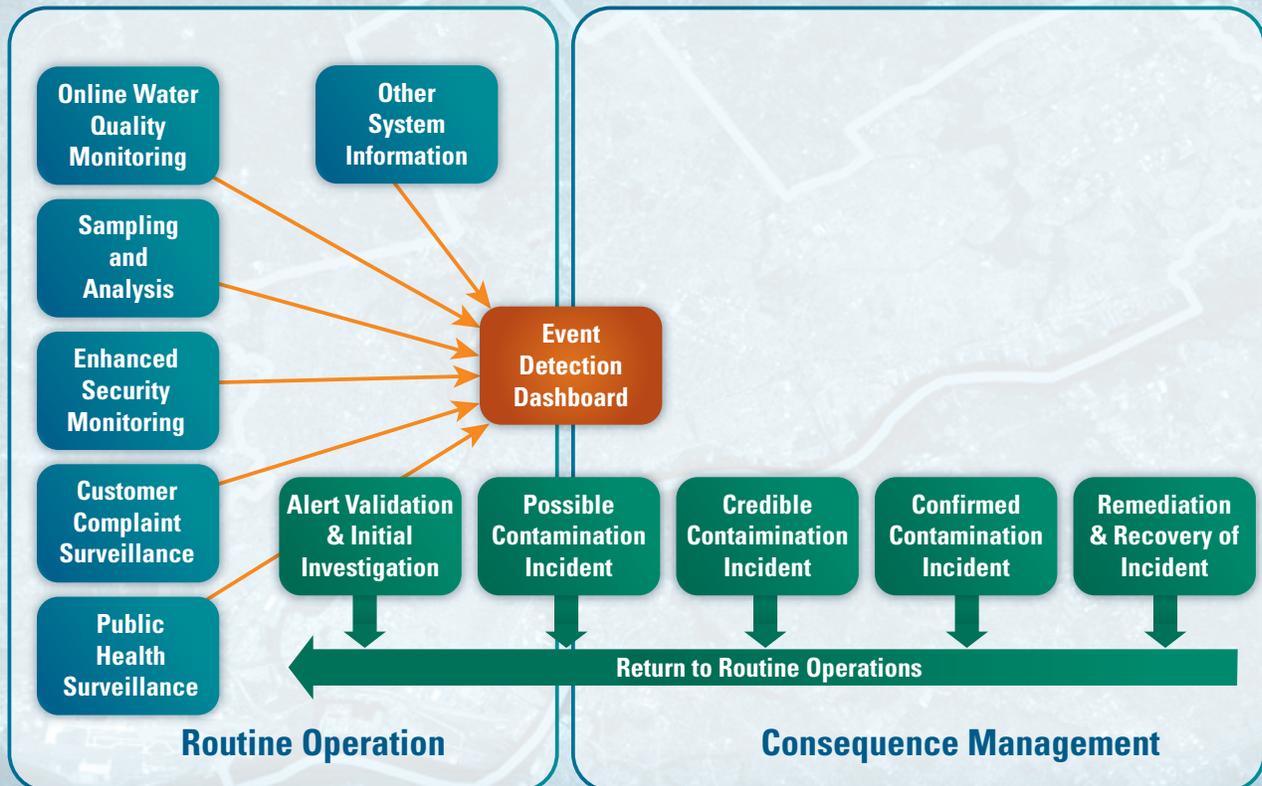


Philadelphia Water Department
 Contamination Warning System Demonstration Pilot Project:

Customer Complaints Surveillance



EPA Disclaimer

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Abstract

The Philadelphia Water Department (PWD) developed a comprehensive contamination warning system (CWS) for its drinking water system under a Water Security (WS) initiative grant from the U.S. Environmental Protection Agency (EPA). Customer complaint surveillance (CCS) provides a critical source of timely information about the drinking water distribution system for rapid indication of potential water quality contamination. Monitoring call frequency, categorizing and analyzing complaints, applying geographic information system (GIS) tools for analysis, and responding to calls effectively can expedite the detection of and response to contamination events. The objective of the Customer Complaint Surveillance component is to support early indication of potential contamination by enhancing the call management system and associated activities.

This paper shares PWD's experience in the design, implementation, and evaluation of CCS as part of a CWS, and provides the operational benefits realized during the implementation of its CCS system. Implementing an enhanced CCS involved the following:

- Selecting and deploying a work order management system with open architecture.
- Using historical complaint data to develop event detection algorithms (EDAs) to alert the utility of any water quality anomalies.
- Providing multiple dual benefits to PWD, allowing routine operations to detect system issues or failures and enhance customer satisfaction.

Water quality complaints are handled by various units within PWD, providing 24-hour coverage for receiving and documenting water quality complaints from customers. Complaints requiring onsite inspections are then referred to field inspectors who try to resolve the complaint onsite. Any water samples taken are delivered to the Bureau of Laboratory Services and analyzed by the water quality group. This group is responsible for reviewing sample results, reporting back to the customer, and conducting follow-up investigations.

A work order management system (WOMS) is used to track complaint data from customer calls and resolve the complaints. PWD has selected Cityworks as its WOMS. Cityworks receives and stores water quality complaint information collected by call takers, site inspectors, sample analysis laboratories, and the water quality group.

Project Background

PWD developed a comprehensive CWS for its drinking water system under a WS initiative grant. The WS initiative is a program developed by the EPA in partnership with drinking water utilities and other key stakeholders in response to Homeland Security Presidential Directive 9. The WS initiative involves designing, deploying, and evaluating a model CWS for drinking water security. A CWS is a systematic approach to collecting information from various sources, including monitoring and surveillance programs, to detect contamination in drinking water early enough to reduce public health or economic consequences. The WS initiative goal is to develop water security CWS guidance that can be applied to drinking water utilities nationwide.

The project has six major components:

1. Online water quality monitoring
2. Sampling and analysis
3. Enhanced security monitoring
4. Consumer complaint surveillance
5. Public health surveillance
6. Consequence management

CCS provides a critical source of timely information about the drinking water distribution system for rapid indication of potential water quality contamination. Monitoring call frequency, categorizing and analyzing complaints, applying GIS tools for analysis, and responding to calls effectively can expedite the detection of and response to contamination events. The objective of the CCS component is to support early indication of potential contamination by enhancing the existing call management system and associated activities.

CH2M HILL served as the project contractor and supported PWD in development of its CWS. CH2M HILL supported PWD in the procurement and integration of the WOMS, development of the CWS Dashboard and CCS operational strategy, and completion of the CCS review and evaluation phase.

Implementation

Procurement of a Work Order Management System

A WOMS serves as a repository for the utility to house preventative maintenance activities assigned to field crews, such as hydrant flushing or valve operations, as well as planned operational and emergency work orders. This allows users to quickly associate high levels of complaints back to field activities that may have caused the water quality issues.

PWD recommends that utilities establish a WOMS for quick and accurate response to customer issues. The WOMS should preferably be web- and GIS-based because the accurate location of water quality-related customer complaints in real time is important. Additionally, the WOMS should be flexible enough to match the organizational workflows and processes.

Customer complaints and work orders should be accurately tracked from initiation, to referral, to associated follow-up activities, through to resolution. An open architecture system is preferred so that it can be integrated with other databases and systems. Further, the integration of service request and work order information with the mapping capabilities of the GIS is crucial for spatial rendering of complaint data for identification of anomalous water quality-related complaint patterns.

Key elements implemented by PWD are explained in this section for the benefit of other utilities. Information about a customer complaint is captured in the form of a “service request.” A service request is created by the call center representatives in response to a complaint received by telephone from a customer, forwarded from Philadelphia 311, from a less direct route such as e-mails, or walkup contact with a utility employee. To help with complaint investigation and to support the event detection system, recommended water quality complaint categories include:

- Complaints of bad taste and odor, such as sewage, chlorine, or chemical smells
- Health-related complaints, such as sickness
- Seasonal complaints, such as geosmin (earthy/odor) occurrence due to algae in the source water
- Complaints indicating anomalies in physical characteristics, such as change in color, foreign particles, etc.
- General water quality information requests from customers.
- Any suspicious activities around facilities and assets tied directly to the water distribution system

A service request must be designed to capture:

- “Date and time” of complaint.
- “Caller information” including customer name and address.
- “Incident information,” allowing call center representatives to enter the exact location of the complaint using an address or intersection. This can be done if geographic coordinates of the incident location are available on the WOMS map.
- “Nature of Complaint” (see categories above).
- “Resolution of Complaint.”

A set of instructions should be provided to personnel answering calls to help mitigate the problem over the phone or schedule sample collection if requested.

A work order is a record of activities performed to resolve a customer’s complaint, including onsite and follow-up investigations of the initial service request. Users of a WOMS should be able to trace the origin of a complaint and to access all pertinent information in the database. This has the benefit of increasing employee effectiveness and

accountability. A WOMS should be configured taking into consideration the needs of the utility, and business process models should be developed by leveraging existing processes.

Development of Event Detection Algorithms

Water quality complaint information in the WOMS database can be automatically analyzed for potential water quality events by EDAs. Potential events are indicated by exceedances of predefined complaint rate thresholds and are generated as component alerts on a CWS Dashboard (explained below). Its purpose is to bring a potential water quality event to the attention of a human investigator using real-time customer complaint information.

Threshold values are counts of complaints that represent the upper bounds of counts within a subpopulation, above which historic occurrences are comparatively rare. To determine appropriate EDA thresholds taking into account the size and operational needs of a particular utility, statistical evaluation of historical data is required to identify the factors that contribute significantly to complaint rates. If complaint rates differ spatially or temporally, or by complaint type over the period of record, then a single threshold applied to all areas, all times, or all complaint types could be overly conservative for some areas, time periods, or complaint types. This would result in high false positive alarm rates. Alternatively, a single threshold value could be insufficiently sensitive to system events for other areas, time periods, or complaint types. This would result in an elevated false negative alarm rate.

The project team recommends the following steps for developing an EDA:

- Establish variables of interest such as complaint type, day of week, month of year, year, pressure district, and water treatment plant service area.
- Use historical complaint data to analyze for complaint rates and perform statistical evaluations to determine how complaint rates differ across variables of interest, i.e., complaint type, day of week, month of year, year, pressure district, and water treatment plant service area.
- PWD utilized hydraulic modeling and Work Order Management System GIS capability and selected 2000 ft as the radius of influence threshold value.
- Use EPA’s Threshold Analysis Tool to identify appropriate complaint thresholds. The Threshold Analysis Tool retrospectively applies a configurable scan algorithm to call and work management data input by the user and outputs when an alert would have been issued. Establish threshold values for the count of complaints for a scan window of 1 day, 2 days, and 7 days. This allows water quality events that have lasting impacts to be captured by the EDAs.

An example EDA matrix is shown below:

		Complaint Type (High --> Low Priority)									
		Sickness	BTO (Other)	Unusual/ Other	Particles	Discolored	Cloudy	BT/O (Chlorine)	BT/O (Algae)	BT/O (Sewage)	Rusty/ Brown
1-Day Scan Window											
WTP Service Area											
Pressure District											
<2000 ft Radius											
2-Day Scan Window											
WTP Service Area											
Pressure District											
7-Day Scan Window											
WTP Service Area											
Pressure District											

If no historical complaint data exist for the utility, new complaint data captured in WOMS can be used to establish baselines and thresholds can be adjusted every 6 months or so to minimize false positives and negatives.

Development of the CCS Dashboard

One of the key elements of a CWS is system engineering and data integration. The system engineering component's primary objective is to combine the five surveillance components into a centralized platform for determining whether a water contamination event has occurred and for facilitating appropriate response and consequence management actions. This centralized platform is the CWS Dashboard.

Thresholds established for CCS complaint types can be used to generate CCS alerts on the CWS Dashboard to provide at-a-glance component status and visualization of complaint data in a spatial context. Work activities such as a water main break or flushing hydrant can be displayed along with the complaint data on the CWS Dashboard to aid in the water quality complaint investigation process. Work activities that can be included are selected based on the operational needs of the utility.

To implement a CWS Dashboard, utilities should preferably have a GIS-based WOMS. The CWS Dashboard should be web-based to enable access by multiple users. Mapping capabilities will play an important role in both data analyses and interpretation for contaminant detection, and in response activities. The user interface and structure of the CWS Dashboard should be developed by gathering user requirements from key personnel and developing use cases through meetings and workshops.

The following are recommendations on how to gather critical information at the user requirements meetings:

- Start with existing and proposed operational strategies.
- Verify sources of information.
- Identify potential data streams.
- Verify the system of records.
- Define the user interface.
- Define navigation/user interaction with data.
- Define map requirements.

Once the user requirements and use cases have been developed, the CWS Dashboard design team should proceed with the software design. A system to send out short message service and e-mail alert notifications can be developed to alert users on their mobile devices.

Development of Operational Strategy

The CCS component of a CWS requires the involvement of multiple units across the utility to receive, respond, investigate, and make decisions about customer complaints. Therefore, it is critical for a utility to come up with a detailed description of all the roles and responsibilities of utility personnel who are likely to respond to an event across a 24-hour timeline.

The CCS project team suggests some critical roles and responsibilities be required to develop a successful CCS operational strategy. Multiple roles can be assigned to a single employee if the utility is short staffed. Table 1 lists suggested roles and responsibilities. Once roles and responsibilities have been established, a step-by-step process indicating response actions of each person and division within the utility, known as an operational strategy, should be developed.

PWD used process flow diagrams to illustrate its operational strategies. PWD's process flow for handling customer complaints was developed as a starting point so that the existing process could be carried over as much as possible.

Three process flows were developed utilizing and incorporating most of the existing routine operations:

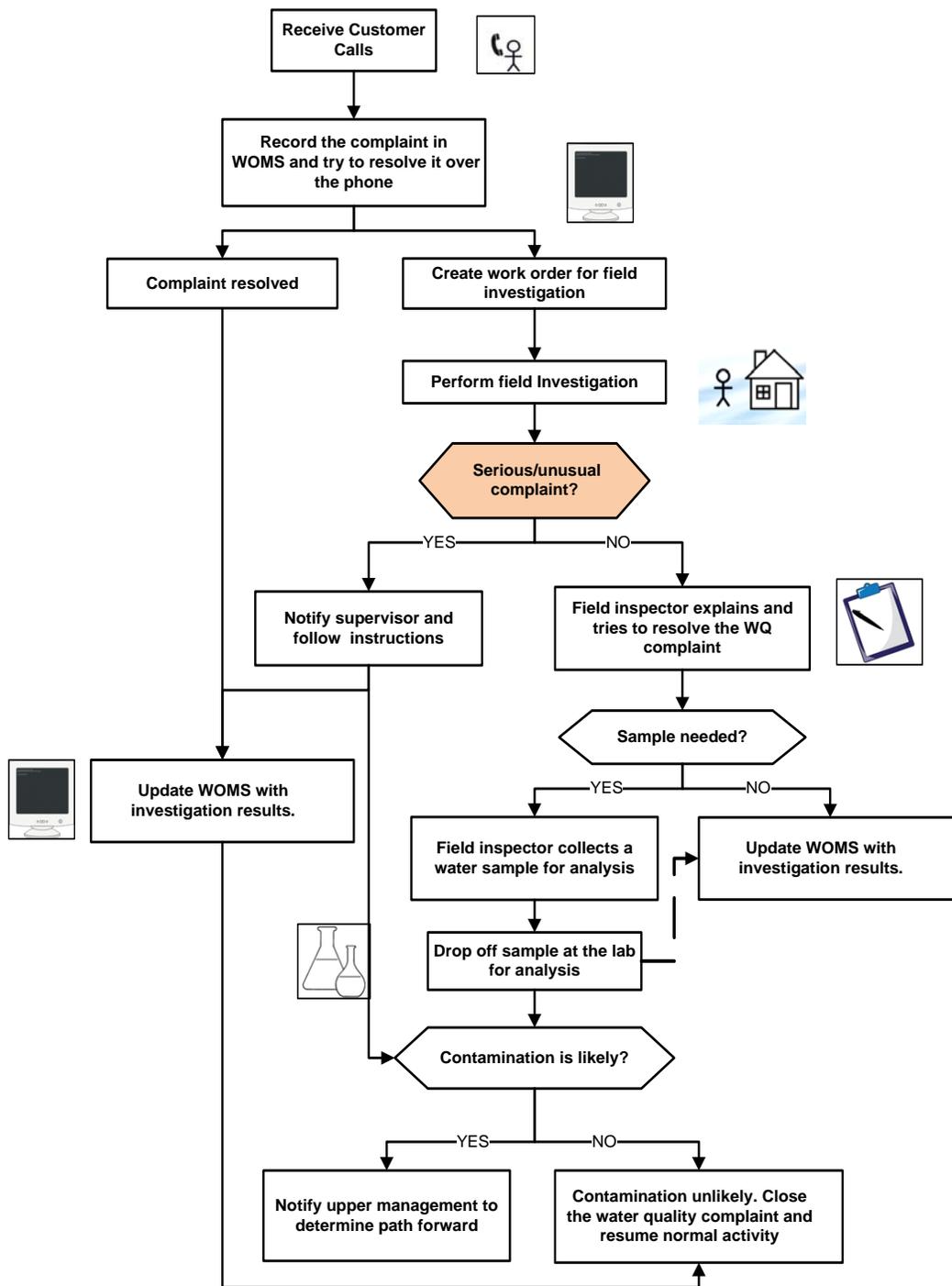
- Routine Customer Complaint Investigation during Normal Business Hours
- Routine Customer Complaint Investigation during Nonbusiness Hours
- Customer Complaint EDA Alert Investigation

TABLE 1
PWD Recommended Roles and Responsibilities for CCS

Roles	Responsibilities
Call taker	Speak with the customer to collect customer and complaint information and record in WOMS database. Try to resolve problem over the telephone using standard operating procedures (SOPs). Submit investigation work order to appropriate personnel/division.
Field crew/Inspector	Conduct site investigation at customer's home, and record field data and investigation results. Notify supervisor of abnormal or inexplicable complaints. Collect sample, complete chain of custody form, and deliver sample to laboratory for analysis. Update WOMS work order with inspection results.
Data clerk	Record inspection results into WOMS and create referral work orders as necessary. Review data input for completeness.
Supervisor	Supervise field inspectors. Assign work orders to field inspectors.
Lab chemists	Record sample information in laboratory information management system (LIMS), analyze samples according to SOPs, and record analytical results in LIMS.
Water quality specialists	Receive and review work order requests and alerts from the WOMS and CCS Dashboard Receive and respond to CCS EDA alerts. Contact customer for follow-up information and to report sample results. Receive notifications of abnormal or inexplicable water quality complaints by field crew or inspector or lab chemists. Conduct alert investigation, which may include follow up onsite investigations and sample collection. Consult with operations and treatment during investigation if needed.
Water Quality Manager	Receive and respond to CCS EDA alerts. Supervise water quality specialists. Assist with the investigation of inexplicable customer complaints by working with other units as needed. Notify upper management if contamination is deemed possible.
Utility operations personnel	Assist with the investigation of inexplicable customer complaints as needed. Run hydraulic model to determine course of action. Conduct distribution operations as necessary during consequence management stage.
Water Treatment Plant Management	Consult during investigation of inexplicable customer complaints as needed. Evaluate available treatment options during consequence management stage. Determine if the abnormality represents a significant threat to water quality and implement response activities.
Standby water quality specialist: nonbusiness hours	Same as water quality specialist.

Throughout the process flow, WOMS should be used to track the receipt of and response to all customer complaints related to water quality. Different types of water quality service requests and work orders are generated throughout the response process. A general overview of PWD's complaint investigation process flow is provided in Figure 1 as an example for other utilities.

FIGURE 1
PWD Customer Complaint Investigation Process Flow



- Receive and record direct calls from customers, or a complaint made in person, in the WOMS. If complaint is resolved by providing appropriate explanation or instructions to the customer, close the service request.
- If the utility personnel could not resolve the complaint over the telephone, create an investigation work order.
- Depending on the type of complaint, submit the request to appropriate personnel within the various divisions of the utility.

- Field crew/inspector will perform site investigation to collect additional water quality information. If evidence of contamination is present, water quality specialists and supervisors are notified by telephone.
- If, during the field investigation, the inspector cannot explain the complaint by routine activities and/or the customer insists on sample collection, the inspector collects a sample and drops it off for analysis at the utility laboratory.
- If the inspector notices signs of sample contamination readily evident by observation of the sample, water quality specialists, supervisors, and managers are notified immediately during business hours or standby during off hours. Field inspectors are not trained to handle non-routine samples and water quality specialists are informed to handle field sampling.
- The water quality group performs its investigation by checking the WOMS and CWS Dashboard, including water quality trends from online water quality monitoring stations.
- Water quality specialists, supervisors, and managers consult with other units within the utility, such as distribution or treatment operations, in the complaint investigation process.
- If, based on the investigation, it is likely that contamination is possible, water quality supervisors and managers notify upper management of the incident and provide the status of the investigation.
- Upper management confirms that appropriate investigation steps have been taken and determines the path forward.
- All the work orders are updated in the WOMS during the investigation, ideally in real time to reduce the response time.

SOPs documenting the process flow should be provided to utility personnel to serve as a reference. SOPs provide step-by-step instructions on proper handling and documentation of water quality customer calls, creating investigation work orders, documenting sample results, and conducting follow-up and alert investigations. Documentation to record response times should be developed to track users' response, record, and refine response times.

Review and Evaluation Phase

Metric Development

The goal of review and evaluation is to demonstrate how well the CWS, along with each of its components, meets the design objectives of CWS as identified by EPA:

- Contaminant coverage to detect a broad spectrum of contaminant classes
- Spatial coverage of the entire distribution system
- Timeliness of detection to identify contamination in sufficient time for effective response
- Operational reliability to maintain a functional system that generates complete and accurate data
- Alert occurrence to indicate a contamination incident with a minimum number of false positives
- A sustainable architecture to monitor distribution system water quality

To achieve these objectives, a systematic evaluation of each component should be performed. Two suggested evaluation techniques are field evaluations and data analysis:

- Field evaluations include drills and exercises, direct observation and performance testing, and staff interviews. The data produced by each component must be monitored and analyzed to determine if it meets design objectives.
- Data analysis and integration require statistical, time series, or other analysis of data. Methods used to analyze data may vary widely depending on the nature of the data and the component, from relatively simple methods to advanced categorical data analysis methods using complex regression models.

To use data analysis as an evaluation tool, metrics should be developed. Below are some recommended ideas on developing metrics:

- Develop general metrics based on CWS design objectives.
- An appropriate evaluation method for each metric must be identified. The evaluation method describes how the necessary information will be gathered to characterize each of the metrics. Examples include a literature review, data analysis, discussion based and operational exercises, laboratory studies, forums, etc.
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- Identify the data source for each metric.
- Identify employees responsible for collecting the data and evaluating the metrics.
- Develop periodic performance reports that include a summary of metrics, descriptions of events, modifications to the system, and recommendations for improvement.

Table 2 lists some recommended CCS metrics used by PWD.

TABLE 2
Recommended Evaluation Metrics for CCS

Operational Mode	CCS Metric	Description
Operation	Availability	Availability of WOMS, servers, personnel, etc.
Operation	Data Completeness	Validity of data captured in WOMS
Operation	Accuracy	Accuracy of data captured in WOMS
Performance	Reliability	Adoption of operational strategy
Performance	Timeliness—Alert Detection and Investigation	Time taken by utility personnel to receive and acknowledge EDA alerts
Performance	Timeliness—Alert Investigation	Time taken by utility personnel to complete the investigation
Sustainability	Acceptability	Usability of the system
Sustainability	Cost	Capital cost of CCS component software

Training and Exercises

WOMS training and periodic refresher training sessions should be provided to all users that have a role in CWS CCS operational strategy. As users start to use the system daily, additional training and documentation may be required.

SOPs should be customized for water quality complaints targeted for all WOMS users within various water department units. SOPs provide step-by-step instructions on proper handling and documentation of water quality customer calls, creating investigation work orders, documenting sample results, and conducting follow-up and alert investigations.

Regular exercises should be conducted to provide the users an opportunity to react and respond to a potential water contamination incident. Homeland Security Exercise and Evaluation Program (HSEEP) and the Target Capabilities List can be used to develop exercise scenarios and objectives.

The purpose of exercises is to provide participants an opportunity to perform duties set forth in the CCS Operational Strategy and Consequence Management Plan. Implementation of the procedures can be evaluated during a simulated contamination scenario to identify gaps in planning, training, interagency communication, and resources.

The following design and performance CCS objectives were selected by a PWD Exercise Planning Team:

- Evaluate responders' understanding of their roles and responsibilities in relation to the Operational Strategy.
- Follow SOPs to record complaints in WOMS.
- Evaluate tactical communication between different units within the water utility and external partners such as the health department.
- Evaluate investigative response and mitigation measures taken in relation to the CCS Operational Strategy.
- Evaluate CCS EDA thresholds.
- Evaluate data flow from WOMS to the CWS Dashboard.

An Exercise Evaluation Guide should be developed and used to evaluate exercise performance objectives. Participant feedback forms should be provided to all exercise participants. Improvement plans can be developed to document recommendations based on participant feedback and observations recorded by the evaluators during the exercise. These plans can be used by the water utility to make necessary changes to its operations.

The After-Action Report is developed to document exercise objectives, analysis of capabilities, observations, recommendations, and exercise feedback summary. At PWD, an improvement plan was developed specifically to tabulate recommendations from participant feedback conducted immediately following an exercise, input from the evaluators, and information contained in the After-Action Report. This plan supports the development of specific post-exercise corrective actions. Exercises may also reveal lessons learned that can be shared with the broader homeland security audience. The Department of Homeland Security maintains the Lessons Learned Information Sharing (LLIS.gov) system as a means of sharing post-exercise lessons learned with the emergency response community.

Recommendations

This section provides recommendations based on PWD's experience with designing, configuring, and implementing the CCS component of a CWS.

Potential system enhancements and any modifications required can only be identified after assessing the implemented CWS. Therefore, evaluating the system and documenting lessons learned is an important part of the CWS evaluation. In PWD's case, as a result of the review and evaluation of the WOMS, CCS process flows, and feedback gathered from training and exercises, changes were made to the complaint investigation process flow for the optimal performance of the system. The EDA was refined after considering the number of false alerts being generated on the CWS Dashboard.

PWD recommends that utilities refine their EDAs and WOMS to suit their respective operational needs once the CCS component is operational. Lessons learned in designing and implementing the CCS component of the CWS project are summarized below:

- Involve all potential units early in the process of CCS implementation.
- Coordinate with GIS and Information Technology units at an early stage in the project.
- Analyze historical trends to establish initial thresholds.
- Be aware of WOMS software requirements and plan EDA development accordingly.
- Perform data integrity analysis and develop quality control reports to promote close attention to the quality of data logged to reduce the number of false alerts.
- Conduct periodic data quality reviews to reduce the number of alerts generated on the CWS Dashboard.
- Develop review and evaluation metrics to help refine responses to complaints.
- Develop user-friendly and simple to understand SOPs.
- Conduct training and exercises periodically to track user performance over time.
- Provide continuous training needed in tools, policies, and procedures to make the program sustainable.
- Seek continuous feedback from users to enhance system operations.

Communications

PWD recommends the following software and hardware equipment for successful implementation of the CCS component:

- Web- and GIS-based WOMS for effectively capturing water quality complaint data.
- WOMS to serve as a central database accessed by all units within the utility.
- An EDA to automatically analyze water quality data for potential water quality events.
- Alert notifications to designated responders by e-mail or short message service.
- Laptops for the field crews to access the WOMS and update work order information in real time.
- Radios for efficient and quick communication with internal staff.

Knowledge management programs can be used successfully to share intelligence, improve performance, and increase levels of innovation. PWD shared its findings and experiences at various national meetings such as American Water Works Association's Annual Conference and Exposition, Water Quality Technology Conference, Distribution Systems Symposium, and Water Security Congress, and conferences on WOMS and GIS, security, instrumentation, information systems, etc. PWD recommends participating in national conferences and conducting regional workshops to enable transfer of knowledge in the implementation of CCS.

Dual-Use Benefits

For utilities to justify the cost of a CWS, documenting dual use benefits is encouraged. Intentional contamination is considered a low probability event. Approximately one-third of the complaints recorded were Rusty brown complaints often, resulting from main breaks and flushing activities. Therefore, utilities must be aware that the majority of the water quality complaints result from benign events. It is important to identify dual-use benefits. Some dual use benefits realized by PWD in its implementation of CCS include:

- Information is readily available on the CWS Dashboard and in WOMS to analyze customer complaint alerts reducing investigation time.
- Improved intradepartmental coordination between Customer Information, Customer Service, Emergency Support Services, and Water Quality groups.
- Geographical view of complaints and work orders minimizes resources deployed to complaint locations.
- Remote access feature enables multiple users to login simultaneously to input real time data from the field, thus reducing response time.
- Gaps identified during complaint data evaluation were used to implement quality checks in Cityworks to maintain data integrity.
- Ability to build workflows within the system aids in proper routing of complaints and alert notifications.
- Ability to track user actions with time stamps improves PWD's day-to-day operations and user accountability.
- Ability to capture customer complaints information through a series of questions and answers facilitates extensive on-site investigation by PWD personnel.

Prioritizing Considerations of the CCS Component for Other Utilities

Critical elements of the CCS component were identified and prioritized by PWD to allow utilities to direct resources, time, and energy to those issues that are most critical and practical to address. Below are the critical elements in order of priority:

- Set up a centralized call center responsible for receiving and documenting water quality complaints from customers.
- Set up water quality complaint types to encompass different characteristics based on historical customer complaint data.
- During complaint intake, capture the location, time, complaint type, customer telephone number and name of person initiating the complaint.

- Develop work order investigation forms and develop standard operating procedures to aid in complaint investigation.
- Develop automated event detection algorithms to send alert notifications in case of complaint threshold exceedences.
- Integrate all data streams on a centralized CWS Dashboard to display EDA alerts, water quality complaint information, and distribution system type work orders.
- Provide field equipment such as laptops, tablets, etc. for field crews to facilitate real-time data capture.

Abbreviations and Acronyms

CCS	Consumer Complaint Surveillance
CWS	Contamination Warning System
EDA	Event Detection Algorithm
EPA	United States Environmental Protection Agency
GIS	Geographic information system
LIMS	Laboratory Information Management System
HSEEP	Homeland Security Exercise and Evaluation Program
PWD	Philadelphia Water Department
SOP	Standard operating procedure
WOMS	Work Order Management System
WS	Water Security

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Additional information on PWD's CCS design and implementation can be found in the following sources:

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- Philadelphia Water Department Regional Water Security Initiative Workshop November 30, 2012.

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