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Benefits Of A Surveillance And Response System (SRS) Dashboard - The Philadelphia Water Department Experience

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BENEFITS OF A SURVEILLANCE AND RESPONSE SYSTEM (SRS) DASHBOARD – THE PHILADELPHIA WATER DEPARTMENT EXPERIENCE

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ABSTRACT

The Philadelphia Water Department developed a comprehensive Surveillance and Response System (SRS) (formerly Contamination Warning System) for its drinking water system under a Water Security Initiative grant from the U.S. Environmental Protection Agency. A full-scale SRS is comprised of four monitoring/surveillance components – Online Water Quality Monitoring, Enhanced Security Monitoring, Consumer Complaint Surveillance, and Public Health Surveillance, and two response components – Consequence Management and Sampling and Analysis. In this project, information from four surveillance components were integrated into a centralized platform and displayed on the SRS Dashboard. The Dashboard is currently used to i) provide integrated information for the user to determine whether a water contamination event has occurred and ii) provide a gateway by which to activate the appropriate response components. This paper provides an overview of the SRS Dashboard and presents some case studies where the Dashboard was used to resolve water quality issues in the water distribution system.

INTRODUCTION AND OBJECTIVES

Background

The Philadelphia Water Department (PWD) provides water, wastewater, and stormwater services to Philadelphia and some of the greater metropolitan area. PWD has two drinking water treatment plants on the Schuylkill River and one on the Delaware River that treat an average of 275 million gallons per day. The drinking water distribution system is split into twelve pressure districts and contains 3,133 miles of water main. Additionally, PWD provides fire protection through more than 25,000 hydrants and maintains an extensive system of tanks, reservoirs, pump stations, and other related distribution and treatment infrastructure.

As a municipal utility, PWD's goal is to provide customers with high quality, reliable, and safe drinking water and to manage wastewater and stormwater collection and treatment. Due to its commitment to providing high quality service and its existing policies being in line with improving security and water quality, Philadelphia was one of the five public water utilities to receive an Environmental Protection Agency (EPA) grant to develop a Contamination Warning

System (CWS) under the EPA's Water Security Initiative (WSI). More information on developing a CWS can be found in EPA [1]. This system has evolved and been rebranded as a Surveillance and Response System (SRS) and will be referred to as such throughout this paper.

SRS Components

A full scale SRS contains four monitoring components: Online Water Quality Monitoring (OWQM), Enhanced Security Monitoring (ESM), Customer Complaint Surveillance (CCS), and Public Health Surveillance (PHS) and two response components: Sampling and Analysis (S&A) and Consequence Management (CM).

The OWQM component monitors the distribution system for typical water quality parameters such as chlorine residual, conductivity, turbidity, pH, water temperature, oxidation reduction potential, sample pressure, and in some cases UV254. This monitoring is performed using a series of sensor panels set up at key locations throughout the city including, pumping stations, tanks, reservoirs, police stations, fire stations, and hospitals. Another important element of the OWQM component is the Event Detection System (EDS). The EDS monitors real time online water quality data and creates alerts based on historical data and threshold settings to ensure rapid response to possible contamination events.

The ESM component is comprised of the systems, equipment, and procedures used to detect and respond to security breaches at key PWD facilities. Monitoring includes physical security components such as cameras, sensors, alarms, and fences as well as actionable intelligence from law enforcement. One of the challenges this component attempts to overcome is differentiating between security alerts related to contamination events and those related to other criminal acts such as trespassing or vandalism.

The CCS component collects and categorizes specific water quality complaints that could be indicative of a contamination event. Customers that call in with complaints are asked a series of questions to help identify the type of water quality issue they are experiencing and this information is stored in a Work Order Management System (WOMS). The data are analyzed by an Event Detection Algorithm which creates threshold alerts based on the grouping of similar complaint types for various time windows within a specific water treatment service area, pressure district, or specified radius around the initial point of complaint.

The PHS component displays health related data to identify widespread illness that may be related to a drinking water contamination event. This component enhances the communication capabilities for illness related to drinking water contamination and enables integrated and enhanced communication between the water utility and the local health department.

The S&A component involves collecting and analyzing distribution system samples for the purpose of establishing baseline water quality. It is also a response component utilized for responding to and investigating suspected contamination events.

The CM component establishes a guideline for the actions taken in response to possible contamination events triggered by surveillance components. CM relies on the Operational Strategy which establishes roles and responsibilities, validation procedures for an SRS contamination alert, and determining factors as to whether a contamination is possible, credible, or confirmed. It also establishes an Incident Command Structure (ICS).

Objectives

Each of these components was developed based on design criteria established by the EPA which includes the following objectives.

1. Contaminant Coverage: Must be able to detect a broad range of contaminants.
2. Spatial Coverage: Must maintain extensive monitoring of the entire distribution system.
3. Timeliness of Detection: Must detect contamination in sufficient time for response.
4. Operational Reliability: Must maintain confidence in system reliability and generation of complete and accurate data.
5. Alert Occurrence: Must be able to minimize false positives while reliably identifying contamination events.
6. Sustainability: Must provide dual use benefits for long term sustainability.

In order to meet the design criteria, PWD developed an SRS Dashboard which integrates data streams from each component into one central map-based application. This Dashboard, which is currently in use, allows users to quickly investigate possible contamination events by utilizing geographic information system (GIS) features to spatially display alerts, conduct intradepartmental communications, and obtain access to important reference documents and information. Users are also notified of alerts through text and email notifications.

The objective of this paper is to highlight how PWD's Dashboard integrates multiple data sources to help staff respond to events and make decisions related to water quality. More information on PWD's Dashboard can be found in the referenced white papers by Philadelphia Water Department and CH2MHILL [2] and [3].

THE DASHBOARD

The Dashboard is a centralized platform that combines the four surveillance and two response components into one user friendly GIS based interface that helps the users investigate possible contamination events. It contains two main features: i) a series of tables which give specific information about alerts and ii) a mapping feature that allows the user to spatially analyze alerts. The following screenshot (Figure 1) and accompanying explanations describe each part of the Dashboard and its function in event investigation and response.

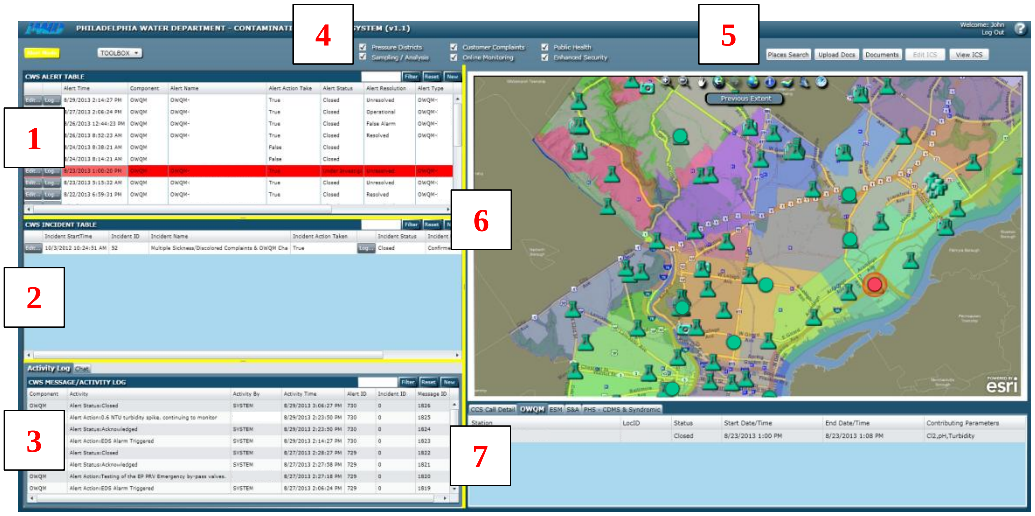

Figure 1. Dashboard screenshot

1. Alert Table: Alerts generated from the four surveillance components are displayed in red in the alert table. It displays the alert start time, component, site/name, action taken, status, resolution, and alert end time. There is also a log feature that allows the user to manually input comments about the alert. Once the status, resolution, and comments have been entered, any user viewing the Dashboard can see what stage the investigation is in and read comments from other users.
2. Incident Table: This table is used to create "incidents," which are more serious than alerts and typically mean that some kind of serious event or contamination has taken place. This is a way of combining alerts from the Alert Table into one incident which is easier to follow. It is important to note that incidents must be manually created, typically by someone in a management or incident command position.
3. Activity/Message Log: This table is split into two tabs. The Activity Log tracks all Dashboard actions allowing users to quickly get up to date on the actions of an ongoing event. The Message Log is used to communicate with other Dashboard users. It is similar to a text or instant messaging service where a sound notifies other users that a message has been received.
4. Components: The components buttons at the top of the screen allow users to turn on and off different components on the map. The map can get crowded and sometimes it helps to focus on one or two of the components at a time.
5. Documents and ICS: These buttons allow Dashboard users to upload and view documents that may be useful during an event. These could be standard operation procedures, water quality graphs, reports, or other useful documents. Additionally, users can view the current ICS structure. Users with certain privileges can also update the ICS during an event to ensure that everyone involved knows who to report to.
6. Map: Like with most mapping applications, Dashboard users have the ability to zoom in and out, pan, and move forward and backward. The map itself shows the boundary lines for pressure districts and displays each component which is represented by different symbols on the map. For the OWQM and CCS components, when the user scrolls over a symbol, a pop-up window appears displaying the most recent data and timestamp along with some locational information about the site.

7. Details: This tab shows specific information regarding an alert from the Alert Table. For example, when a user selects a customer complaint alert, all the complaints that contributed to that alert will be displayed in the Details Tab. Basic information including the customer's address, phone number, time of complaint, type of complaint, etc. is displayed, which is useful for investigating and contacting customers. There is also a link to each complaint in the WOMS which can be used to obtain more information regarding customer responses to water quality questions and the overall process of the investigation.

CASE STUDIES

This section of the paper focuses on two particular events that demonstrate how the SRS, and specifically the Dashboard, were used to investigate and respond to an incident. The first is a 48" main break that resulted in reduced pressure and turbidity, and the second is a wide spread turbidity event caused by an operational activity.

Main Break

The first case study is a large main break that produced significant demand on the system resulting in pressure drops and minor water quality disturbances. The demand caused by the break was so great that EDS alerts were generated at multiple online water quality monitoring sites for turbidity spikes, decreased chlorine residuals, and minor drops in sample pressure.

When these alerts were generated, PWD Dashboard users received text and email notifications indicating general information about the event including location, start time, and the related parameters. The Dashboard was then used to spatially analyze where the alerts occurred, what pressure district they were in, nearby sampling stations, and if other components including CCS were involved. In this case the OWQM was the only component to alert. A Dashboard user verified the alert through the Alert Table and provided comments regarding the progress of the investigation.

The EDS and water quality data management system were then used to further evaluate water quality at nearby monitoring sites. Similar water quality events were noted at two additional online sensor stations not being monitored by the EDS. In conjunction with the data investigation, the Dashboard user contacted other PWD units to inquire about the possible break and discuss whether other actions were required.

In this case it was determined that routine samples collected from within the pressure district that day would be sufficient in fulfilling the S&A component of this investigation. Analysis revealed slightly elevated levels of turbidity and iron but all other water quality parameters were normal. Samples for bacteria evaluations were also negative indicating there was no microbial contamination. Additional samples were collected the following day to ensure that turbidity and iron levels had returned to baseline levels which S&A had previously established. This example highlights four major benefits of the SRS and Dashboard:

1. The EDS will generate water quality alerts in real-time which could otherwise go unrecognized for an extended period of time.

2. Dashboard users can spatially analyze alerts, track event response, and evaluate other monitoring components.
3. Responding to Dashboard alerts improves intradepartmental communication by providing a shared subject of investigation.
4. The S&A component’s routine grab samples provide additional testing, verification of online sensors, and confirmation of system stabilization.

Rusty Water Event

The second case study is a rusty water event which was caused by operational activity that involved crews working on a large control valve.

Unlike the previous case study, this event originated from customer complaints. Two CCS alerts were generated from “rusty brown” and “discolored” complaints which Dashboard users were notified of via text and email alerts. Users then reviewed the Dashboard to analyze proximity, verify complaint types, and evaluate the other monitoring components. See Figure 2 for an example of clustered customer complaints on the Dashboard map.

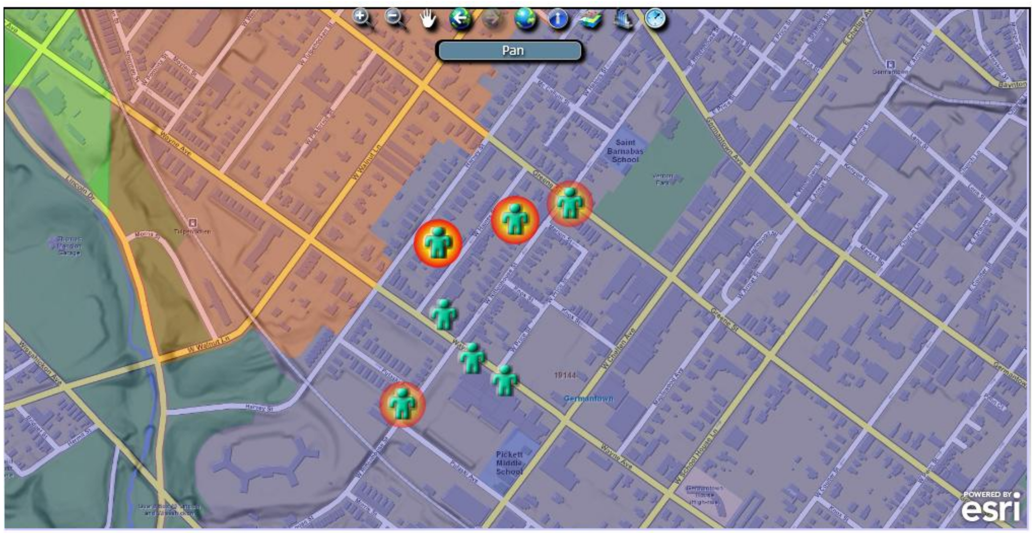

Figure 2. Customer complaint clustering indicating a rusty water event

Next, inquiry was made to determine if there was a main break or work going on in the area. It was initially thought to be a main break due to the close proximity of the complaints; however, leak detection crews were not able to identify any breaks.

Additionally, an analysis of a nearby OWQM stations yielded a large, sustained turbidity spike. Unfortunately this online sensor station was not part of the EDS network and was therefore not displayed on the Dashboard. This information was passed on to other PWD units through phone calls, emails, and updates to the Dashboard Alert Table.

Once it was determined that the rusty water event was caused by the operational activity of performing a valve repair, the hydraulic model was used to simulate how rust would spread throughout the system. Based on this information, hydrants were flushed to remove remnants of rust left over from the repair work.

As part of the S&A component, two routine grab samples were reviewed from the affected area for a comparison to the baseline. Analysis of the samples revealed high turbidity but otherwise normal water quality. To ensure that flushing was effective, additional samples were collected the following day revealing that turbidity had returned to normal. OWQM data were also used to confirm that turbidity had returned to baseline levels.

This example highlights five benefits of having an SRS and Dashboard.

1. CCS alerts will notify the Dashboard user of clustered complaints in real-time which improves response time.
2. Dashboard users can spatially analyze alerts, track event response, and evaluate other monitoring components.
3. Responding to Dashboard alerts improves intradepartmental communication by providing a shared subject of investigation.
4. The S&A component's routine grab samples provide additional testing, verification of online sensors, and confirmation of system stabilization.
5. Analysis of real-time OWQM data allows for a more in-depth understanding of when an event started, how long it lasted, and how water quality changed during the event.

BENEFITS

One of the most important benefits of having an SRS and Dashboard is improved intradepartmental communication and access to information. The PWD unit responsible for maintaining pressure and distributing water throughout the system now has access to customer complaints and OWQM alerts. The Dashboard also improves response time to alerts and investigations. Having multiple data streams in one location and being able to quickly communicate with other PWD units reduces the time required to pull up several programs and allows Dashboard users to quickly compare multiple alerts. Going through the process of investigating, and in some cases responding to alerts, has also increased staff knowledge and experience thus better preparing them in case of a true emergency.

In depth water quality monitoring, made possible through the extensive online water quality monitoring network, has also greatly improved PWD's understanding of the distribution system. For example, conductivity fluctuations have provided additional understanding of source water changes. Collecting real-time data during main breaks has improved PWD's understanding of their effect on water quality and the distribution system. PWD has been able to use water quality data to locate closed valves which can disrupt flow and decrease water quality for customers. Online water quality data from PWD's distribution system storage facilities has also been used to help optimize treatment processes by increasing or decreasing chlorine residual levels during the summer and winter months respectively.

The Dashboard also enhances spatial monitoring and data visualization by displaying water quality alerts, complaints, and live data on the same map. This is crucial for investigating alerts and determining if they are related to a single event.

LOOKING AHEAD

In addition to monitoring for security, the operational benefits provided by the SRS have motivated PWD to expand and improve on existing Dashboard features. This includes adding additional OWQM sites to the EDS at key locations such as tanks, distribution storage facilities, and pump stations. PWD also plans on improving text message and email alerts. Experience has taught PWD that text and email alerts should be very specific as to what and where the alert has occurred, yet simplistic and easy to understand.

Another feature which would be useful for alert investigation is providing additional GIS layers from the WOMS. Many of the OWQM alerts stem from turbidity spikes which can be explained by main breaks, valve operations, construction work, or other system maintenance activities which are generally recorded in the WOMS. Additionally, developing a search bar as part of the Dashboard map would be a useful tool when investigating alerts. Dashboard users could easily find specific locations by searching for an address or intersection.

Creating a historical data store for grab sample results would also be beneficial for alert investigation. Unlike the OWQM component, which displays two days of historical data, the CCS component only displays the most current grab sample results. Being able to see a trend of grab data would allow the Dashboard user to compare current results to historical data and baseline levels.

An active SRS requires the development of a Dashboard which allows users to quickly monitor and respond to water quality events. Integrating multiple data monitoring streams not only improves detection and response times in the case of an accidental or intentional contamination event, it can also improve communications, operations, water quality, and the general status of the distribution system.

REFERENCES

[1] *EPA, "Water Security Initiative: Interim Guidance on Planning for Contamination Warning System Deployment", Office of Water, EPA 817-R-07-002 (2007).*

[2] *Philadelphia Water Department and CH2MHILL, "Philadelphia Water Department Contamination Warning System Demonstration Pilot Project: Contamination Warning System Dashboard Development Guidance", (2013), White Paper Submitted to EPA as part of the Water Security Initiative Grant Awarded to Philadelphia Water Department, https://www.ch2m.com/corporate/markets/water/white-papers/CH2M-HILL-Dashboard-Development.pdf (accessed Mar 03, 2014).*

[3] *Philadelphia Water Department and CH2MHILL, "Philadelphia Water Department Contamination Warning System Demonstration Pilot Project: Development of User Requirements and Use Cases for a Contamination Warning System Dashboard", (2013), White Paper Submitted to EPA as part of the Water Security Initiative Grant Awarded to Philadelphia Water Department, https://www.ch2m.com/corporate/markets/water/white-papers/CH2M-HILL-Warning-System-Dashboard-Requirements.pdf (accessed Mar 24, 2014).*