CASE STUDY

# City of Santa Cruz Adopts Online THM Analyzer for DBP Management

In drought-ridden California water utilities such as the City of Santa Cruz Water Department (SCWD) are tasked with addressing water supply challenges from current and future drought conditions while continuously providing safe drinking water meeting all federal and state regulatory demands. With the implementation of Stage 2 DBPR, reducing trihalomethane (THM) formation has been of vital concern to the SCWD, which has experienced elevated levels of THM formation potential (THM-FP) since placing a greater reliance on a lake as source water for the Graham Hill Water Treatment Plant (GHWTP). The SCWD has undertaken feasibility studies on aeration methodologies, enhanced coagulation, chlorine dioxide, and distribution system realignment to reduce distribution system THM levels. An online THM and THM-FP analyzer has aided the SCWD in their daily operations and management of feasibility studies by providing real-time and reliable data on THM and THM-FP levels within the WTP and the distribution network.

## Background

The GHWTP is an 18 MGD conventional filtration facility serving the needs of more than 66,000 residents within the City of Santa Cruz and surrounding county. Surface water to the GHWTP comes from three water sources; 47% from the San Lorenzo River, 25% from a series of small dams and spring box operated by the SCWD called North Coast Streams, and 24% from a large lake in the Santa Cruz Mountains holding 2.8 billion gallons called the Loch Lomond Reservoir.

The quality of SCWD source waters varies greatly and has a direct effect on the effluent THM-FP discharged from the GHWTP. THM-FP is the measurement of water quality characterizing the maximum quantity of THMs formed over time, often called a 'maximum TTHM-FP'. Whereas THM values can be low at the exit of a WTP, they can increase dramatically in a distribution network depending on residence time and water quality variables such as temperature, pH, precursors such as organic matter and bromide, chlorination level, number of re-chlorination stations in the network and the level of re-chlorination. When the Loch Lomond Reservoir is the main raw water source to the GHWTP, effluent THM-FP levels are at a maximum of 140 µg/L . When the San Lorenzo River and other Coastal Sources are the main raw water sources to the GHWTP, effluent THM-FP levels are at a maximum of 70 µg/L .

In an effort to further protect local aquatic environments and species; the California Department of Fish & Wildlife requested in 2007 a decrease in water usage from rivers and streams. As a result of this change, the SCWD has placed a greater reliance on lake water from Loch Lomond Reservoir. A large part of the lake water is composed of organic matter, which reacts with chlorine at the GHWTP to form THMs. At present, the GHWTP is limited to treating source water with turbidity levels no more than 15 nephelometric turbidity units (NTU) and TOC levels no more than 4 mg/L. When turbidity levels exceed 15 NTU, such as from a storm event, the GHWTP must switch over to using lake water until the river and coast stream clean up. This prohibits the City from pumping water up to the lake and reduces the volume available during the summer months.

## Aeration Study

To ensure regulatory compliance with Stage 2 DBPR while adhering to new source water requirements, the SCWD began a feasibility study on commercially available aeration technologies to remove THMs from their reservoirs and complement existing operational THM mitigation efforts. A series of isolated tank experiments were undertaken and results were presented as a percentage comparing the reduction in THM concentrations at the end of the experiment to the baseline THM concentrations.

The SCWD was looking to achieve a 40% reduction in THM concentrations from maximum, minimum and average THM baseline levels of 83.4 µg/L, 68.6 µg/L and 77.7 µg/L respectively.

The water quality parameters continuously monitored throughout the study included THM concentration, temperature covariance, and chlorine residual. Grab samples for THM concentration and chlorine residual were taken three times per day for the first week of the study. After which, the grab sample frequency was reduced to once per week because it became too costly, time consuming, and labor intensive to keep the original grab sampling schedule.

A contract laboratory was hired to test the grab samples for THM concentrations. Analyses took approximately two to three weeks to be returned; and as a result, the SCDW conservatively operated the aerators while waiting to receive THM results to ensure they remained in regulatory compliance. This approach resulted in increased operational expenses on chemicals, sludge removal, power and other resources being used during the aeration feasibility study. Additionally, the long durations between sampling and obtaining the analytical results hindered the timely progression of the feasibility study.

## Online THM Monitor Aids Aeration Study

In June 2014 The SCWD began continuous online monitoring of THM values in the GHWTP effluent with the THM-100™ manufactured by Aqua Metrology Systems. Split sampling was used to determine how the THM-100 compared to certified third-party laboratory analyses. The validation of the THM-100 monitor found the instrument to be consistent and highly reproducible with a standard error of deviation of five percent between the two methods. The automated online THM analyzer uses a traditional “purge-and-trap” sampling method, followed by desorption of the THMs into a chemical mixture that generates a colored product and time-resolved spectrophotometric analysis for determination of speciated THM levels. The throughput for each THM analysis is approximately two hours.

The THM-100 allows manually collected ‘grab’ samples from other locations within the water plant and distribution network to be analyzed alongside samples taken automatically by the monitor in its online mode. The THM-100 is scheduled to perform six online samples per day, and the grab-samples are queued to start immediately when the instrument is idle. Grab samples from the Bay Street Reservoir, where the four tanks in the aeration study reside, were collected and analyzed by the THM-100, as well as 11 other locations within the distribution network.

The real-time THM data provided through the online THM-100 instrument proved essential in understanding the performance of the aeration systems under the varying test operational conditions. Recognizing that in-network THM-FP values were two times effluent TTHM levels measured at the GHWTP, the SCWD aimed to consistently limit in-plant TTHM levels to less than 35 µg/L to ensure the GHWTP remained in regulatory compliance with the 80 µg/L limit.

The average THM concentration of the in-house aeration unit was 28 µg/L and 29 µg/L for the Medora Corporation SN5. The THM and THM-FP profile for the GHWTP and its network are depicted in Figure 1.

The online THM analyses provided through the THM-100 aided the SCDW to cost-effectively characterize and monitor THM levels resulting from aeration, and to efficiently manage the study in a timely manner.

Following the conclusion of the aeration study, the SCWD has installed two Medora Corporation aeration systems (SN5 and SN15) at the Bay Street Reservoir. The THM-100 continues to be used for daily online analyses of TTHM and THM-FP levels.

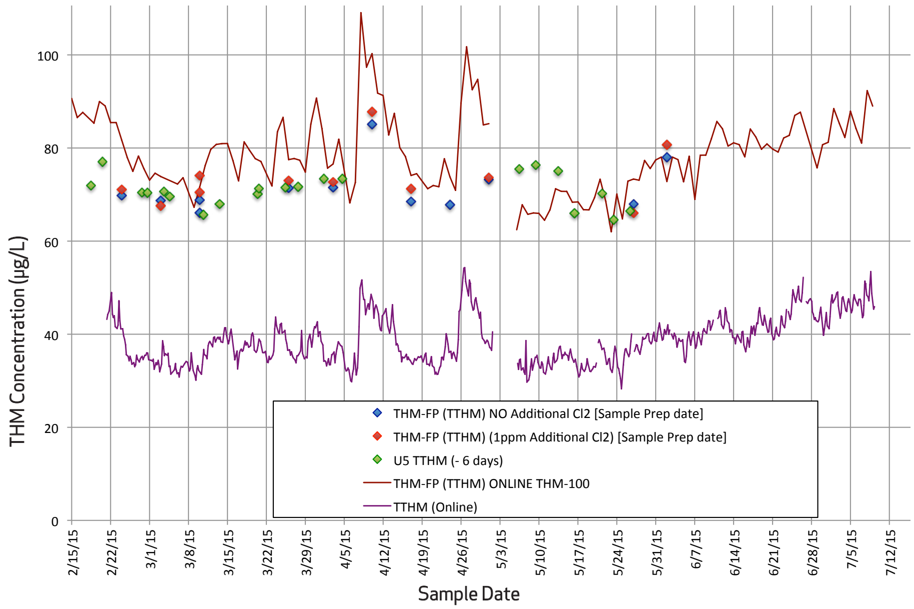


**Figure 1:** THM and THM-FP Profile of the GHWTP and Network. From February through July 2015, the effluent TTHM levels varied from 22.26 to 66.01 µg/L and THM-FP levels varied from 60 to 110 µg/L. The THM-FP was observed to change from ~68 to ~110 µg/L in less than two days, further demonstrating the need for high frequency monitoring.

## Chlorine Dioxide Study

Studies indicate that chlorine dioxide disinfection forms less DBPs than sodium hypochlorite disinfection because of its ability to oxidize organic compounds in water. The SCWD is currently exploring the use chlorine dioxide disinfection to reduce THM formation at the GHWTP. To determine the effectiveness of chlorine dioxide the GHWTP conducts jar tests with six different jars three times per week. One jar is used to model plant operations while different parameters are varied in the other jars. After the jar test is completed, water samples from each jar are put into THM-100 grab sample bottles and stored in a cool dry place for 24 hours. At the end of the 24-hour period the THM and chloroform concentration in each sample is measured using the THM-100 analyzer in its offline mode.

The THM-100 analyzer allows the GHWTP to obtain real-time analytical results of the manually collected samples. If the samples were sent to an external laboratory for analysis the GHWTP would have to wait weeks to receive results. A large amount of THM data can be acquired, in real-time, because of the THM-100 analyzer's quick response. The results of the study indicate that chlorine dioxide is a viable solution for THM management (Figure 2) at the GHWTP.

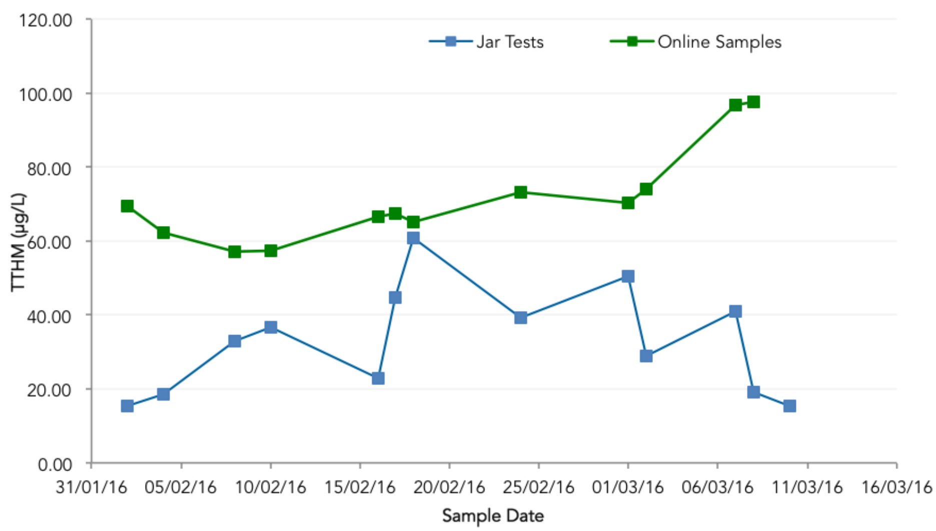


**Figure 2:** Chlorine Dioxide Jar Test THM Results Compared to GHWTP Finished Water - 13 jar tests/month, 6 bottles/jar test, 78 samples/month.

## Accelerated Online THM Formation Potential at GHWTP

In November 2014 the analyzer was upgraded to a THM-100-FP™ system capable of providing online THM-FP characterization of the GHWTP effluent. Whereas a standard laboratory method for THM-FP analysis typically requires sample manipulation ($Cl_2$ adjustment, temperature control and 7 day incubation period) and an analytical laboratory analysis of THM levels, this new online methodology is automated and returns the THM-FP level in near real-time (within three hours).

The THM-100-FP uses software modifications applied to the THM-100 analyzer, to accelerate the formation of THMs in a water sample acquired inside the heated purge-of the THM-100-FP, by the reaction between the residual DOC, bromide and $Cl_2$, at elevated temperature (~50-70 °C) with a reaction time of less than 60 minutes.

Both the THM-forming reaction time and temperature are customizable parameters in the THM-100-FP software, with the objective of tuning the THM-FP level so that they are similar in magnitude to the TTHM levels at the furthest node in the network (in this case, at 'University 5', a storage tank, with an average age of 7 days after exiting the GHWTP) (Figure 3).

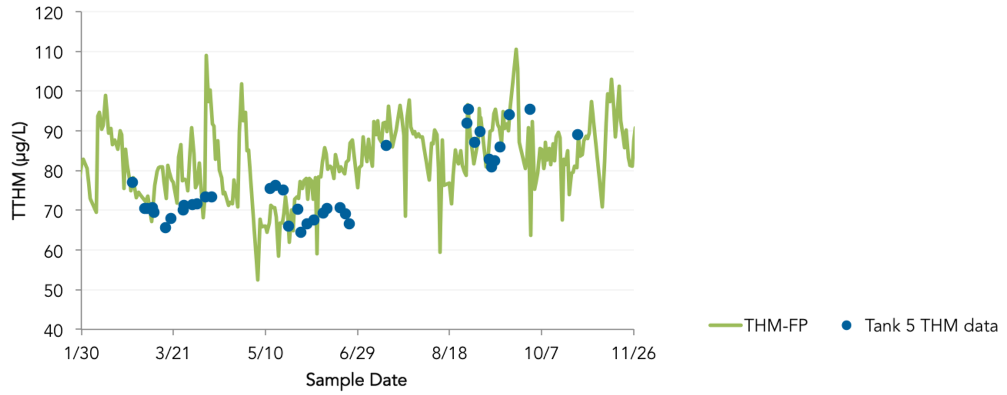


**Figure 3:** THM-FP data predicting THM levels at an end-point of the GHWTP's distribution system.

This customization period is typically completed in less than three months, with only a few iterations. It is difficult to precisely correlate WTP THM-FP levels with network TTHM levels because the former is an instantaneous characterization of the water quality leaving the GHWTP, whereas in the network it is a hydrodynamic blend of water of different ages. With the THM-100-FP configuration, the online schedule at the GHWTP was modified to five daily online TTHM samples and one daily online THM-FP sample. In addition, lab-prepared THM-FP samples (that have been held for seven days) can have the TTHM levels analyzed by the THM-100-FP unit, allowing for comparisons between the online accelerated method (~3 hours) and the traditional standard method (seven days incubation).

Online THM and THM-FP analyses provided a high frequency of rapid and reliable DBP data, compared to external laboratories. Network TTHM values and lab-based THM-FP values helped drive and refine the experimental conditions, settling on a correlation of online THM-FP values being two times greater than online TTHM effluent values at the plant.

The SCWD is currently in negotiations to transfer wintertime water to the Soquel Creek Water District (SQCWD). The transfer would offset ground water pumping and allow the SQCWD's aquifers to recharge. The SQCWD is concerned about the THM levels in the SCWD's water. THM-FP results from the analyzer will allow the SCWD to ensure the water transferred to SQCWD is in compliance.

## THM Mitigation in the Distribution System

The THM and THM-FP data from the THM-100 have aided the SCWD to manage THMs in the distribution system. If THM-FP data is high, the SCWD makes process changes to reduce THM concentrations at the system's end points. For example, when THM-FP data is high the SCWD isolates one of the Bay Street Reservoir Tanks. The water is held in the tank for a period of 7 days and then the aerator in the tank is turned on (Figure 4). When THM values have decreased the isolated tank is put in service and water is allowed to move through the system up to 'University 5'. This method allows the SCWD to manage THM concentrations at one of the end points of the distribution system. Additionally, using the aerators only when necessary allows the SCWD to reduce energy costs.

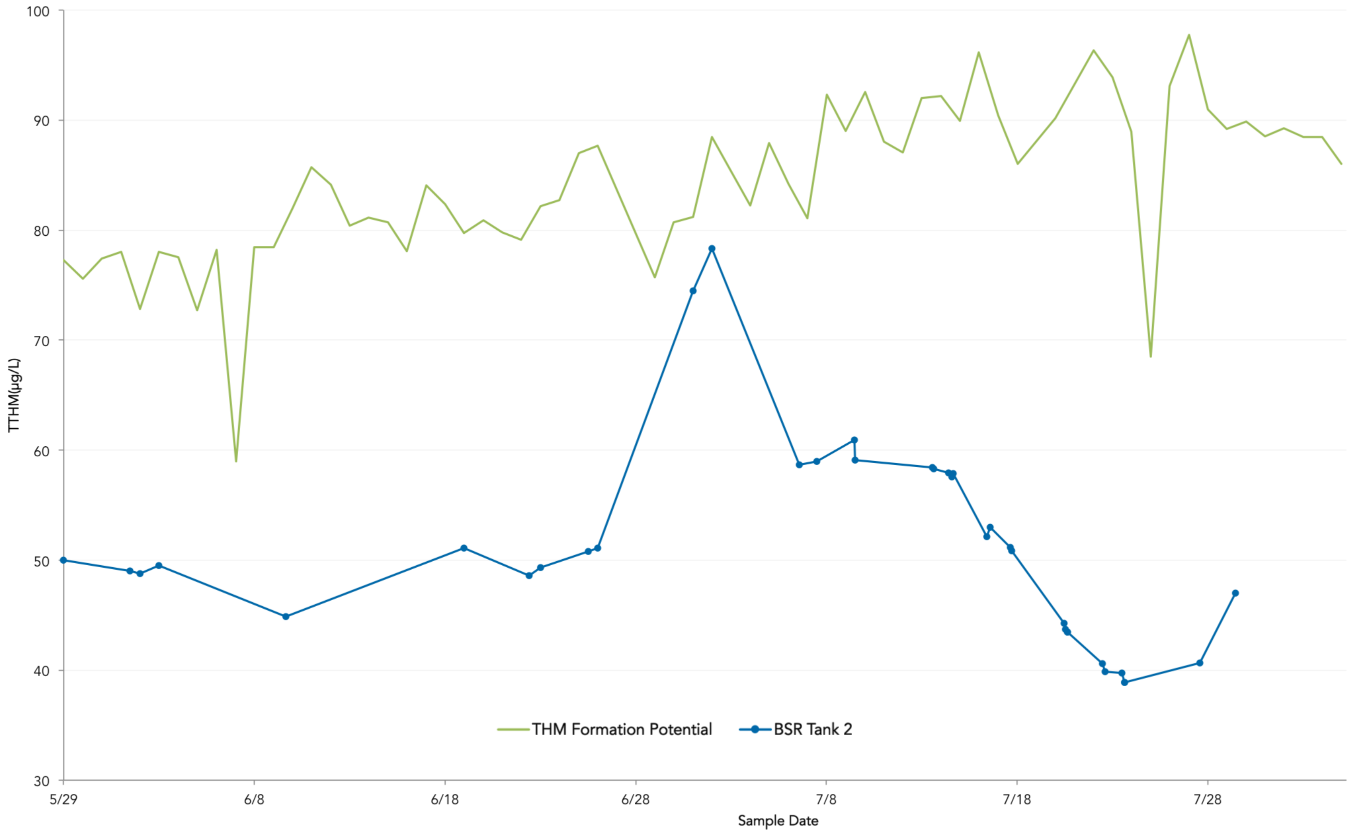


**Figure 4:** THM mitigation in BSR Tank 2 based on THM-FP period.

The THM-100 has helped the SCWD optimize flushing flow rates and flushing times at the end points of the distribution system. The SCWD flushes the end points of the distribution system weekly. The THM-100 manually collected bottle sample analysis feature has allowed the SCWD to develop baseline THM concentrations for the system's end points.

The online THM and THM-FP analyzer has proved essential to daily operations and management to the SCWD by providing real-time and reliable data on THM and THM-FP levels within the WTP and the distribution network.

## Aeration Technology Performance Review

The SCWD initially considered using tank mixers to remove THMs by their surface evaporation into the tank headspace. A 0.25 MG tank was isolated from the distribution system, fitted with mixers, and THMs were allowed to form over seven days to approximately 95% of the maximum THM-FP. At the end of the formation time an initial baseline sample was taken from the tank and the mixers were placed in operation. Manual samples were routinely taken to monitor THM levels. Results indicated a 20% THM reduction rate through the use of mixers over the course of a month, a removal level that was inadequate for the SCWD.

The SCWD then considered implementing a blower in addition to a mixer to achieve effective THM removal. A blower was installed on the ceiling of the tank to displace the THM-saturated tank headspace, and the same testing and sampling program from the mixing study was implemented. The combined mixer/blower achieved a 30% THM reduction rate over the course of a month, a removal level that was still inadequate for the SCWD.

Following the lackluster results of mixers and blowers to achieve the THM removal rates desired by the utility, the SCWD undertook a study to evaluate spray aeration systems. Aeration treatment techniques were evaluated based on a variety of criteria including their ability to improve water quality, life cycle cost, energy efficiency, noise, ease of installation and availability of manufacturer's assistance for maintenance.

The spray aeration study evaluated an in-house built unit and a Medora Corporation SN5 unit. Four tanks were used in the study. Tank 1 was the baseline. The in-house unit and Medora Corporation SN5 unit were placed in a variety of operational modes and tested:

1. Isolating tanks following normal operation
2. Isolating tanks for 7 days following normal operation » turning on aeration system
3. Maintaining tanks in service for extended period » turning on aeration system
4. Isolating tanks » dosing tanks with specified amount of sodium hypochlorite » turning on aeration system
5. Maintaining tanks in service » dosing tanks with specified amount of sodium hypochlorite » turning on aeration system

### The results of the spray aeration study included:

- The In-house unit removed 79% of the THMs that were formed.
- The Medora Corporation SN5 unit removed 83% of the THMs that were formed.
- The Medora unit was significantly more expensive than the in-house unit.
- An in-house aeration unit, while not as energy efficient as the Medora Corporation SN5 unit, provided the necessary THM reduction.
- The removal efficacy of the Superior Technologies unit was considerably low after the initial review; further evaluation of the system was not undertaken as part of the spray aeration study.
- The trade-offs in this study are THM concentration reduction/cost of aeration unit, THM concentration reduction/operation and maintenance cost of the aerator, and THM concentration reduction/predicted life of the aerator.

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