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2008 Annual Disinfection By-Products Summary of Greater Victoria's Drinking Water

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April 30, 2009

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Executive Summary

The *2008 Annual Disinfection By-Products Summary of Greater Victoria's Drinking Water* is the third report in the Water Quality Division's 2008 annual report series. It extends the disinfectant and disinfection by-products information provided in the *2008 Annual Overview of Greater Victoria's Drinking Water Quality* and details the disinfection by-products results across the Greater Victoria Drinking Water System.

The primary observations and conclusions contained in this report are listed below:

1. **Overall Summary.** In general, while some disinfection by-products continue to be detected, all of the values were well within the Guidelines and the quality of the drinking water in Greater Victoria in 2008 continued to be very good.
2. **Trihalomethanes.** In 2008, the average concentration of trihalomethanes (THMs) for the entire Greater Victoria Distribution System was 16.6 µg/L. This is well below the limit of 100 µg/L in the *Guidelines for Canadian Drinking Water Quality* and also below the USEPA maximum contaminant level (MCL) of 80 µg/L (**Figure 2**). Chloroform was the predominant type of THM detected.

The first customer sampling location just below the Japan Gulch Treatment Plant had relatively low THMs concentrations that ranged from 7.8 to 26.4 µg/L. As expected, during the period of time since the rechlorination ceased at the Deep Cove Pumpstation in North Saanich in 2007, the levels of THMs have dropped quite significantly (**Figures 4 and 5**) without any significant increase in bacterial numbers.

3. **Haloacetic Acids.** In 2008, the levels of HAAs were well below both the USEPA maximum contaminant level (MCL) of 60 µg/L and the newly established limit of 80 µg/L (set in July 2008) in the *Guidelines for Canadian Drinking Water Quality* (**Figure 6**). (As expected, stopping rechlorination at the Deep Cove Pumpstation in North Saanich caused dramatic and significant decreases in the levels of HAAs (**Figures 8 and 9**).
4. **Chloramine Species.** Ideally, the majority of the chloramine species in a chloraminated drinking water system should be monochloramine. However, over the past several years, the dichloramine concentration has, a times, exceeded the target of 20%. This has the potential to produce a stronger chlorinous taste and odour in the water.

RECOMMENDATIONS

1. Continue to operate the Deep Cove Pumpstation without rechlorination. This should achieve the lowest possible THM and HAA concentrations without compromising the effectiveness of the water disinfection.
2. It is recommended that the current process used to chloramine the water be reviewed and corrected to reduce dichloramine production.

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1. Introduction

The *2008 Annual Disinfection By-Products Summary of Greater Victoria's Drinking Water* is the third report in the Water Quality Division's 2008 annual report series. It extends the disinfection by-products (DBPs) information provided in the *2008 Annual Overview of Greater Victoria's Drinking Water Quality* and details the DBP results for the various types of treatment processes used in the Greater Victoria Drinking Water System. All of the annual reports are posted on the Capital Regional District (CRD) website at <http://www.crd.bc.ca/water/waterquality/annualreports.htm>

In drinking water, disinfection by-products (DBPs) are formed when the disinfecting chemical or process changes one or more of the components present in the raw (untreated) source water into another type of chemical compound – hence, producing a by-product of the disinfection process.

In the raw source water entering the Greater Victoria Drinking Water System, the principal components that act as precursors for the production of DBPs are naturally occurring organic compounds (often humic substances such as humic and fulvic acids that result from the passage of the rainwater through the leaves and vegetation on the forest floor) and algae that are present within the reservoir. These components may change into new types of compounds called disinfection by-products (DBPs). In the past, the primary concern about DBPs has been long term (chronic) exposure, but more recent evidence points to some potential for short term (acute) health effects. Since most drinking water utilities use some form of chlorine to disinfect the water, the DBPs most commonly associated with chlorine that have public health implications are trihalomethanes (THMs) and haloacetic acids (HAAs).

Trihalomethanes and haloacetic acids are the two major groups of disinfection by-products found in drinking water that can be used as indicators for the presence of all DBPs in drinking water supplies. Controlling the levels of THMs and HAAs is expected to reduce the levels of all DBPs and the corresponding risks to human health.

It should be noted that disinfection is essential to safeguard drinking water and that the health risks from disinfection by-products, including trihalomethanes and haloacetic acids, are much less than the risks from consuming water that has not been disinfected. The use of chlorine as a water disinfectant has virtually eliminated waterborne microbial diseases. Health Canada emphasizes that utilities should maintain concentrations of DBPs as low as reasonably achievable without compromising the effectiveness of disinfection. Chlorine-based disinfectants are still the most convenient and easily controlled disinfectants due to chlorine's strong oxidizing power allowing a residual to be maintained in the distribution system to prevent bacterial regrowth and to serve as protection against possible main breaks or cross connections.

Some background information about the two major groups of by-products of the chlorine disinfection process is provided below.

1.1. TRIHALOMETHANES AND HALOACETIC ACIDS

Trihalomethanes (THMs) and haloacetic acids (HAAs) are groups of compounds that form when the chlorine that is used to disinfect the drinking water reacts with naturally occurring organic matter in the water. The trihalomethanes most commonly found in drinking water are:

- Chloroform (CHLF)
- Bromodichloromethane (BDCM)
- Dibromochloromethane (DBCM)
- Bromoform (BRFM)

The 5 haloacetic acids (HAAs) most commonly found in drinking water are:

- Monochloroacetic acid (MCAA)
- Dichloroacetic acid (DCAA)
- Trichloroacetic acid (TCAA)
- Monobromoacetic acid (MBAA)
- Dibromoacetic acid (DBAA)

The most extensively studied HAAs are DCAA and TCAA. In addition to the five most common HAAs found in drinking water there are 4 additional HAAs which are monitored in the distribution system:

- Bromochloroacetic acid (BCAA)
- Bromodichloroacetic acid (BDCAA)
- Chlorodibromoacetic acid (CDBAA)
- Tribromoacetic acid (TBAA)

The formation of trihalomethanes and haloacetic acids is dependent on a number of factors including

- concentration of precursors (organic material) in the source water
- concentration of chlorine used to disinfect the water (disinfectant dose)
- form of chlorine used in the disinfection process (i.e. free or combined chlorine)
- amount of contact time between the chlorine and the water
- water temperature
- concentration of bromide in the water
- pH of the water

1.1.1. CONCENTRATION OF PRECURSORS

One of the major factors leading to the production of DBPs is the concentration of total organic carbon (TOC) that may be present in the source water. In the absence of organic carbon, very little DBPs are formed. The TOC concentration directly affects the amount of disinfectant that must be added to achieve a target residual since it is the organic matter that exerts the main proportion of the disinfectant demand. Ideally, the source water supply should contain a very low TOC concentration.

1.1.2. DISINFECTANT DOSE

As the concentration of chlorine or chloramines increases, the production of DBPs increases. In distribution systems, DBP formation reactions may become limited by the disinfectant concentration when the free chlorine residual drops to low levels (below 0.3 mg/L).

1.1.3. TIME DEPENDENCY ON DBP FORMATION

THM levels are expected to be highest in those seasons when the water temperature and/or organic concentrations are elevated. Generally in distribution systems, THM concentrations tend to increase with increasing age of the water. Thus, the THM formation process will continue until all of organic material or chlorine has completely reacted and then the concentration will level out. High THM levels occur where the water age is the oldest especially in systems using chlorine. However, in systems using chlorine-chloramine treatment, THM concentrations do not, in general, increase significantly with distance (time) in the distribution system.

The behaviour of haloacetic acids is more complex. HAAs cannot be consistently related to water age as they are known to biodegrade over time (i.e. they may be used as nutrients by bacteria). This might result in relatively low HAA concentrations in areas of the distribution system where the disinfectant residuals are depleted. In addition, HAAs values may be higher in winter than in the summer depending on the biological activity in the distribution system.

Thus, it is clear that no single location site or time of year can be selected to provide simultaneous maximum values for the THMs and HAAs.

1.1.4. WATER TEMPERATURE

The rate of formation of both THMs and HAAs increases with increasing temperature. The highest THM and HAA levels are expected to occur in the warm summer months. However, water demands are often higher in the summer and this usually results in lower water age within the distribution system which, in turn, helps to control DBP formation in the summer. In addition, higher water temperatures in the distribution system promote the depletion of residuals which can mitigate DBP formation and promote biodegradation of HAAs unless chlorine dosages are increased to maintain high residuals.

For these reasons, depending on the specific system, the highest THM and HAA levels may be observed during months which while warm, are not necessarily the warmest. Higher DBP precursor levels in the fall or spring may also cause the highest THM and HAA levels to be observed in relatively cool months.

Seasonal trends affect THM and HAA concentrations differently. When the water in the distribution system is colder, bacteriological activity is typically lower and DBP formation reactions are slower. Under these conditions, the highest THM and HAA concentrations might appear in the oldest water in the system. In warmer water, the highest HAA concentrations might appear in fresher water, which is likely to contain higher disinfectant residuals that can prevent the biodegradation of HAAs.

1.1.5. WATER PH

Water pH also affects THMs and HAAs differently. Typically, THM formation increases with increasing pH, while the formation of HAAs decreases with increasing pH. Water pH also affects the concentration of bromides. The overall formation of bromate decreases as the pH decreases.

1.1.6. HEALTH EFFECTS OF THMS

Chloroform is considered to be a possible carcinogen in humans and is a proven animal carcinogen. Chloroform is one of the THMs detected most frequently and at the highest concentrations in drinking water. Other types of THMs have not been studied for toxicity to the same extent as chloroform. For these reasons, the THM guideline is based on health risks linked to chloroform.

Animal studies have shown links between exposure to specific trihalomethanes and liver and kidney tumours in mice. Human studies suggest a link between exposure to trihalomethanes and colorectal cancers. Preliminary animal studies indicate that trihalomethanes that contain bromine, such as bromodichloromethane (BDCM), may be more toxic than chlorinated trihalomethanes such as chloroform (CHLF). Preliminary studies have also suggested that exposure to BDCM at high levels (above 16 µg/L) may be linked to a possible increase in reproductive effects such as spontaneous abortion or stillbirth. Health Canada has set a MAC for BDCM of 16 µg/L.

1.1.7. HEALTH EFFECTS OF HAAS

Health effects of HAAs vary with the specific HAA. Studies investigating the possible adverse effects of HAAs have suggested that dichloroacetic acid (DCAA) and trichloroacetic acid (TCAA) may have toxic effects in the liver of laboratory animals. Health Canada considers DCAA to be a probable carcinogen to humans while TCAA is considered to be a possible carcinogen in humans. There is only one small population-based study, cited by Health Canada, that found a link between exposure to haloacetic acids and risk of stillbirths. The World Health Organization has set a provisional guideline of 50 µg/L for DCAA and 100 µg/L for TCAA. Health Canada released a guideline for haloacetic acids of 80 µg/L in July 2008. The guideline is designed to be protective of the health effects of the individual haloacetic acids.

2. Regulatory Limits

The regulatory limits for disinfection by-products are listed below. CRD Water Services uses the Federal Guideline as a de facto limit and has adopted the limits in the United States Environmental Protection Agency (USEPA) for those parameters where the Canadian regulations are silent or less stringent for a given test parameter.

2.1. PROVINCIAL

In British Columbia, there are no Provincial regulatory limits for any disinfection by-products in drinking water.

2.2. FEDERAL REGULATIONS

In Canada, the Federal regulations are provided in the latest edition of the *Guidelines for Canadian Drinking Water Quality*. The Health Canada website is listed below:
http://www.hc-sc.gc.ca/ewh-semt/pubs/water-eau/sum_guide-res_recom/index-eng.php

2.2.1. TRIHALOMETHANES

The Guideline for Trihalomethanes is provided on the Health Canada website at:
<http://www.hc-sc.gc.ca/ewh-semt/pubs/water-eau/trihalomethanes/guide-eng.php>

Current Guideline (2006)

- *The proposed maximum acceptable concentration (MAC) for trihalomethanes (THMs) in drinking water is 0.100 mg/L (100 µg/L) based on a locational running annual average of a minimum of quarterly samples taken at the point in the distribution system with the highest potential THM levels.*
- *The maximum acceptable concentration (MAC) for bromodichloromethane (BDCM) in drinking water is 0.016 mg/L (16 µg/L) monitored at the point in the distribution system with the highest potential THM levels.*
- *Utilities should make every effort to maintain concentrations as low as reasonably achievable without compromising the effectiveness of disinfection.*

2.2.2. HALOACETIC ACIDS

The Guideline for Haloacetic Acids is provided on the Health Canada website at

<http://www.hc-sc.gc.ca/ewh-semt/pubs/water-eau/haloaceti/index-eng.php>

Current Guideline (July 2008)

- *The maximum acceptable concentration (MAC) for total haloacetic acids (HAAs) in drinking water is 0.08 mg/L (80 µg/L) based on a locational running average of a minimum of quarterly samples taken in the distribution system.*
- *Utilities should make every effort to maintain concentrations as low as reasonably achievable (or ALARA) without compromising the effectiveness of disinfection*

2.3. USEPA REGULATIONS

In January 2006, the USEPA Stage 2 Disinfectants/Disinfection By-Products Rule (DBPR) was released

- The Stage 2 DBPR focuses on identifying the higher risks through the Initial Distribution System Evaluation (IDSE). The rule then addressed reducing exposure and lowering DBP peaks in distribution system by using a new method to determine MCL.
- The IDSE requires THM and HAA monitoring for one year on a regular schedule. The IDSE is intended to identify sample locations for Stage 2 compliance. These locations must be ones that are representative of high DBP levels. Stage 2 compliance is based on a location running annual average where the annual average at each sampling location in the distribution system is used to determine compliance with MCL of 80 µg/L for THM and 60 µg/ for HAA.

3. Water System Description

The following provides a brief description of the Greater Victoria Drinking Water System pertinent to this topic. A more complete description of the water system can be found in the *2008 Annual Overview of Greater Victoria's Drinking Water Quality* and the *2008 Annual Bacteriological Summary of Greater Victoria's Drinking Water* at <http://www.crd.bc.ca/water/waterquality/annualreports.htm>

3.1. SOURCE WATER SYSTEM

Drinking water for Greater Victoria comes from a protected watershed called the Greater Victoria Water Supply Area. This area, approximately 11,000 hectares in size and protected from public access, is located about 30 km northwest of the city. The five reservoirs in the Supply Area have been used as a source of drinking water since the early 1900's. Sooke Reservoir, the largest of the reservoirs, is the primary water source for the city, supplying approximately 98% of Greater Victoria's drinking water. The four reservoirs in the Goldstream system, including Butchart Reservoir, Lubbe Reservoir, Goldstream Reservoir and Japan Gulch Reservoir, typically remain off-line and are used as a backup water supply.

During 2008, all water received at the Japan Gulch Treatment Plant originated from Sooke Reservoir.

3.2. DISINFECTION PLANT

Water in the Greater Victoria Drinking Water System receives ultraviolet disinfection at the Japan Gulch Treatment Plant followed by disinfection with free chlorine (contact period approximately 10-15 minutes) and then by the addition of ammonia. During 2008, CRD Water Services used a chlorine dosage rate of 1.6 mg/L for most of the year.

3.3. CHLORINE BOOSTER STATIONS

Deep Cove Pump Station. Prior to April 11, 2007, CRD Environmental Services added additional chlorine using sodium hypochlorite at the Deep Cove Pumping Station. In 2008, this rechlorination remained off-line.

Upper Dawson and McTavish Reservoirs. Small amounts of free chlorine are added at the Upper Dawson Reservoir and at McTavish Reservoir to enhance the chlorine residual in these reservoirs and reduce the potential for bacterial regrowth.

Rocky Point Reservoir Rechloramination Station. In the fall of 2002, a booster station located at Rocky Point Reservoir was commissioned using a chloramine process. This station provided increased chloramine residuals to the extremities of the system on Rocky Point Road and Deer Park Reservoir. During 2008, the chlorine dosage varied to provide a target total chlorine residual of 1.0 mg/L at the outlet of Rocky Point Reservoir. The target chlorine to ammonia dosage ratio was 5:1.

4. Sampling Locations

In 2008, three sampling locations were sampled for disinfection by-products (DBPs every two months). The locations chosen included an extremity of the distribution system. In addition, the first customer sampling point at 2828 Lakehurst was sampled daily for mono and dichloramine levels. Health Canada requires at a minimum, quarterly monitoring of treated water for both THMs and HAAs. Sampling every two months was established to capture the variation in disinfection by-products that can occur depending of precursor concentration, water temperature, and contact time.

A description of the sampling location (and sampling code number) along with the rationale for choosing the sampling locations is provided below.

First Customer DBP Sampling Location

- **PRV at 2818 Lakehurst (JGO-TR-01).** This sampling point is located downstream of the Japan Gulch Treatment Plant near the first customer. The water at this location has been in contact with the chlorine disinfectant the shortest period of time of any of the sampling locations. This location provides a baseline for comparison to all the other sampling locations further downstream.

Saanich Peninsula DBP Sampling Locations

- **Cloake Hill Reservoir (CLR-01-01).** This sampling point is located just downstream of Cloake Hill Reservoir. Prior to April 11, 2007, the water at this location was rechlorinated at Deep Cove Pumping Station and passed through Cloake Hill Reservoir. This location provides information on the quality of water received by the first customers in North Saanich downstream of Cloake Hill Reservoir.
- **Boas in North Saanich (NOS-CP-01).** This sampling point is located in the north eastern

extremity of the North Saanich distribution system and provides information on the quality of water typically received in the Curteis Point pressure zone. This location is an extremity of the Cloake Hill Reservoir pressure zone.

5. Results

The 2008 results for chlorine residuals, total organic carbon, trihalomethanes, haloacetic acids and mono and dichloramines are provided below.

5.1. CHLORINE RESIDUAL RESULTS

The concentration of chlorine and the form that it is in (i.e. free chlorine or combined as total chlorine) can have a major impact on the concentration of disinfection by-products found in the water. The chlorine residuals measured at the various sampling locations used for DBP monitoring in 2008 are shown in **Figure 1**.

First Customer DBP Sampling Location (Figure 1)

- **PRV at 2818 Lakehurst (JGO-TR-01)**. In 2008, at the first customer sampling location downstream of the plant, the median total chlorine residual (middle value between the maximum and minimum) was 1.18 mg/L (264 sampling dates in 2008). The chlorine residual concentration ranged between a minimum of 0.66 and a maximum of 1.76 mg/L. On the six sampling days that DBP samples were collected from this location, the chlorine residual ranged from a minimum of 1.14 mg/L to a maximum of 1.29 mg/L with a median of 1.21 mg/L. The total chlorine residual data in this subset for DBP samples mimicked the values in the larger dataset and provided assurance that the six samples collected for DBP monitoring were representative of conditions during the entire year. No free chlorine residual is typically present at this sampling location.

Saanich Peninsula DBP Sampling Locations (Figure 1)

- **Cloake Hill Reservoir (CLR-01-01)**. Downstream of Cloake Hill Reservoir and prior to the first customer in that service area, the median total chlorine residual was 0.64 mg/L (59 sampling dates) and ranged from a minimum of 0.36 mg/L to a maximum of 0.88 mg/L. On the six days that DBP samples were collected from this location, the total chlorine residual ranged from a minimum of 0.44 mg/L to a maximum of 0.68 mg/L with a median of 0.64 mg/L.
- **Boas in North Saanich (NOS-CP-01)**. In a lower use, extremity area of the Cloake Hill Reservoir service area, the median total chlorine residual was 0.14 mg/L (36 sampling dates) and ranged from a minimum of 0.04 mg/L to a maximum of 0.29 mg/L. On the six days that DBP samples were collected from this location in 2008, the total chlorine residual ranged from a minimum of 0.06 mg/L to a maximum of 0.27 mg/L with a median of 0.156 mg/L.

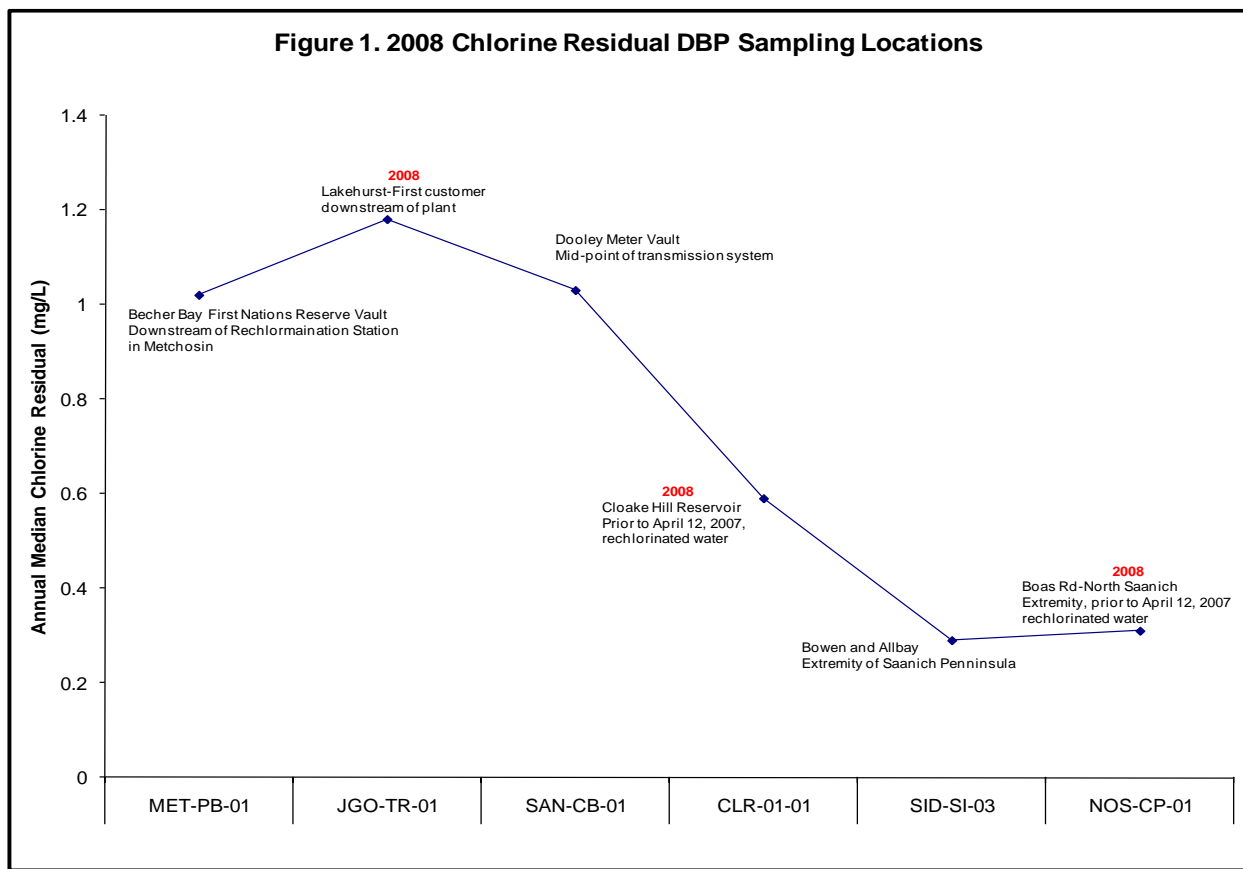


TABLE 2. 2008 GREATER VICTORIA DISTRIBUTION SYSTEM ORGANIC CARBON AND OTHER ANALYTICAL RESULTS

LOCATION DESCRIPTION		DATE	ANALYTICAL RESULTS (ug/L)			Field Measurements	
			MDL - 1.0	MDL - 1.0	MDL - 10	mg/L	Degrees C
LOCATION CODE	SAMPLING DESCRIPTION	SAMPLING DATE	DOC Dissolved Organic Carbon	TOC Total Organic Carbon	HPC7D Heterotrophic Plate Count	Total Chlorine Residual	Water Temperature
JGO-TR-01	PRV at 2818 Lakehurst Dr.	26-Feb-08	2.3	2.4	70	1.14	4.9
		16-Apr-08	2.4	2.4	ND	1.29	6.5
		17-Jun-08	NA	NA	10	1.23	11.6
		13-Aug-08	2.4	2.5	50	1.23	15.8
		29-Oct-08	NA	NA	100	1.18	11.0
		17-Dec-08	2.5	2.5	ND	1.14	5.3
CLR-01-01 *	Cloake Hill Reservoir Subject to rechlorination on specified date	26-Feb-08			NA	0.63	6.3
		16-Apr-08			ND	0.68	7.9
		17-Jun-08			70	0.64	15.0
		13-Aug-08			330	0.68	16.7
		29-Oct-08			60	0.44	13.0
		17-Dec-08			ND	0.51	8.5
NOS-CP-01 *	Lot N. of 10943 Boas Rd. Subject to rechlorination on specified date	26-Feb-08			110	0.13	7.5
		16-Apr-08			2500	0.22	9.3
		17-Jun-08			320	0.17	13.0
		13-Aug-08			1100	0.27	16.8
		29-Oct-08			2420	0.06	12.6
		17-Dec-08			460	0.09	9.7

MDL Method Detection Limit
 NA Not Available
 ND Not Detected

5.2. TOTAL ORGANIC CARBON RESULTS

As noted earlier, in addition to chlorine, the amount of total organic carbon (TOC) that is present in the water is a primary determinant of the concentration of disinfection by-products that may be found in the drinking water. Based on monthly samples collected from the raw source water entering the Japan Gulch Treatment Plant, in 2008, the median TOC concentration was 2.4 mg/L and ranged from 2.3 to 2.9 mg/L. The vast majority of this total organic carbon is dissolved organic carbon. Similar to previous years, there did not appear to be any particular seasonality to the TOC data in 2008. These TOC levels entering the Greater Victoria Drinking Water System in 2008 are considered to be in the moderate range for water utilities in Canada. The total organic carbon concentrations collected on the DBP sampling dates is provided in **Table 2**.

5.3. TRIHALOMETHANE RESULTS

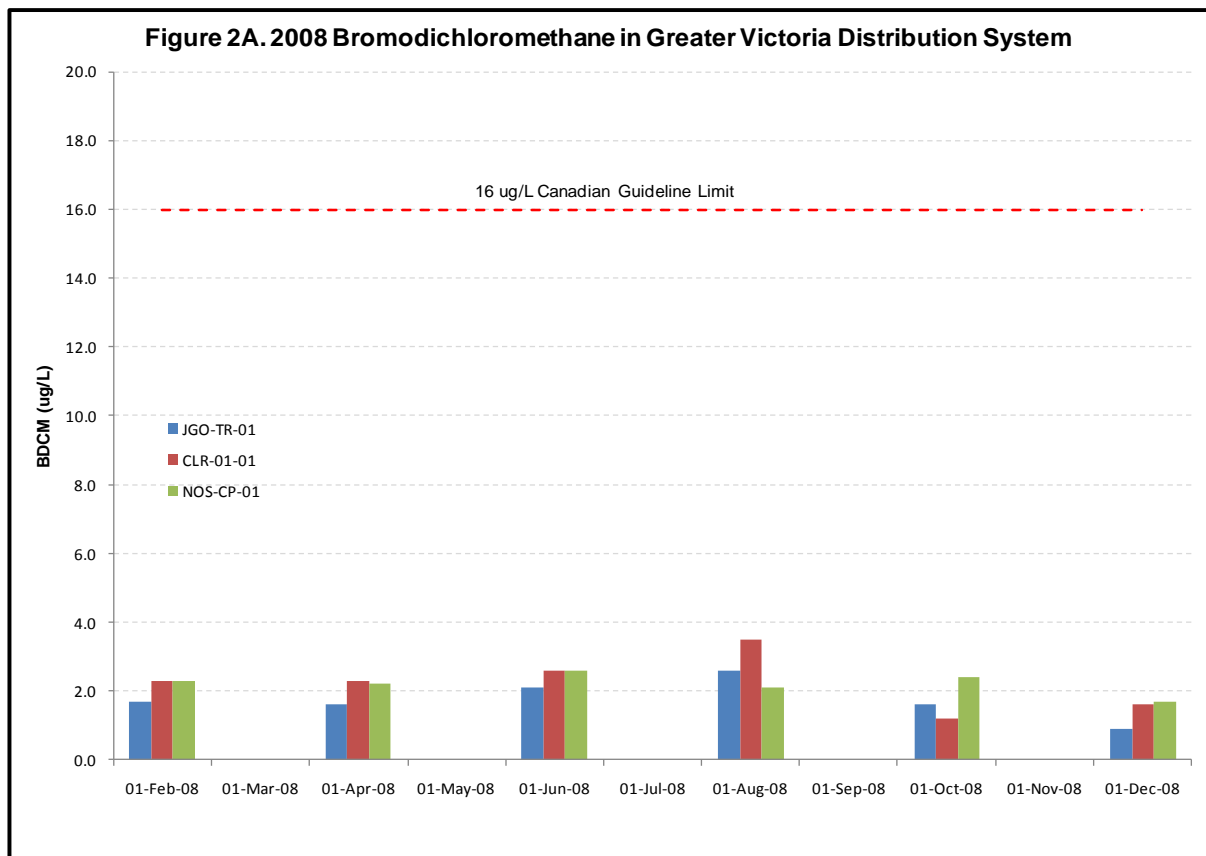
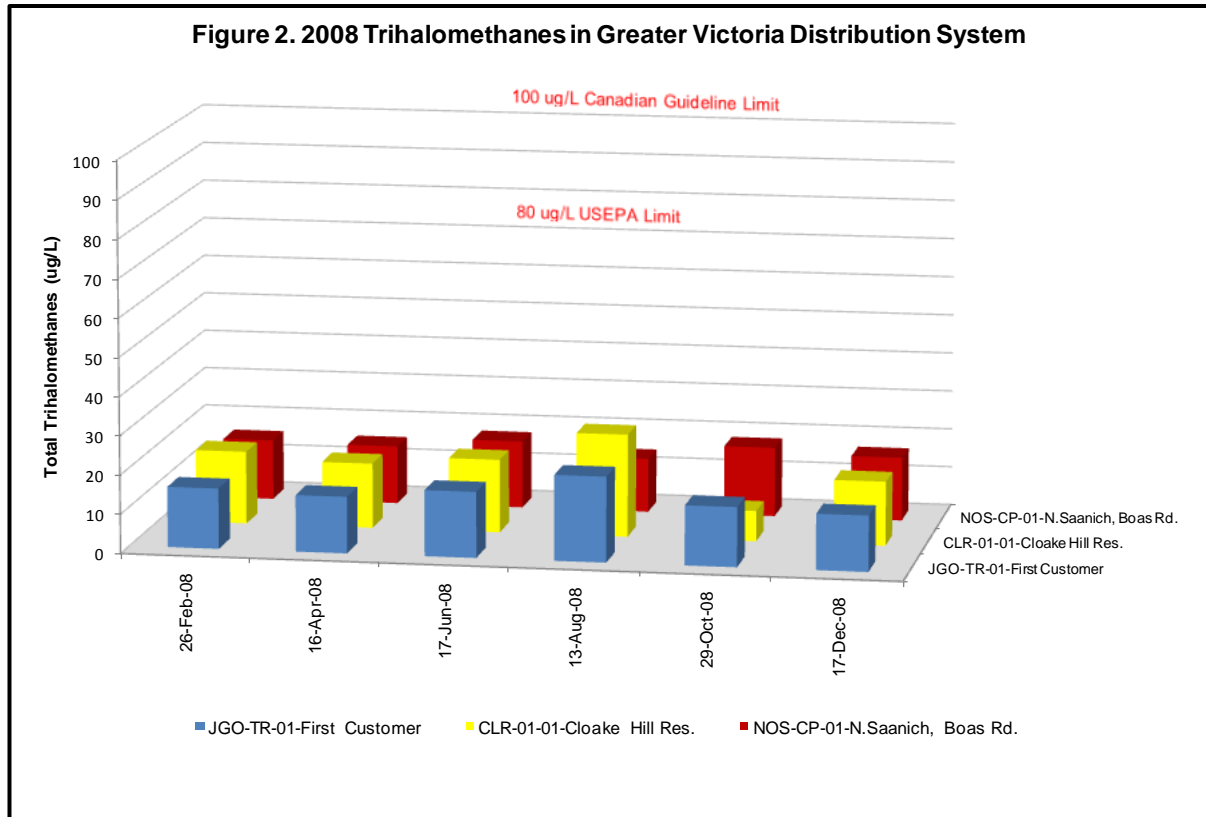
Since the rechlorination on the Saanich Peninsula was stopped on April 11th, 2007, the trihalomethane sampling results for 2008 were kept in one grouping.

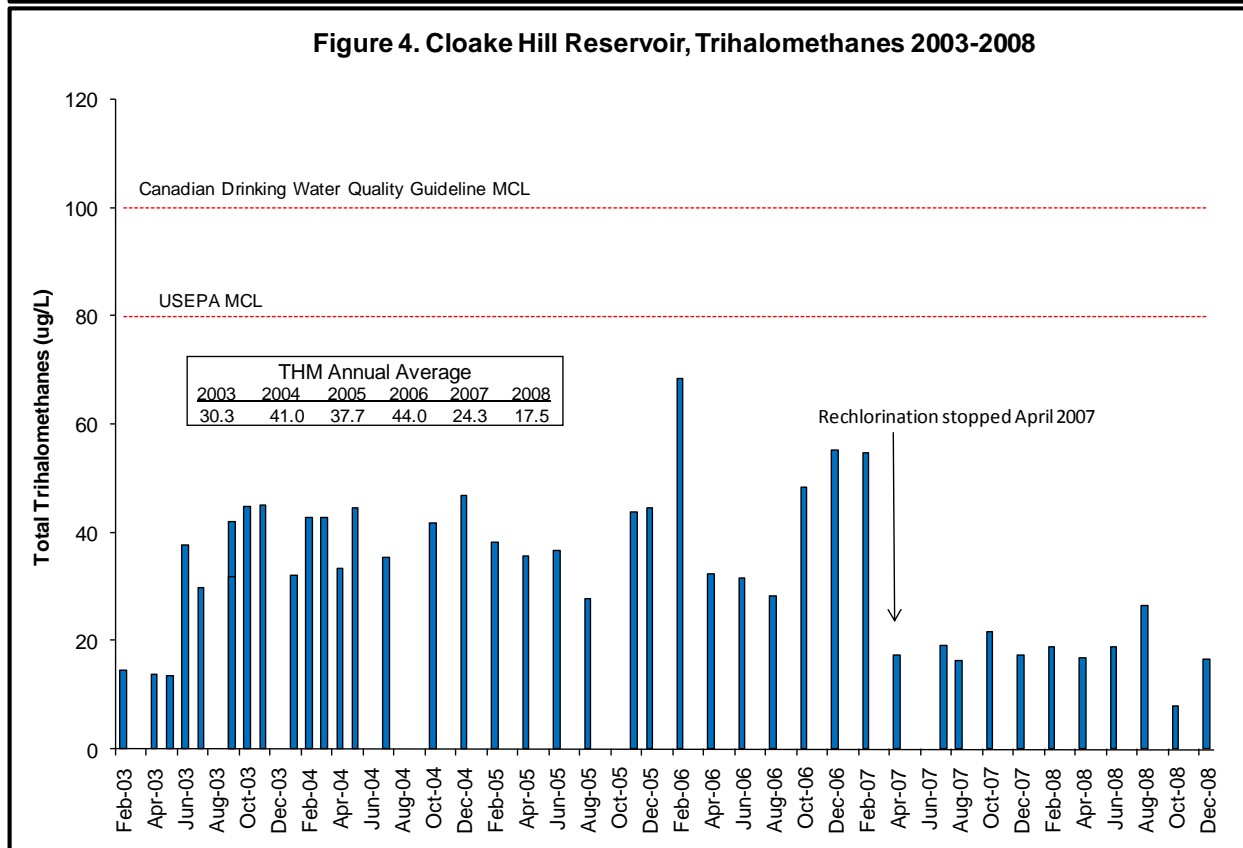
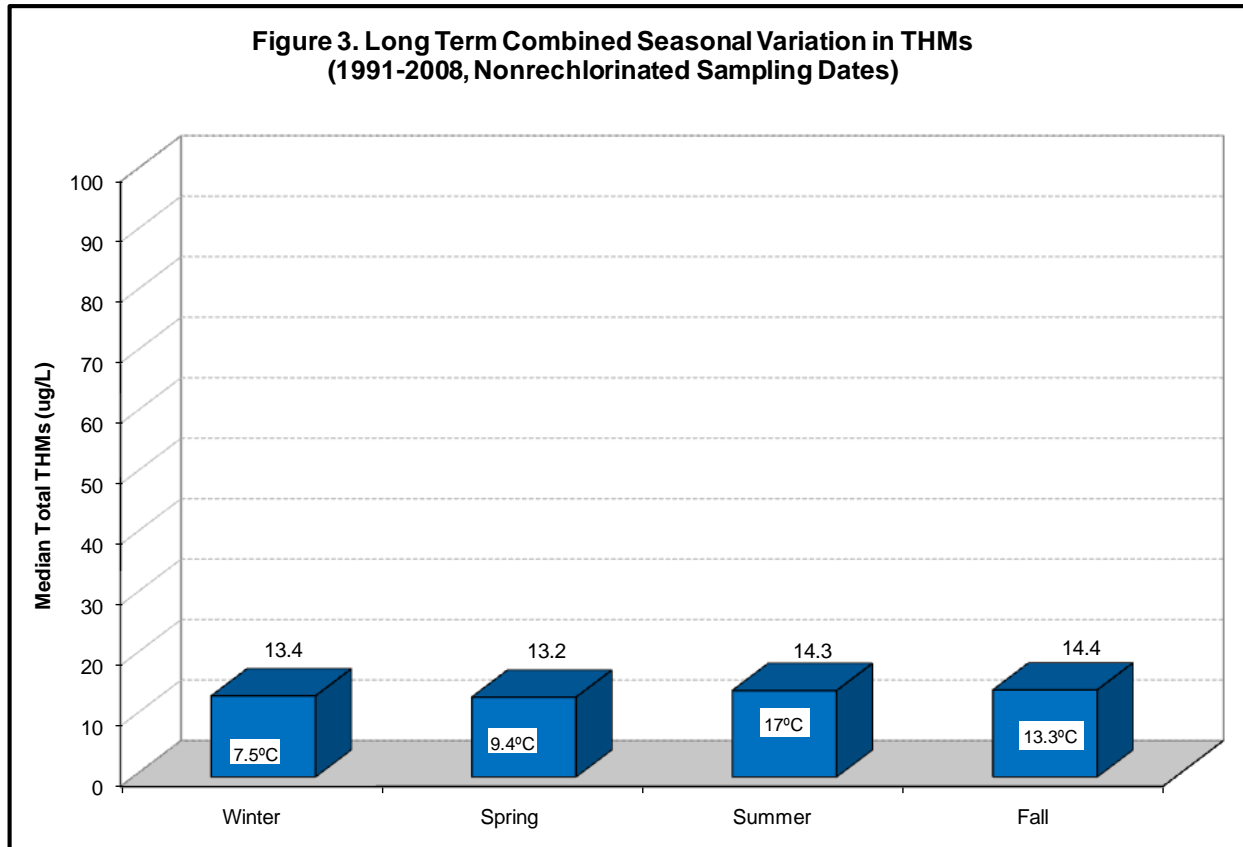
5.3.1. ALL SAMPLING LOCATIONS (COMBINED DATA)

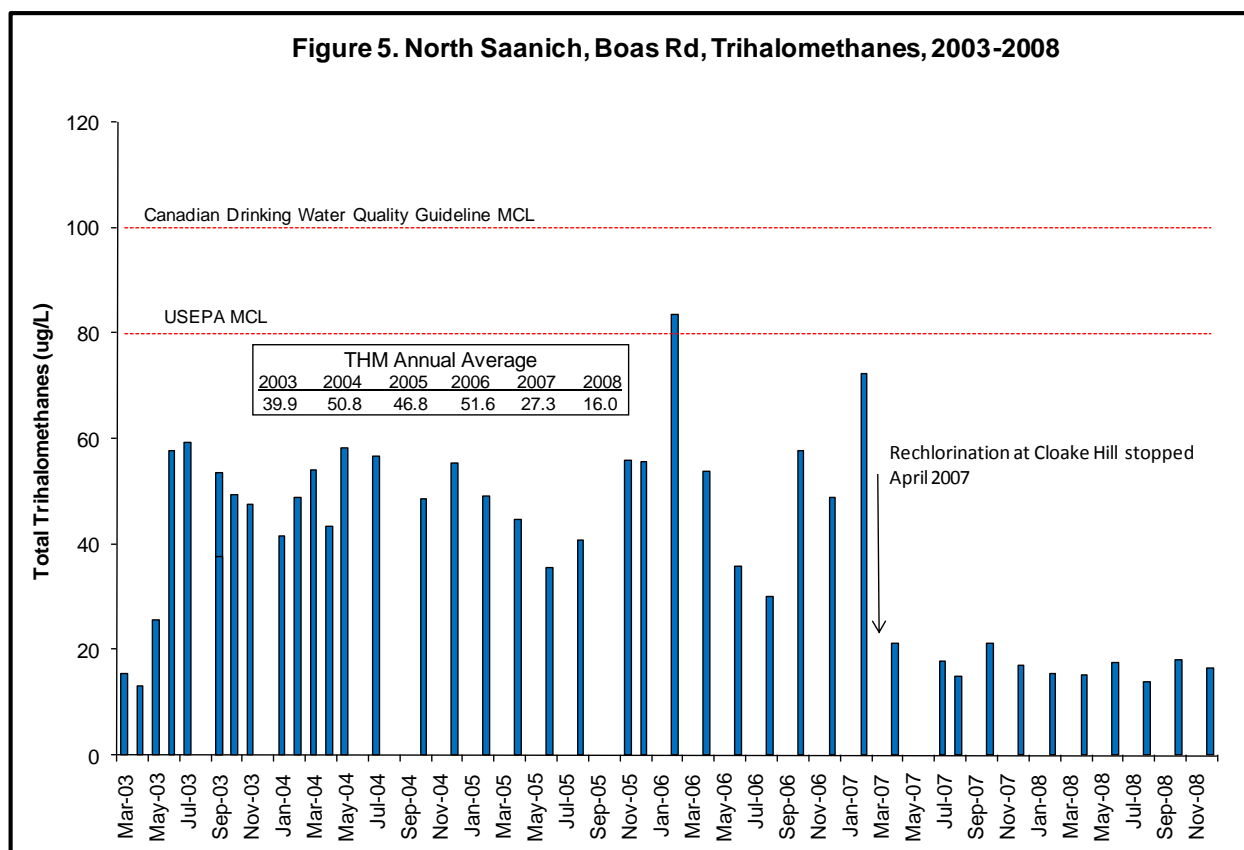
In 2008, a total of eighteen samples were collected from the Greater Victoria Drinking Water System and analyzed for trihalomethanes (THMs). These results were combined into a single data set (see **Table 1** at end of document). When combined, the average annual concentration of total THMs was 16.6 µg/L, almost identical to the average in 2007 (16.4 µg/L). This is well below the Canadian Guideline maximum concentration of 100 µg/L. None of the individual samples analyzed had THM levels greater than the Guideline limit. These results are illustrated in **Figures 2, 2A, 3, 4, and 5**.

The lowest concentration of total THMs found was 7.8 µg/L at the Cloake Hill Reservoir sampling point on August 13, 2008 while the maximum was 26.4 µg/L at the same location, sampled on October 29, 2008 (**Table 1**). These results are well within the regulatory limits. Chloroform was the primary type of THM detected and represented between 74 and 94% of the total THM concentration for locations sampled in 2008, similar to the results in 2007. Chloroform concentrations were relatively constant within the distribution system with the exception of the lower values for North Saanich in August and Cloake Hill in October 2008. Bromoform was not detected in any of the samples analyzed while dibromochloromethane was detected at very low concentrations at Cloake Hill Reservoir in December and at the Boas Road location in October and December. Bromodichloromethane (BDCM) was detected at very low concentrations ranging from 0.9 µg/L to 3.5 µg/L, well below the Canadian Guideline limit of 16 µg/L (**Figure 2A**). In the long term from 1990 through 2008, the BDCM level has only reached a maximum of 8 µg/L (this includes all sampling dates for both non-rechlorinated and rechlorinated sampling locations, prior to April 2007).

Based on the sampling in 2008, there was no indication of any seasonality in THM levels as THM levels remained fairly constant throughout the seasons (**Figure 3**). The average water temperature of the samples collected in the spring was 9.4°C versus 7.5°C in the winter months, 17.0°C in the summer and 13.3°C in the fall sampling period. This is similar to the results of 2007 and in contrast to 2006 when there seemed to be lower THM levels in the spring sampling period. In 2004 the summer THM levels were higher than those in any other season by 22 to 43%. In 2005 the summer sampling period was 30 to 39% lower. This indicates that for the non-rechlorinated sampling locations there is no seasonality over time for THM concentrations. When sampling values are combined over the long term (from 1991 through 2008, from 32 to 90 sampling dates for each season) the mean and median THM values do not show any significant seasonality (**Figure 3**).







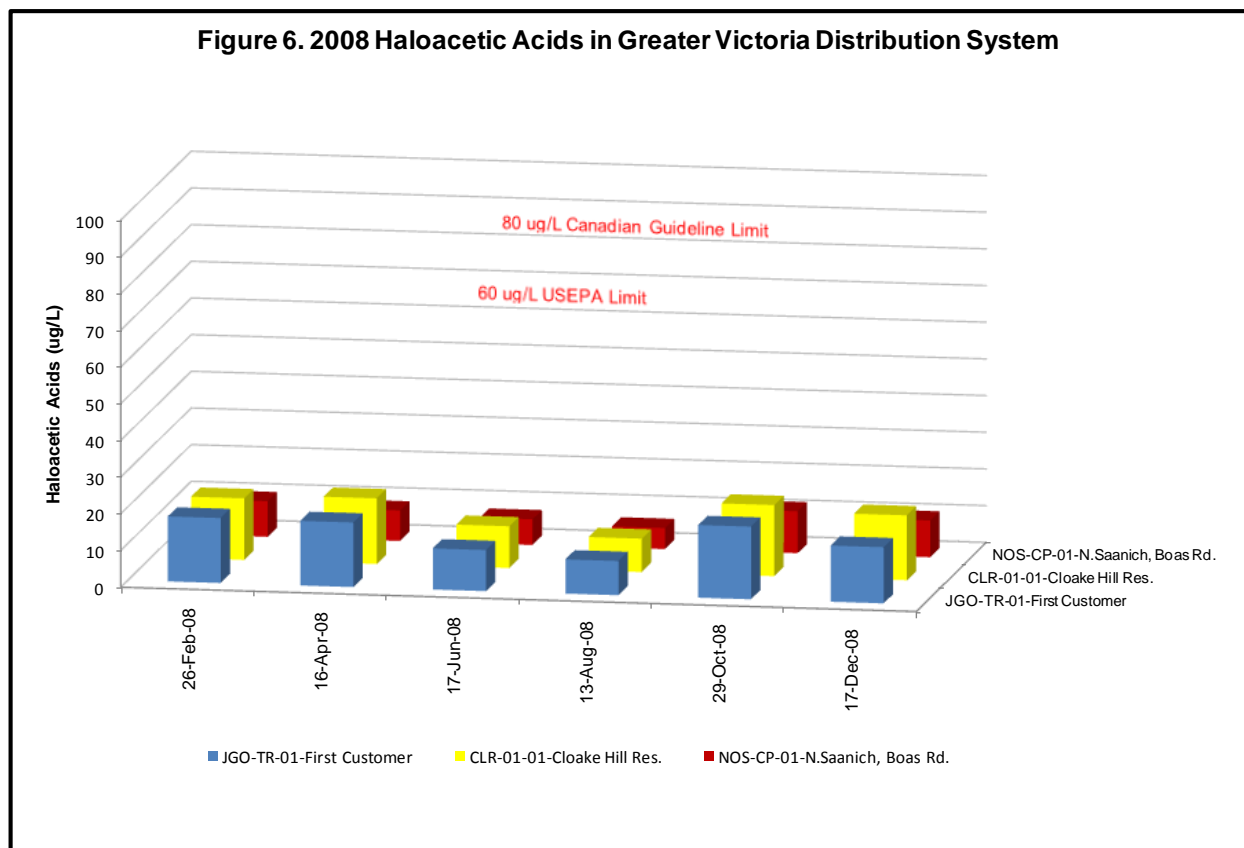
During the period of time since the rechlorination at Cloake Hill ceased in April 2007, THM levels have decreased significantly in that portion of the distribution system. Prior to April 2007, the annual average THM for the Cloake Hill sampling location ranged from 30.3 $\mu\text{g/L}$ to 44.0 $\mu\text{g/L}$ while after April 2007 the annual average fell by 53% with THM levels ranging from 7.8 $\mu\text{g/L}$ to 26.4 $\mu\text{g/L}$ during the period since chlorination was stopped (**Figure 4**). The same drop in THM values is evident at the North Saanich sampling location at Boas Road (**Figure 5**).

5.4. HALOACETIC ACID RESULTS

In addition to monitoring for THMs, samples from the distribution system were monitored for haloacetic acids (HAAs). All of the haloacetic acids sampling results for 2008 were summarized together because the rechlorination at the Deep Cove Pumping Station ceased on April 12th, 2007.

HAAs (the five most common, HAA5) were found at relatively low levels (5.7-19.8 $\mu\text{g/L}$) in the Greater Victoria Distribution System (**Table 3** and **Figure 6**). HAA levels were as high as in some cases higher than the THM concentrations found for the same sampling locations. In the long term, from 2003 through 2008 THM concentrations were higher than HAA concentrations in 46% of the samples. All of the HAA levels were well below the Canadian guideline of 80 $\mu\text{g/L}$ for haloacetic acids and the US Environmental Protection Agency (USEPA) MCL of 60 $\mu\text{g/L}$ (**Figure 6**).

HAA levels showed little variation between sampling locations in the distribution system and little variation from sampling date to sampling date (**Figure 6**). The average seasonal HAA levels were relatively similar throughout the year ranging from a low of 5.73 $\mu\text{g/L}$ in August to a high of 19.8 $\mu\text{g/L}$ in October (**Figure 6**). This is similar to the previous four years.



In the long term, from 2001 through 2008, there is no clear evidence of seasonal variation in HAA concentrations for the non-rechlorinated locations although the winter season does have the highest HAA concentration and the summer has the lowest concentration (**Figure 7**). This finding supports HAA biodegradation kinetics as the biological activity is less in the winter than in the summer.

Similar to the THMS, during the period of time since the rechlorination at Cloake Hill ceased in April 2007, HAA levels have decreased significantly in that portion of the distribution system. Prior to April 2007, the annual average HAA for the Cloake Hill sampling location ranged from 36.5 µg/L to 53.9 µg/L while after April 2007 the annual average fell by 68% with levels ranging from 9.1 µg/L to 26.6 µg/L (**Figure 8**). The decrease in HAA levels is even more dramatic at the North Saanich sampling location at Boas Road as the average decreased from a high of 52.7 µg/L in 2006 to an average HAA level of only 8.7 µg/L in 2008, a drop of 83% (**Figure 9**).

5.4.1. INDIVIDUAL HALOACETIC ACIDS

Monochloroacetic acid (MCAA) and monobromoacetic acid (MBAA) were not detected at any of the sampling locations while dibromoacetic acid (DBAA) was detected in very small amounts (0.17-0.22 µg/L). Both dichloroacetic acid (DCAA) and trichloroacetic acid (TCAA) were found in all of the sampling locations ranging from a minimum of 4.4 µg/L to a maximum of 15.1 µg/L for DCAA and ranging from a minimum of 1.24 µg/L to a maximum of 7.44 µg/L for TCAA. Both the DCAA and the TCAA levels were well below the provisional World Health Organisation guidelines (50 and 100 µg/L respectively) for all locations and sampling dates in 2008 (**Figures 10 and 11**). DCAA levels were significantly higher than TCAA levels for all sampling locations and all sampling dates (**Figures 8 and 9**).

The Canadian Drinking Water Guideline for HAAs is designed to be protective of the health effects of DCAA as the haloacetic acid that would pose the most significant health concerns and is found at the highest levels in drinking water.

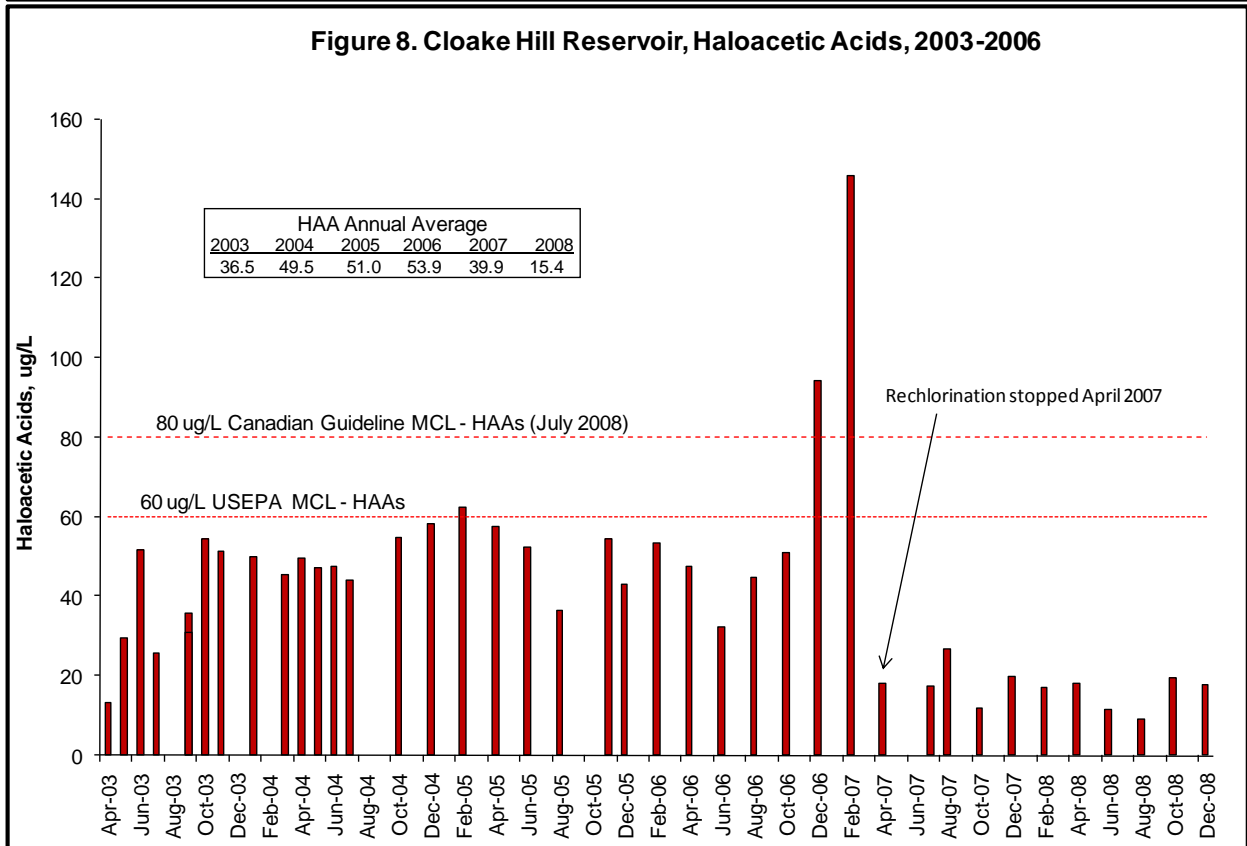
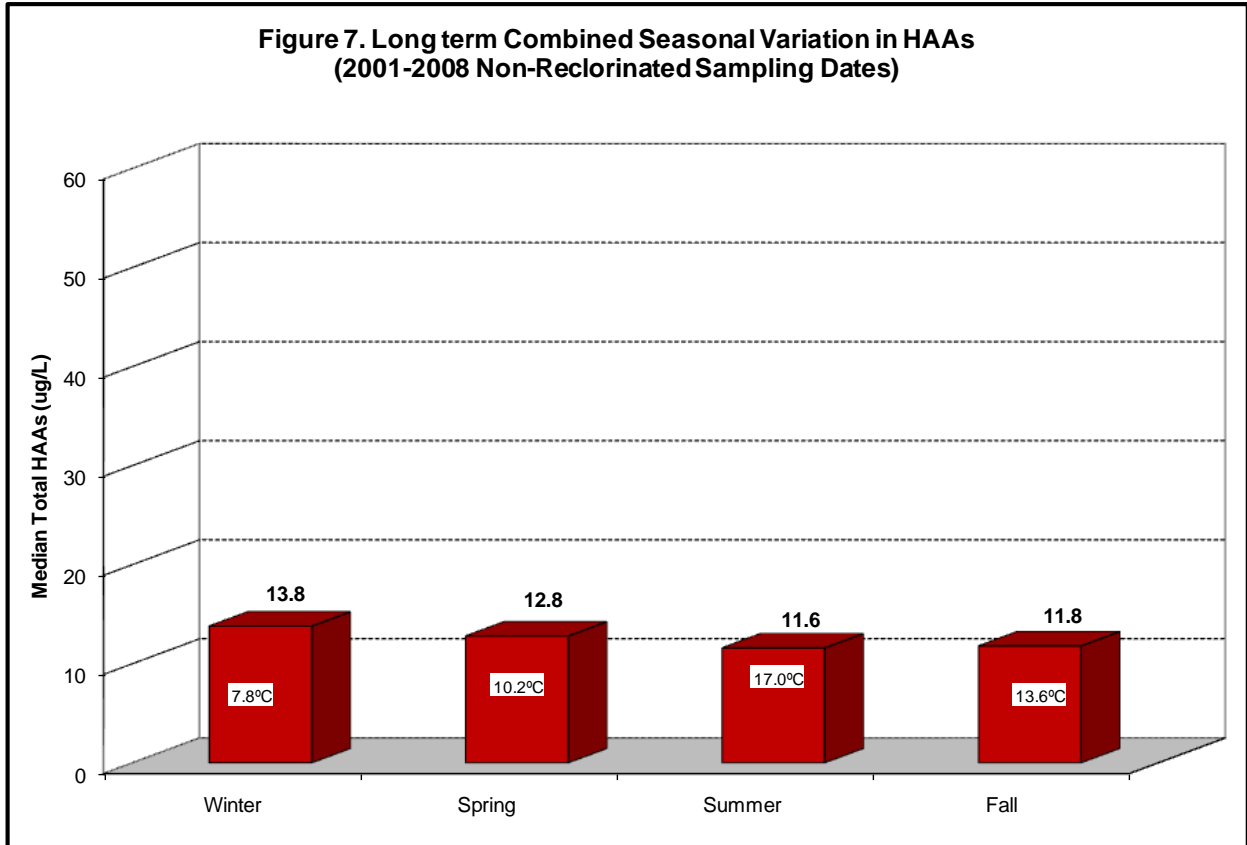


Figure 9. North Saanich Boas Rd, Haloacetic Acids, 2003-2008

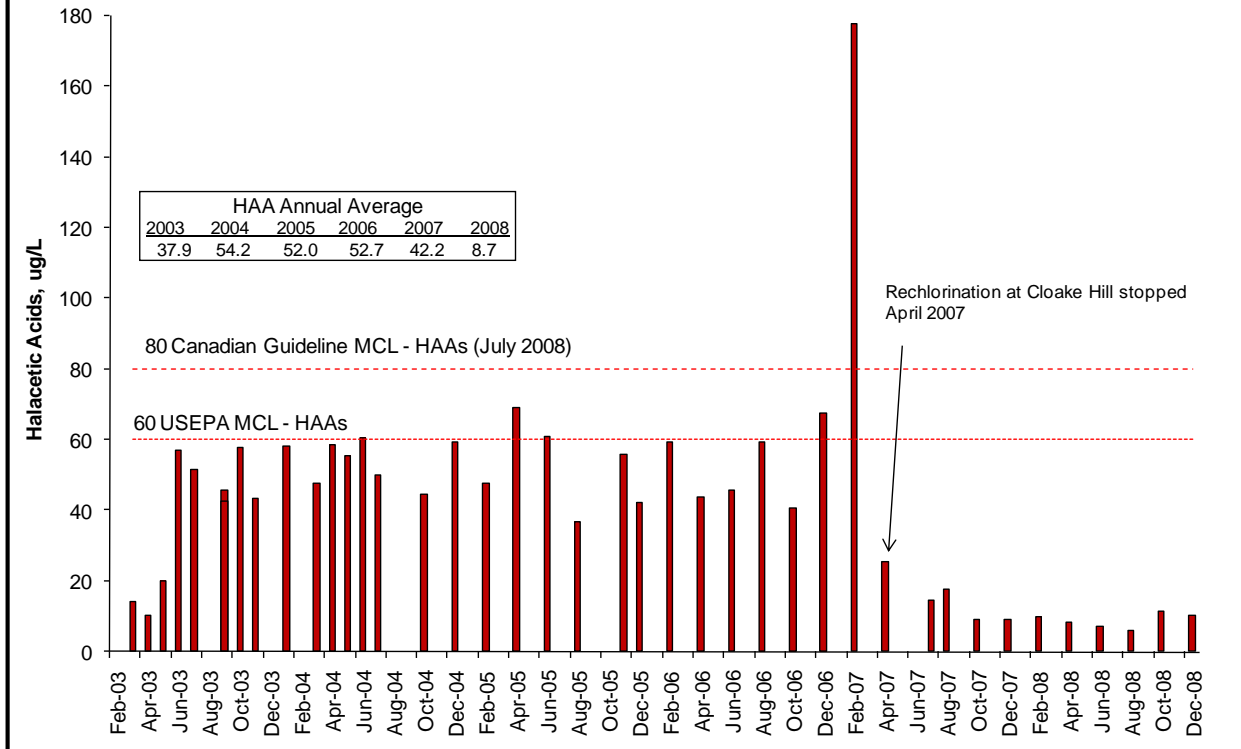


Figure 10. 2008 DCAA in Greater Victoria Distribution System

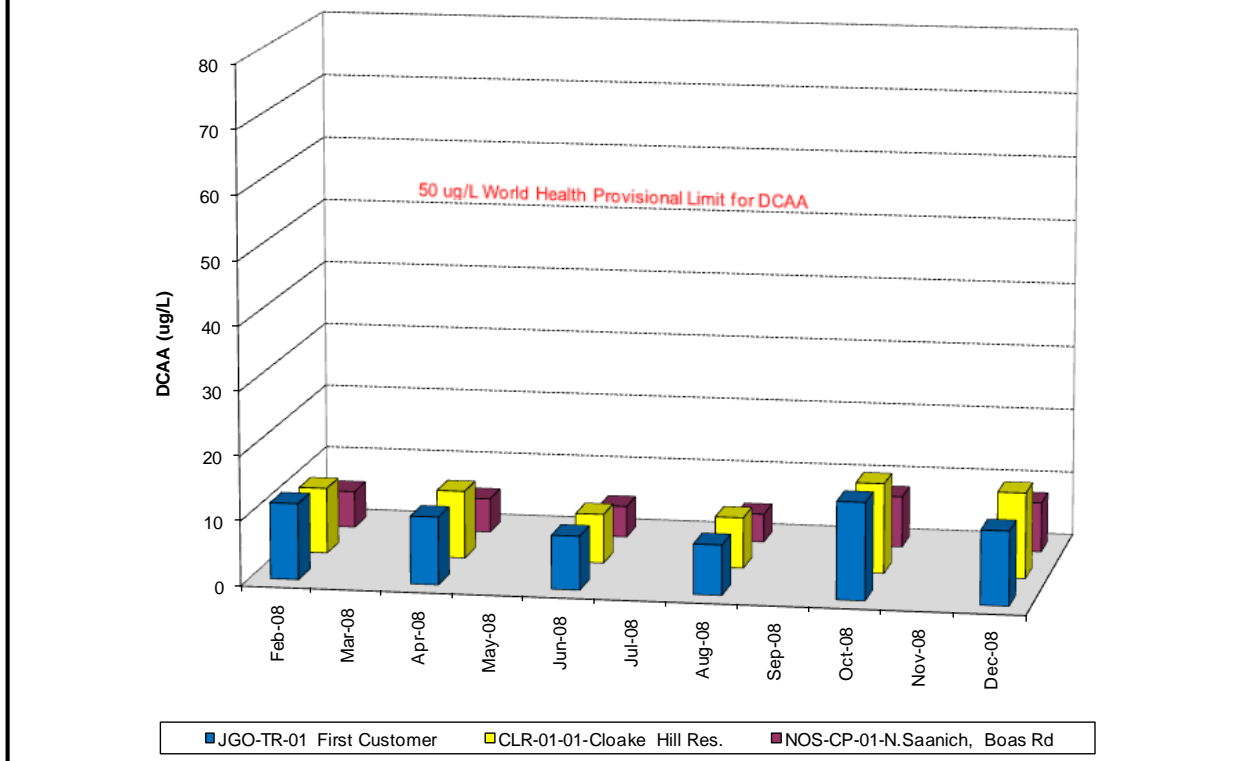


Figure 11. 2008 TCAA in Greater Victoria Distribution System

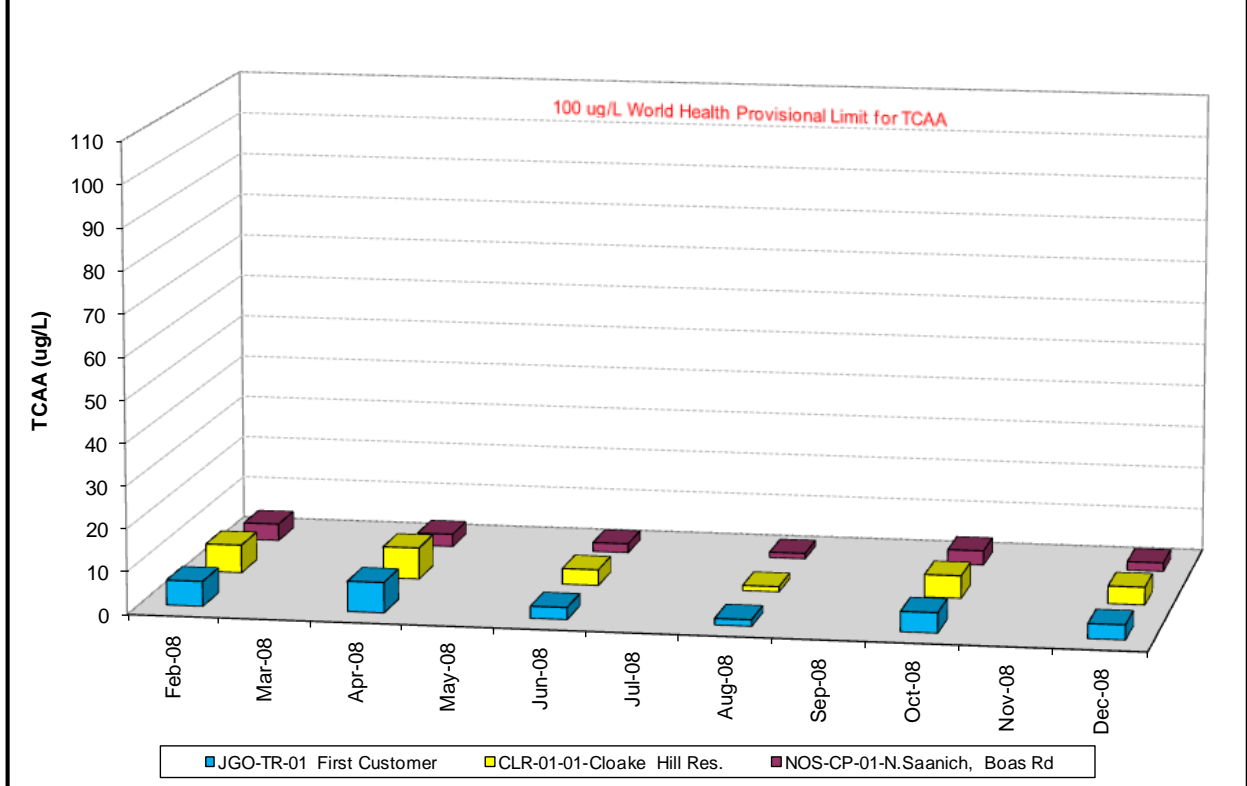
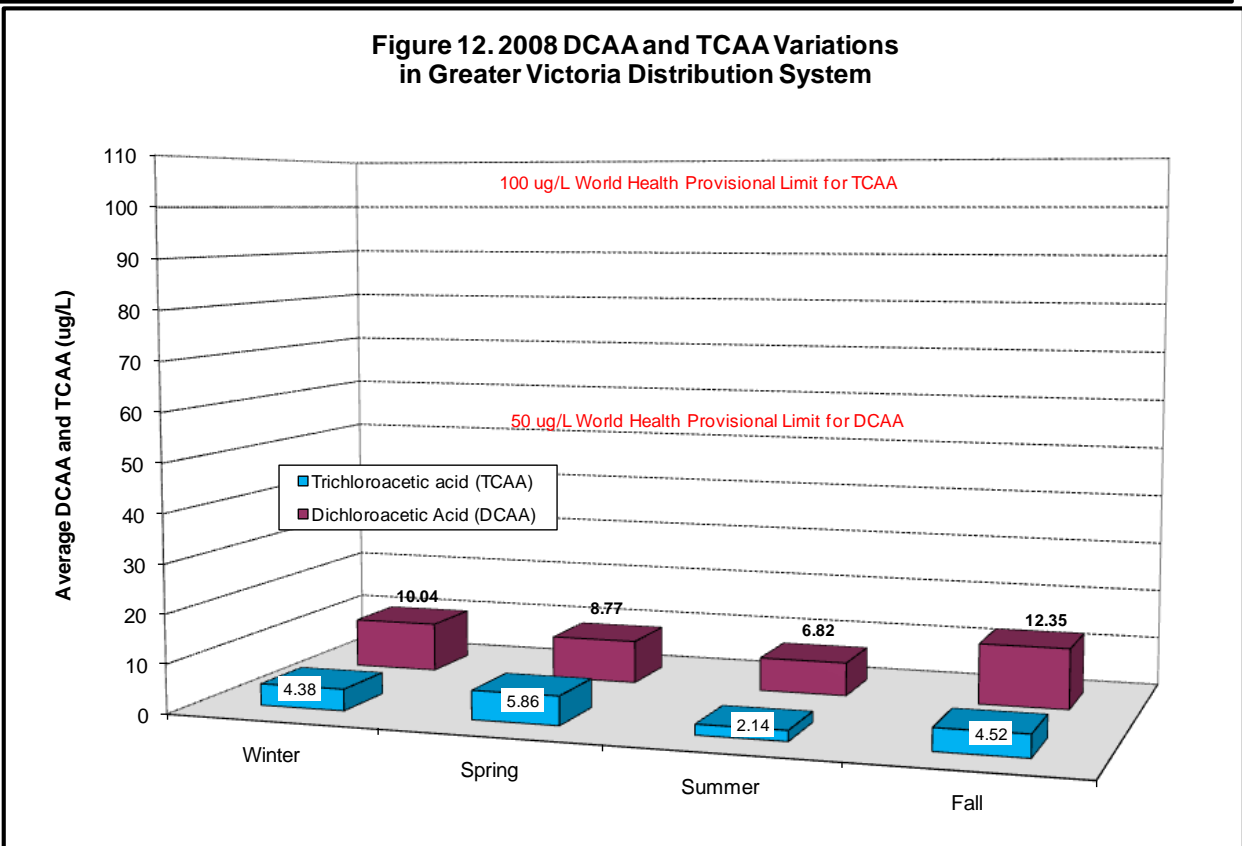


Figure 12. 2008 DCAA and TCAA Variations in Greater Victoria Distribution System



When combined, there is little evidence of seasonal variation in either DCAA or TCAA levels in 2008 although the summer values are slightly less than in other seasons for both DCAA and TCAA values (**Figure 12**). These results are similar to those found in 2004 through 2007.

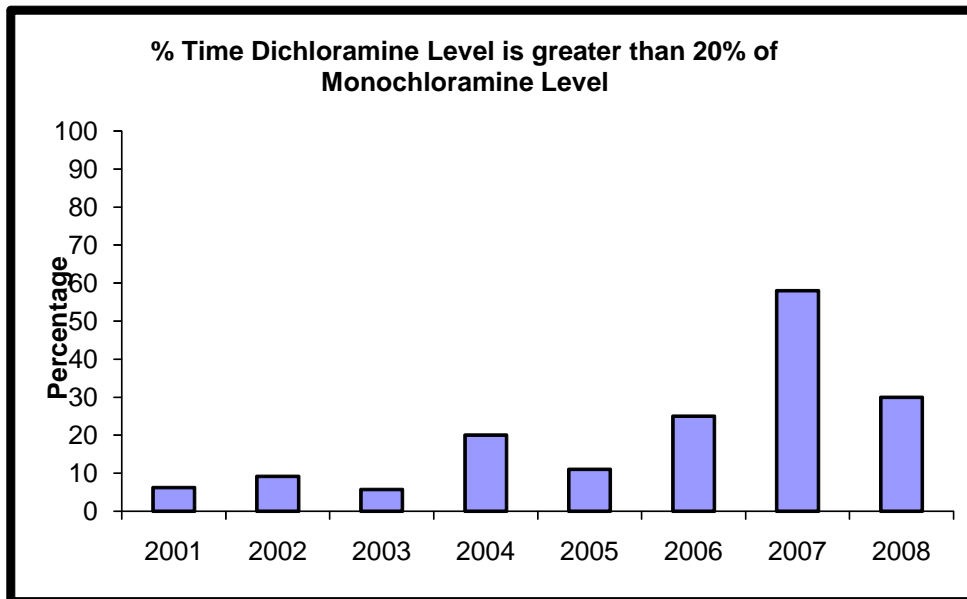
5.5. MONO AND DICHLORAMINES

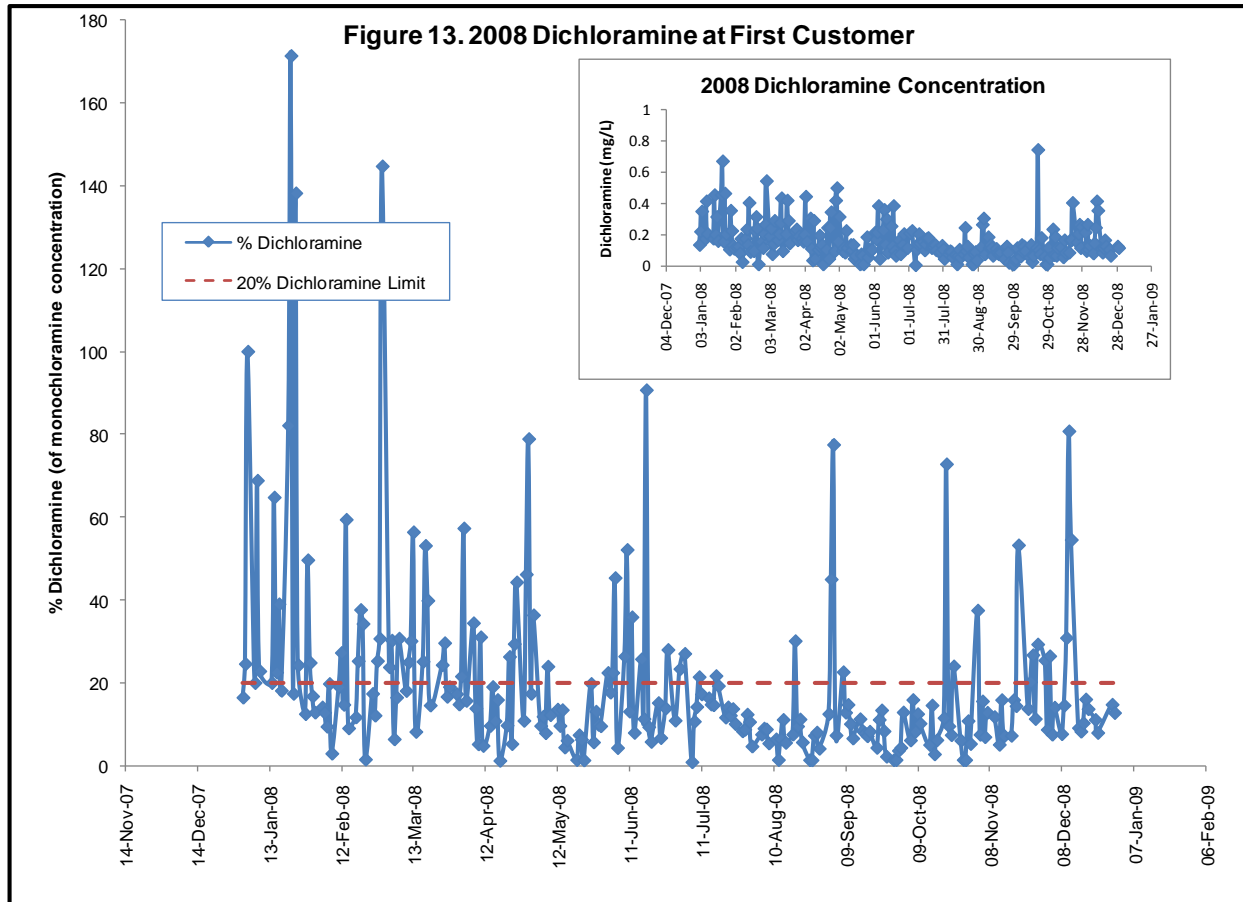
In general, chloramines are less effective biocides than free chlorine, ozone or chlorine dioxide for inactivation of pathogenic microorganisms. However, using chloramines as a disinfectant results in THM reductions of 40 to 80 percent relative to levels seen when free chlorine is used as the disinfectant. When using chloramines as a disinfectant, it is best to set conditions to favour the production of monochloramines over dichloramines due to the former's chemical stability, sustained disinfection capabilities and minimal taste and odour problems. Chlorine to ammonia weight ratios of 3:1 to 5:1 are considered best for forming the desired monochloramine species. Ratios above 5:1 favour more dichloramine and trichloramine formation which will negatively impact taste and odour by producing more chlorinous odours. Dichloramines and trichloramines have low flavour and odour thresholds when compared to monochloramine. The odour threshold for dichloramine is 0.15 mg/L as compared to 0.65 mg/L for monochloramine. It has been suggested that objectionable chlorinous odours are more closely related to the ratio of dichloramine to monochloramine than to their absolute concentrations. It is best to maintain dichloramine below 20 percent of the monochloramine concentration to prevent the more chlorinous odours. The optimum pH range is 7.5 to 9.0 for the formation of monochloramine and optimal temperatures should be in the range of 10 to 25 °C. At cold temperatures, free chlorine can persist for a short period prior to the formation of monochloramine.

In late October 2002, the CRD Water Services stopped using chloramines as a primary disinfectant and started using free chlorine as the primary disinfectant with chloramines as a secondary disinfectant. In 2008, CRD Water Services used a 5:1 target ratio of chlorine to ammonia. In 2008, the dichloramine levels were above the desired 20% of the monochloramine values 72 times (30%) during routine monitoring (**Figure 13 and Table 4**).

In previous years of monitoring for chloramines, the dichloramine 20% level was exceeded 6.2% of the time in 2001, 9.2% in 2002, 5.7% in 2003 (all years when monitoring occurred at a frequency of once weekly), 20.5% in 2004 (the first year that testing was done daily from October 2004 onwards), 11% in 2005, 25% in 2006, and 58% in 2007 (**Table 4**). It is evident that in recent years the target level for dichloramines is being missed more often.

Table 4. %Dichloramine and %Monochloramine at First Customer Sampling Location								
% Dichloramine (Target is less than 20% of Monochloramine Level)								
	2001	2002	2003	2004	2005	2006	2007	2008
Median	9.1%	8.0%	3.3%	11.8%	9.4%	12.9%	17.2%	13.4%
Minimum	0%	2.2%	1.1%	0%	0%	0.8%	1.8%	0.90%
Maximum	24%	91%	30%	125%	250%	117%	279%	171%
No. times sampled	48	54	53	78	232	238	247	244
Missed 20% Target	6.2%	9.2%	5.7%	20%	11%	25%	58%	30%
% Monochloramine (Target is at least 95% of Total chloramines)								
	2001	2002	2003	2004	2005	2006	2007	2008
Median	92.6%	92.6%	97.5%	89.4%	91.4%	88.6%	85.3%	88.2%
Minimum	52.2%	52.2%	77.1%	44.3%	28.6%	46.1%	26.4%	36.8%
Maximum	98.8%	98.8%	99.2%	100%	100%	99.2%	98.2%	99.1%
No. times sampled	48	54	53	78	232	238	247	244
Missed 95% Target	83%	76%	45%	85%	82%	85%	92%	89%





Recommendations

1. It is recommended that the rechlorination process at Deep Cove Pumpouse be stopped permanently. This will maintain the reduced level of disinfection by-products in that portion of the North Saanich distribution system and still retain satisfactory bacterial disinfection.
2. It is recommended that the sampling frequency remain bimonthly in 2008 as required by the USEPA Stage 2 DBP requirements.
3. It is recommended that the current process used to chloramine the water be reviewed and corrected to reduce dichloramine production.

TABLE 1. 2008 GREATER VICTORIA DISTRIBUTION SYSTEM TRIHALOMETHANES - All Locations									
			ANALYTICAL RESULTS (All units are in ug/L)					Field Measurements	
LOCATION DESCRIPTION		DATE	BDCM	BRFM	CHLF	DBCM	TTHM	Water Temperature	Total Chlorine Residual
LOCATION CODE	SAMPLING DESCRIPTION	SAMPLING DATE	MDL - 1.0	MDL - 0.6	MDL - 0.3	MDL - 0.2	MDL - 1.0	Degrees Celcius	mg/L
JGO-TR-01	PRV at 2818 Lakehurst Dr.	26-Feb-08	1.7	ND	13.7	ND	15.5	4.9	1.14
		16-Apr-08	1.6	ND	12.9	ND	14.5	6.5	1.29
		17-Jun-08	2.1	ND	14.8	ND	16.9	11.6	1.23
		13-Aug-08	2.6	ND	19.4	ND	21.9	15.8	1.23
		29-Oct-08	1.6	ND	13.7	ND	15.3	11.0	1.18
		17-Dec-08	0.9	ND	13.4	ND	14.3	5.3	1.14
CLR-01-01 *	Cloake Hill Reservoir Subject to rechlorination on specified date	26-Feb-08	2.3	ND	16.4	ND	18.7	6.3	0.63
		16-Apr-08	2.3	ND	14.3	ND	16.7	7.9	0.68
		17-Jun-08	2.6	ND	16.2	ND	18.8	15.0	0.64
		13-Aug-08	3.5	ND	22.9	ND	26.4	16.7	0.68
		29-Oct-08	1.2	ND	6.6	ND	7.8	13.0	0.44
		17-Dec-08	1.6	ND	14.6	0.2	16.5	8.5	0.51
NOS-CP-01 *	Lot N. of 10943 Boas Rd. Subject to rechlorination on specified date	26-Feb-08	2.3	ND	13.3	ND	15.5	7.5	0.13
		16-Apr-08	2.2	ND	12.8	ND	15.0	9.3	0.22
		17-Jun-08	2.6	ND	14.8	ND	17.4	13.0	0.17
		13-Aug-08	2.1	ND	11.8	ND	13.9	16.8	0.27
		29-Oct-08	2.4	ND	13.3	2.2	17.9	12.6	0.06
		17-Dec-08	1.7	ND	14.4	0.2	16.4	9.7	0.09
Average:			2.1		14.4	Average:	16.6		
Canadian Guideline: (Maximum Concentration)			16	Canadian Guideline: (Maximum Concentration)			100		

ND Not detected

MDL Method Detection Limit

TABLE 3. 2008 GREATER VICTORIA DISTRIBUTION SYSTEM HALOACETIC ACIDS

ANALYTICAL RESULTS (All units are in ug/L except as otherwise noted)

LOCATION DESCRIPTION		DATE	HAA5 Haloacetic Acids (5 in total)	HAA9 Haloacetic Acids (9 in total)	MCAA Monochloroacetic Acid	DCAA Dichloroacetic Acid	TCAA Trichloroacetic Acid	MBAA Monobromoacetic Acid	DBAA Dibromoacetic Acid
LOCATION CODE	SAMPLING DESCRIPTION	SAMPLING DATE	MDL - 2.0	MDL - 0.5	MDL - 0.5	MDL - 0.5	MDL - 0.5	MDL - 0.2	MDL - 0.1
JGO-TR-01	PRV at 2818 Lakehurst Dr.	26-Feb-08	17.7	18.2	ND	11.8	5.86	ND	ND
		16-Apr-08	17.6	18.3	ND	10.5	7.15	ND	ND
		17-Jun-08	11.2	11.6	ND	8.33	2.83	ND	ND
		13-Aug-08	9.32	10.0	ND	7.78	1.54	ND	ND
		29-Oct-08	19.8	20.5	ND	15.1	4.75	ND	ND
		17-Dec-08	15.3	15.9	ND	11.5	3.52	ND	ND
CLR-01-01 *	Cloake Hill Reservoir Subject to rechlorination on specified date	26-Feb-08	16.8	17.5	ND	10.2	6.62	ND	ND
		16-Apr-08	17.9	18.4	ND	10.5	7.44	ND	ND
		17-Jun-08	11.4	11.8	ND	7.65	3.74	ND	ND
		13-Aug-08	9.13	10.2	ND	7.89	1.24	ND	ND
		29-Oct-08	19.4	20.1	ND	14.0	5.36	ND	ND
		17-Dec-08	17.7	18.4	ND	13.3	4.18	ND	0.17
NOS-CP-01 *	Lot N. of 10943 Boas Rd. Subject to rechlorination on specified date	26-Feb-08	9.72	9.72	ND	5.70	4.02	ND	ND
		16-Apr-08	8.31	8.31	ND	5.31	3.00	ND	ND
		17-Jun-08	7.02	7.02	ND	4.86	2.16	ND	ND
		13-Aug-08	5.73	5.73	ND	4.40	1.33	ND	ND
		29-Oct-08	11.4	11.4	ND	7.95	3.45	ND	ND
		17-Dec-08	10.0	10.0	ND	7.74	2.06	ND	0.22
Average:			13.1	13.5					
Canadian Guideline (Maximum Acceptable Concentration, MAC)			80						

HAA5: Monochloroacetic Acid
Dichloroacetic Acid
Trichloroacetic Acid
Monobromoacetic Acid
Dibromoacetic Acid

HAA9: HAA5 and: Bromochloroacetic Acid
Bromodichloroacetic Acid
Chlorodibromoacetic Acid
Tribromoacetic Acid