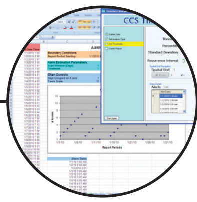
United States
Environmental Protection
Agency

Designing Customer Complaint Surveillance

For Water Quality Surveillance and Response Systems


Office of Water (MC 140) EPA 817-B-15-002C November 2017

Disclaimer

The Water Security Division of the Office of Ground Water and Drinking Water has reviewed and approved this document for publication. This document does not impose legally binding requirements on any party. The information in this document is intended solely to recommend or suggest and does not imply any requirements. Neither the U.S. Government nor any of its employees, contractors or their employees make any warranty, expressed or implied, or assumes any legal liability or responsibility for any third party's use of any information, product or process discussed in this document, or represent that its use by such party would not infringe on privately owned rights. Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

Version History: The 2019 version is the second release of the document, originally published in November 2017. This release includes updated component names (Enhanced Security Monitoring was changed to Physical Security Monitoring and Consequence Management to Water Contamination Response), an updated version of Figure 1.1 that reflects the component name changes and includes the Advanced Metering Infrastructure component, an updated Glossary, updated target capabilities and updated links to external resources.

Questions concerning this document should be addressed to WSD-Outreach@epa.gov or one of the following contacts:

Nelson Mix
U.S. EPA Water Security Division
MC 4608T, 1200 Pennsylvania Ave, NW
Washington, DC 20460
(202) 564-7951
Mix.Nelson@epa.gov

or

Steve Allgeier
U.S. EPA Water Security Division
26 West Martin Luther King Drive
Mail Code 140
Cincinnati, OH 45268
(513) 569-7131
Allgeier.Steve@epa.gov

Acknowledgements

The document was developed by EPA's Water Security Division, with additional support provided under EPA contract EP-C-15-012.

- Nelson Mix, EPA, Water Security Division
- Adam Bucher, General Dynamics Information Technology
- Adam Haas, General Dynamics Information Technology
- Amy Posner, General Dynamics Information Technology

Peer review of this document was provided by the following individuals:

- Steve Allgeier, EPA, Water Security Division
- Yves Mikol, New York City Department of Environmental Protection
- Connie Schrepal, Mohawk Valley Water Authority
- David Travers, EPA, Water Security Division

Table of Contents

List of Figures

List of Tables

Abbreviations

AET	Alarm Estimation Tool
AWWA	American Water Works Association
CCR	Customer Confidence Report
CCS	Customer Complaint Surveillance
CSR	Customer Service Representative
DWU	Dallas Water Utilities
EPA	United States Environmental Protection Agency
GCWW	Greater Cincinnati Water Works
GIS	Geographic Information System
IT	Information Technology
IVR	Interactive Voice Response
MMS	Multimedia Messaging Service
O&M	Operation and Maintenance
SCADA	Supervisory Control and Data Acquisition
TAT	Threshold Analysis Tool
SFPUC	San Francisco Public Utilities Commission
SMS	Short Messaging Service
SRS	Water Quality Surveillance and Response System

Section 1: Introduction

The United States Environmental Protection Agency (EPA) designed a ***Water Quality Surveillance and Response System***[1] (SRS) that employs multiple ***components*** to detect water quality ***anomalies*** that could have potential public health and economic ***consequences***. **Figure 1-1** shows the components of an SRS grouped into two operational phases, surveillance and response. Procedures guide the systematic investigation of anomalies detected by the surveillance components in order to identify causes of contamination. If distribution system contamination is detected, response plans guide actions intended to minimize consequences, and ultimately, to return the distribution system to normal operations. EPA intends the design of an SRS to be flexible and adaptable based on each utility's goals and the resources available to support implementation and operation of the system.

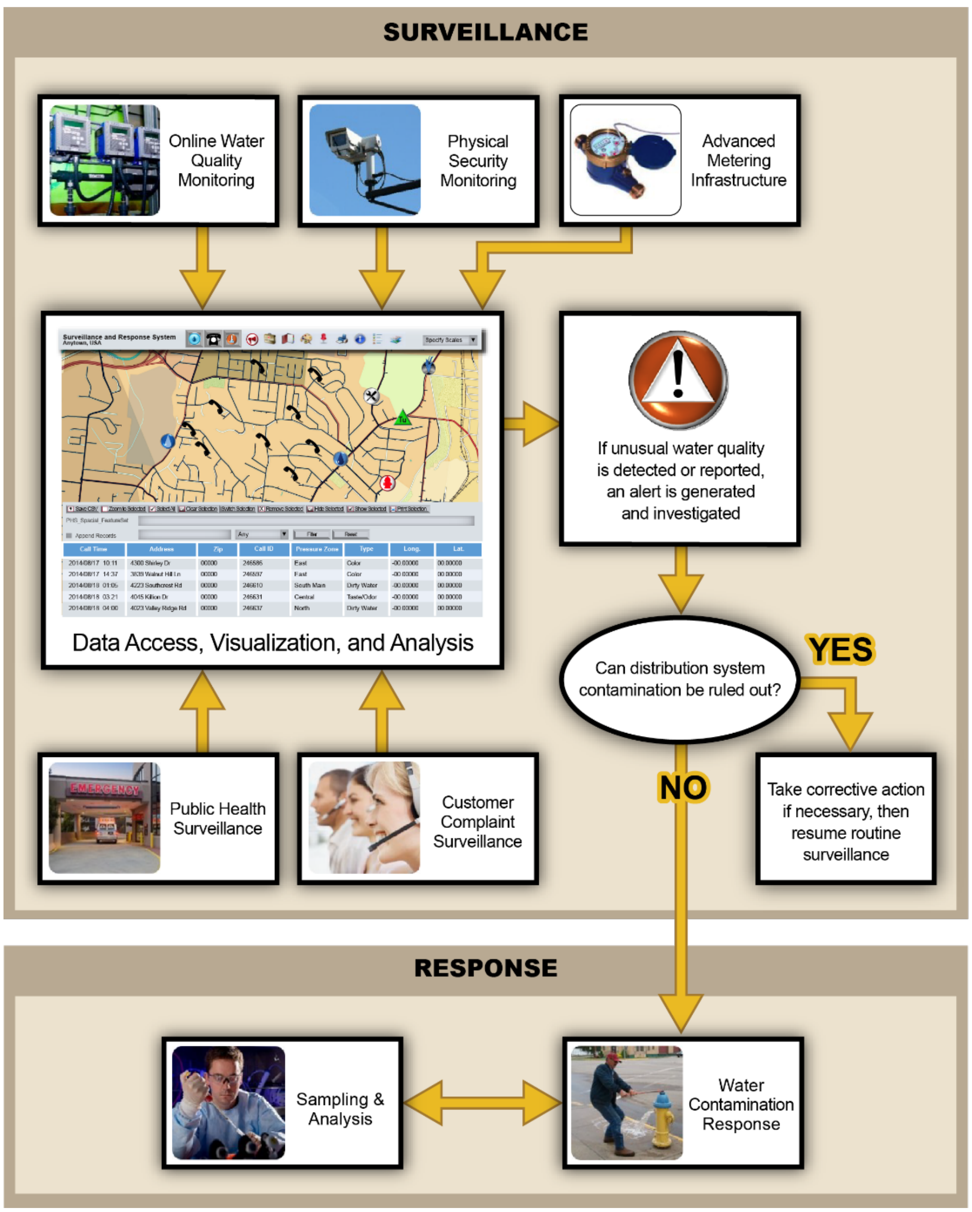


Figure 1-1. Surveillance and Response System Components

---

[1] Words in bold italic font are terms defined in the Glossary at the end of this document.

The purpose of this document is to provide guidance for designing the ***Customer Complaint Surveillance*** (CCS) component of an SRS. It is written for drinking water professionals who are involved with the planning, design, or operation of CCS. The document is organized into the following major sections:

- **Section 2** provides an overview of CCS and a description of the design elements that define the component. Guidance on developing each design element is presented in subsequent sections. Section 2 also introduces the concepts of design goals and performance objectives and explains how they inform the design of CCS.
- **Section 3** provides guidance on topics related to complaint collection and the sub-elements that define this design element. Complaint collection determines how the water utility educates customers about appropriate methods of contacting the utility, identifies systems to receive water quality complaints, and ensures that complaints are directed to a central location for analysis.
- **Section 4** provides guidance on topics related to information management and analysis and the sub-elements that define this design element. Information management and analysis determines how the water utility systematically tracks water quality-related complaints from initial receipt to closure.
- **Section 5** provides guidance on investigating CCS alerts. It describes attributes of an effective alert investigation procedure, explains utility roles in a CCS alert investigation, describes tools to support the investigation, and provides guidance on investigating alerts in real-time.
- **Section 6** describes the process for developing a preliminary design for the CCS component of an SRS.
- **Resources** presents a comprehensive list of documents, tools, and other resources cited in this document, including a summary and link to each resource.
- **References** presents a comprehensive list of published literature cited within the document.
- **Glossary** presents definitions of terms used in this document, which are indicated by bold italic font at first use in the body of the document.

This document is written in a modular format in which the guidance provided on a specific topic is largely self-contained, allowing the reader to skip sections that may not be applicable to their approach to CCS or that include capabilities that have already been implemented. Furthermore, this document was written to provide a set of core guidance principles that are sufficient to design the CCS component, while pointing the reader to additional technical resources useful for a specific design task.

Section 2: Overview of CCS Design

CCS relies on customer feedback for effective monitoring of distribution system water quality. Customers throughout a utility's distribution system can provide near ***real-time*** input regarding changes in the taste, odor, or appearance of drinking water. In fact, ***water quality complaints*** may provide one of the earliest warnings of a ***water quality incident*** if an effective system is in place to detect anomalous trends in water quality complaints. CCS provides additional benefits to utilities such as enhancing customer service.

2.1 CCS Approach

CCS is based on a "Funnel, Filter, and Focus" approach that allows a utility to separate water quality complaints that could indicate a water quality incident from other types of customer contact. The approach is described below and illustrated in **Figure 2-1**:

- Funnel: All customer contact should be directed to a central location.
- Filter: Utility employees who routinely handle calls, such as ***customer service representatives*** (CSRs), should be able to respond to billing and meter reading concerns, as well as general water quality complaints related to benign issues, such as degassing, subtle pressure changes, or temporarily switching from chloramine to free chlorine.
- Focus: Based on complaint descriptions, more serious water quality complaints should be forwarded to water quality personnel, who will gather in-depth information from the customer and make a determination if sampling is needed.

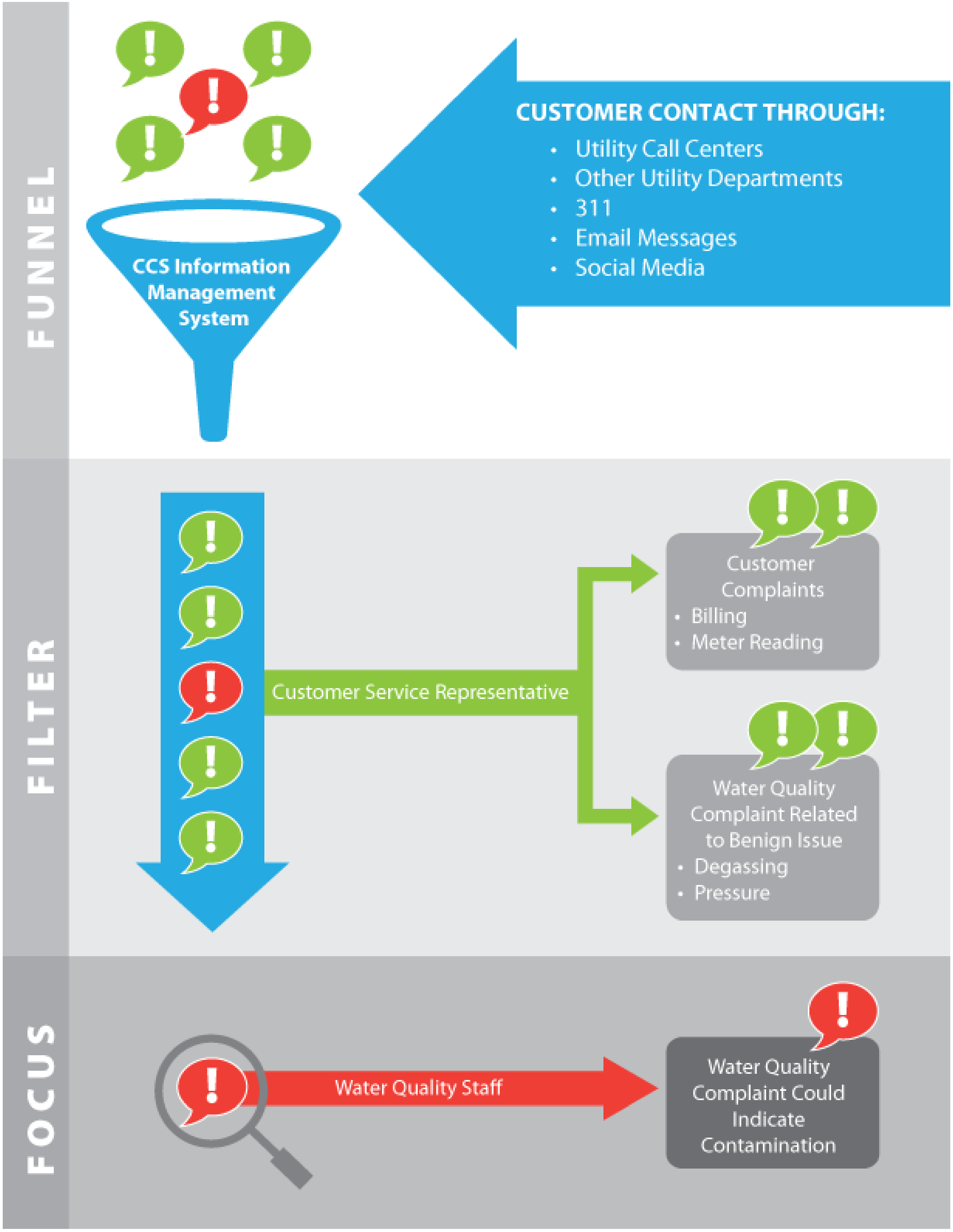


Figure 2-1. Funnel, Filter, and Focus Approach to Customer Complaint Surveillance

2.2 CCS Design Elements, Design Goals, and Performance Objectives

Design elements are the functional areas which comprise each component of an SRS. CCS consists of three design elements, which are described in **Table 2-1**.

Table 2-1. Design Elements for Customer Complaint Surveillance

Design Element	Description
Complaint Collection	Program to educate customers on communicating water quality concerns and an established system to funnel complaints from all ***datastreams*** into a central location.
Information Management and Analysis	Established complaint categories and ***thresholds*** for complaints that generate ***alerts*** and notify designated personnel when thresholds are exceeded.
Alert Investigation Procedure	Documented procedure for the timely and systematic investigation of CCS alerts, with clearly defined roles and responsibilities for each step of the process.

An effective CCS component should have capabilities for each of the design elements listed in Table 2-1. Sections 3 through 5 of this document define a ***target capability*** for each of these design elements, which, if achieved, will result in a fully functional CCS component. However, the implementation of each design element can vary for different utilities, and it is possible to substantially improve CCS capabilities without fully achieving the target capability for each design element. Likewise, utilities can implement CCS in a manner that exceeds the target capability.

The decision regarding how to implement each of these design elements and build CCS is informed by ***design goals***, which are the specific benefits a utility hopes to realize through implementation of an SRS. **Table 2-2** presents examples of common design goals for CCS.

Table 2-2. Common CCS Design Goals

CCS Design Goal	Description
Detect contamination incidents	Provide an early indicator of water ***contamination incidents*** that alter the aesthetic characteristics of the water and may impact the health of customers or damage utility infrastructure.
Monitor the impact of operational changes noticed by customers	Detect a change in water quality resulting from ***operational changes*** by monitoring for changes in the nature or volume of customer water quality complaints.
Increase the level of customer service, through improved communications	CCS provides early detection of aesthetic degradation of water quality, resulting in situational awareness that can be shared with other customers. Early detection promotes faster resolution of problems and increases customer service by reducing the number of customers affected, and the duration of the problem.
Improve response to water quality complaints	Develop procedures to streamline and standardize a utility's decision-making process for investigating water quality complaints, thereby reducing the utility response time.

Additional factors to consider when designing CCS are ***performance objectives***, which are metrics used to gauge how well the SRS or its components meet the established design goals. While specific performance objectives must be developed in the context of a utility's unique design goals, general performance objectives for an SRS are defined in the *Water Quality Surveillance and Response System Primer*. CCS performance objectives and recommended targets are described in **Table 2-3**.

Table 2-3. Example CCS Performance Objectives

CCS Performance Objectives	Description	Recommended Target
Spatial coverage	The percentage of the distribution system service area monitored by CCS, which is dependent on customer awareness of how to contact their utility and communicate water quality concerns	100% of the distribution system service area
Timeliness of detection	The time between when a water quality complaint is received and when a CCS alert is generated, which is dependent on how quickly water quality complaint data is available for analysis and how often the analysis is performed	15 minutes or less
Operational reliability	The percentage of time that equipment, personnel, and other support functions are available to support collection and analysis of CCS data and the investigation of a CCS alert	Availability of surveillance capabilities and coverage of CCS procedures 24/7/365
Alert occurrence	The ability to reliably indicate water quality incidents (through generation of a ***valid alert***) with a minimum number of ***invalid alerts***	95% confidence that an alert is related to a water quality incident
Sustainability	The ability to maintain and operate CCS using available resources, which is dependent on the benefits derived from the component relative to the costs to maintain it	All aspects of CCS are incorporated into routine utility operations within one year of transitioning to real-time operation

The design goals and performance objectives provide the basis for designing an effective CCS component, within any ***constraints***. Sections 3 through 5 present guidance on potential approaches to enhance capabilities for each of the three CCS design elements described in Table 2-1. Additional background on the design elements, design goals, and performance objectives for CCS can be found in the *Customer Complaint Surveillance Primer*.

Section 3: Complaint Collection

CCS requires that customers know how to communicate complaints to their utility and that all complaints are captured and funneled into one location, regardless of how they are received. This improves data completeness and the reliability of CCS for detecting water quality incidents. The Complaint Collection design element contains two ***design sub-elements***, which are described in **Table 3-1**.

Table 3-1. Design Sub-elements for Complaint Collection

Design Sub-element	Description
Communicating Water Quality Concerns	Ensure customers understand how to communicate all water quality concerns to their drinking water utility.
Consolidating Water Quality Complaints	Funnel all complaints to a central location to facilitate analysis of water quality complaint data.

Considerations for implementing the Complaint Collection design element are described in the following subsections:

- Subsection 3.1 provides guidance on communicating water quality concerns.
- Subsection 3.2 provides guidance on consolidating water quality complaints.

3.1 Communicating Water Quality Concerns

This design sub-element addresses educating customers on how to communicate water quality concerns effectively with their utility. Information on how to contact the utility can be provided through the annual Consumer Confidence Report, email messages, bill inserts, or a media campaign and should be displayed prominently on the utility website home page. Methods of communication should include all applicable utility contact information customers can use to register a water quality complaint, such as utility phone numbers, email addresses, links to web forms, links to instant message services, numbers for short messaging services (SMS), and social media accounts. Utilities should coordinate with a public communications specialist to ensure that any information provided to customers is non-technical and easy to understand.

TARGET CAPABILITY

Customers are fully aware of how to communicate water quality concerns to their utility.

3.1.1 Leveraging the Consumer Confidence Report

Consider placing utility contact information in a prominent area of the Consumer Confidence Report and clearly explaining how to report water quality issues. Also, consider providing examples of the types of information that customers should provide in a water quality complaint, such as a description of the taste, odor, and appearance of the water. Additionally, provide tips on how to recognize and report suspicious activity.

Example Language for a Consumer Confidence Report (CCR) provides examples that can be modified and included in a CCR to instruct customers how to report water quality concerns. The document can be opened in Word by clicking the icon in the callout box.

This document includes example language for inclusion in a CCR.

3.1.2 Communicating with Customers through Direct Marketing

Utilities can communicate with customers through direct marketing with email or bill inserts. When utilizing direct marketing, the frequency of customer contact should be carefully considered, as frequent messaging can result in communication fatigue. The ease and relatively low cost of email allows for regular contact with all customers that provide an email address to a utility. A current email distribution list may be generated from customer billing information. A utility should inform customers of the potential for mass electronic communication when they enroll in electronic billing or create online accounts, as an email message may be ignored if it looks unfamiliar, non-urgent, or is automatically routed to a spam folder.

The *Email Message Template* can be used as a guide for crafting communications to customers about reporting water quality concerns. The template can be opened in Word by clicking the icon in the callout box.

This document includes an example email message communication.

For customers who do not enroll in electronic billing, a utility can provide inserts, such as flyers or promotional materials, in their billing statements. Bill inserts reach customers each billing cycle and allow a utility to describe important issues or announce specific utility programs. Flyers should be easily distinguishable from the billing material. Promotional materials, such as refrigerator magnets that advertise utility contact information, can be distributed with bill inserts or sent in a separate mailing. These physical materials can also be delivered to customers who enroll in electronic billing in addition to emails, for greater impact.

The *Generic Bill Insert Template* provides an example of the text that can be included in a bill to instruct customers about how to report water quality concerns. The template can be opened in PowerPoint by clicking the icon in the callout box.

This document includes example bill insert text.

3.1.3 Implementing a Media Campaign

Implementing a media campaign involves the use of radio, television, billboards, internet, and social media to promote widespread customer education and awareness of reporting water quality concerns. A media campaign may require a significant expenditure but can be an extremely effective way to ensure that customers are knowledgeable about how to report water quality concerns to their utility.

Utilities should develop customized materials and use different media during the campaign. The campaign should target all geographic areas, customer demographics, and prevalent languages used in the service area. An important consideration is the timing of communications, such as non-business hours for television advertising or rush hour for radio. In a city with a large university, many customers may be out of town during the summer months when school is not in session. Billboards may be most useful if located in high volume areas, such as city centers or major traffic arteries.

MEDIA CAMPAIGN CASE STUDY

San Francisco Public Utilities Commission (SFPUC) implemented a media campaign to encourage customers to utilize the new 311 citywide call center to report water quality issues. The campaign increased customer awareness while improving data collection, detection, and response to possible water quality issues in the distribution system. Details of the SFPUC media campaign can be found in *Summary of Implementation Approaches and Lessons Learned from the Water Security Initiative Contamination Warning System Pilots*.

3.2 Consolidating Water Quality Complaints

All customer contact should be routed to one point of contact within a utility and integrated into a consistent format, as shown in **Figure 3-1**. Technology has evolved with the growth of the internet and emergence of social media, and call centers have increasingly been superseded by contact centers. In addition to traditional phone services, contact centers allow customers to communicate through email, web forms, instant message, text message, and social media. These forms of complaints are CCS datastreams that should be used to detect water quality issues. As the number of complaint datastreams increase, the chances of complaints getting trapped in data silos increases. If water quality complaints are received by multiple, disconnected sources, such as a ***311*** city call center, utility field crews, or a utility contact center, then a utility could be unaware of total complaint volumes.

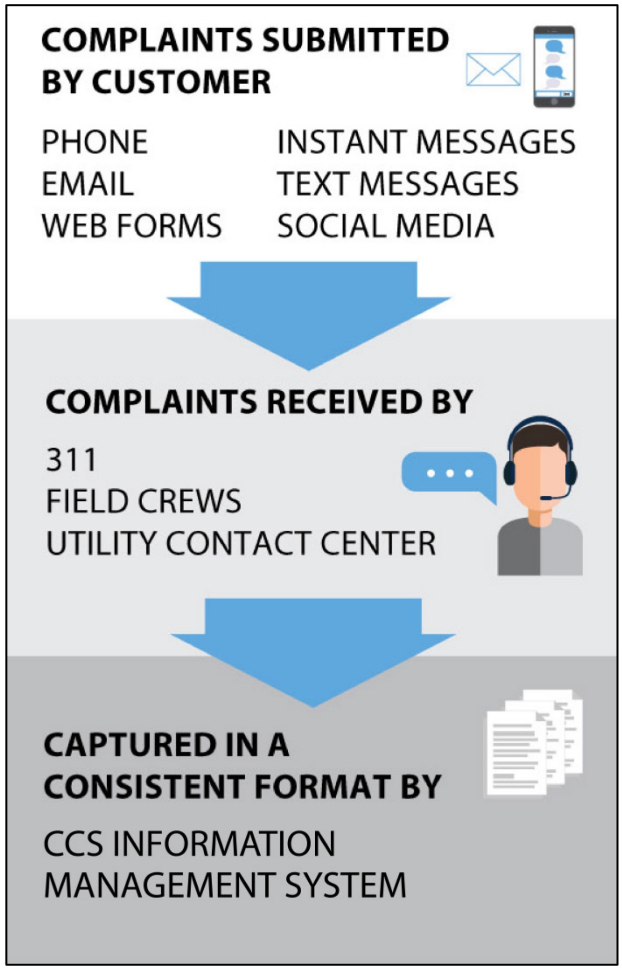


Figure 3-1. Summary of Process to Funnel Customer Complaints to a Central Location

Organizations that might receive water quality complaints should have procedures in place to direct all water quality complaints to the correct point of contact. If water quality complaints are managed outside of the utility, priority should be given to funneling water quality complaints to the utility in a timely manner. Funneling complaints to a central location ensures that no water quality complaints are lost or overlooked and facilitates data analysis. Utilities can use a ***CCS Information Management System*** that is either a manual tracking system, such as a notebook, or an automated system that digitally and consistently formats all information. Methods for consolidating complaints are described in the following subsections.

> **TARGET CAPABILITY**
>
> All water quality complaints, regardless of the format or location where they are received, are collected and integrated into a single CCS Information Management System.

3.2.1 Implementing Procedures to Manually Route Complaints to a Single System

All personnel that receive complaints, such as the 311 call center, other city departments, or utility field crews, should be trained to route complaints to a single location. Modifying existing practices is a cost-effective way to improve water quality complaint funneling and help standardize information. Additionally, a utility may prioritize water quality complaints over other customer issues, ensuring water quality complaints are quickly routed to a CCS Information Management System and available for analysis.

3.2.2 Establishing a Single Phone Number for Reporting Complaints

Utilities should consolidate phone numbers and phase out those not frequently used. This may involve updating contact information distributed to the public, such as information listed in bill inserts, reports, or on the utility's website. Consolidating phone numbers will reduce confusion, response time, and training needs. The single phone number should be widely publicized.

3.2.3 Automatically Forwarding Complaints to One Location within a Utility

A utility can use automated call distributors to forward calls from internal and external sources to one system. A utility can also use an electronic routing process for complaints. Using existing methods of communication and information systems eliminates the need to educate utility personnel on new procedures, since customers can continue to use all existing methods of communication. Electronic routing processes can also prioritize water quality complaints. Storing water quality complaint records in one CCS Information Management System allows for automated analysis of the datastreams.

3.2.4 Electronically Integrating Systems to Capture all Complaints

Electronic integration involves development of a CCS Information Management System to merge complaint records from phone calls, email messages, web forms, instant messages, text messages, SMS, social media, work orders from a ***work management system***, and other datastreams. For example, a utility could design forms with data fields identical to fields in other utility applications for CSRs or field crews to complete during customer interactions. These forms can then be automatically uploaded into the CCS Information Management System and seamlessly integrated with data from other datastreams. Integrating these datastreams will allow for easier analysis and better surveillance of water contamination incidents.

Integrating datastreams using ***information technology (IT)*** may involve ***implementation costs***; however, these costs can be minimized by implementing the integration of electronic records during routine life cycle upgrades for the system. **Table 3-2** lists different IT systems that can be leveraged for CCS information management. These systems may support multiple CCS datastreams, which allows the ***technical requirements***, coding language, alerting algorithms, and operating systems to be streamlined. These systems may also share a common ***user interface***.

Table 3-2. Potential IT Systems to Integrate into a CCS Information Management System

IT System(s)	Description	CCS Datastreams
Interactive Voice Response (IVR) **System**	Facilitates customer communication with the utility through phone calls and messages. Data from this system can be one of the earliest records of a complaint. CSRs can also use this system to provide information to customers about ongoing concerns.	Phone calls
Web Form Submissions, Utility Email Inbox, or Social Media Accounts	Receives water quality complaints. Manual triage or automated searching and sorting may occur.	Email message, web forms, instant messages, text messages, and social media
Customer Information System/Customer Relation Management System/Meter Data Management System	Tracks customer billing information, complaint information, customer history, or frequency of reported issues. CSRs or water quality staff review complaint information stored in these systems to identify if the complaint could be indicative of a water quality incident.	Data fields imported from information system or input by CSRs
Work Management System/Asset Management System	Generates work orders and may be used to investigate or address complaints received from the customer contact center or from field crews. CSRs, field crews, and other utility staff may track responses to a confirmed customer issue.	Work orders

The *Water Quality Complaint Processing Form Template* includes an example form that CSRs or other utility personnel can use to capture data about a water quality complaint and track datastreams associated with the complaint. The document can be opened in Word by clicking the icon in the callout box.

This document includes an example form to capture information on complaints and suspicious activity.

The document also contains a checklist for CSRs to document threats and intrusions reported by customers. The Proposed Customer Feedback Checksheet (Whelton et al., 2007) is another example of how complaint data could be captured.

CCS IS A CENTURY OLD

Checksheets are consistent with “Complaint Books” that have tracked customer complaints for over 100 years. Assigning the complaint a serial number, plotting the complaint on a map, and following up with laboratory analysis as needed has been standard practice for over a century (Mercer, 2017).

Section 4: Information Management and Analysis

Once customer water quality complaints have been captured, the data needs to be stored, displayed, and analyzed to determine if there is a water quality incident. Data analysis methods should be capable of detecting an ***anomaly***, such as unusually high numbers or spatial clustering of water quality complaints with similar problem descriptions. CCS ***anomaly detection systems*** are a vital part of the CCS Information Management System and usually operate continuously behind the scenes. The Information Management and Analysis design element contains three design sub-elements listed in **Table 4-1**.

Table 4-1. Design Sub-elements for Information Management and Analysis

Design Sub-element	Description
Complaint Categories	Capture descriptive data from complaints using free text or pre-defined categories.
Alert Generation	Establish thresholds and generate an alert when water quality complaints exceed a threshold value indicative of a possible water quality incident. Processes used to generate alerts may also include spatial analysis of water quality complaint data.
Alert Notifications	Implement a system to notify designated utility personnel when a CCS alert is generated.

Considerations for development of the CCS Information Management and Analysis Design Element are described in the following subsections:

- Subsection 4.1 provides guidance on developing complaint categories.
- Subsection 4.2 provides guidance on alert generation.
- Subsection 4.3 provides guidance on alert notifications.

4.1 Complaint Categories

Customers contact a utility for a variety of reasons, from questions about billing to concerns about water quality. Complaints also arise from common distribution issues that are usually benign, such as degassing, pressure changes, or turbidity caused by flushing or water main breaks. Water quality complaint categories can be useful for quickly identifying the nature of the issue (e.g., cloudy water, rusty water, musty odor) and allow for a more precise analysis of water quality complaints within each category. Utilities may have pre-defined categories for complaints that customers can self-select through an automated menu prompt or that utility personnel can identify after communicating with the customer. Categories can also be determined from descriptive data if free text is used to capture water quality complaints from customers or CSRs.

TARGET CAPABILITY

Categories are established to track customer water quality complaints and descriptive information about each complaint is captured.

4.1.1 Capturing Descriptive Data from Free Text

Utilities can design their CCS Information Management System to receive information as free text, entered either by customers through a web form or by CSRs during customer calls. If a utility is using an automated system for analysis, all complaint records must be readable by the anomaly detection system. Data entry fields can collect descriptive information about the taste, odor, or appearance of the water. An investigator will look for similar problem descriptors in the free text to determine whether the complaints are related.

Allowing customers to provide information as free text has advantages and disadvantages. Some customers will be descriptive and provide important information to their utility, but long entries could include information that is incorrect or difficult for an automated system to interpret. Descriptive data should be categorized using a structured methodology or a library of terms to prevent the grouping of unrelated water quality complaints. The taxonomy can aid in the classification and prioritization of complaints and can provide clues to the sources of potential contamination.

Utilities should train CSRs to capture information in free text when fielding customer calls, so the information will be compatible with any CCS Information Management System taxonomy. Utilities should consider allowing CSRs or water quality chemists to modify or validate water quality complaints submitted directly by customers through email messages, web forms, instant messaging, text messaging, SMS, or social media.

4.1.2 Establishing Complaint Categories

Utilities should identify complaint categories that correlate with common water quality issues and other reasons that customers may contact a utility. Customers or CSRs should select a specific category in a data entry field when submitting a complaint. This system of categorization separates calls related to billing, main breaks, or water quality concerns. The categories must be transparent to the customer, and technical terms should be avoided. For example, a category related to turbidity issues could be listed as "rusty" or "brown" water.

The water quality complaint categories can be grouped into different tiers or priority levels based on potential severity. Each tier should have an established threshold level that generates an alert if exceeded. **Figure 4-1** provides an example of a tiered approach for water quality complaint categories, adapted from EPA SRS program pilot utilities, with Tier 1 representing the highest priority complaints and lowest threshold. Utilities should determine the most appropriate order of the tiers and whether subcategories are necessary for their own automated systems.

COMPLAINT CATEGORY CASE STUDY

Greater Cincinnati Water Works (GCWW) added a sub-menu to the phone system's IVR water quality menu selection to filter rusty or cloudy water and water pressure issues from taste, odor, and appearance complaints. Previously, GCWW analyzed a general water quality IVR menu prompt, which captured many water quality complaints that were not related to contamination.

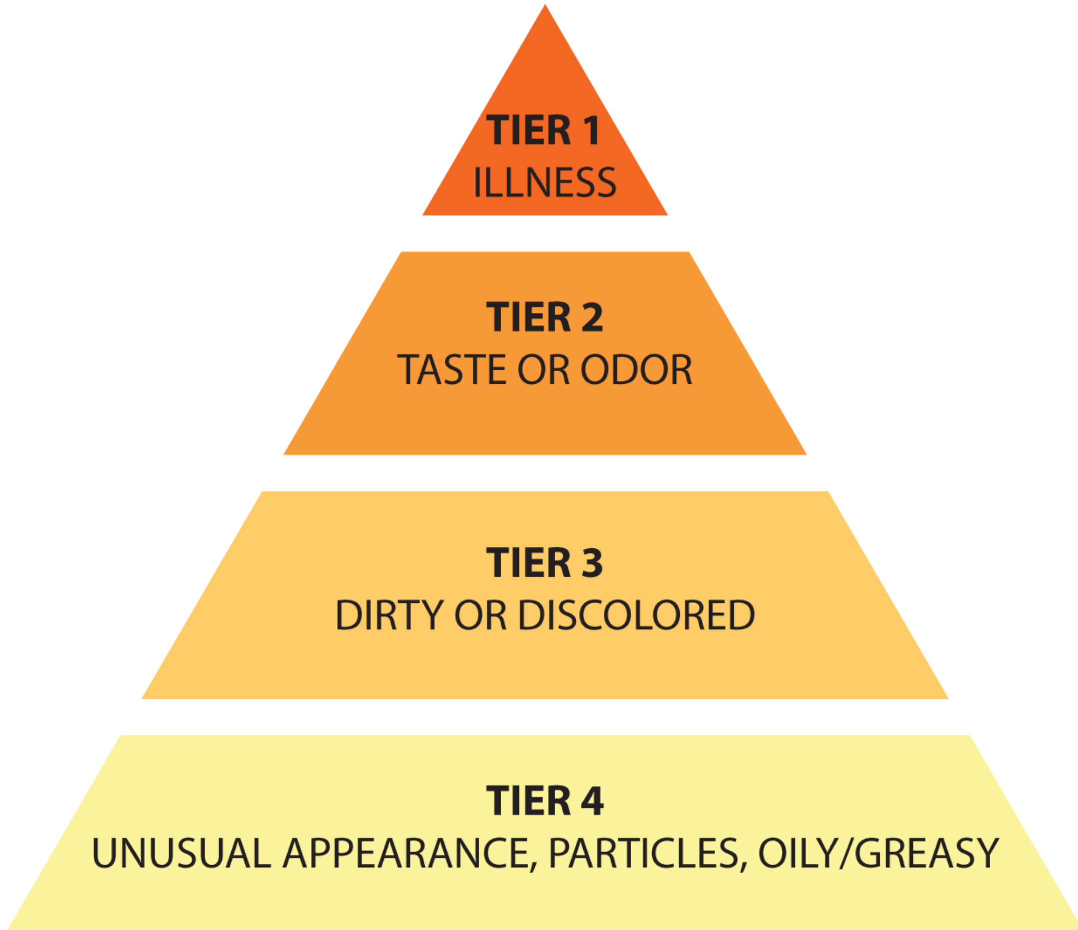


Figure 4-1. Example Complaint Category Tiers

For additional information and guidance on defining water quality complaints, as well as short- and long-term utility actions, see the following American Water Works Association (AWWA) resources:

- *Taste and Odor: An Operator's Toolbox* – Video that provides methods for determining the causes of taste and odor in potable water and treatment responses.
- *Diagnosing Taste and Odor Problems Field Guide* – Field guide that provides all the information water utilities need to diagnose and remove objectionable tastes and odors at the tap.
- *Early Warning and Management of Surface Water Taste-and-Odor Events* – Report that focuses on strategies to head off taste and odor problems before they can cause complaints, offering a set of practical guidelines and tools that any utility can use.
- *Taste at the Tap: A Consumer's Guide to Tap Water Flavor* – Informative booklet that assists utilities in helping their customers understand what can cause tastes and odors in tap water and why tastes and odors do not necessarily indicate a problem with the water.

4.2 Alert Generation

CCS alerts are generated when one or more thresholds are exceeded. Alerts can be generated through a manual review of complaint records or automated algorithms that calculate the frequency of similar water quality complaints in real time. Alerts may also factor in thresholds based on the spatial clustering of complaints. Ultimately, the goal is to identify patterns in water quality complaints that indicate a significant change in water quality.

TARGET CAPABILITY

A process is in place to detect volumes of water quality complaints that exceed threshold levels derived from historical data. This capability may be further enhanced through spatial analysis to detect high complaint volumes within defined spatial areas.

4.2.1 Establishing Thresholds for Water Quality Complaints

Establishing appropriate thresholds for water quality complaints is a key step in implementing CCS, since alerts will only be generated when complaint levels rise above the threshold. Any threshold exceedance could indicate poor water quality in the distribution system. Establishing thresholds based on ***historical data*** can be more accurate and robust than basing thresholds on knowledge of utility personnel. For efficient analysis, historical data should be captured electronically in a format conducive for analysis, such as an Excel spreadsheet. Thresholds generated from historical data can be validated through employee experience and optimized after implementation.

An important tradeoff exists when determining a threshold value. Each CCS alert must be investigated, which requires time and effort by utility personnel, resulting in a cost to the utility. A threshold that is set too low will result in a high number of invalid alerts that may be caused by the day-to-day variation in complaint frequency. A low threshold is also more likely to detect real water quality problems. A threshold that is set too high can result in not detecting true water quality problems that do not generate alerts and are missed. Utilities need to balance a minimum frequency of invalid alerts against the ability of CCS to detect real water quality incidents.

TOOLS TO HELP SET THRESHOLDS

EPA tools assist utilities in analyzing historic water quality data to establish a ***baseline*** for water quality complaint data that can inform the development of threshold values. The tools apply a configurable scan algorithm to historical data input by the user, and output when an alert would have been generated. These tools allow the user to easily:

- Analyze the performance of different thresholds using historical complaint data
- Re-assess thresholds by analyzing new complaint data collected during real-time operation of CCS
- Compare CCS alert occurrence during real-time operation to estimated CCS alert occurrence

EPA's ***Alarm Estimation Tool*** (AET) is a simple Excel spreadsheet with macros that generate alerts based on historical complaint data. This data must be properly formatted and input either by hand or copied and pasted into the spreadsheet. The alerts can be viewed in a list or on a time-series plot for visual interpretation. For users unfamiliar with statistical methods, the AET provides a straightforward approach to establishing thresholds using historical data with the visual interpretation of alerts.

EPA's ***Threshold Analysis Tool*** (TAT) is an application that analyzes a variety of data file formats, including .txt, .csv, .xls, .xlsx, and .tab. The TAT offers three different statistical methods (percentile, standard deviation, and recurrence intervals) to determine thresholds for CCS. Users can also set thresholds for temporal or spatial units (e.g., week days, weekends, treatment source, pressure zone, etc.), if the complaint data contains those details.

Three common statistical methods can be used for establishing thresholds: percentile, standard deviation from the mean, and recurrence interval. Any of these methods can generate acceptable thresholds, and the choice of method can be based on a user's familiarity or comfort with a specific method.

The AET and TAT use prospective scan statistic algorithms to determine alert occurrence in historical CCS data. A prospective scan statistic allows for a comparison of the number of customer complaints received by the utility within a rolling time window, or the "scan window," to a preset threshold. The scan window is typically between one and seven days. These algorithms can be implemented using either a reset or continuous mode. In reset mode the algorithm begins counting from zero after any alert and ignores preceding data when an alert occurs. In continuous mode the algorithm will not report a new alert until the number of complaints within the scan window falls below the threshold. The reset algorithm will issue multiple alerts if complaint volume remains high for an extended time; whereas, the continuous algorithm will only issue one alert. Multiple alerts can signal that the issue still persists, but may also be a nuisance. In most cases, reset and continuous modes will generate a similar number of alerts, except when the threshold is low, in which case reset mode could generate many more alerts compared with continuous mode.

Alerting logic may need to consider historical complaint patterns, such as cyclical trends in customer complaints. For example, a utility could use a daily parameter to establish thresholds for weekdays and use two-day, seven-day, and monthly parameters to establish weekend, weekly, and monthly thresholds. It is important to consider how customer activities may differ during weekends, holidays, and other events when establishing thresholds. Additionally, parameters for the algorithms should reflect a utility's distribution system characteristics, such as service areas and residence times. For example, if the residence time in the distribution system is typically less than four days, it may not be necessary to have an algorithm that uses a seven-day rolling time window.

Regularly Review and Update Thresholds

Because the water quality complaint baseline may shift over time, thresholds should be periodically re-evaluated. A shift in the complaint baseline can occur due to changes in business processes, technology, or utility operations. Unless thresholds are adjusted to accommodate the shift in baseline, CCS may generate too many alerts or may not alert when there is a water quality incident. Utilities should re-evaluate thresholds following any activity that can impact call volume or the geographic distribution of water quality complaints, such as:

- Adding new complaint categories to data entry record logs
- Media campaigns that promote a single utility phone number
- Updates to, or replacement of, ***software*** that processes complaint data
- Integrating new IT systems and datastreams into a CCS Information Management System
- Extension of the distribution system into a new geographical area

An annual review of thresholds is optimal, but if thresholds are re-evaluated every two years, a utility would be able to capture most gradual changes in normal complaint volume.

4.2.2 Methods for Generating Alerts

Alerts are generated by a CCS Information Management System that uses algorithms, most commonly the prospective scan statistic, to detect when complaints exceed thresholds. The algorithms used to evaluate thresholds in the AET and TAT may also be used to generate alerts during real-time data analysis. The most effective methods for generating alerts utilize an automated anomaly detection system that promptly notifies personnel when complaint thresholds are exceeded. Alternatively, alerts can be generated following a manual review of complaint data. Both of these methods are described in more detail below.

CCS data can have attributes related to descriptive information, temporal information, spatial information, and timeliness. **Table 4-2** describes different target levels for each attribute.

Table 4-2. Target Attributes of CCS Data

	Good	Better	Target
Descriptive Information	Descriptive text	Complaint categories	Water quality complaint categories with detailed descriptions
Temporal Information	Date of complaint	Date and time of complaint	Date, time, and distinction between business/non-business hours or day of the week
Spatial Information	Zip code of complaint	Hydraulic area of complaint	Precise location
Timeliness	24 hours from complaint	< 24 hours from complaint	< 15 minutes from complaint

The attributes of the data to be analyzed impact the types of anomaly detection systems that can be used. For example, if the data does not contain spatial information or if there are no ***Geographic Information System*** (GIS) capabilities, maps or spatial statistical models cannot be used. However, all data must have at least the date, preferably the date and time, available for analysis.

Conducting Regular Manual Reviews of Water Quality Complaint Data

If resources are not available to implement an automated anomaly detection system, a utility can establish a manual process to review water quality complaints. A periodic, manual review of existing records that track water quality complaints can be conducted. Many contact center and work management applications have the ability to generate reports on complaint volume and activity. Alternatively, a utility may use simpler recordkeeping methods, such as paper call logs, a spreadsheet, or a whiteboard. Regardless of the form of these records, designated utility personnel, such as a contact center manager or a shift manager, can conduct regular reviews of the records to detect anomalous volumes or patterns of water quality complaints.

Manual reviews should be conducted on an established schedule, at least daily. Utilities can review water quality complaint data at the beginning or end of the day, or reviews could be incorporated into shift change procedures. This provides utilities with a consistent process for establishing baseline complaint volumes and reliably detecting when a threshold is exceeded. To increase the timeliness of detection, complaints can be reviewed more frequently.

Implementing an Automated Anomaly Detection System

Automated anomaly detection systems analyze water quality complaint data and generate alerts when thresholds are exceeded without manual intervention. Automated anomaly detection systems are preferred over manual review of water quality complaints, since they can aggregate data from multiple IT systems and do not require active participation in the surveillance. Automated anomaly detection systems only require activity by utility personnel when anomalous complaint volumes are detected and an alert is generated. By deploying an automated anomaly detection system, CCS can be implemented with minimum interruption in day-to-day business operations.

Automated anomaly detection systems should execute every 15 minutes or less to take full advantage of the early warning capabilities of CCS. However, a utility may not have the ability to implement an anomaly detection system that executes every 15 minutes, due to technical limitations. For example, complaint data may only be available at certain times (hourly or daily), or frequent execution of the anomaly detection system may strain IT system resources. In this case, the anomaly detection system should execute as frequently as is technologically feasible.

4.2.3 Spatial Clustering Analysis Techniques

During a water quality incident, water quality complaints will cluster in space and time. Complaints that are both temporally and spatially clustered are more likely to have a common cause. Spatial clustering of complaints can be identified manually by plotting the complaint location on a map using push pins (or dropping pins in free, web-based maps). More accurate automated anomaly detection systems can perform spatial analysis by examining the frequency of complaints within hydraulically related areas, such as pressure zones or service areas. Anomaly detection systems can also analyze complaints using GIS functions.

Spatial data can be analyzed using (in order from least to most effective):

- Administrative Areas (city quadrants, zip codes)
- Hydraulic Areas (water source, pito zone, pressure zone, pressure district)
- Hydraulic Areas and Spatial Algorithms (proximity measurements using GIS functions)

Administrative areas may be used as surrogates or approximations of hydraulic areas, if this is the only data available to identify clusters. Hydraulic boundaries offer a better degree of certainty than administrative boundaries or zip codes because hydraulically defined regions share common water quality within a distribution system.

See Appendix A for more guidance on spatial clustering analysis techniques.

4.3 Alert Notifications

An anomaly detection system will generate alerts when thresholds are exceeded. Personnel responsible for investigating CCS alerts must be notified when alerts are generated to ensure that all CCS alerts are acknowledged and that the ***alert investigation*** begins in a timely manner. Automated notifications can be electronically configured so utility personnel do not need to manually send a notification. An optimal notification system brings the alert to the attention of the investigator immediately and provides selected details from the alert to support the investigation. Notification methods through direct messaging and a routinely monitored system are described in the subsections below.

TARGET CAPABILITY

An automated process is in place to notify designated personnel when a CCS alert has been generated.

4.3.1 Notifications through Direct Messaging

A utility can have automated phone, email, or text message notifications sent electronically when their CCS anomaly detection system recognizes that alert thresholds have been exceeded. Direct message alerts require investigators to be present at a workstation or have access to a smart phone with internet connectivity to receive the alert.

A utility should determine if "dedicated" versus "on-call, after hour personnel" will receive the notifications. This decision impacts the choice of technology deployed such as phone ***autodialers***, email messages, text messages, or any combination thereof.

The *CCS Email Alert Template* is an example of an email alert message, with important details about the alert and instructions for alert investigation. The document can be opened in Word by clicking the icon in the callout box.

This template can be used to craft an email alert.

The *CCS Text Message Template* is an example of a text message or a Short Messaging Service (SMS) alert notification, which contains only basic text information about the alert. This short communication does not provide instructions for investigation or details about the alert; therefore, the investigator will need to go to another source to get information about the alert. SMS alert notifications do not contain pictures, video, or audio, unlike a Multimedia Messaging Service (MMS). A MMS can also be integrated into a CCS Information Management System. The document can be opened in Word by clicking the icon in the callout box.

This template can be used to craft a text message or SMS alert.

4.3.2 Notifications through a Routinely Monitored System

A utility can use a system that is monitored 24/7, such as a ***dashboard*** or ***Supervisory Control and Data Acquisition (SCADA)*** system, to send alert notifications and provide information about an alert to investigators. Notification through a routinely monitored system is optimal, since investigators can access complaint records, complaint descriptions and locations, operations and water quality data, and information about other SRS datastreams. A routinely monitored system can be configured to require alert acknowledgment.

Figure 4-2 is an example dashboard interface with CCS complaints displayed. The toolbar at the top of the figure shows different data layers available for viewing. The dashboard uses a map that displays icons to indicate different types of information. In this example, a user can access additional information on CCS complaints, such as the complaint ID, status, tier, pressure zone, date and time, and comments. For more information on building notifications into a dashboard, consult the *Dashboard Design Guidance for Water Quality Surveillance and Response System*.

ESTABLISHING IT REQUIREMENTS

If CCS will require enhancements to existing IT systems or the implementation of new systems, it is important to establish requirements for the work. The utility must clearly define requirements for an information management system to ensure that it meets all of the needs for CCS. The *Information Management Requirements Development Tool* guides a user through a series of questions that help define:

- Expected Uses of the System: identification of users and the manner in which they will interact with the CCS information management system
- Data to be Managed: types and quantity of data that will need to be managed for CCS
- Functional Requirements Rating: user ratings indicating the importance of system features commonly used for CCS information management, which will be used to prioritize functional requirements for CCS

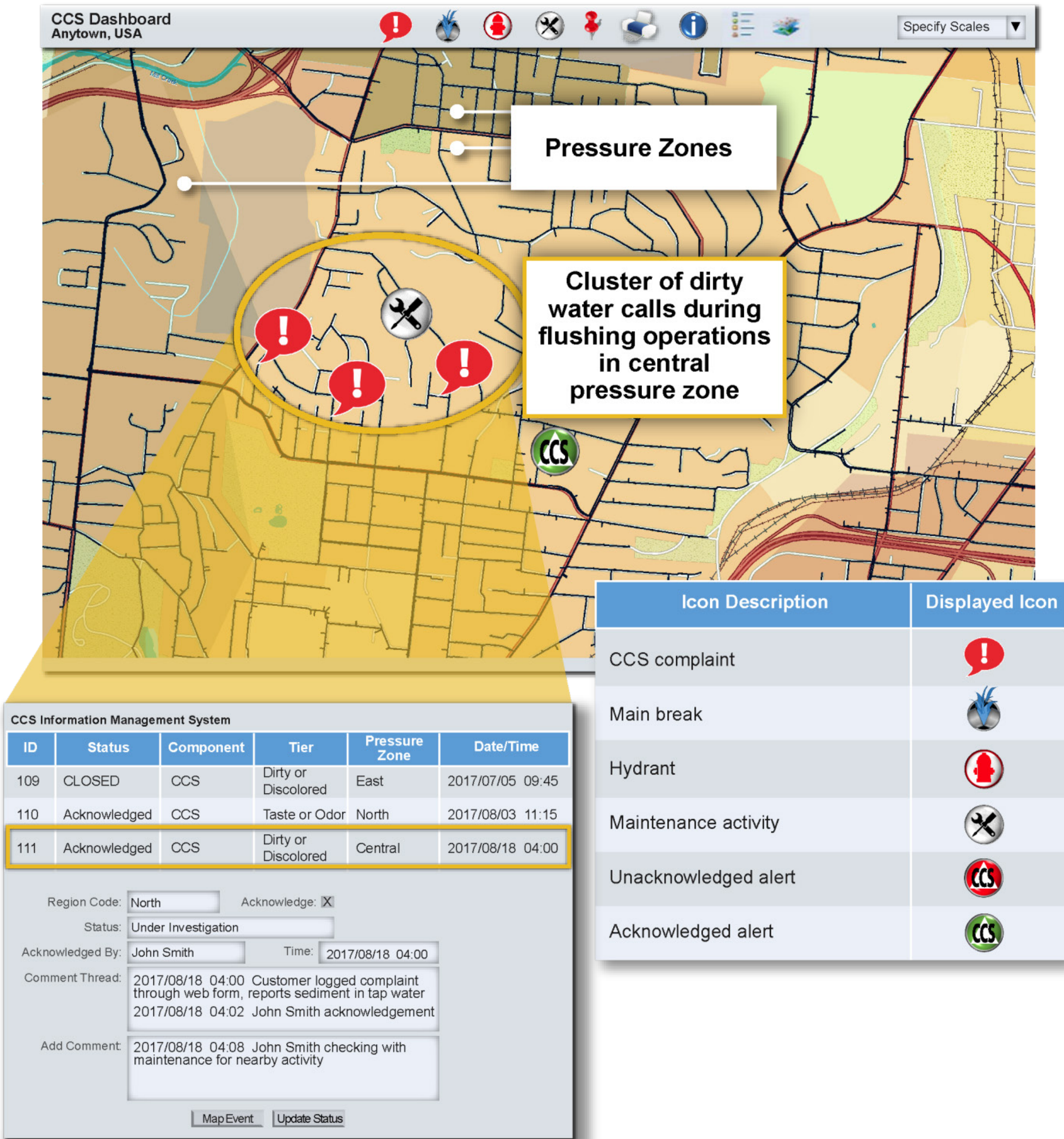


Figure 4-2. Example Dashboard Displaying a CCS Alert

Section 5: Alert Investigation Procedure

Once a CCS alert is received by utility personnel, it should be promptly investigated to determine the underlying cause of the alert. This process should be documented in an ***alert investigation procedure*** that guides personnel through a consistent and methodical approach.

> **TARGET CAPABILITY**
>
> Your utility has developed, documented, and put into practice a procedure that facilitates timely and efficient investigation of CCS alerts.

This section describes considerations for development of a CCS alert investigation procedure and consists of the following subsections:

- Subsection 5.1 provides guidance on developing an effective alert investigation procedure.
- Subsection 5.2 provides guidance on developing tools to support the investigation.
- Subsection 5.3 provides guidance on preparing for real-time alert investigation.

5.1 Developing an Effective Alert Investigation Procedure

Utilities should follow a methodical process when developing a CCS alert investigation procedure. The following steps of the process are described in the sections below:

- Define Potential Alert Causes: develop a discrete list of alert causes used to classify each alert.
- Establish an Alert Investigation Process: list detailed, sequential steps for investigating an alert.
- Assign Roles and Responsibilities: identify all personnel who have a role in alert investigations and summarize their responsibilities.

5.1.1 Defining Potential Alert Causes

The objective of the alert investigation process is to identify the cause of an alert. Pre-defined alert categories can be used to classify alerts based on common causes at the conclusion of each investigation. Awareness of the common causes of CCS alerts can be used to develop the steps of an investigation procedure and identify information resources helpful in confirming or ruling out potential causes of an alert. **Table 5-1** lists and summarizes the most common causes of CCS alerts, based on experience from utilities that have implemented CCS. The causes are grouped into invalid and valid alerts.

Table 5-1. Common Causes of CCS Alerts

	Alert Cause	Description
Invalid Alerts	Procedural Error	Utility personnel miscoding complaints as water quality-related or using the wrong water quality category.
	Background Variability	Normal variance occasionally resulting in higher than expected complaint volumes.
Valid Alerts	Change in System Operations	A water quality change caused by unusual system operations, such as a change in pumping, valving, or treatment processes.
	Distribution System Issue	A water quality change caused by distribution work or a distribution system upset, such as a main break or pressure surge.
	Contamination Incident	An accidental or intentional introduction of a foreign substance into the distribution system, which may or may not be harmful.

5.1.2 Establishing an Alert Investigation Process

With potential causes of a valid CCS alert defined, the next step is to develop an alert investigation process to guide investigators through a detailed sequence of steps to determine the cause of an alert. This process will generally begin with an initial review of complaint characteristics and locations, followed by a review of water quality data, treatment plant operations, distribution work in the area, and utility operations that may impact water quality.

If the review of complaints shows dissimilar descriptions or dispersed locations, the alert is not likely indicative of a localized deterioration of water quality in the distribution system. Instead, the alert may be due to normal variations in the number of water quality complaints received by the utility. If the complaints are related, i.e., similar in nature and clustered in one general area, the investigation may reveal a likely cause for the alert, such as a main break or localized flushing activities. In this case, a utility may choose to implement standard procedures for addressing water quality complaints. If the investigation concludes that the CCS alert is not an indicator of contamination, the investigation is closed.

If, however, the alert investigation reveals clustered complaints that are similar in nature and are not the result of known utility operations in the area, then the alert may be due to a more serious water quality problem. In this case, the ***SRS Manager*** is contacted and additional investigative and response actions are implemented under ***Water Contamination Response***.

Utilities should document their CCS alert investigation procedure in a diagram that walks through the entire process. This simplified representation of the alert investigation process allows individuals with responsibilities for discrete steps to see how their activities support the overall investigation.

The *CCS Alert Investigation Procedure Template* includes an editable table, process flow diagram, and ***alert investigation checklist*** that can be used to develop a CCS alert investigation procedure for a utility. The template can be opened in Word by clicking the icon in the callout box.

This template includes an editable alert investigation process diagram and checklist.

Figure 5-1 provides an example of a CCS alert investigation procedure diagram. The major steps and decision points are shown, as well as additional detail on the actions implemented. A range of estimated times for properly trained personnel to complete groups of steps is provided to the left of the steps and decision points. The total time for utility personnel to complete a CCS alert investigation could range from 2 to 85 minutes, based on experience with SRS pilot utilities.

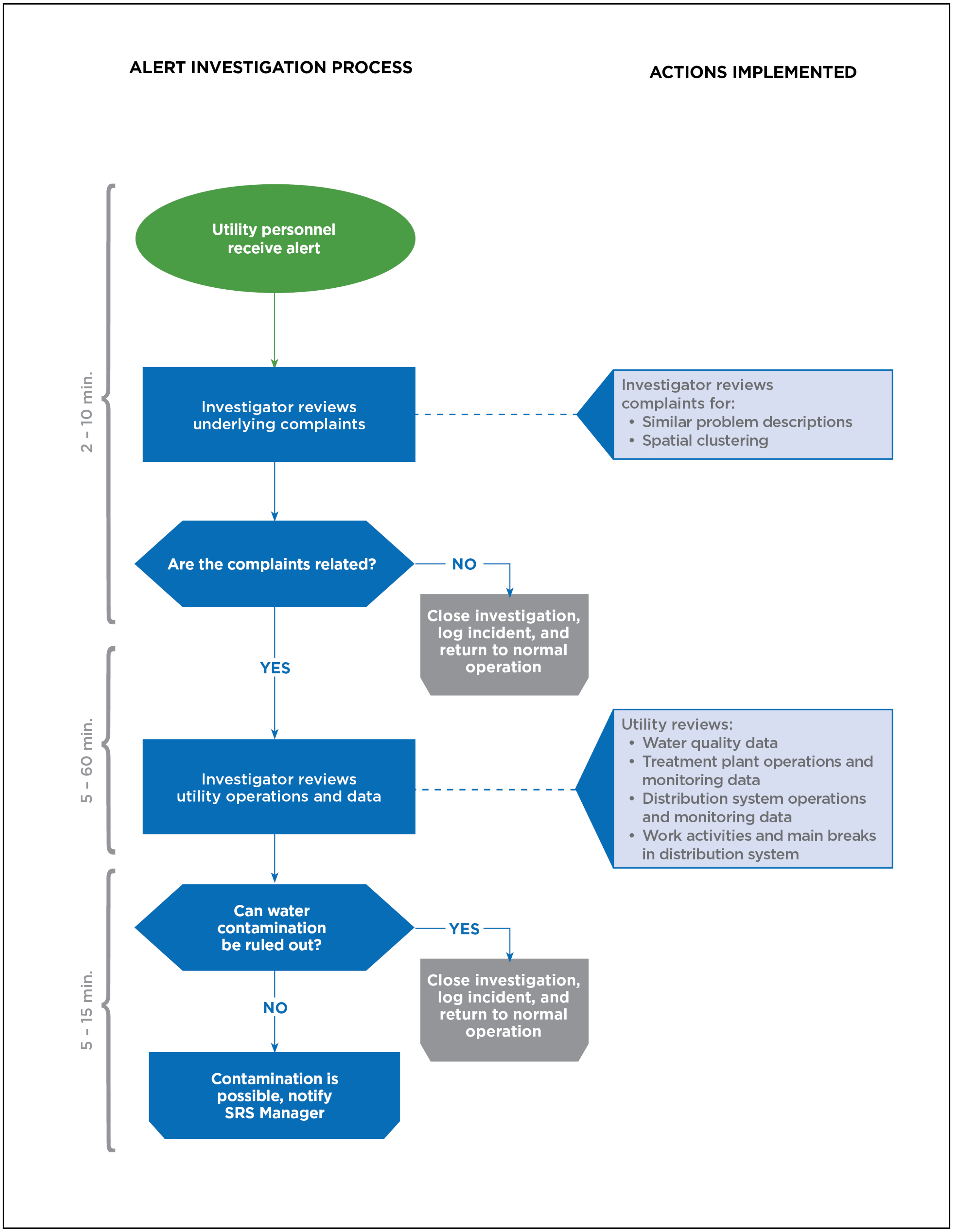


Figure 5-1. Example CCS Alert Investigation Process

5.1.3 Roles and Responsibilities

Different utility personnel may be involved in investigating CCS alerts. **Table 5-2** shows an example of roles and responsibilities during CCS alert investigations. If utility water quality complaints are handled by a 311 system or city call center, partners external to the utility may need to be involved in the investigation.

Table 5-2. Example of Roles and Responsibilities for CCS Alert Investigations

Role	Alert Investigation Responsibilities
Water Quality Chemist	• Receive notification of CCS alerts and lead the investigation in collaboration with the CSR Supervisor. • Coordinate support from the Distribution System Operator, Distribution Dispatch Supervisor, and CSR Supervisor during investigation of the CCS alert. • Review water quality data in the area of the CCS alert. • Document the alert investigation and close out.
Distribution Dispatch Supervisor	• Review distribution system work orders during investigation of a CCS alert.
Distribution System Operator	• Monitor SCADA alerts and review operational data to support the investigation of alerts.
CSR	• Collect detailed information from customers regarding water quality complaints during normal business hours. • Advise customers about water quality incidents related to typical distribution system issues (e.g., rusty water due to flushing, chlorine odor due to operations). • Provide details on specific water quality complaints to the CSR Supervisor.
CSR Supervisor	• Receive and assist in the investigation of contact alerts in conjunction with the Water Quality Chemist.
SRS Manager	• Receive notification of possible water quality contamination.

5.2 Developing Investigation Tools

CCS alert investigation tools help guide implementation of the investigation procedure. The following investigation tools are discussed in the sections below:

- Checklists
- Record of Alert Investigations
- Quick Reference Guides

5.2.1 Alert Investigation Checklists

Alert investigation checklists are job aids that guide personnel through their investigative responsibilities and document investigation findings. Checklists also ensure consistency among investigators and improve recordkeeping. Checklists are derived from the process flow and serve to prompt investigators to check resources, evaluate information, and perform actions. They generally list the activities assigned to specific roles; therefore, more than one checklist may be developed to support the CCS alert investigation procedure.

CONSISTENCY

If other SRS components are being implemented, strive for consistency in investigation tools and roles and responsibilities across components.

The checklist should be presented concisely and require that only critical information be documented. This will allow the user to focus on conducting the investigation without needing to track or record unnecessary details. A checklist is most useful when limited to one double-sided page, which should be adequate for most utilities. Refer to the *CCS Alert Investigation Procedure Template* in Section 5.1.2 for an editable checklist.

5.2.2 Record of Alert Investigations

A record of alert investigations provides documentation of key information, such as date/time and name of the investigator, including the actions implemented during the investigation and the likely cause of the alert. This record may also serve as a resource during the investigation of future alerts and provides a means to analyze the frequency of alert investigations by a variety of factors (e.g., alert cause, investigator, time of day, season of year).

There are a variety of ways to document alert investigations. For example, a spreadsheet can be maintained that can be accessed by the SRS Manager and all necessary investigators on a shared drive. Electronic tools and mobile applications make it easy to standardize, synchronize, and compare data, while increasing accuracy. These tools can be aggregated to capture response times and conclusions, which may provide valuable insight into the implementation of the alert investigation procedure. **Figure 5-2** provides an example of electronic alert investigation records.

Alert Investigation Information

Alert Date/Time	Alert Location	Investigator	Investigation Start Date/Time	Investigation End Date/Time	Conclusion	Notes
4/3/2017 9:21	Abbington Village	Pat Field	4/3/2017 9:23	4/3/2017 10:45	Invalid alert procedural error	CSR miscoded two complaints
6/24/2017 17:02	Mongo Court	Joe Rogers	6/24/2017 17:12	6/24/2017 17:25	Invalid alert background variability	Complaints did not have similar descriptions
7/12/2017 8:03	Spruce Center	Sue Williams	7/12/2017 8:10	7/12/2017 8:58	Valid alert, cause identified: distribution system issue	Main break resulted in a cluster of rusty water complaints

Figure 5-2. Example of Alert Investigation Records

If a dashboard will be used to support the SRS, the electronic tracking of investigations may be incorporated into the design. For example, electronic checklists can be developed that automatically enter investigation records and updates into an SRS's ***information management system***. See *Dashboard Design Guidance for a Water Quality Surveillance and Response System* for more information.

5.2.3 Quick Reference Guides

While many alert investigation activities will become second nature to investigators, additional tools may be useful for completing complex or less frequently implemented tasks. Key information can be summarized using quick reference guides or factsheets to ensure investigators can easily get the information they need. For example, quick reference guides could be developed for checking a call queue volume, recalling additional CSRs, or using a reverse 911 system to notify customers about a potential water quality issue.

5.3 Preparing for Real-time Alert Investigations

After the CCS alert investigation procedure is developed, a utility will need to develop a plan to put it into practice. The benefits of CCS can be fully realized only if CCS alerts are investigated in real time and responded to appropriately. The following topics are covered under this section:

- Training
- Preliminary operation
- Real-time operation

5.3.1 Training

Proper training on the alert investigation procedure ensures that all personnel with a role in investigating CCS alerts are aware of their responsibilities and have the knowledge and expertise needed to execute those responsibilities. Training on the alert investigation procedure could include the following:

- An overview of the purpose and design of CCS
- A detailed description of the alert investigation procedure and the role of each participant
- A review of checklists, quick reference guides, information management systems, and other tools available to support CCS alert investigations
- Instructions for entering new alert investigation records and retrieving previous records

Section 6 of *Guidance for Developing Integrated Water Quality Surveillance and Response Systems* provides information on implementing a training and exercise program. In general, classroom training is used first to orient personnel to the procedure and their responsibilities during CCS alert investigations. Once CCS personnel are comfortable with the procedure, exercises can be conducted to provide personnel with an opportunity to implement their responsibilities in a controlled environment. The *SRS Exercise Development Toolbox* is an interactive software program designed to help utilities design, conduct, and evaluate exercises specific to CCS and the other SRS components.

5.3.2 Preliminary Operation

A period of preliminary operation should follow initial training, allowing utility personnel to practice their responsibilities in test mode before the transition to real-time operation. For example, personnel can be asked to investigate alerts in batches as they have time, not necessarily as the alerts are generated. During this period, investigators may or may not receive alert notifications.

During preliminary operations, it may be useful to hold regular meetings with all investigators to discuss recent data and alerts. It is generally most effective if participants are asked to perform specific analyses or alert investigations before each meeting and then discuss conclusions, observations, insights, and challenges as a group. These meetings can be held more frequently initially (such as weekly) but become less frequent as proficiency increases and issues are resolved. Meeting monthly during the period of preliminary operation would be appropriate and sufficient for most CCS applications.

DO NOT RUSH

Do not rush preliminary operation. This period provides an opportunity for personnel to practice their responsibilities and become familiar with the data typically used during investigations, improving the efficiency of alert investigations.

Preliminary operation provides personnel with opportunities to refine the alert investigation procedure and investigation tools. Based on feedback from investigators, responsibilities can be clarified, unnecessary steps can be eliminated, existing tools can be refined, new tools can be developed, and procedures can be better integrated into existing job functions.

5.3.3 Real-time Operation

During real-time operation, CCS alerts are investigated as they are generated, and the Water Contamination Response component is activated if a contamination incident is considered ***possible***. The transition from preliminary operation to real-time operation should be clearly communicated to all utility personnel with a role in CCS alert investigations. This includes establishing a date for the transition to real-time operation and providing expectations for how alert investigations will be performed and documented.

After transitioning to real-time operation, it is important to continue to oversee and support investigators. The record of alert investigations should be regularly reviewed to ensure that personnel are accurately and thoroughly carrying out their responsibilities, and instruction should be provided to individuals who are not. Ongoing drills, exercises, and training are important to ensure that personnel remain familiar with their responsibilities and to address any changes, such as updates to the procedure or investigation tools. Maintenance of the alert investigation procedure during real-time operation may involve periodic review to verify that it is working as intended. Because CCS alerts may be infrequent, refresher training may be needed to maintain proficiency. Finally, it is important to thoroughly train new CCS personnel on their responsibilities and alert investigation procedures.

REGULARLY REVIEW AND UPDATE THE ALERT INVESTIGATION PROCEDURE

Routine updates to the alert investigation procedure and investigation tools are necessary to maintain their usefulness. Recommendations for procedure maintenance include:

- Designate one or more individuals with responsibility for maintaining alert investigation materials
- Establish a review schedule (annual reviews should suffice in most cases)
- Review the record of alert investigations, conduct tabletop exercises, and solicit feedback from investigators to identify necessary updates
- Establish a protocol for submitting and tracking change requests

Section 6: Preliminary CCS Design

The information presented in the previous sections of this document can guide the development of a preliminary CCS design that supports a utility's SRS design goals and performance objectives. If CCS will be a component in a multi-component SRS, the design of the integrated system will likely be guided by a project management team. In this case, guidelines for design of the individual components should be provided to the component implementation teams and should include:

- Overarching design goals and performance objectives for the SRS
- Existing resources that could be leveraged to implement the SRS components, including personnel, procedures, equipment, and information management systems
- Project constraints, such as budget ceilings, schedule milestones, and policy restrictions
- Instructions or specific guidelines for the development of preliminary component designs

Regardless of whether CCS will be developed as a standalone component or as part of a multi-component SRS, the preliminary CCS design should be documented in sufficient detail to assess whether or not it can achieve the design goals established for the component within project constraints.

This template can be used to develop a preliminary CCS design.

A *Preliminary CCS Design Template* can be opened and edited in Word by clicking the icon in the callout box. This template covers the following aspects of CCS design:

- Component implementation team: Identify personnel from the utility that will have a role in the design and implementation of CCS. Document the role, responsibilities, and estimated time commitment of each team member.
- Design goals and performance objectives: Using the overarching design goals and performance objectives established for the SRS, develop specific CCS goals and performance objectives to guide the design process.
- Customer complaint surveillance systems: Identify all datastreams and IT systems that will be used to monitor water quality complaints. If existing systems will be enhanced or integrated, describe the enhancements or integration. If new systems will be deployed, provide specifications, including the datastreams that will be monitored.
- Preliminary information management requirements: Identify all information management systems that would be used during operation of CCS. This will likely include utility systems that will be accessed during the investigation of CCS alerts. Develop an information flow diagram depicting user-to-machine and machine-to-machine interactions. Document ***technical*** and ***functional requirements*** for any new or modified information management systems. Note any data sharing agreements that will need to be developed in order to implement the information management system.
- Initial training requirements: Develop a training plan to educate personnel about their responsibilities during operation of CCS.
- Budget: Develop a line item budget for the CCS component noting the method for covering each cost item. It is recommended that the budget include implementation as well as ***operation and maintenance (O&M) costs***, which can be used to develop a ***lifecycle cost*** estimate. The budget should indicate the year in which each cost is incurred. Contingencies should be included to avoid cost overruns.
- Schedule: Develop a schedule that shows the planned sequencing of activities and key dependencies. The schedule may reflect a phased implementation over multiple years, which may be advantageous or necessary to overcome resource (financial or personnel) limitations.

It is also a good idea to develop a preliminary alert investigation procedure using the template provided in Section 5. This procedure can help to identify information resources needed to conduct a CCS alert investigation, which can inform CCS design, particularly information management requirements.

In some cases, multiple design alternatives may emerge. A ***benefit-cost analysis*** should be performed to identify the preferred option. The resource *Framework for Comparing Alternative Water Quality Surveillance and Response Systems* provides an objective process for comparing design alternatives with respect to their lifecycle costs and capability.

Resources

Overview of CCS Design

Water Quality Surveillance and Response System Primer

This document provides an overview of SRS for drinking water distribution systems. It covers possible applications of an SRS, provides information about the monitoring and surveillance components, describes common design goals and performance objectives, and includes an overview of the approach for implementing an SRS. EPA 817-B-15-002, May 2015.
https://www.epa.gov/sites/production/files/2015-06/documents/water_quality_sureveillance_and_response_system_primer.pdf

Customer Complaint Surveillance Primer

This document provides an overview of the CCS component and presents information about the goals and objectives of CCS in the context of an SRS. EPA 817-B-15-002C, May 2015.
http://www.epa.gov/sites/production/files/2015-06/documents/customer_complaint_surveillance_primer.pdf

Complaint Collection

Example Language for a Consumer Confidence Report (Word File)

The case study includes examples of how a customer can be directed to the best method for communicating water quality concerns. November 2017.
Click this link to open the template

Email Message Template (Word File)

The email message template is an example of how a utility can communicate directly with customers. November 2017.
Click this link to open the template

Generic Bill Insert Template (PowerPoint File)

The generic bill insert template is an example of how a utility can communicate directly with customers. November 2017.
Click this link to open the template

Summary of Implementation Approaches and Lessons Learned from the Water Security Initiative Contamination Warning System Pilots

This summary report contains case studies from the Water Security Initiative, including each pilot's implementation of CCS. EPA 817-R-15-002, October 2015.
https://www.epa.gov/sites/production/files/2015-12/documents/wsi_pilot_summary_report_102715.pdf

Water Quality Complaint Processing Form Template (Word File)

The template includes of a form that CSRs or other utility personnel can use to capture information about a water quality complaint and track any work orders associated with the complaint. November 2017.
Click this link to open the template

Information Management and Analysis

Taste and Odor: An Operator's Toolbox [DVD]

This video provides methods for determining the causes of taste and odor in potable water, as well as treatment responses. AWWA. (2001).

Diagnosing Taste and Odor Problems Field Guide

This field guide provides all the information water utilities need to diagnose and remove objectionable tastes and odors at the tap. Burlingame, G., Booth, A., Dietrich, A., Gallagher, D., Khiari, D., Suffet, I.H., and Watson, S. (2011). Washington, DC: AWWA.

Early Warning and Management of Surface Water Taste-and-Odor Events

This report focuses on strategies to head off taste and odor problems before they can cause complaints, offering a set of practical guidelines and tools that any utility can use. Taylor, W., Losee, R., Torobin, M., Izaguirre, G., and Sas., D. (2006). Washington, DC: AWWA.

Taste at the Tap: A Consumer's Guide to Tap Water Flavor

This informative booklet assists utilities in helping their customers understand what can cause tastes and odors in tap water and why tastes and odors do not necessarily indicate a problem with the water. Burlingame, G. (2010). Washington, DC: AWWA.

Alarm Estimation Tool (Excel File)

Estimates the number of CCS alerts generated at a given alert threshold using a spreadsheet interface. EPA, January 2011.
https://www.epa.gov/waterqualitysurveillance/customer-complaint-surveillance-tools-establish-alert-thresholds

Threshold Analysis Tool

Supports the analysis of a variety of data file formats and offers three different statistical methods (percentile, and standard deviation, and recurrence intervals) to determine thresholds for use in identifying anomalous water quality complaint volumes. EPA 817-B-13-005, 2013.
https://www.epa.gov/waterqualitysurveillance/customer-complaint-surveillance-tools-establish-alert-thresholds

CCS Email Alert Template (Word File)

The CCS email alert template is an example communication which provides significant detail on alert data and instructions for investigation. November 2017.
Click this link to open the template

CCS Text Message or SMS Alert Template (Word File)

The CCS text message or SMS alert template is an example communication which provides only basic alert data. This short communication does not provide instructions for investigation. November 2017.
Click this link to open the template

Dashboard Design Guidance for Water Quality Surveillance and Response Systems

This document provides information about useful features and functions that can be incorporated into an SRS dashboard. It also provides guidance on a systematic approach that can be used by utility managers and IT personnel engaged in the process of designing a dashboard to define requirements. EPA 817-B-15-007, November 2015.

https://www.epa.gov/sites/production/files/2015-12/documents/srs_dashboard_guidance_112015.pdf

Information Management Requirements Development Tool

This tool is intended to help users develop requirements for an SRS information management system, thereby preparing them to select and implement an information management solution. Specifically, this tool (1) assists SRS component teams with development of component functional requirements, (2) assists IT personnel with development of technical requirements, and (3) allows the IT design team to efficiently consolidate and review all requirements. EPA 817-B-15-004, October 2015.
https://www.epa.gov/waterqualitysurveillance/information-management-requirements-development-tool

Alert Investigation Procedure

CCS Alert Investigation Procedure Template (Word File)

The alert investigation procedure template includes an editable table, flow diagram, and checklist that can be used to document the utility's role in a CCS alert investigation process. November 2017.
Click this link to open the template

Guidance for Developing Integrated Water Quality Surveillance and Response Systems

This document provides guidance for applying system engineering principles to the design and implementation of an SRS to ensure that the SRS functions as an integrated whole and is designed to effectively perform its intended function. EPA 817-B-15-006, October 2015.
https://www.epa.gov/sites/production/files/2015-12/documents/guidance_for_developing_integrated_wq_srss_110415.pdf

SRS Exercise Development Toolbox (EPA, 2016)

The SRS Exercise Development Toolbox assists utilities and response partner agencies to design, develop, conduct, and evaluate SRS-related discussion and operations-based exercises. These exercises help to develop, teach, refine, and improve SRS procedures. EPA, 2016.
https://www.epa.gov/waterqualitysurveillance/water-quality-surveillance-and-response-system-exercise-development-toolbox

Preliminary CCS Design

Preliminary CCS Design Template (Word File)

The preliminary CCS design template can be used to document aspects of CCS component design, such as the component implementation team, design goals and performance objectives, CCS systems, preliminary information management requirements, initial training requirements, budget, and schedule. November 2017.
Click this link to open the template

Framework for Comparing Alternatives for Water Quality Surveillance and Response Systems (EPA, 2015g)

This document provides guidance for selecting the most appropriate SRS design for a utility from a set of viable alternatives. It guides the user through an objective, stepwise analysis for ranking multiple alternatives and describes the types of information necessary to compare the alternatives. EPA 817-B-15-003, June 2015.
https://www.epa.gov/sites/production/files/2015-07/documents/framework_for_comparing_alternatives_for_water_quality_surveillance_and_response_systems.pdf

References

Grabinski, J. and Hesner, R., 2011. Calls Taken Here: How a Joint Pilot Project Streamlined Operational Response for Consumer Water Quality Issues. *Proceedings of AWWA Water Security Congress*. Nashville, TN.

Mercer, Kenneth L., 2017. Pages From the Past: Experience in Handling Bad Water Complaints and Laboratory Control, by Earl T. Kirkpatrick, 1916. *JAWWA*, 109 (4):64-66.

Whelton, A.J., Dietrich, A., Gallagher, D.L., and Roberson, J.A., 2007. Using Customer Feedback for Improved Water Quality and Infrastructure Monitoring. *JAWWA,* 99 (11): 62-76.

Glossary

311. A municipal phone number used for non-emergency requests and information.

alert. An indication from an SRS surveillance component that an anomaly has been detected in a datastream monitored by that component. Alerts may be visual or audible and may initiate automatic notifications such as pager, text, or email messages.

alert investigation. The process of investigating the validity and potential causes of an alert generated by an SRS surveillance component.

alert investigation checklist. A form that lists a sequence of steps to follow when investigating an SRS alert. This form ensures consistency with an alert investigation procedure and provides documentation of the investigation of each alert.

alert investigation procedure. A documented process that guides the investigation of an SRS alert. A typical procedure defines roles and responsibilities for alert investigations, includes an investigation process diagram, and provides one or more checklists to guide investigators through their role in the process.

anomaly. A deviation from an established baseline in a monitored datastream. Detection of an anomaly by an SRS surveillance component generates an alert.

anomaly detection system. A data analysis tool designed to detect deviations from an established baseline. An anomaly detection system may take a variety of forms, ranging from complex computer algorithms to thresholds.

autodialer. An electronic device or software application that automatically dials pre-determined phone numbers. Once a call has been answered, an autodialer either plays a recorded message or connects the call to a live person.

baseline. Values for a datastream that include the variability observed during typical system conditions.

benefit-cost analysis. An evaluation of the benefits and costs of a project or program, such as an SRS, to assess whether the investment is justifiable considering both financial and qualitative factors.

CCS Information Management System. Used to manage customer and water quality complaints. The system may integrate datastreams and parts of other IT systems including Asset Management Systems, Customer Information Systems, Customer Relation Management Systems, Geographic Information Systems, Interactive Voice Response, Meter Data Management Systems, and Work Management Systems.

component. One of the primary functional areas of an SRS. There are five surveillance components: Online Water Quality Monitoring (including source water and distribution system monitoring); Physical Security Monitoring, Advanced Metering Infrastructure, Customer Complaint Surveillance, and Public Health Surveillance. There are two response components: Water Contamination Response and Sampling and Analysis.

consequence. An adverse public health or economic impact resulting from a contamination incident.

constraints. Requirements or limitations that may impact the viability of an alternative. The primary constraints for an SRS project are typically schedule, budget, and policy issues (e.g., zoning restrictions, IT restrictions, union prohibitions).

contamination incident. The presence of a contaminant (microorganism, chemical, waste, or sewage) in a drinking water distribution system that has the potential to cause harm to a utility or the community served by the utility. Contamination incidents may have natural (e.g., toxins produced by a source water algal bloom), accidental (e.g., chemicals introduced through an accidental cross-connection), or intentional (e.g., purposeful injection of a contaminant at a fire hydrant) causes.

Customer Complaint Surveillance (CCS). One of the surveillance components of an SRS. CCS monitors water quality complaint data in call or work management systems and identifies abnormally high volumes or spatial clustering of complaints that may be indicative of a contamination incident.

customer service representative (CSR). Personnel at a utility or city contact center who receive customer information or interact with customers. These personnel often resolve issues related to water quality, service, or billing.

dashboard. A visually-oriented user interface that integrates data from multiple SRS components to provide a holistic view of distribution system water quality. The integrated display of information in a dashboard allows for more efficient and effective management of distribution system water quality and the timely investigation of water quality incidents.

datastream. A time series of values for a unique parameter or set of parameters. Examples of SRS datastreams include chlorine residual values, water quality complaint counts, and number of emergency department cases.

design elements. The functional areas which comprise each component of an SRS. In some cases design elements are divided into design sub-elements. In general, the information presented in SRS guidance and products is organized by design elements and sub-elements.

design goal. The specific benefits to be realized through deployment of an SRS and each of its components. A fundamental design goal of an SRS is detecting and responding to distribution system contamination incidents. Additional design goals for an SRS are established by a utility and often include benefits to routine utility operations.

design sub-element. Features, capabilities or attributes that comprise a design element. In general, the information presented in SRS guidance and products is organized by design elements and sub-elements.

distribution system model. A mathematical representation of a drinking water distribution system, including pipes, junctions, valves, pumps, tanks, reservoirs, and other appurtenances. A model predicts flow and pressure of water through the system, and, in some cases, water quality.

functional requirement. A type of information management requirement that defines key features and attributes of an information management system that are visible to the end user. Examples of functional requirements include the manner in which data is accessed, types of tables and plots that can be produced through the user interface, the manner in which component alerts are transmitted to investigators, and the ability to generate custom reports.

Geographic Information System (GIS). Hardware and software used to store, manage, and display geographically referenced information. Typical information layers used by water utilities include utility infrastructure, hydrants, service lines, streets, and hydraulic zones. GIS can also be used to display information generated by an SRS.

historical data. Data that has been generated and stored, including recent data that is readily available in an information management system and older data that has been stored or archived in a historian.

implementation costs. Costs to procure and install equipment, IT components, and other assets necessary to build an operational system.

information management. The processes involved in the collection, storage, access, and visualization of information. In the context of an SRS, information includes the raw data generated by SRS surveillance components, alerts generated by the components, ancillary information used to support data analysis or alert investigation, details entered during alert investigations, and documentation of Water Contamination Response activities.

information management system. The combination of hardware, software, tools, and processes that collectively supports an SRS and provides users with information needed to monitor real-time system conditions. The system allows users to efficiently identify, investigate, and respond to water quality incidents.

information technology (IT). Hardware, software, and data networks that store, manage, and process information.

interactive voice response (IVR). An automated call management system that transfers utility customer calls to designated customer service representatives, based on customer selected issues such as billing or water quality concerns.

invalid alert. An alert from an SRS surveillance component that is not due to water quality incident or public health incident.

lifecycle cost. The total cost of a system, component, or asset over its useful life. Lifecycle cost includes the cost of implementation, operation and maintenance, and renewal.

operational change. A change in the way the distribution system is operated, including changes in pumping or valving.

operation and maintenance (O&M) costs. Expenses incurred to sustain operation of a system at an acceptable level of performance. O&M costs are typically reported on an annual basis and include labor and other expenditures, such as supplies and purchased services.

performance objectives. Measurable indicators of how well an SRS or its components meet established design goals.

possible. In the context of the threat level determination process, water contamination is considered possible if the cause of an alert from one of the surveillance components cannot be identified or determined to be benign.

real-time. A mode of operation in which data describing the current state of a system is available in sufficient time for analysis and subsequent use to support assessment, control, and decision functions related to the monitored system.

remote access. The ability of a user to access an information management system from a location other than the physical location of the hardware that hosts the system.

software. A program that runs on a computer and performs certain functions.

Supervisory Control and Data Acquisition (SCADA). A system that collects data from various sensors at a drinking water treatment plant and locations in a distribution system, and sends this data to a central information management system.

target capability. A level of performance or an outcome for a design element that is necessary for an effective CCS component. Even if the target capability is not completely achieved, a design element can be enhanced to improve performance of the component.

technical requirement. A type of information management requirement that defines system attributes and design features that are often not readily apparent to the end user but are essential to meeting functional requirements or other design constraints. Examples include attributes such as system availability, information security and privacy, back-up and recovery, data storage needs, and integration requirements.

threshold. A value that is compared against current or recent data to determine whether conditions are anomalous or atypical of normal operations.

user interface. A visually oriented interface that allows a user to interact with an information management system. A user interface typically facilitates data access and analysis.

valid alert. Alerts due to water contamination, verified water quality incidents (e.g., occurrence of rusty water), intrusions at utility facilities, or public health incidents.

Water Contamination Response. One of the response components of an SRS. This component encompasses actions taken to plan for and respond to possible drinking water contamination incidents in order to minimize the response and recovery timeframe and, ultimately, minimize consequences to a utility and its customers.

water quality complaints. Complaints received by a utility from a customer indicating that water quality is not as expected. Traits such as an unusual taste, odor, or appearance can all indicate abnormal water quality within the distribution system.

water quality incident. An incident that results in an undesirable change in water quality (e.g., low residual disinfectant, rusty water, taste and odor, etc.). Contamination incidents are a subset of water quality incidents.

Water Quality Surveillance and Response System (SRS). A system that employs one or more surveillance components to monitor and manage distribution system water quality in real time. An SRS utilizes a variety of data analysis techniques to detect water quality anomalies and generate alerts. Procedures guide the investigation of alerts and the response to validated water quality incidents that might impact operations, public health, or utility infrastructure.

Water Quality Surveillance and Response System Manager (SRS Manager). A role within an SRS typically filled by a mid- to upper-level manager from a drinking water utility. Responsibilities of this position include: receiving notification of valid alerts, coordinating the investigation and response, integrating information across the different surveillance components, and activating the Distribution System Contamination Response Plan.

Water Security Initiative. A program developed by EPA to design, evaluate, and promote adoption of Water Quality Surveillance and Response Systems within the drinking water sector.

work management system. Software used by a utility to schedule and track maintenance, repairs, or other operations in the distribution system. The system may generate work orders or work requests that can be leveraged as a CCS datastream.

Appendix A: Spatial Clustering Analysis Techniques

This appendix expands on the topics discussed in Section 4.2.3: Spatial Clustering Analysis Techniques. Spatial analysis reduces the frequency of invalid alerts by only generating an alert when a threshold of complaints within a defined area is surpassed. Spatial data can be analyzed using (in order from least to most effective):

- Administrative Areas (city quadrants, zip codes)
- Hydraulic Areas (water source, pito zone, pressure zone, pressure district)
- Hydraulic Areas and Spatial Algorithms (proximity measurements using GIS functions)

Analyze Data within Administrative Areas

Analyzing the frequency of complaints within an administrative area can improve the ability of CCS to detect water quality incidents. Administrative areas such as neighborhoods, zip codes, or school districts can be used to spatially delineate and capture water quality complaints. To identify a cluster of spatially related complaints, a utility should develop different thresholds for each administrative area. An alert will be generated whenever the threshold within the area is surpassed, regardless of alert occurrence in neighboring areas. While this results in alerts that are easily understood by the end user, it does not incorporate information from neighboring areas. The complaints generated by water contamination could be spread out over several adjacent areas. Thus, a rise in water quality complaints in a region containing multiple areas may be missed by focusing on individual areas.

One method to account for the possibility that a water quality incident will extend beyond a single area is to use spatial filtering methods. Spatial filtering, or "smoothing," techniques use data from surrounding areas or regions to even out areas of high variance. A smoothing of values across regions can create one estimated value. The area around the regions used for smoothing estimates can be defined by the user, such as a one mile radius around the region. There are a number of spatial smoothing techniques such as locally-weighted average, empirical Bayesian models, and the Head-bang algorithm. The Bayesian models are more flexible than other methods, but can be more cumbersome to use and understand. Visualizing spatially smoothed data with GIS can provide investigators with a real-time view of data across the distribution system. These tools allow investigators to see if adjacent regions have more complaints which may not have reached a threshold.

Analyze Data within Hydraulic Areas

Analyzing the frequency of complaints within a hydraulic area can improve the ability of the CCS anomaly detection system to detect a water quality incident. Hydraulic areas correlate with distribution system operations, so complaints within hydraulic areas are more likely to be related to the same underlying cause. A utility can program an automated mapping function for plotting complaints within a GIS layer showing hydraulic areas. This layer is created using a utility's ***distribution system model***.

Complaints that originate from the same hydraulic area should be evaluated to determine whether there are similar problem descriptions amongst spatially related complaints. To determine whether there is a hydraulic relationship between complaints, it is

HYDRAULIC AREAS CASE STUDY

Dallas Water Utilities (DWU) established hydraulic areas consisting of four aggregated "mega" pressure zones. The mega pressure zones, shown in **Figure A-1**, consist of multiple, smaller pressure zones that share a common water source. Each mega-pressure zone has its own set of characteristics in terms of population and water demand. For example, Central Low contains the business district, which presents a unique monitoring challenge because the weekday population and demand during work hours is much greater than after work hours and on weekends.

recommended that source water data, service area data, pressure zone data, pressure district data, or any other descriptor of normal distribution system hydraulics be captured in IT systems used to report water quality complaints.

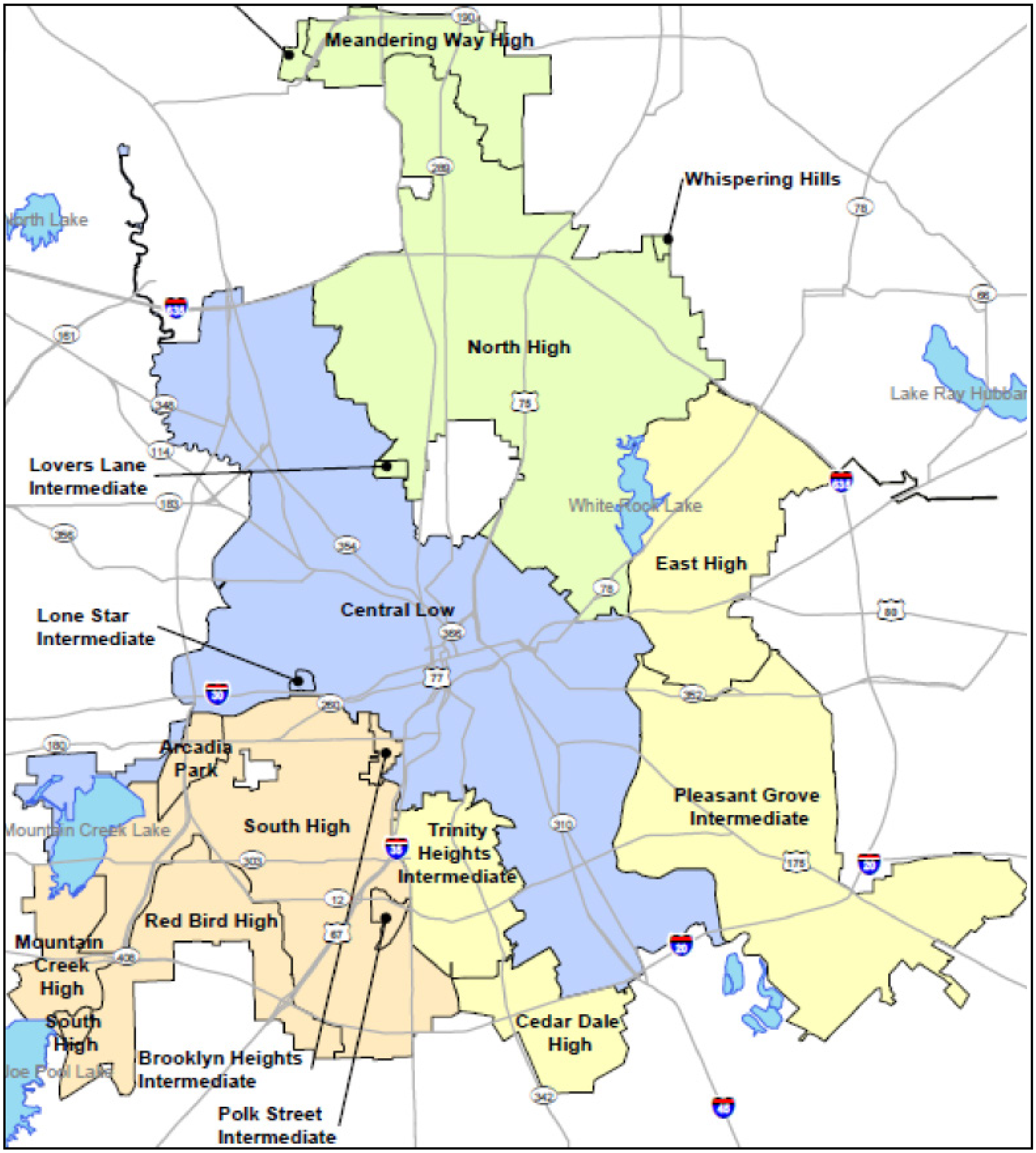


Figure A-1. Hydraulically Connected Mega Pressure Zones within the DWU Distribution System (Grabinski, 2011)

Analyze Data Using Hydraulic Areas and Spatial Algorithms

CCS can apply many of the algorithms utilized by public health organizations to detect outbreaks. Spatial scan statistics typically apply statistical measures of proximity to determine if complaint locations constitute a cluster. Proximity measurements can result in the identification of very small clusters within administrative areas or hydraulic areas, providing a clear focus for the investigation. Alternatively, these algorithms can identify clusters which are spread across adjacent spatial areas, which may get lost if examining complaints only within a specific spatial area. Leveraging a GIS system's analytical and data capabilities to determine the relative distances between all water quality complaint locations is more comprehensive than an analysis on a regional basis.

Another algorithm available through the use of GIS is network tracing. Many GIS applications have the capability to identify hydraulically connected customers through automated tracing along the distribution system model network. Combined with a scan window parameter, this algorithm could theoretically determine if the number of complaints has surpassed a critical level and if the complaints are hydraulically related.

SPATIAL ALGORITHMS CASE STUDY

The Philadelphia Water Department uses a GIS-based work management system in which CSRs enter complaints. The anomaly detection system analyzes the complaint data by using predetermined hydraulic pressure district areas. Additionally, the system searches a 2,000-foot radius around the complaints to identify any service requests or work orders for main breaks, distribution work, hydrant activity, and valve operations in the area. This expedites the response by investigators, since common explanations for customer complaints are displayed with the alert.