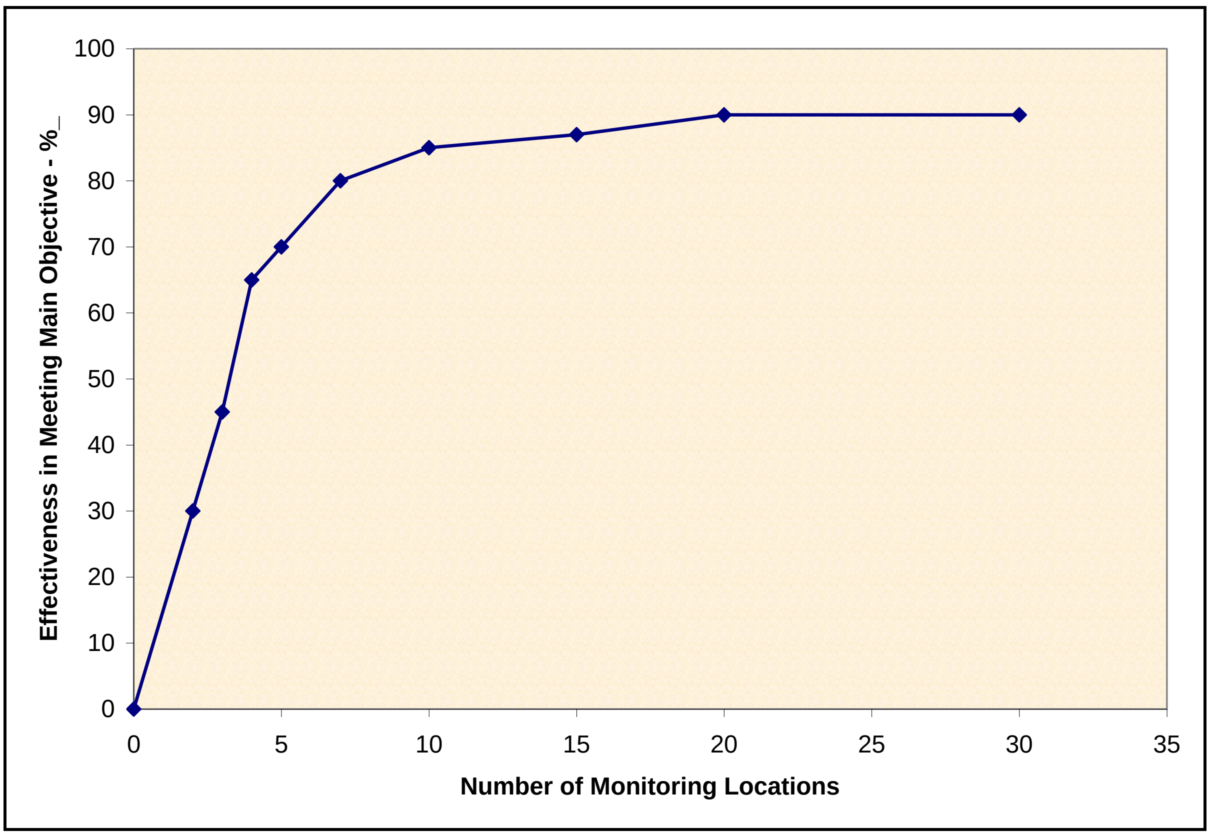

Figure 4. Number of Monitoring Locations Versus Effectiveness in Meeting Main Objective.

Communications and Data Management

No less important than online monitoring equipment and an EDS is the consideration of managing the data generated by sensors. Large amounts of data can be generated when even a few sensors are located throughout the distribution system. This requires adequate communication and storage infrastructure that can centrally retrieve and store data. Military water systems with an existing SCADA system are at an advantage. In fact, EPA considers SCADA systems a critical feature for managing data produced by an online water quality monitoring system (reference 3). SCADA systems can provide the communication and data acquisition infrastructure necessary to manage the data produced. The main concern for military water systems with a SCADA system is the ability to integrate the online water quality monitoring system components. Military water systems that do not have a SCADA system must consider alternatives for managing the data produced. Water systems without SCADA must install communications equipment (e.g., transmitters, receivers) to obtain data from online water quality monitoring systems. Data can be transmitted using radio, direct wire, digital subscriber line, and cellular telephone among others (reference 2). The facility Local Area Network may be used. Security of generated and transmitted data must also be considered. Ideally, military water systems using SCADA should isolate their SCADA from other facility communication networks. Water systems without SCADA should also consider the security of the communication method of choice.

IMPLEMENTATION OF AN ONLINE WATER QUALITY MONITORING SYSTEM

Overview

A recommended process for implementing an online water quality monitoring system is outlined in the flowchart shown in Figure 5. Specifics of the implementation process are discussed in this section. The implementation process shown in the flowchart and discussed here is intended as a guide for military facilities with varying levels of resources that have decided to invest in an online water quality monitoring system. In general, military water systems should have a distribution system water quality model prior to beginning the process of implementing their online water quality monitoring system. Systems without a distribution system model should plan to develop one prior to investing in an online water quality monitoring system. Systems that have a distribution system model should plan to update and calibrate it. The design, installation, and operation of the online water quality monitoring system can then be implemented.

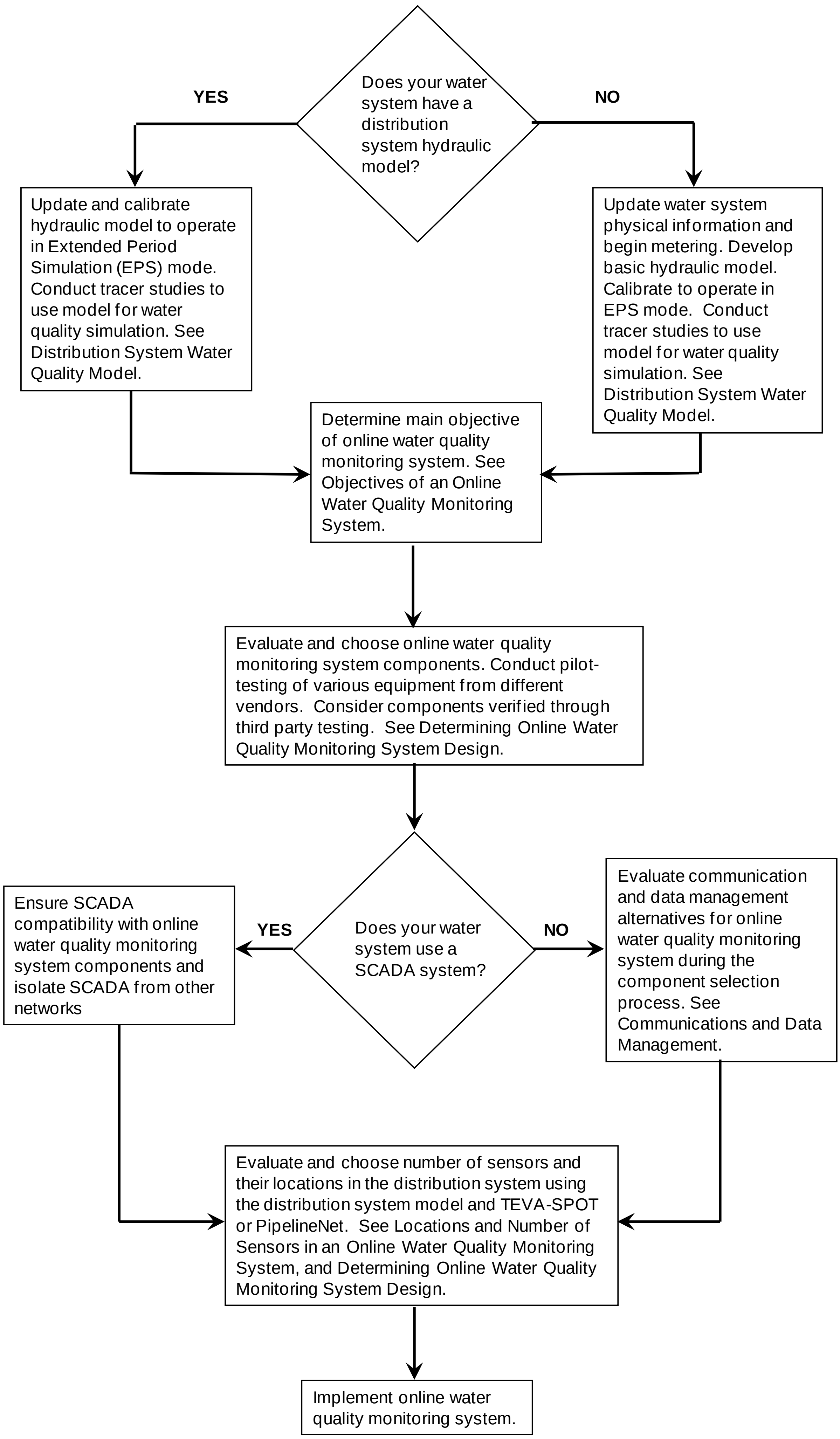

Figure 5. Implementation Process Flowchart.

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Distribution System Water Quality Model

Before facility personnel begin the process of implementing an online water quality monitoring system, they must ensure that an accurate distribution system model capable of running water quality simulations has been developed. Distribution system water quality models should be considered an integral part of an online water quality monitoring system. As discussed earlier, distribution system water quality models are critical in determining optimum locations of sensors in the distribution system. It has been demonstrated that using distribution system models with sensor placement software results in determination of locations providing the maximum benefit. Thus, the need to have a distribution system model is strongly recommended.

Multiple Benefits of a Distribution System Water Quality Model

A distribution system water quality model provides additional benefits. Should a distribution system contamination event occur the water quality model can provide information on location, extent, and concentrations of contaminants that will help in decision making during emergency response actions. The USACERL initiative will provide better fate and transport information making water quality models even more accurate and useful in emergency response. Distribution system water quality models can also be useful in master planning (e.g., sizing mains for new construction or evaluating water quality issues from reduced operations); evaluating operational strategies to maximize energy and cost savings; fire flow analysis; developing unidirectional flushing programs; and models can be used for regulatory compliance (e.g., Stage 2 Disinfectants Disinfection Byproducts Rule – Initial Distribution System Evaluation).

Developing a Distribution System Water Quality Model

A distribution system model capable of running water quality simulations is a highly accurate and calibrated hydraulic model that simulates a real distribution system for extended periods of time (e.g., hours or days). This type of hydraulic model is also called an Extended Period Simulation (EPS) model. An EPS model can be further calibrated using tracer studies to allow its use for simulating water quality in a distribution system. For purposes of this document, EPS models are referred to as water quality models. To develop a water quality model, water systems need to first develop a basic hydraulic model (if they do not already have one). This requires three critical pieces of information – elevation data, physical information of the water system, and demand/water usage data. Elevation data is fairly accurate and readily available through most master planning offices. Handheld Global Positioning System devices are a source of additional, although less accurate, elevation data. Physical information includes pipe lengths and diameters, valve and hydrant locations, and storage tank and pump information. Facility personnel must ensure that distribution system maps are up-to-date and accurate. The most difficult to determine is demand/water usage data. Typically, military water systems lack metering in the distribution system. Knowing where, when, and how much water goes in a distribution system is critical in developing a water quality model accurately representing actual distribution system operation. Most distribution system modeling software includes algorithms to optimize accuracy with respect to water usage. However, to develop the most accurate water quality model, facilities should implement a water metering plan and begin installing water meters throughout the distribution system. Since Service Component regulations exist requiring metering (e.g., Army Regulation 420-1, reference 19) and metering can be a part of an overall sustainability initiative, funding could be obtained for a metering plan. Once the basic water hydraulic model has been developed, it can be further calibrated to accurately simulate operation over extended periods of time. Finally, tracer studies must then be conducted to calibrate the EPS model to be able to accurately simulate water quality. References 20 and 21 contain detailed guidance on distribution system water modeling.

Determining Online Water Quality Monitoring System Design

System Components

The first task in the design of an online water quality monitoring system is determining the main objective. Although increasing protection of public health can be considered the "default" alternative, other objectives such as increasing protection of mission-critical facilities may be a better choice depending on the facility's physical size, mission, and population served. This is a decision that must involve several organizations. In addition to the facility Command and DPW, Security and Preventive Medicine should also be involved in this process. After determining the main objective, the process of choosing water quality parameters to monitor and locations and number of sensors can then begin. Choosing parameters to monitor should be based on existing treatment processes and current water quality information. At a minimum, consider TOC (or UV_{254}), FAC, and conductivity. Plan to conduct pilot testing of online water quality monitoring equipment from at least one or two local or regional vendors. Consider pilot testing equipment that has been verified under the EPA ETV or TTEP programs. Additionally, consider operation and maintenance requirements. For water systems having their own source and treatment, conduct pilot testing on the treated water and at least one location in the distribution system. For water systems that purchase all their water, conduct pilot testing at the point-of-purchase and at least one location in the distribution system. Determine which EDS to use. HACH and Clarion Sensing Systems provide packaged sensor systems containing both online water quality monitoring equipment and an EDS. If evaluating an EDS from a different vendor than the online monitoring equipment, ensure compatibility. The Frontier Technology EDS system is compatible with existing online water quality monitoring equipment.

Locations and Number of Sensors

The first step in identifying locations is to use the water quality model and sensor placement software (i.e., TEVA-SPOT or PipelineNet) to develop a list of locations and number of sensor systems. Using this list, evaluate identified locations to develop a prioritized list. Conduct site visits of identified locations. Consider operator access, site security, environmental conditions, and existing infrastructure when developing the prioritized list of locations. Locations identified by the sensor placement software may not be suitable and water system personnel may identify a nearby location not chosen by the software. Determine if any identified locations are scheduled to receive additional physical or operational security upgrades as a result of a past Vulnerability Assessment. The facility Force Protection Office should be contacted. For example, a past Water System Vulnerability Assessment identified a storage tank as a high risk and the Force Protection Office programmed funds to provide Closed Circuit Television, an IDS, and increased security patrols. If the storage tank is chosen as a location for a sensor by the sensor placement software, it may no longer be a good location based on the impending security upgrades. Available resources (i.e., funding) may limit the ability to choose the full number of optimum locations identified by the placement software and/or the types of water quality parameters that can be monitored. Consider a phased approach where, for example, sensors can be installed at all locations over the course of several fiscal years. Some sensors can monitor for fewer water quality parameters with the understanding that contaminant coverage becomes limited when fewer water quality parameters are monitored.

Installation

Two objectives must be considered when installing sensor components in the distribution system. First, and foremost, components must be installed to ensure accurate, long-term operation. Second, sensor components should be installed to optimize operator and/or vendor access and maintenance. To ensure proper operation, components should be located in an enclosed, temperature-controlled facility, and protected from direct sunlight (reference 22). Interdependent infrastructure (electrical, sewer, communications) should be accessible. Access to drinking water should be as close as possible to the sensor equipment (e.g., within 6-10 feet) to minimize sample delay time and potential water quality inaccuracies due to increased detention time in long sample lines. To optimize access and maintenance, the sensor equipment should be mounted reasonably close with adequate space to allow easy access for maintenance, cleaning, and calibration. Avoid confined spaces. Facility personnel responsible for the routine operation and maintenance should work closely with the vendor representatives during installation.

Operation

Start-up

System start-up primarily consists of the EDS tool “learning” water quality. At start-up, the EDS tool alarm trigger is set to a fairly insensitive level to allow the EDS software to begin learning baseline water quality and typical events that change water quality. Facility water system personnel must plan on devoting significant time during start-up to help the EDS recognize and learn normal variations and known changes in water quality. The intent is to set an alarm trigger set point that minimizes false positives, yet is sensitive enough to detect abnormal water quality changes, possibly indicating a contamination event. Also during this time the online monitoring equipment is checked frequently to ensure proper operation and accuracy.

Routine

Routine, long-term operation requires ongoing calibration, cleaning, and maintenance. Several support alternatives are available for routine operation and maintenance. Contracting with vendors, conducting in-house routine operation and maintenance with facility personnel, or a mix of contracting and in-house support are all effective alternatives. The most effective will be specific to each facility. Careful consideration must be made on how much responsibility for the routine operation of an online water quality monitoring system is given to facility personnel. A phased approach can be considered where routine operation is turned over from the vendor to facility personnel over a period of 1-2 years.

Responsibilities

Determining responsibilities and which organizations to involve in the process of designing, installing, and operating an online water quality monitoring system is also critical. From the very beginning responsible parties must be identified and involved. Key personnel to involve include:

- Water system personnel
- Facility security
- Information Technology personnel
- Environmental personnel
- Preventive Medicine personnel
- Contracting personnel
- Facility leadership
- SCADA vendor representative (if facility has SCADA)
- Water system model vendor representative (if facility has model)
- Water supplier representative (if facility purchases water)

Each stage (design, installation, and operation) of an online water quality monitoring system will require the involvement of personnel from several of these organizations. The most critical involvement in this entire process comes from the water system and public works personnel. There must be a willingness to accept the additional responsibilities for an online water quality monitoring system to be effective. Many military facilities have, over the years, experienced a downsizing in personnel and remaining personnel have subsequently been given more responsibilities in their daily operations. Adding the duties of operating and maintaining an online water quality system needs to be evaluated and discussed with personnel.

CONCLUSIONS

An online water quality monitoring system is a valuable component of an overall CWS that can be effective in detecting distribution system contamination early enough to reduce or minimize potentially devastating consequences. Military facilities considering investing in an online water quality monitoring system must carefully evaluate the multiple benefits of such a system against available resources and develop a plan of action for implementing the system. An effective online water quality monitoring system requires a significant long-term commitment. Capital costs are high and routine operational costs must be included in future budgets. Such a system requires a long-term commitment by facility personnel who will be responsible for operating and maintaining it. In many situations, this results in additional duties for personnel already assuming more duties from a down-sized staff. A recommended process for implementing an online water quality monitoring system is outlined in the flowchart shown in Figure 5. The implementation process is intended as a guide for military facilities with varying levels of resources that have decided to invest in an online water quality monitoring system. In general, military water systems should have a distribution system water quality model prior to beginning the process of implementing their online water quality monitoring system. The design, installation, and operation of the online water quality monitoring system can then be determined and implemented. The most effective online water quality monitoring system will be one designed, implemented, and operated with the involvement of personnel from several facility organizations.

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APPENDIX A

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