Application of Real Time Models for Event Detection

Following the terrorist attacks of September 11, 2001, and the creation of the Department of Homeland Security, the EPA was designated as the sector specific agency lead for water and is responsible for protecting water systems and for detecting and recovering from terrorist attacks affecting water systems. In response, EPA developed and initiated a research program to comply with the 2002 Public Health Security and Bioterrorism Preparedness and Response Act. The Act amends the Safe Drinking Water Act (SDWA) and its 1996 amendments by adding the following requirements: drinking water systems serving more than 3,300 persons are required to perform vulnerability assessments; and EPA is required to conduct research and to review methods and means to prevent, detect, and respond to various chemical, biological, and radiological contamination events. In addition to the amendments of the SDWA, a number of Homeland Security Presidential Directives (HSPDs) also drive the EPA research program. The research has also been guided by the reports of several different standing committees of the National Research Council (NRC 2005, 2006a, 2006b, 2007).

The EPA Homeland Security Research Program seeks to develop products and expertise to protect, detect, respond to, and recover from terrorist attacks on the nation's water and wastewater infrastructure. The research primarily supports the Office of Water and is relevant to both drinking water and wastewater systems. As part of this program, EPA has developed the Threat Ensemble Vulnerability Assessment Program.

(see http://www.epa.gov/NHSRC//water/teva.html).

Thus far, this program had developed two decision support systems (i.e. TEVA-SPOT and CANARY) for use in protecting the nation's water distribution systems. More specifically, TEVA-SPOT <http://www.epa.gov/NHSRC//news/news112607.html. has been developed to:

- Recommend sensor placement in water distribution systems for the detection of contamination incidents
- Quantitatively compare the benefits of different sensor designs
- Assess the consequences of contamination incidents
- Improve water distribution system network models

CANARY (Hart., et al., 2009) evaluates standard water quality data (e.g. free chlorine, pH, etc.) over time and uses mathematical and statistical techniques to indentify the onset of anomalous water quality incidents. Before using CANARY for the first time, historical utility data must be used to determine the natural variation of these water quality parameters. This allows the water utility to adapt CANARY for particular locations within the water distribution system and helps utility operators to understand the expected false alarm rates associated with CANARY and contamination incident detection. While TEVA-SPOT currently employs EPANET, a hydraulic/water quality distribution model for modeling the flow and transport of potential contaminants through a water distribution system, CANARY relies purely on the local history of water quality at sensor locations, in order to predict deviations from normal baseline water quality caused by system contamination. Thus CANARY has no specific knowledge of the system design, operation, or treatment conditions, which may also cause significant variability in water quality parameters, and which should not be flagged as alarms.

Both CANARY and TEVA-SPOT can be envisioned as individual components of a Water Quality Monitoring System (WQMS) (see Figure 2) that fits into a larger Contamination Warning System (CWS) as part of EPA's Water Security Initiative (Pickard, 2010). Such a system consists of nine different levels, where each level can be seen as dependent upon the levels or components beneath it. The hierarchy provided in Figure 2 also serves as a relative indication of both the complexity and anticipated level of use of such technologies in the water utility industry. For example, it is anticipated that all water distribution systems have some level of basic telemetry (e.g. pump discharge and tank water level), while CANARY may find more limited application because of the potential need for additional field sensors and/or inherent difficulties in developing a reliably calibrated model (Irving, et. al., 2010). Following the initial pilot demonstration of the CWS approach at the Greater Cincinnati Water Works (Fencil, 2010), EPA selected four additional utilities for contamination warning system pilots (Pickard, 2010). However, following the completion of these additional demonstration studies, future utilities will likely be required to bear the financial burden of any subsequent CWS implementations. As a consequence, it is important that a range of technologies for use in support of CWS be available to the water utility industry that can be customized based on the size, expertise, and financial resources of the particular utility.

While CANARY and TEVA-SPOT have been recently introduced by USEPA, both models have seen limited application, partly due to the costs of implementation and partly due to reliability concerns (especially with regard to CANARY). Nonetheless, it is anticipated that the use of such technologies can be expected to increase, especially with larger utilities which may have the personnel and budgets to successfully implement such technology.

Real-time simulation models hold the potential to improve operational decisions, including detection and response to potential contamination events. For example, one way that flow modeling approaches could be incorporated into CANARY (or other event detection approaches) is model-based event detection. The central idea behind model-based event detection is the use of a real-time hydraulic/water quality model to predict water quality at sensor locations, as a function of measured source water quality conditions and system operational variables, and estimated water usage rates. Such real-time predictions of water quality would constitute the "real-time baseline" conditions used to compare with actual sensor measurements, rather than the purely statistical baseline analysis currently used by CANARY. The deviation between model predicted and measured water quality would then be processed by CANARY, to determine the presence or absence of a contamination event, as opposed to processing the raw water quality signals as is currently done. While model based event detection promises increased sensitivity for detecting contamination events, as well as a reduced rate of false positives, it has not been implemented for water supply systems. The potential pitfall of model-based event detection is the damaging effects of various modeling errors on the accuracy of the water quality predictions. Thus if such approaches are to be used, it is critical to carefully evaluate the likely accuracy of real-time water quality predictions, and calculate the sensitivity and specificity of event detection algorithms that would rely on them.

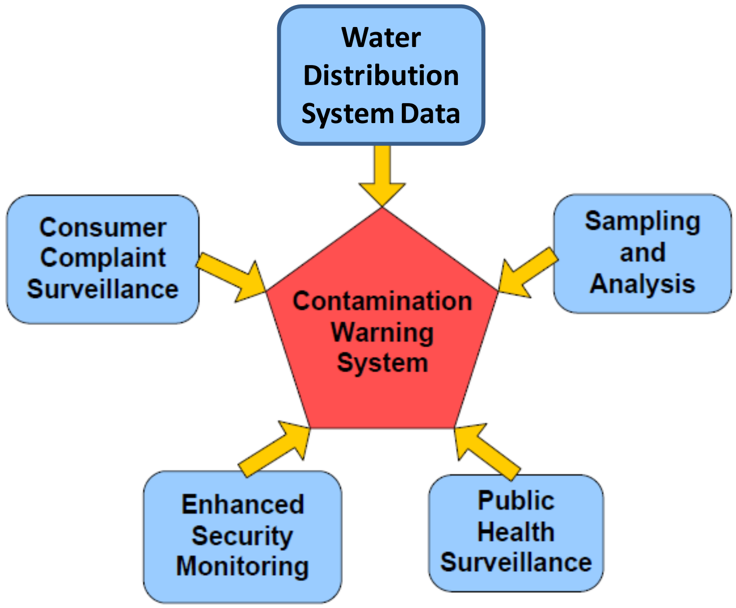

Figure 1. Components of a Contamination Warning System (EPA 2008)

The use of such data in a comprehensive CWS operational plan is envisioned in Figure 2.

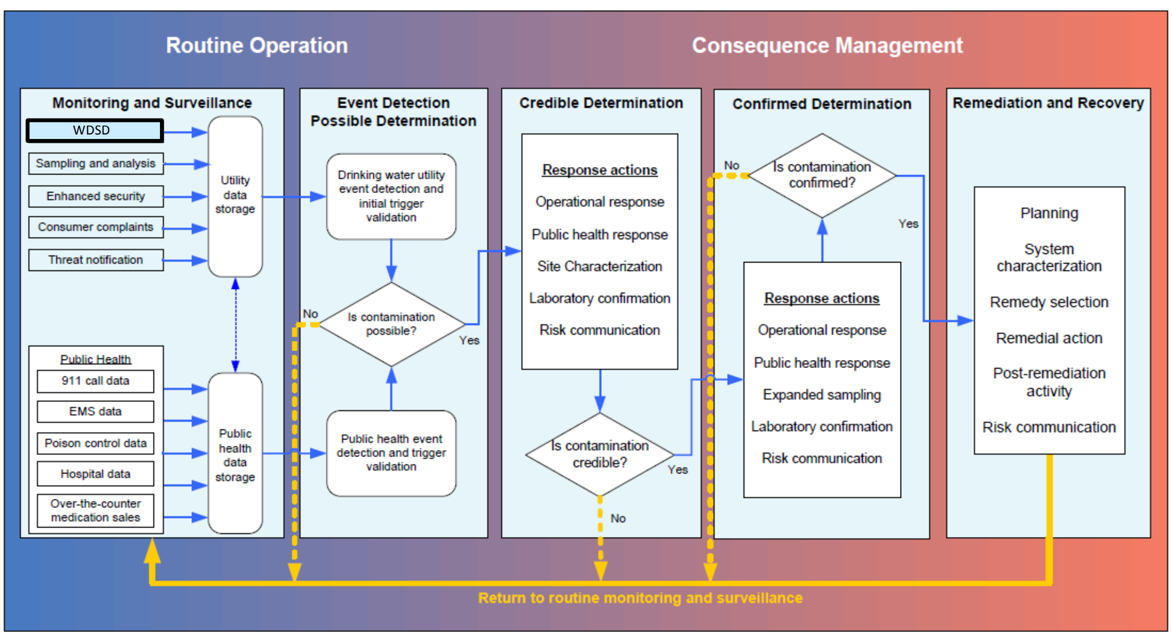

Figure 2. Incorporation of WDSD into a CWS Operational Plan (EPA 2008)