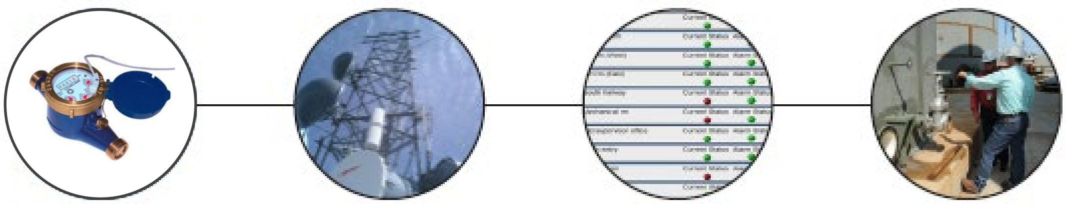
United States Environmental Protection Agency

Using Advanced Metering Infrastructure in a Water Quality Surveillance and Response System



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Acronyms and Abbreviations

AMI	Advanced Metering Infrastructure
AMR	Automated Meter Reading
CCS	Customer Complaint Surveillance
EPA	U.S. Environmental Protection Agency
IT	Information Technology
MIU	Meter Interface Unit
OWQM	Online Water Quality Monitoring
psi	Pounds per Square Inch
S&A	Sampling and Analysis
SCADA	Supervisory Control and Data Acquisition
SRS	Water Quality Surveillance and Response System
WCR	Water Contamination Response

Section 1: Introduction

Advanced Metering Infrastructure (AMI)[1] comprises the equipment, ***communications***, and information management systems for utilities to remotely collect customer water usage data in ***real time***. AMI can provide a wide range of benefits including improved utility operations, improved water conservation and non-revenue water initiatives, and enhanced security and resilience. Utilities generally choose to implement AMI for operational efficiencies and cost savings, but the data produced can be incorporated into a ***Water Quality Surveillance and Response System*** (SRS) to achieve additional benefit.

An SRS is a framework developed by the United States Environmental Protection Agency (EPA) to support monitoring and management of water quality from source to tap. The system consists of one or more ***components*** that provide information to guide drinking water utility operations and enhance a utility's ability to quickly detect and respond to water quality changes. An SRS overview can be found in the *Water Quality Surveillance and Response System Primer*. **Figure 1-1** shows the components of an SRS grouped into two operational phases: surveillance and response.

AMI is a ***surveillance component*** as it generates data and ***alerts*** that may indicate system contamination or other tampering. ***Alert investigation procedures*** guide the systematic investigation of alerts produced to identify their cause. If ***distribution system*** contamination is detected, response actions are implemented to minimize ***consequences***.

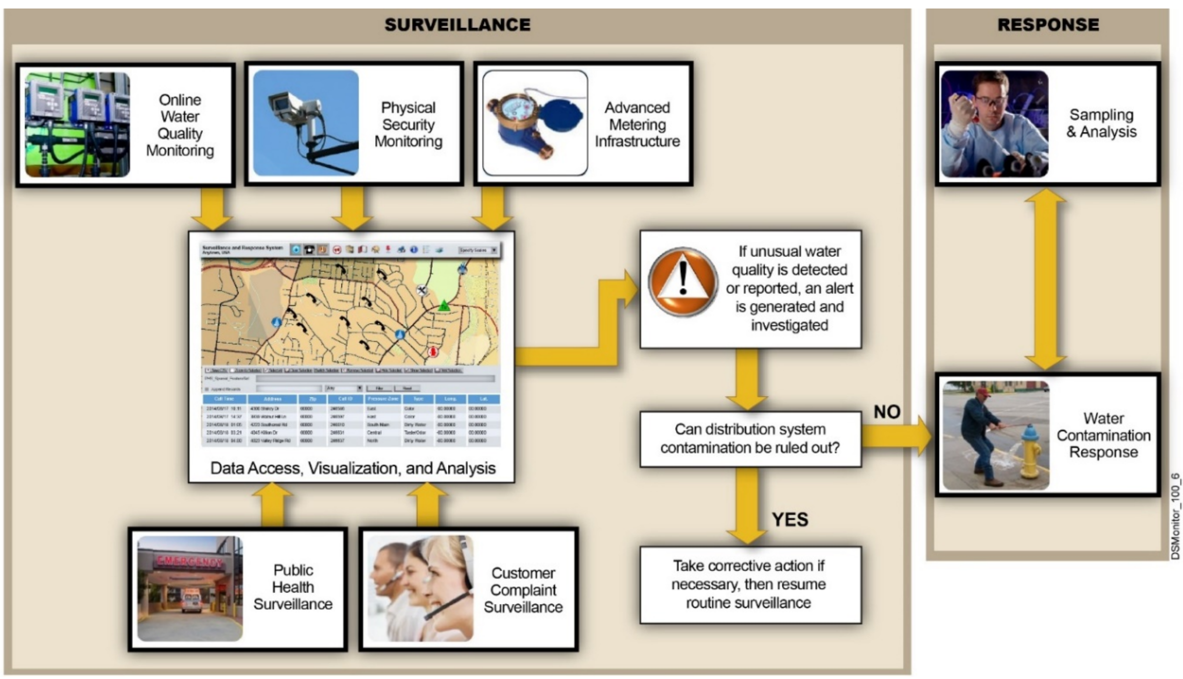

Figure 1-1: Surveillance and Response System Components

EPA intends the design of an SRS to be flexible and adaptable based on a utility's goals and the resources available to support implementation and operation of the system. It is recommended that all SRS designs include at least one surveillance component and basic capabilities for ***Sampling and Analysis*** (S&A) and ***Water Contamination Response*** (WCR). S&A is important because the surveillance components of an

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

SRS typically provide only a general indication of a potential water quality problem; S&A establishes the capability to confirm or rule out specific contaminants or contaminant classes. WCR establishes relationships with response partners and procedures for responding to serious water quality problems such as contamination.

The purpose of this document is to provide guidance for incorporating AMI as a component of an SRS. It is written for drinking water professionals responsible for utility metering and investigating the cause of ***backflow*** and ***tampering*** alerts produced by AMI.

In addition to this introductory section, the document is organized into the following major sections:

- **Section 2** provides an overview of AMI and how AMI can be incorporated as a surveillance component of an SRS.
- **Section 3** provides information about ***meters*** and ancillary equipment used with AMI.
- **Section 4** provides information about communications systems that transmit data between metering locations and a central data repository.
- **Section 5** provides guidance on ***information management,*** encompassing collection, storage, analysis, and display of AMI data and alerts.
- **Section 6** provides guidance on procedures for investigating AMI alerts.
- **Resources** presents a comprehensive list of documents, tools, and other resources useful for integration of AMI into an SRS. A link to a summary of each resource is provided, which are listed in order of use.
- **References** presents a list of published literature cited within the document.
- **Glossary** presents definitions of key 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 AMI, or that describe capabilities that have already been implemented. Furthermore, this document was written to provide a set of core guiding principles that are sufficient to implement the AMI component, while pointing the reader to additional technical resources useful for a specific task. The reader may benefit from locating and downloading technical resources of interest from the Resources section for ease of reference while reading this document.

Section 2: Overview of Incorporating AMI into an SRS

Traditional meters are read manually by utility personnel visiting each site. Automated Meter Reading (AMR) was introduced in the mid-1980s and allows data collection by walking or driving near a meter (Schlenger, et.al., 2011). Many utilities implemented AMR to improve meter reading efficiency, timeliness, and safety. Advanced Metering Infrastructure was introduced in the mid-2000s, extending the benefits of AMR and allowing for automated, frequent, real-time and on-demand access to meter data from a central location.

AMI can be incorporated into an SRS to improve system security and resilience. AMI can provide real-time notification of backflow from a customer connection and meter tampering, both of which could indicate accidental or intentional introduction of a contaminant into a water distribution system. Active monitoring of these alerts can facilitate a timely and effective response, helping to mitigate potential consequences.

Backflow is the reversal of water flow in which water or other substances from a premise plumbing system flows back into the water distribution system. Backflow occurs when water pressure on the premise side of the meter is higher than that on the distribution system side of the meter. This shift in relative water pressure can occur in two ways (USEPA, 2001 and 2003):

- Backsiphonage is caused by a pressure drop in the distribution system due to a main break, system flushing, fire flow, or any situation where large volumes of water flow out of the distribution system at a rapid rate.
- Backpressure is the result of increased pressure on the premise side, such as by high pressure equipment at a residence or industry that is connected to the home or facility's premise plumbing system.

Intentional contamination where a perpetrator pumps contaminant into a distribution system is an example of backpressure. Staff notification of both types of backflow is valuable, as potentially nonpotable water entering the drinking water supply can pose public health risks. Backflow alerts should be investigated immediately.

Tampering refers to the unauthorized handling or damage of an AMI meter. Tampering alerts should be investigated as soon as possible, as most tampering incidents are due to water theft. A less likely, although possible cause of a tampering alert, is removing or disabling a meter to avoid detection when injecting a contaminant. Thus, the combination of backflow and tampering alerts could indicate an intentional injection of contamination. Contaminant injection could have catastrophic consequences for the utility and region (AWWA, 2013). Prompt response to an AMI backflow or tamper alert allows for a reduction in consequences, as early awareness could allow for a contaminated portion of a distribution system to be isolated, customers to be notified, or flushing to be performed. If an extended injection of contaminant is attempted, fast response may provide responders with an opportunity to interrupt the injection, if the utility has a WCR protocol for AMI.

The bulleted list below further describes how AMI contributes to achieving standard SRS ***performance objectives***. Performance objectives are measurable indicators of SRS benefits and are defined in the *Water Quality Surveillance and Response System Primer*.

- ***Incident coverage***: AMI provides reliable detection of intentional or accidental contamination due to backflow and tampering.
- ***Spatial coverage***: AMI provides coverage throughout the metered portion of the distribution system since every meter becomes a ***monitoring location***.

- ***Timeliness of detection***: AMI alerts occur immediately at the time backflow or tampering occurs, allowing for fast response to minimize the spread of contaminant and potentially interrupt the introduction of a contaminant.
- ***Operational reliability***: AMI meters and communications equipment are reliable, and experience little downtime[2].
- ***Alert occurrence*****:** Backflow and tampering alerts are generally ***valid alerts*** and also often help identify needed meter repair, detect water theft, and identify potential cross connections.
- ***Sustainability***: Integration of AMI into an SRS is relatively inexpensive with minimal maintenance costs if AMI has already been implemented for utility operations and conservation.

In the construct of an SRS, AMI is comprised of four basic design elements: Equipment, Communications, Information Management, and Alert Investigation Procedures as summarized in **Table 2-1**. The first three elements are inherent to any AMI system and can generally support integration into an SRS with minimal modifications. Alert investigation procedures are developed during development of the AMI SRS component, as described in Section 6.

Table 2-1: Elements of an AMI SRS Component

AMI Element	Description
AMI Equipment	The hardware that generates AMI data, especially meters that measure the flow to a customer connection.
Communications	Equipment and systems used to transmit data from the meter or endpoint to the information management system.
Information Management	System(s) that retrieve and store data and alerts from meters and other AMI equipment, and then provides data access, visualization and analytics.
Alert Investigation Procedures	A documented procedure for the timely and systematic investigation of alerts with clearly defined roles and responsibilities for each step of the process.

Incorporating AMI into an SRS generally involves limited capital investment, as existing equipment can generally be directly leveraged. Planning for effective AMI integration can include a review of the existing communications, information management systems, visualization tools and how to best leverage these existing resources. The business case for implementing AMI may be driven by other applications of AMI such as leak detection, customer-facing interfaces, and real-time modeling and should also acknowledge equipment lifecycles, technology maturity, and sustainability.

[2] A typical AMI system performance metric is read success rate (RSR). With several solution providers, the range of RSRs from all meters within a three-day period is between 98.5% and 99.5%.

Section 3: AMI Equipment

Understanding your utility's ***AMI equipment*** is important when integrating AMI alerts into an SRS, as several factors impact alert generation, alert occurrence, and the timeliness of information available for ***alert investigation***. This section describes AMI equipment types, which are summarized in **Table 3-1**.

Table 3-1: AMI Equipment Types

Equipment	Description
Meter	Measures the flow to a customer connection. This data can be used to calculate water usage and to detect backflow. Meters can also detect tampering.
Meter Interface Unit (MIU)	Receives a hardwired signal from a meter, converts this signal to a flow value, stores flow values, and wirelessly transmits stored data to the information management system. Alerts or faults generated are also transmitted.
Other Sensors	Meters may be coupled with other sensor types including pressure monitors, temperature sensors, acoustic sensors, and water quality monitors. This data is also transmitted to the information management system.
Remotely Controlled Valves	Allows a utility to shut off or turn on water service at a customer connection from the information management system.

3.1 Meters

Meters generally fall into one of two categories: ***mechanical*** or ***solid-state meters***. The standard flow meters used by utilities are mechanical with an embedded mechanism that rotates, and the number of rotations is translated to flow. Solid-state meters are newer electronic devices with no moving parts and employ a variety of measurement techniques to more reliably measure flow such as acoustic waves and magnetic fields. They may also achieve improved flow resolution, integrate sensors or valves, have self-monitoring functions, and have integrated Meter Interface Units (MIUs).

The meters included in your utility's AMI system can impact how AMI alerts are generated and configured for an SRS and information available for alert investigations. Functionality to consider related to meters include:

- Built-in alerting capabilities for backflow and tampering,
- Measurement range, precision, flow direction, and
- Error codes or values generated that provide information on meter function.

Current equipment configuration should be considered. Functionality not in use that could enhance SRS benefit should be enabled if possible. For example, meters may have the ability to generate backflow alerts that is not currently implemented. If a utility enables the unused functionalities, they should update their WCR to include a protocol for investigating and responding to alerts.

3.2 Meter Interface Units

MIUs are the gateway between meters and the data communications network, allowing the data and analytics generated on site to be transmitted to the information management system. For this document, the term MIU includes common industry terms such as register, encoder and in some cases data collection unit. Some MIUs contain advanced features. For example, they may perform self-monitoring functions such as checking the remaining life of the onboard battery and determining if the meter is communicating properly with the information management system. MIUs with an embedded Global Positioning System (GPS) chip may generate a tamper alarm when communications to the meter has been lost (e.g., the connector cable has been severed) and if MIU movement has been detected. Also, some MIUs may have logic enabling preset or configurable ***threshold*** alerts for backflow. The MIU contains a battery and a computer chip if data is sent by cellular communications, or either a transmitter or transceiver if the data is communicated by Radio Frequency (RF).

The MIU logic defines how data is stored and when it is transmitted to the utility's information management system, which impacts the timeliness of detection aspect of AMI in an SRS. Typically, the MIU periodically (e.g., every 15 minutes or hourly) collects, timestamps, and stores the flow and other data. The MIU logic impacts the subsequent elements of Communications, Information Management and Alert Investigation Procedures. The frequency of the data collection does not have a significant on impact on the battery life, but the transmission frequency can be very significant. Your utility will have to find the optimal balance between data collection and data transmission to balance any competing goals of the AMI system.

3.3 Other Sensors

In addition to flow meters, a utility may choose to install other sensors to improve overall system awareness, support operations, and augment the SRS incident coverage and sustainability performance objectives. These may include water quality monitors, pressure sensors, and temperature sensors. Pressure and temperature are the sensor types more commonly included with AMI, though their inclusion is not standard. Additional sensors may be integrated directly with AMI equipment, connect to AMI communications hardware, or otherwise leverage the AMI architecture. AMI equipment vendors are increasingly providing gateways to allow for the connection of additional hardware.

Inclusion of additional sensors in an AMI system can support an SRS by providing additional data to help detect hydraulic or water quality issues or support the investigation of alert causes. For example, a change in pressure could corroborate backflow, and abnormal water quality data could support the possibility that a contaminant has been injected. AMI meters near ***Online Water Quality Monitoring*** (OWQM) locations can possibly provide additional data to help corroborate alerts generated by other SRS components.

3.4 Remotely Controlled Valves

Some meters include an integrated remotely controlled valve. In other cases, a standalone, remotely controlled valve can be installed next to the meter and either hardwired to the MIU or separately connected to the utility's information management system. Remotely controlled valves are useful for managing ***customer connections***, as service can be turned on or off for customers without utility staff visiting the site. Due to cost, it is uncommon for utilities to install valves at every customer connection. Remotely controlled valves may be installed at select locations such as customers with frequent changes in service status, e.g. summer homes or student housing.

These valves can also support SRS response. In the case of backflow, valve closure (automatically or by utility staff) to inhibit intentional or unintentional flow into the distribution system from a premise could minimize contamination. Additionally, closing remotely controlled valves could stop water from reaching customers if distribution system contamination is confirmed.

AMI PRESSURE SENSORS AND ALERTS

The availability of pressure alerting varies by sensor manufacturer. Typically, an alert is generated when a sensor detects a pressure drop or spike that is outside the normal operating pressure range as established by the utility. The response to a pressure alert will depend on the duration of the pressure deviation and how low the pressure reaches. A continuous low-pressure condition should be investigated immediately because of the potential risk to public health during a negative pressure situation. Most states have mandated minimum pressure requirements (usually 20 psi during fire flow conditions). Some states have required pressure monitoring for pipe repair and different disruptions in service, which in turn correlate to state response requirements, e.g. Ohio requires a pressure of at least 20 psi (Ohio, 2018). A pressure alert may also indicate that there is an operational problem such as a main break, or an issue with a pump or valve. Some sensors may collect pressure data as frequently as 20 times per second for transients and transmit the data to the AMI system hourly.

Section 4: Communications

AMI requires a means to transmit data from the meter to the information management system. Guidance for Designing Communications Systems for Water Quality Surveillance and Response Systems describes various evaluation criteria, communications technologies, and requirements for the various SRS components, including AMI. It also contains information about design and implementation factors such as security, transmission rates, redundancy, topology, and architecture diagrams.

AMI has rigorous communications needs due to the large number of meters deployed. For AMI, communications logic is defined at the MIU, and there are two general transmission kinds:

- ***Scheduled data transmission:*** Data is transferred to the information management system at a pre-defined, recurring ***polling interval***. An interval of 4, 6, 12, or 24 hours is common. The lower frequency may be selected to preserve battery life and reduce communications requirements, though more frequent transmission allows for more timely access to data.
- ***Conditional data transmission:*** Each MIU may initiate data transfer immediately upon defined logic being met. For example, alerts generated within the AMI meter or through MIU self-monitoring may be immediately sent instead of waiting for the next scheduled data transmission. This allows for more timely notification of backflow and tampering alerts, thereby increasing the timeliness of detection performance objective of an SRS.

The transmission type and frequency significantly impact AMI alerting. Most significantly, the timeliness of transmission of data and alerts to the information management system determines how quickly staff can be notified of abnormal conditions, which subsequently impacts how quickly investigation and ***response actions*** can be taken. A low data transmission frequency causes a delay in alert notification since data is not available for analysis until it is transmitted, and alerts cannot be conveyed to staff until they are in the information management system. ***Local data analysis*** generates alerts at the individual meters, allowing for faster notification if the MIU is programmed to push alerts to the information management system when they occur.

Two-way communications provide the most functionality for an SRS, in which commands can also be transmitted from the information management system back to the AMI meters and sensors. Two-way communication enables utility personnel to interact with the MIU, such as querying for the latest meter read, rather than waiting for the next scheduled data transmission. This on-demand data access allows for remote management of meters and remote control of valves and supports the investigation of AMI alerts. Some AMI systems use ***one-way communications***, from the meter to the information system, which allows for integration into an SRS but may impose some limitations on data access and functionality. These communications may utilize a proprietary wireless network or networks using unlicensed frequencies, as described below.

There are two main types of AMI communication networks, and AMI solutions can be deployed as one homogeneous network or can be a hybrid of these:

- ***Proprietary Communications Networks*** are owned and managed by a private entity. These include cellular networks and RF networks on Federal Communication Commission licensed or unlicensed frequency spectrums. Wireless technologies have been rapidly evolving, beginning with third generation (3G) data rates. Long-Term Evolution (LTE) is a cellular method of transmitting data used in some solid-state meters. At least one company has a licensed RF capable of transmitting more data over longer distances.
- ***Open Standard Communications Networks*** provide an open architecture concept which expands the market of wireless devices that can operate over an AMI communication network. Examples of Open Standard Networks include Lora WAN, Wi-SUN and Narrowband IoT. These networks

are favored by some city or state-owned metropolitan entities because of lower energy requirements and increased coverage.

As with any communications system, AMI equipment and the networks used to transmit AMI data are vulnerable to cyberattack. This can allow perpetrators to infiltrate utility systems, disrupt utility operations, or steal information. Thus, it is important to incorporate effective physical security, encryption and ***cybersecurity*** controls into the system. For information about cybersecurity best practices, refer to the *Framework for Improving Critical Infrastructure Cybersecurity*.

Section 5: Information Management

An information management system retrieves and stores data and alerts from meters and other sensors, and then provides analysis, access, and visualization of that data. This section describes AMI data management, analysis for common types of AMI alerts and staff notification, and access and visualization of AMI information as part of an SRS.

5.1 AMI Data Management

For AMI systems, meter and sensor data from the endpoints is generally communicated to an ***AMI headend*** system where it is stored and processed. AMI headend software is typically offered by the AMI vendor and used to administer the system, monitor system health, and initiate and receive communications. Some AMI headend systems contain ***business intelligence*** (BI) functionality for data analysis, and specialized applications.

The headend is also typically an integration hub, communicating to other utility systems to leverage the benefits for operations, conservation, and resilience. These can include GIS, distribution system models, ***work management systems***, billing systems, and customer information systems. For integration of AMI into an SRS, the AMI headend may be connected to the SRS-related information management system(s) for data analysis, visualization, alert notifications, and investigation tools and tracking. *Guidance for Developing Integrated Water Quality Surveillance and Response Systems* provides guidance on information management system requirements for an SRS.

5.2 AMI Data Analysis

When integrated into an SRS, AMI data is analyzed in real time for values or data patterns that suggest backflow or tampering. Analysis of AMI data to produce alerts is generally straightforward, using built-in alerting capabilities of AMI equipment or analysis of single data points. The alert types used for the AMI SRS component are inherent to many AMI systems and can be directly leveraged for an SRS.

As discussed in Section 3, local data analysis can occur at individual meters or MIUs (also called edge computing). Local data analysis can provide faster notifications if alerts are immediately pushed to the AMI headend, particularly if scheduled data communication is infrequent. However, not all meters and MIUs are capable of local data analysis, and local data analysis only considers data from that single meter location.

IT SUPPORT AND DATA STORAGE

Internet technology support is needed to fully leverage the benefits of AMI. Data may be hosted securely in-house, or in the cloud. In-house allows for more control of the data. Cloud hosted data can be more scalable, require a smaller capital investment, and may use a software, platform or infrastructure as a Service, i.e., SaaS, PaaS, and IaaS. Specific data analytic types (anomalous conditions, pattern recognition, and predictive analysis) may vary by meter vendor, IT support and mode of data hosting.

Analysis can also occur once data has been transmitted to the centralized information management systems, which can allow for more advanced and customizable data validation and analytics. Unlike the MIU where a single meter location is considered, using a headend or centralized information management system allows all historical meter data to be included in analyses, along with different data types. A headend or information management system can automate portions of some initial data analyses to identify invalid data or group related alerts into a single incident for staff to investigate. An AMI headend can also connect to a general analytics engine or AMI-specific software (e.g. to detect meter data errors and simultaneous backflow and tampering alerts) to provide for more complex analysis of the large amount of data produced through AMI and an SRS. Data patterns and methods are different for detecting backflow and tampering, as described in this section.

Backflow Alerts

Many meters and MIUs have the capability to detect and produce an alert for backflow, either directly or by monitoring the flow values recorded. Alternately, detection of backflow can be implemented in the headend or information management system by assigning a preset alerting threshold for negative flow. Many AMI systems already incorporate backflow alerts, and preset alerts can be directly leveraged for an SRS.

If using a flowrate threshold for the detection of backflow, the differences in the data can be calculated at the MIU, or by the headend or information management system. Threshold values can also be configured at the headend. In this case, the threshold for multiple meters can be customized relatively easily from a single interface. In addition, thresholds can be easily changed, to adjust the threshold system-wide to minimize **invalid alerts**, e.g. from the slight expansion of water from a water heater back through a meter. Settings and algorithms will depend on the specifics of the MIU logic and AMI headend software provided.

ALERT SENSITIVITY AND TERMINOLOGY

A meter may sense movement and measure 'negative' flow not indicative of a true backflow. Water can move back and forth in a pipe due to changes in pressure or entrapped air, thereby potentially affecting the meter read. A utility may see one or two 'reverse flow', 'invalid consumption', 'negative consumption' or other vendor alarm terms suggesting a backflow, even during a 'positive' flow for a reporting interval. For example, the data may show the meter moved backwards by a tenth of a gallon within an hour period, but the overall consumption is positive, and the meter moved forward when the hourly data was transmitted at a four-hour interval.

Meter sensitivity for backflow may be preset by the manufacturer. A meter preset is generally based on flow directionality and not time, so if the meter moves backward the MIU records an alarm. Mechanical meters with nutating discs may be less sensitive to reverse flows than solid-state meters. While rare, electromagnetic meters can have air trapped in the chamber and be slightly prone to invalid alerts. The meter for at least one vendor generates alerts for the abnormal condition of 'empty pipe'. Headend analytics may be used to detect when hourly readings are not aligned with a previous four-hour interval read.

Tampering Alerts

Tampering refers to the unauthorized handling or damage of an AMI meter. The most common reason for tampering is an attempt of water theft. However, an intruder may remove or disable the meter when injecting contaminant to avoid detection or if there is a backflow prevention device at the meter. Meters can directly detect tampering with alerts generated if there is a cut wire, meter movement, or magnetic tampering. Meters may have a GPS tracker to detect if the meter or MIU has moved. Information management systems can also help to detect tampering indirectly, by applying logic and algorithms to AMI headend systems. For example, a sudden stop in flow data corresponding with meter removal or a significant change in pressure corresponding with an increase in turbidity could suggest a disturbance at the meter.

Alert Notifications

When an AMI alert is generated, personnel responsible for investigating the alerts must be notified to ensure that all AMI alerts are acknowledged and that the alert investigation begins in a timely manner. An optimal notification system brings the alert to the attention of the investigator immediately and provides selected details to support the investigation.

A utility can have automated phone, email, or text message notifications sent electronically to specified staff when an AMI alert is generated. Alternately, alerts can be conveyed via a visual or audible display on a routinely monitored ***dashboard***. Some systems require a user to acknowledge that the alert has been received, with follow-up notifications automatically occurring if acknowledgement has not occurred within a specified time period.

5.3 Data Access and Visualization

An important element of AMI information management is providing utility staff access to the information they need in a clear, useful format. When incorporating AMI into an SRS, data access and visualization can be provided through the AMI headend or other applications that are connected to the AMI headend, including the applications used for other SRS components.

Users generally interact with data through ***user interfaces,*** which can range from simple screens developed in a standard computer application to complex dashboards created by development tools that make accessing and visualizing information intuitive. SRS dashboards generally show near real-time data and information and can include a single source of data or can integrate multiple information types on one or more screens. Geospatial dashboards can provide context for the data and help staff identify patterns, such as alerts from AMI and other SRS components that are spatially clustered.

Dashboards are an important component of an SRS, as they convey alerts to staff, support alert investigation, and capture and store information about investigation activities. Accuracy, completeness, and documentation of investigations can be improved if activities are integrated into a user dashboard. For example, screens can guide users through specific alert investigation responsibilities and require users to select from a pre-defined list of alert causes before closing each alert.

An example AMI dashboard is shown in **Figure 5-1.** In this example, the functionality needed for an alert investigation procedure is integrated into a general AMI user interface. Typical AMI monitoring and analysis information is shown, such as total system consumption and a variety of AMI alert types including non-reporting meters, pressure events, intermittent leaks, continuous leaks, backflow and tampering. SRS alerts for backflow and tampering are shown on the geospatial display, with specific details available in individual information boxes. The alert investigation information panel lists AMI alerts and shows the alert date/time, location, type, investigator, start and end times, conclusion, and notes.

AMI DATA AND RESILIENCE

AMI data has been leveraged to make water utilities more resilient, as illustrated by the following case studies.

During Hurricane Sandy in 2012, one utility identified areas with disrupted power service by noting where AMI data was missing. This information was provided to the city and used to prioritize response activities (Mix, 2016).

During the COVID-19 pandemic, many buildings were closed for an extended period due to stay-at-home orders. This resulted in stagnant water, degraded water quality, and potential public health risks (USEPA, 2020a). To identify areas where this could be a problem, Cleveland Water used AMI data to identify the accounts with the largest reduction of usage. These account holders were directly messaged about the importance of flushing premise plumbing to avoid stagnant water, thus ensuring acceptable water quality and protecting public health (Smith, 2020).

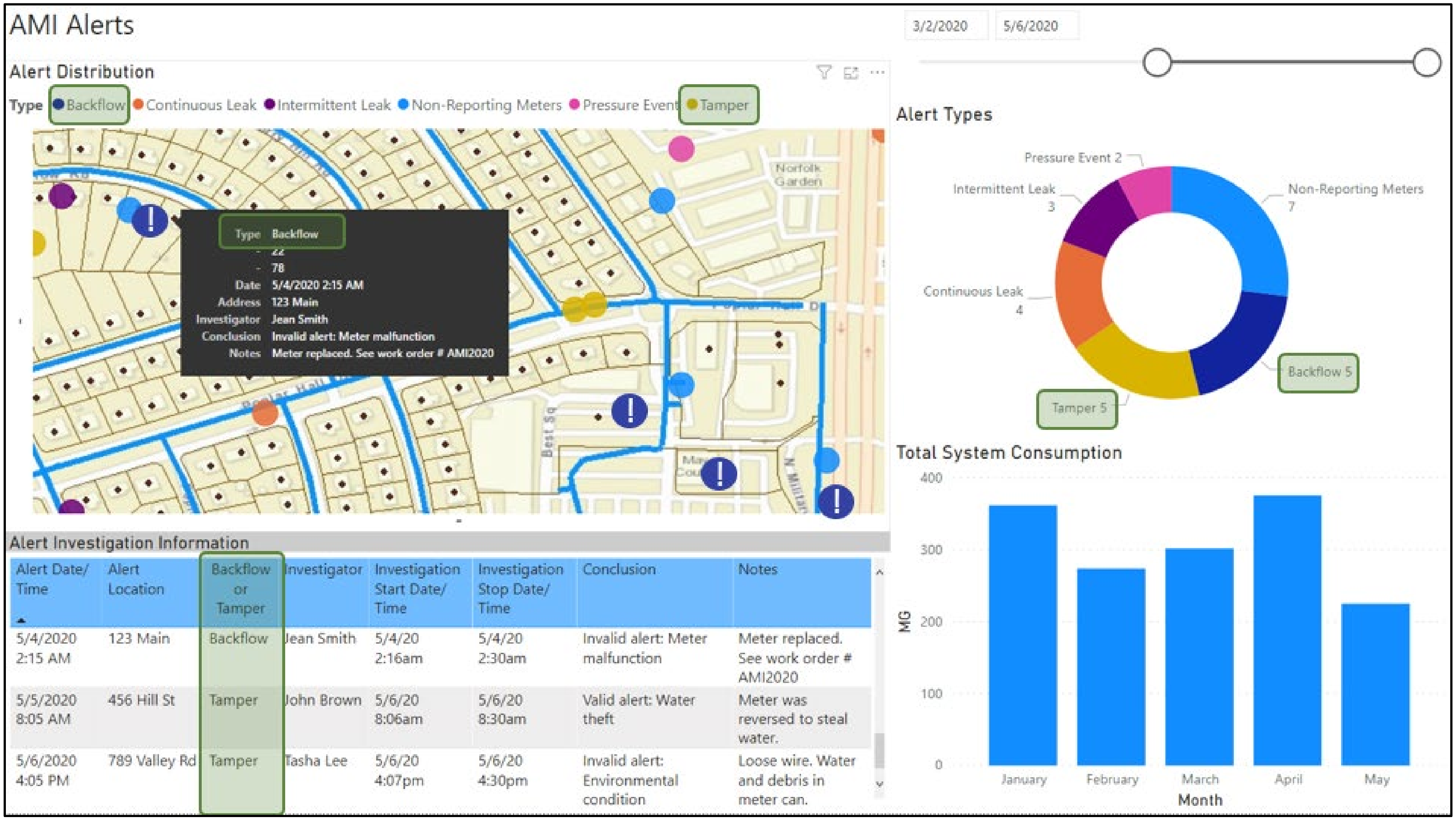

Figure 5-1: Example Dashboard for AMI Information

Section 6: Alert Investigation Procedures

Once an AMI alert is received by utility personnel, it should be promptly investigated to identify the underlying cause of the alert. AMI investigations are guided by documented procedures and include data review and onsite investigations to determine whether the alert can be explained by a known, benign cause. If the cause cannot be determined, contamination is considered ***possible***, and Water Contamination Response is used to determine the credibility of the incident and respond appropriately.

An alert investigation procedure guides consistent and efficient investigation and documentation activities. This section describes considerations for developing and implementing an effective AMI alert investigation procedure.

6.1 Developing an Effective Alert Investigation Procedure

This section describes a methodical process for developing an AMI alert investigation procedure. The steps of the process, listed below, are described in the following subsections:

- Defining potential alert causes: develop a discrete list of alert causes used to classify each alert;
- Establishing an alert investigation process: list detailed, sequential steps for investigating an alert; and
- Assigning roles and responsibilities: identify all personnel who have a role in alert investigations and summarize their responsibilities.

The *AMI Alert Investigation Procedure Template* includes an editable process flow diagram, table and checklist that can be used to document the utility's role during an AMI alert investigation. The template can be opened in Word by clicking the icon in the callout box.

This template can be used to develop an AMI alert investigation procedure.

Defining Potential Alert Causes

A main objective of the alert investigation process is to identify the cause of an alert. Pre-defined alert categories can be used to classify alerts during each investigation. Awareness of the common causes of AMI alerts can be used to develop the steps of an investigation procedure and identify resources helpful in confirming or ruling out potential causes of an alert.

Table 6-1 lists and summarizes common causes of AMI alerts. The causes are grouped into invalid alerts and valid alerts based on if the alert is caused by true backflow or tampering. The list of acceptable alert causes should be customized by each utility and may be adjusted based on experience investigating alerts. Determining the alert cause is useful for revealing problems, e.g. a malfunctioning meter, even if the alert is not indicative of a true backflow or tamper incident.

Table 6-1: Common Causes of AMI Alerts

	Alert Cause	Description
Invalid Alerts	Employee Error	Employee or contractor installed a meter backwards.
		Employee or contractor accidently cut a wire at the meter.
		Employee or contractor moved a meter without proper reporting.
	Equipment Issue	Sensor malfunction.
		Communications fault or power failure.
		Water heater expansion causing backflow.
	Data Analysis Error	Automated data validation or analysis algorithm incorrectly generated an alert.
	Environmental	Flooding, freezing, or damage by animals.
Valid Alerts	Non-contamination	Water theft.
		Vandalism.
		System activities caused by flushing, hydrant testing, firefighting or mainline break.
		Operational changes caused by exercising valves or pumping operations.
	Possible contamination	Cross connection (at customer connection).
		Signs of contamination at the location of the AMI alert.
		Investigators cannot rule out the possibility that the premise is a source of contamination introduced into the water distribution system.

Establishing an Alert Investigation Process

With potential causes of AMI alerts 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. AMI alerts need to be promptly investigated by utility personnel to determine if the incident might be related to or cause drinking water contamination. The sooner response actions are initiated, the more effective they can be in minimizing consequences.

In general, the process begins with receipt and acknowledgement of an alert and ends with a determination of alert cause. The steps between involve a review of all available relevant and accessible information to investigate potential causes of the alert. The alert investigation process is generally structured to consider the most likely causes first, allowing contamination to be quickly ruled out for the majority of alerts. The AMI alert investigation is then closed and documented. There are four key actions of AMI alert investigations:

Continuous Monitoring

As part of an SRS, there is ***continuous monitoring*** for backflow and tampering, as the real-time data generated through AMI is analyzed as it is generated or communicated, and alerts are automatically conveyed to staff. An AMI investigation begins when utility staff receive and acknowledge an AMI alert. Receipt of and response to alerts 24 hours per day and seven days per week is recommended but may be constrained by utility staffing. Backflow alerts should be investigated immediately, especially if accompanied by a tamper alert (Mix, 2020). Backflow into the system could pose a risk to public health, and a prompt response and field investigation, if necessary, which can significantly reduce consequences.

The urgency of investigating a tampering alert may be a risk management decision during non-work hours, as tampering alerts may be attributed to water theft and generally do not result in water contamination. However, prompt investigation of tamper alerts is important because if a meter is removed to intentionally contaminate a distribution system, only a tamper alert may be received.

Data Review

Utility personnel review available information to investigate potential causes of the alert, developed as described in Table 6-1. Examples of data sources to review include the AMI headend system, the customer connection history, water quality complaint details, system pressure or water quality data from a Supervisory Control and Data Acquisition (SCADA) or SRS system, ongoing work orders in a work management system, newsfeeds, and alerts from other SRS components. Investigators may also reach out to other departments and stakeholders to access relevant information that may explain why the alert occurred.

Other factors used to determine the validity of alerts include:

- Records of recent meter installation or maintenance of the meter could point to invalid alerts that are employee error causes (as in Table 6-1).
- Invalid backflow and tamper alerts can generally be identified promptly by reviewing AMI data values and instrument alerts, the status of the communications system, and if any utility meter or system work is occurring nearby.
- If backflow alerts are received from multiple meters, if alerts from other SRS components have been received, or if abnormal pressure data is observed in the area, then backflow is likely caused by a distribution system issue. Clustering of backflow alerts provides for early detection of a main break.
- System activities or operational changes such as flushing, hydrant testing, changes in nearby valving or pumping, main breaks or firefighting reported in the area of a backflow alert may also suggest a distribution system disturbance. Referencing ongoing work orders and contacting stakeholders working in the area could suggest the alert cause.
- Exercising valves could cause a backflow alert for a district meter.
- A poorly designed, constructed or inspected system that is stressed could potentially see low pressures with high demands, depending on elevation, equipment and activity resulting in a backflow alert.
- The prevalence or absence of backflow prevention devices and the potential for a cross connection on both sides of the meter are factors for backflow alerts.
- If customer calls indicate unusual behavior at the site of the alert, meter tampering or intentional contamination is deemed possible and Water Contamination Response procedures are immediately initiated.

Field Investigation

If definitive evidence is not available to identify a cause for the alert through data review, an investigation is conducted on site to identify the cause of the alert and determine if there is potential contamination of the finished water supply. Safety measures should be taken including wearing PPE, having appropriate staff onsite or standing by, and requesting police escort if at any time the incident seems suspicious or dangerous. *Guidance for Building Field Capabilities to Respond to Drinking Water Contamination* provides guidance for performing field activities safely.

When staff arrive at the site, they should immediately inspect the site for signs of contamination before proceeding. This includes perpetrators still on site, suspicious vehicles or equipment (e.g., containers, hoses, or discarded PPE), unusual vapors or odors, or dead or distressed vegetation or animals. Subsequent inspection activities at the site and meter, as needed, are specified in the **alert investigation checklist**. These potential causes include:

- Meter installation error
- Malfunctioning meter or MIU

- Flooding in meter box, loose wire or damage by an animal, rodent or pest
- Distribution system valve exercising or flushing of main
- Fire demands
- Main break or customer service line break with visible water on the ground
- Water theft
- Pressure Releasing Valve (PRV) failure or blockage
- Backflow prevention failure

For tampering alerts, investigators should verify if the meter is removed, reversed, bypassed, or has a magnet on it, and if the communications cable been damaged. For backflow alerts, investigators should check that the meter has been installed in the correct direction, shut off the water, check the pressure on the customer side of the meter (e.g., at a hose bib), and check for cross connections (e.g., at a private well, irrigation system, or swimming pool).

Resolution

All alert investigations should be officially closed, and the cause of the alert documented. Even if the cause of an alert is not determined once the investigation is closed, the details of the investigation should still be documented to support future investigations. If the investigator concludes that there is potential contamination of finished water, the ***SRS manager*** is notified and additional investigative and response actions are implemented under the utility's Water Contamination Response Plan. This plan includes procedures to establish the credibility of the possible contamination incident, minimize public health and economic consequences by implementing response activities such as operational changes (e.g., close valves, turn off pumps) or public notification, and guide the remediation and recovery effort. The credibility of an AMI alert can quickly escalate, requiring notifications to external partners, such as the drinking water primacy agency. The *Guidance for Responding to Drinking Water Contamination Incidents* provides more details on developing and implementing response protocols.

In some cases, follow-up activity may be required, such as meter repair, and standard utility procedures are initiated as necessary. If intentional meter tampering occurred, procedures for water theft should be initiated, which may include notifying the police. For alerts caused by distribution system activities, the specific AMI alerts are closed and standard procedures for investigating and responding to distribution system issues are initiated to investigate the situation holistically.

Table 6-2 summarizes the example key actions that are specific to investigation of tampering and backflow alerts.

Table 6-2: Differences in Key Action Examples for Backflow and Tampering

Key Action	Backflow	Tampering
Continuous Monitoring	Respond to alerts immediately.	Respond to alerts as soon as possible.
Data Review	Check for other backflow alerts in the area, drops or spikes in system pressure, flushing, hydrant testing, valve operations, mainline breaks or firefighting in the area.	Check for customer potential to cause the alert or history of water theft.
Dispatch Staff	Shut off water, check pressure, and look for causes of backflow and contamination.	Check for signs of meter removal, reversal, bypass tampering and water theft.
Resolution	Consult with public health officials if necessary.	Consult with law enforcement if necessary.

The alert investigation process can be visually depicted in a diagram that shows a simplified representation of the progression of steps. Separate procedures may be developed for business and after-hours incidents, specific types of alerts, and specific investigatory roles. **Figure 6-1** provides an example of an AMI alert investigation process flow diagram.

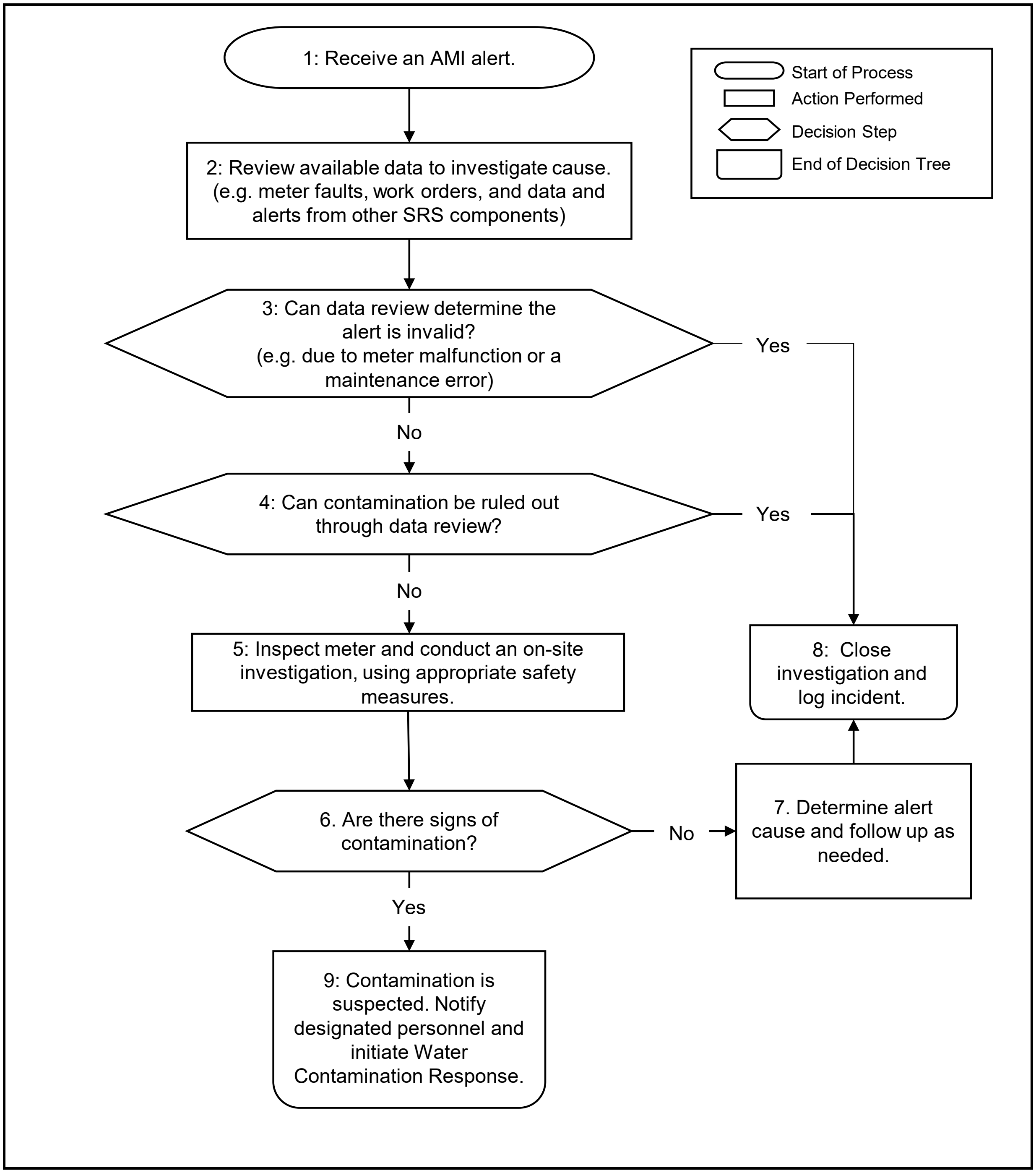

Figure 6-1: Example Alert Investigation Process Flow Diagram for AMI Alerts

Assigning Roles and Responsibilities

Different utility personnel may be involved in investigating AMI alerts. **Table 6-3** shows an example of roles and responsibilities during AMI alert investigations. These will vary by utility and should be customized by information sources available for review by your utility.

Table 6-3: Example of Generic Roles and Responsibilities for AMI Alert Investigations

Role	Alert Investigation Responsibilities

AMI Manager	• Monitor AMI alerts including backflow/tamper alerts.
	• Perform the data review of alert information to determine if the backflow/tamper alert is invalid, such as:
	  o Reviewing information from additional SRS components, if available.
	  o Reviewing work orders in the work order management system, including activities such as flushing, hydrant testing, pump and valve operations, and mainline breaks.
	  o Reviewing communications between engineering and maintenance dispatch groups that describe work in the area, if there is no work management system.
	  o Check reports of high or unusual demand, such as due to firefighting activities.
	• Notify utility onsite investigation personnel if a backflow/tamper is suspected.
	• Notify local public health officials of any backflow alerts that may require their involvement. For example, if a site investigation reveals plumbing conditions that may make drinking water within the premise plumbing system unsafe for use (e.g., an apparent cross-connection).
	• Notify local law enforcement of tamper alerts that may require their involvement.
	• Notify the SRS Manager if signs of contamination are observed on backflow/tamper.
	• Determine whether contamination of the water supply is possible and initiate Water Contamination Response.

Utility Control Center Operator	• Monitor all SCADA alerts 24/7/365, including AMI and pressure alerts. • Perform AMI Manager duties during non-business hours or if the AMI Manager is off duty or does not acknowledge the AMI alert.
Water Quality Supervisor or SRS Manager	• Monitor for OWQM alerts. • Implement Water Contamination Response.
Customer Service	• Monitor for ***Customer Complaint Surveillance*** (CCS) alerts. • Review account history for tampering and theft.
Meter Technician	• Lead the on-site investigation of all AMI alerts. • Coordinate site investigation activities with distribution field crews and local law enforcement, as necessary. • If backflow/tampering is confirmed, determine if contamination at the customer connection could have entered the distribution system. • Make the determination regarding if there was an opportunity to contaminate the drinking water. • Review distribution system work activity to determine if an AMI alert could have been inadvertently caused by utility personnel. • Ensure employees, equipment or environmental factors didn't cause the alert. • Look for cross connections at the premise.
Local Law Enforcement	• Help conduct an investigation at the premise for a tampering alert, or significantly consequential backflow incident, if warranted or entry and inspection is needed.
Local Public Health	• Evaluate whether a public health or safety violation has occurred, if backflow/tampering is confirmed. • Advise on health issues related to contamination as result of backflow.

6.2 Developing Investigation Tools

While the detailed alert investigation procedure materials described in Section 6.1 are necessary when developing and documenting the procedure, that level of detail is generally not used during real-time alert investigations. This section describes checklists, alert investigation records, and quick reference guides that can be developed to assist investigators in efficiently carrying out their responsibilities.

Checklists

Alert investigation checklists are job aids that guide personnel through their investigative responsibilities and document investigation findings. Checklists can help ensure consistency among investigators, verify that all activities are completed, and reduce the time required to conduct alert investigations. They generally list the activities assigned to specific roles, and more than one checklist may be developed to support the AMI alert investigation procedure.

Depending on the number of utility roles involved in an investigation and the overall complexity of the alert investigation process, a utility may have single or multiple checklists. The *AMI Alert Investigation Procedure Template* contains an editable AMI alert investigation checklist.

Record of Alert Investigations

A record of alert investigations provides documentation of key information such as the date and time of the alert and investigation, the name of the investigator, actions implemented during the investigation, and the conclusion as to the cause of the alert. This record may serve as a resource during the investigation of future alerts and provides a means to analyze the frequency and validity of alert investigations by a variety of factors (e.g., alert cause, location, thoroughness of the investigation, 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. Records can then be analyzed to show alert frequency, average delay before investigation begins, staff time required for investigation, common alert types and spatial clustering. In addition, previous conclusions can be referenced to support current alert investigations. These tools may provide valuable insight into the need to update alert algorithms, the alert investigation procedure, and highlight the need for training or exercises on the procedure. **Figure 6-2** provides an example of electronic alert investigation records.

Alert Investigation Information							
Alert Date / Time	Alert Location	Backflow or Tamper	Investigator	Investigation Start Date / Time	Investigation End Date / Time	Conclusion	Notes
5/4/20 2:15 AM	123 Main	Backflow	Jean Smith	5/4/20 2:16 AM	5/4/20 2:30 AM	Invalid alert: Meter malfunction.	Meter replaced. See work order # AMI2020.
5/5/20 8:05 AM	456 Hill St	Tamper	John Brown	5/6/20 8:06 AM	5/6/20 8:30 AM	Valid alert: Water theft.	Meter was reversed to steal water.
5/6/20 4:05 PM	789 Valley Rd	Tamper	Tasha Lee	5/6/20 4:07 PM	5/6/20 4:30 PM	Invalid alert: Environmental condition.	Loose wire. Water and debris in meter can.

Figure 6-2: 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. *Dashboard Design Guidance for a Water Quality Surveillance and Response System* provides more detail on guiding and recording alert investigations via a dashboard.

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 that list meter error codes.

6.3 Preparing for Real-time Alert Investigations

After the AMI alert investigation procedure is developed, a utility will need to develop a plan to put it into practice. The benefits of the AMI SRS component can be fully realized only if the alerts are investigated and responded to appropriately. The following topics are to help prepare for real-time alert investigations: Training, Preliminary Operation, and Real-time Operation.

Training

Proper training on the alert investigation procedure ensures that all personnel with a role in investigating AMI 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 integration of the AMI system into an SRS;
- 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 AMI alert investigations; and
- 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 AMI alert investigations. Once 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 SRS components.

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. 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. 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.

Real-time Operation

During real-time operation, AMI 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 AMI 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. Finally, it is important to thoroughly train new 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; and
- Establish a protocol for submitting and tracking change requests.

6.4 Next Steps

Incorporating an AMI component into an SRS can provide significant benefits for utility security and resilience. Utilities with AMI are strongly encouraged to implement backflow and tampering alerts, if not already in place, and develop alert investigation procedures to further optimize the investment made in the AMI system. In general, existing AMI system elements can be directly leveraged, making the required investment for this additional application of AMI data relatively low.

Visit the Water Quality Surveillance and Response website at https://www.epa.gov/waterqualitysurveillance for more information about SRS practices. The website contains guidance and tools that will help a utility to enhance surveillance and response capabilities, as well as case studies that share utility experiences with SRS implementation and operation.

Resources

Section 2: Overview of Incorporating AMI into an SRS

Water Quality Surveillance and Response System Primer (USEPA, 2015)

This document provides an overview of Water Quality Surveillance and Response Systems (SRS) for drinking water distribution systems. It defines the components of an SRS, describes common design goals and performance objectives for an SRS, and provides an overview of the approach for implementing an SRS. The SRS primer is referenced in the Introduction and Topic 3 of this document. EPA 817-B-15-002, May 2015.
http://www.epa.gov/sites/production/files/2015-06/documents/water_quality_sureveillance_and_response_system_primer.pdf

Section 4: Communications

Guidance for Designing Communications Systems for Water Quality Surveillance and Response Systems (USEPA, 2016)

This guidance document describes an approach for evaluating and selecting communications technologies to support the transmission of data generated by AMI. The document provides users with a description of attributes that should be considered when evaluating communications systems alternatives and a general assessment of common technologies relative to these attributes. EPA 817-B-16-002, September 2016.
https://www.epa.gov/sites/production/files/2017-04/documents/srs_communications_guidance_081016.pdf

Framework for Improving Critical Infrastructure Cybersecurity (NIST, 2020)

The National Institute of Standards and Technology (NIST) provides tools to help organizations better understand and improve their management of cybersecurity risk. This includes a framework that describes how to use business drivers to guide cybersecurity activities and consider cybersecurity risks as part of an organization's risk management processes.
https://www.nist.gov/cyberframework

Section 5: Information Management

Guidance for Developing Integrated Water Quality Surveillance and Response Systems (USEPA, 2015)

This document provides guidance for applying system engineering principles to the design and implementation of a Water Quality Surveillance and Response System (SRS) to ensure that the SRS functions as an integrated whole and is designed to effectively perform its intended function. Section 4 provides guidance on developing information management system requirements, selecting an information management system, and IT master planning. Section 5 provides guidance on developing alert investigation procedures for the surveillance components of an SRS. Section 6 provides guidance on developing a training and exercise program to support SRS operations. EPA 817-B-15-006, October 2015.
http://www.epa.gov/sites/production/files/2015-12/documents/guidance_for_developing_integrated_wq_srss_110415.pdf

Section 6: Alert Investigation Procedures

Guidance for Building Field Capabilities to Respond to Drinking Water Contamination (USEPA, 2017)

Provides utilities with planning and implementation guidance, templates, customizable report forms, and other documentation for visual site hazard assessment, sample collection, water quality parameter testing, and sample packaging and shipping. EPA 817-R-16-001, January 2017. https://www.epa.gov/sites/production/files/2017-01/documents/field_capabilities_guidance_january2017.pdf

Guidance for Responding to Drinking Water Contamination Incidents (USEPA, 2018)

This resource provides an editable template for developing a utility-specific Distribution System Contamination Response Procedure. Elements of this plan include investigation of a possible distribution system contamination incident, planning for site characterization, implementing operational response activities, issuing public notification, and planning for remediation and recovery. An accompanying guide helps the user populate the template to customize the plan to a specific utility. EPA 817-B-18-005, April 2018. https://www.epa.gov/sites/production/files/2018-12/documents/responding_to_dw_contamination_incidents.pdf

AMI Alert Investigation Procedure Template (USEPA, 2020)

The alert investigation procedure template includes editable flow diagrams and checklists that can be used to document the utility's role in an AMI alert investigation process. March 2021. Click this link to open the template

Dashboard Design Guidance for Water Quality Surveillance and Response Systems (USEPA, 2015)

A dashboard is a visually oriented user interface that integrates data from multiple Water Quality Surveillance and Response System (SRS) components to provide a holistic view of distribution system water quality. This document provides information about useful features and functions that can be incorporated into an SRS dashboard. It also provides example user interface designs. EPA 817-B-15-007, November 2015. http://www.epa.gov/sites/production/files/2015-12/documents/srs_dashboard_guidance_112015.pdf

SRS Exercise Development Toolbox (USEPA, 2016)

The Exercise Development Toolbox helps drinking water utilities to design and conduct exercises to evaluate procedures developed to support a Water Quality Surveillance and Response System (SRS). These exercises can be used to refine SRS procedures and train personnel in the proper implementation of those procedures. The toolbox guides users through the process of learning about training programs, developing realistic contamination scenarios, designing SRS discussion-based and operations-based exercises, and creating exercise documents. February, 2016. The Exercise Development Toolbox is Homeland Security Exercise and Evaluation Program compliant. https://www.epa.gov/waterresiliencetraining/develop-and-conduct-water-resilience-tabletop-exercise-water-utilities

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Glossary

alert. An indication from an SRS surveillance component that an anomaly has been detected. 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 roles in the process.

alert occurrence. The frequency of detection of true water quality incidents, the frequency of incidents that do undetected, and the frequency of invalid alerts.

Advanced Metering Infrastructure (AMI). Systems that measure, collect, and analyze water usage, and communicate with water meters, either on request or on a schedule. These systems include hardware, software, and communications for data access, visualization, and analysis. An AMI system may include consumer use displays, customer associated systems, meter data management software, and supplier business systems. The meters may be coupled with pressure monitors, temperature sensors, other devices, outside data streams (e.g. weather), and alert for backflow and tampering incidents.

AMI equipment. The hardware that generates AMI data, especially meters that measure the flow to a customer or premise.

AMI headend. Software typically offered by the AMI vendor and used to administer the AMI system, monitor system health, and initiate and receive communications. This may typically be referred to as a Meter Data Management System.

backflow. The reversal of water flow in which water or other substances from a residential, industrial, or institutional piping system flows back into the water distribution system.

business intelligence. Technologies, applications, and procedures for the analysis, integration, and presentation of business information.

communications. Equipment and systems used to transmit data from the meter or endpoint to the information management system.

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.

conditional data transmission. MIU initiates the data transfer immediately upon defined logic being met. For example, when an MIU receives an alert signal from the meter or detects an internal alert through self-monitoring, it may be configured to immediately send the alert signal to the information management system instead of waiting for the next scheduled data transmission. This method is also referred to as “non-synchronized data transfer” and allows for more timely notification of backflow and tampering alerts.

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

contamination response procedure. A planned decision-making framework that establishes roles and responsibilities and guides the investigative and response actions following a determination that distribution system contamination is possible.

continuous monitoring. Uninterrupted collection and analysis of data. Collection and analysis frequency can range from seconds to hours.

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 connections. Metered premise location at which a residential, industrial, or institutional piping system is connected to a utility water distribution system main.

cybersecurity. Measures implemented to protect an information management system and network from unauthorized access, damage, or attack. Common examples include password protected computers, encryption, and use of anti-virus software.

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

distribution system. Networks of storage tanks, valves, pumps and pipes that transport finished water to customer connections.

incident coverage. The number and type of incidents that can be detected by the SRS, including those resulting from natural, accidental or intentional contamination.

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 investigations, details entered during alert investigations, and documentation of Water Contamination Response activities.

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

local data analysis. Analysis of data at a meter, meeting defined logic conditions using embedded computing, that is interoperable with internet infrastructure. Analytics may encompass anomalous detection for data excursions from the norm, e.g. "If flow is negative (or meter movement = yes), then send alert" or pattern recognition by identifying previous occurrences in current time frame, e.g. "If sum of hourly flow is negative before a four-hour data push, then send backflow alert".

mechanical meter. Standard positive displacement type of flow meter with an embedded mechanism that rotates, and the number of rotations is translated to flow.

meter. Measures the flow of water to a service district or customer's connection at a premise. Meter data can be used to calculate water usage and to detect backflow and tampering.

meter interface unit. Receives a hardwired signal from a meter, converts this signal to a flow value, stores flow values, and wirelessly transmits stored data to the information management system. Alerts generated are also transmitted.

monitoring location. A specific point in the water distribution system where SRS component data is collected, such as the location of OWQM sensor hardware, PSM video surveillance camera, or AMI meter.

one-way communications. A communications path that only allows the flow of data in one direction. Also referred to as unidirectional or simplex communications.

Online Water Quality Monitoring (OWQM). One of the surveillance components of an SRS. OWQM utilizes data collected from monitoring stations that are installed at strategic locations in a utility's source water and/or a distribution system. Data from the monitoring stations is transferred to a central location and analyzed for water quality anomalies.

open standard communications network. Provides an open architecture concept which expands the market of wireless devices that can operate over an AMI communication network. Examples of Open Standard Networks include LoRaWAN, Wi-SUN and Narrowband IoT. These networks are becoming increasingly common with lower energy requirements and increased coverage.

operational reliability. The percentage of time that the SRS is functioning at a level that achieves the other performance objectives.

Other sensors. Pressure, temperature, and acoustic sensors, and water quality monitors, whose data is also transmitted to the information management system, along with meter data.

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

polling interval. The frequency at which data is collected, reported, or transmitted.

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.

proprietary communications network. Owned and managed by a private entity and include Cellular Networks and Fixed Radio Frequency Networks.

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.

remotely controlled valves. Allow a utility to shut off or turn on water service at a customer or premise from the information management system. These valves could aid Water Contamination Response.

response action. An action taken by a utility, public health agency or another response partner to minimize the consequences of an undesirable water quality incident. Response activities may include issuing a public notification, changing system operations, flushing the system or other actions.

Sampling and Analysis (S&A). One of the response components of an SRS. S&A is activated during Water Contamination Response to help confirm or rule out possible water contamination through field and laboratory analyses of water samples. In addition to laboratory analyses, S&A includes all the activities associated with site characterization. S&A continues to be active throughout remediation and recovery if contamination is confirmed.

scheduled data transmission. Data is transferred at a pre-defined, recurring polling interval. At the time of writing, a transmission frequency of 4, 6, 12, or 24 hours is common. The lower frequency can be selected to preserve battery life.

solid-state meter. Newer meter type with a variety of measurement techniques to more reliably measure flow such as using acoustic waves or a magnetic field. Common types are ultrasonic, electromagnetic and fluid oscillation.

spatial coverage. The percent of a utility's distribution system monitored by the SRS.

surveillance component. An SRS component in which real-time data is constantly analyzed to detect and notify staff of potentially abnormal and potentially harmful conditions.

sustainability. The degree to which the benefits derived from the SRS justify the cost to implement and maintain the system.

tampering. Unauthorized handling or damage of an AMI meter.

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

timeliness of detection. The amount of time between the start of a water quality incident and detection by an SRS component, and the amount of time between detection and implementation of response actions to minimize the consequences of the incident.

two-way communications. A communications path that allows the flow of data in both directions. Also referred to as bi-directional or duplex communications. For AMI, this means that in addition to data being sent from the MIU to headend system, the commands or queries can be transmitted to the MIU.

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. An alert due to water contamination, verified water quality incidents, intrusions at utility facilities, or public health incidents.

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

Water Quality Surveillance and Response System (SRS). A system that employs one or more surveillance components to monitor and manage source water and 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 threat level determination process, integrating information across the different surveillance components, and activating the Water Contamination Response component.

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 data stream.