Halifax Harbour
Water Quality Monitoring Program
Quarterly Report #11
(December 20, 2006 to March 13, 2007**)**

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PREFACE

The Halifax Harbour Water Quality Monitoring Project (HHWQMP) is an ongoing project, part of the Halifax Harbour Solutions Project (HRM and JWEL, 2002). It commenced in June 2004, before any of the proposed sewage treatment changes were put into effect, and is slated to continue for a year following the commission of the final plant (June 2009). The project is based on water quality surveys that include over 30 sites distributed from the Bedford Basin to the Outer Halifax Harbour. Water samples taken at 1 m and 10 m depths are analyzed for a range of parameters. In addition, continuous profiles of basic hydrographic properties (salinity, temperature and density), dissolved oxygen and fluorescence are collected. From June 2004 to June 2006 the surveys were conducted weekly and from July 2006 onward, slightly modified surveys are conducted biweekly. The sample and profile data are presented in survey reports (weekly or biweekly, as appropriate) along with ancillary data including water level, wind, rainfall and other parameters. The reports are generated as inserts into a binder (JWEL and COA, 2004). Electronic copies of the reports and data files are also delivered to the client. A detailed description of the program is contained in the introduction section of the report binder.

The weekly/biweekly data sets are reviewed on a quarterly basis (13 weeks). The main objective of the quarterly reports is to summarize and evaluate the weekly/biweekly data sets in terms of water quality objectives and concerns. The quarterly report also provides an opportunity to review the effectiveness of various aspects of the program and recommend changes that will improve the program. Project reports and data are available on the Halifax Regional Municipality (HRM) website:
http://www.halifax.ca/harboursol/waterqualitydata.html

The HHWQMP program involves an extensive network of personnel including boat operators, field technicians, laboratory technicians and their associated equipment and procedures. The study team also includes managers, oceanographers and water quality experts. The routines, procedures, report and data archive formats are evolving as the project proceeds. These are documented in the project report binder.
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1 Introduction

This quarterly report is a summary of Halifax Harbour Water Quality Monitoring Project (HHWQMP) data collected from 20 December 2006 to 13 March 2007 (surveys 119 to 125). The data for the period are discussed in terms of compliance/exceedance of applicable water quality guidelines (Halifax Harbour Task Force, 1990), and how they affect recommendations for program modification. An emphasis in this report is on the continued assessment of the efficacy of the sampling program and of the potential introduction of systematic sampling bias in the data. This is a necessary step in the more detailed statistical analysis of the data that can occur subsequently. This report discusses just the eleventh quarter. Every fourth quarterly report includes an annual summary of data and trends over the previous four quarters. In the interest of making each quarterly report useful as stand alone documents, there is a significant amount of repetition of background information among the quarterly reports.

2 Reporting

The basic report format is discussed in detail in the introduction of the project report binder and in Quarterly Report 1 (QR1, JWL and COA, 2004). Slight modifications and enhancements to the reports continue to be made as experience dictates. There have been no changes this quarter.

In earlier quarterly reports (up to Quarterly Report 8), the data from the center of Bedford Basin (Station G2) was compared with data collected at a nearby site by the Bedford Basin Phytoplankton Monitoring Program (BBPMP), a project of the Department of Fisheries and Oceans at Bedford Institute of Oceanography. The BBPMP discontinued the summary time series contour plots that were used for comparison purposes. The data is still available in the form of individual profile plots and time series plots at selected depths. Selected points from the BBPMP Dissolved Oxygen (DO) profiles are now compared with the HHWQMP DO for purposes of ground truthing. The time series contour plots of the HHWQMP data in the centre of the Basin are instructive in the description of longer term variability in the harbour and are continued in the annual summary discussions in every fourth quarterly report.

From time to time, errors are discovered in the reports after they have been issued. An Errata/Changes section is included in the Introduction section of the report binder and is updated on a quarterly basis. In addition to errors the Errata/Changes section documents the changes in the sampling program and reporting.

3 Sampling Program

Survey sampling as of July 2006 is done on a biweekly basis. Sampling is conducted from one of several vessels, operated by Connors Diving Services Ltd., based at the Armdale Yacht Club. The details of the sampling program are discussed in the introduction section of the project report binder and Quarterly Report 1. The locations of the 34 regular sampling sites are included in Figure 1. These sites are a combination of historically occupied sites (Jordan, 1972), some project specific sites and identified recreational (yacht club/beach) sites. Sampling involves the collection of continuous profile data and discrete water samples at 1 and 10 m water depth. The level of analysis varies from site to site as depicted in Figure 1: CTD only (CTD only stations); CTD and coliform bacteria (Coliform stations); or CTD, Bacteria, and additional contaminant analysis (Chemistry stations). In addition to the regular sites, Figure 1 includes a sample site in Dartmouth Cove (DC), established in response to public concern. At this site, a 1 m water sample and profile data are obtained. The water sample is analyzed for the full suite of parameters. This site is sampled once a month during the summer. The "supplemental sample" procedure that has been established allows water samples to be taken at additional sites, based on visual observations, at the discretion of the field team.

Sampling protocol/sample handling has been dictated by experience and specific lab directions. CTD casts are performed according to the manufacturer's recommendation and data analysis follows standard procedures. These protocols are documented in the project binder with weekly and quarterly reports.

3.1 Program Changes

There have been no program changes this quarter. A summary of the sampling and analysis schedules and relevant established criteria in place at the end of eleventh quarter (13 Mar 07) are in Table 1. This table indicates that the carbonaceous biochemical oxygen demand ($CBOD_5$) and total oil and grease (TOG) analyses, discontinued from regular sampling due to lack detection, are now performed only for "supplemental samples".

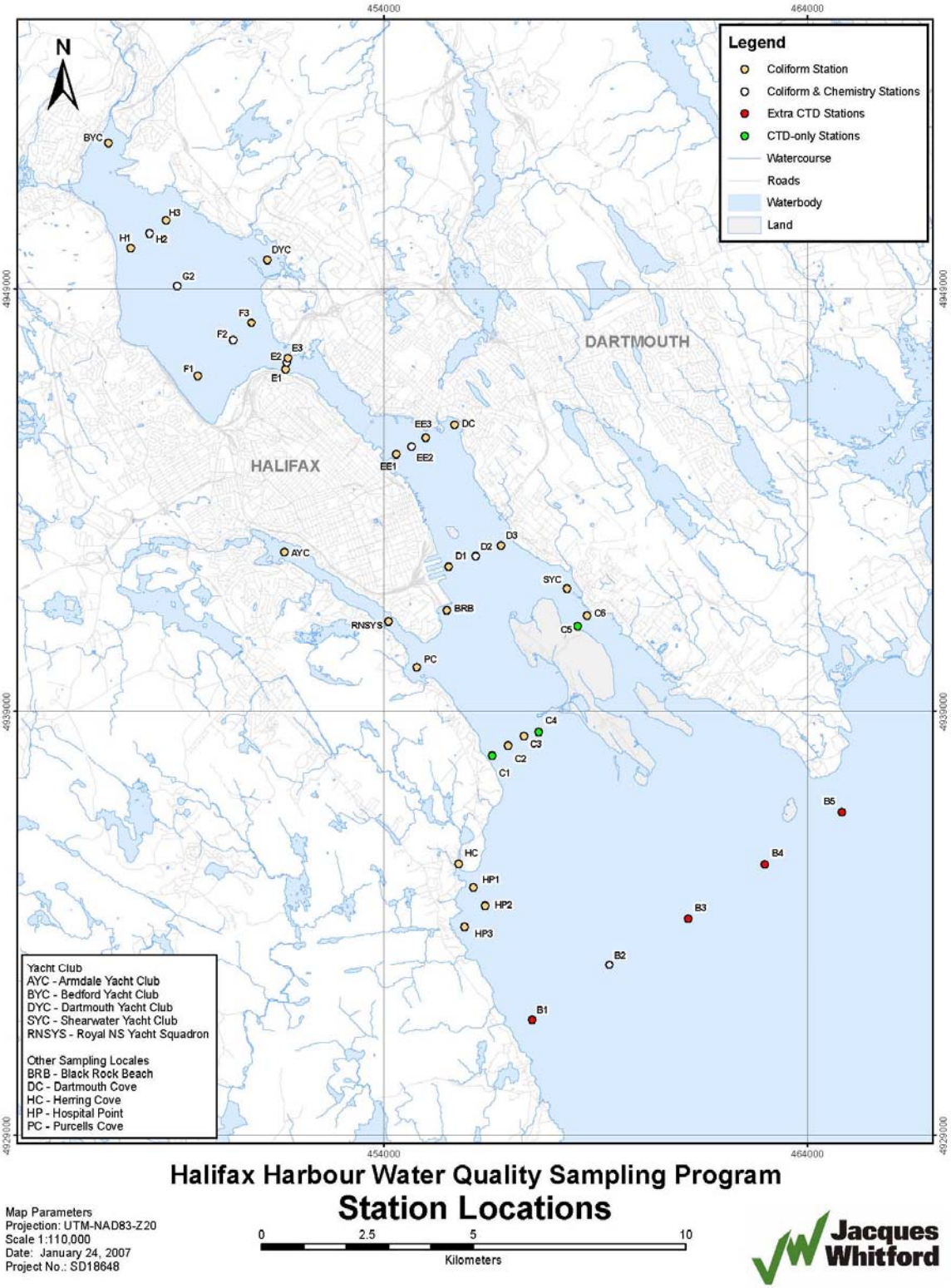

Figure 1. Halifax Inlet sample locations.

Table 1. Summary of measured parameters as of 13 March 2007.

	RDL		Harbour Task Force Guideline	Water Use Category	Sampling Stations (refer to Fig. 1)	Sampling frequency
	value	units				
Profile Data					All	biweekly
Salinity	n/a	PSU	n/a	n/a		
Temperature	n/a	C°	n/a	n/a		
Chlorophyll *a*	n/a	ug/L	n/a	n/a		
			8	SA		
Dissolved Oxygen	n/a	mg/L	7	SB		
			6	SC		
Secchi depth	n/a	m	n/a	n/a		
Bacteria Samples					Bacteria + Chemical	biweekly
Fecal Coliform	1	cfu/ 100mL	14	SA		
			200	SB		
			none	SC		
Chemical Samples						
CBOD	5	mg/L	none		Supplemental sites	unscheduled
Ammonia Nitrogen	0.05	mg/L	none		Chemical sites	bi-weekly
			<10%			
TSS	0.5	mg/L	background	all	Chemical sites	bi-weekly
Total Oil and Grease	5	mg/L	10	all	Supplemental sites	unscheduled
Metal scan						bi-weekly
Cadmium	0.1	ug/L	9.3	all	Chemical sites	
Copper	0.1	ug/L	2.9	all	Chemical sites	
Lead	0.1	ug/L	5.6	all	Chemical sites	
Manganese	1	ug/L	100.0	all	Chemical sites	
Nickel	0.5	ug/L	8.3	all	Chemical sites	
Zinc	1	ug/L	86.0	all	Chemical sites	
Mercury	0.01	ug/L	0.025	all	Chemical sites	
Cobalt	0.1	ug/L	none		Chemical sites	
Iron	1	ug/L	none		Chemical sites	

3.2 Supplemental Samples

Based on recommendations from Quarterly Report 2, a supplemental sample protocol has been instituted to take opportunistic samples of visible water quality features in the Harbour, or to document unusual discharge conditions (e.g. bypass etc). These samples are acquired on a discretionary and exploratory basis when an interesting feature, such as a visible front, plume, or patch of visibly deteriorated water quality is encountered. It is anticipated that these samples will have lower water quality than most normal samples. As such, the samples are processed for the full range of parameters specified at the beginning of the program, including parameters that have been eliminated from normal sampling due to lack of detection. During this quarter there was a supplemental sample taken in Fairview Cove for survey 124 (28 Feb 07). There were also some additional individual samples taken for $CBOD_5$ at sites F1 and F2 in surveys 119 (20 Dec 06) and 120 (3 Jan 07).

3.3 Sampling Order

Sampling generally occurs on Tuesday, with Wednesday and Thursday as contingency days. Every survey the sampling order is varied to minimize biasing the collected data with respect to known diurnal variations in sewage load and sunlight. A variable circuit is used that results in 'quasi' random sampling, subject to certain operational constraints. This procedure is discussed in Quarterly Report 1. Wind, waves and visibility can limit operations in the Outer Harbour. Each week, a primary and an alternate sampling route are provided to the field team. If the primary route has the Outer Harbour sampled early in the day, the alternate route will have it sampled late in the program. The decision on which route to take is made between the field team and the boat operator considering the weather forecast for the day. The sampling order for each survey in the eleventh quarter is presented in Table 2.

Also, Table 2 lists the missed stations and additional samples (described above) for each survey. Overall, during this quarter the DYC site was missed three times due to ice. Much of the quarter the BYC site was relocated due to ice. The sample was taken at the ice edge as close to the BYC site as possible. The actual site coordinates are documented in the individual survey reports and data files.

3.4 Data Return

In addition to the missed sites detailed above, there were other sporadic data losses, generally associated with quality control issues in the data that were discovered in data processing. These are discussed in the individual survey reports. All factors considered, the overall data return for the quarter is summarized in Table 3.

3.5 Sampling Bias

There are two issues regarding potential bias in the dataset. The first is the relative bias between sites, that is, whether the statistics from one site can be compared with those from another site. The second is the absolute bias with respect to the environmental forcing, or how well the dataset represents typical conditions in the Harbour. Our sampling has operational constraints which introduce a morning/early afternoon bias to the entire dataset. It is impractical to address this fully, except to document it. The following section is a first look at potential bias with respect to time of day, water level, and rainfall during the eleventh quarter.

Table 2. Sample collection order (green sites are CTD only).

Date	20 Dec 06	3 Jan 07	18 Jan 07	30 Jan 07	14 Feb 07	28 Feb 07	13 Mar 07
Survey	119	120	121	122	123	124	125
1	HC	PC	PC	AYC	HC	AYC	EE1
2	HP3	C2	C2	RNSYS	HP1	RNSYS	D1
3	HP2	C1	C1	PC	HP2	BRB	BRB
4	HP1	HC	HC	C1	HP3	D1	C2
5	B2	HP1	HP1	C2	B2	EE1	C1
6	C1	HP2	HP2	HC	C1	E1	HC
7	C2	HP3	HP3	HP1	C2	E3	HP1
8	C3	B2	B2	HP2	C3	E2	HP2
9	C4	C3	C3	HP3	C4	F1	HP3
10	SYC	C4	C4	B2	C5	H1	B2
11	C5	C5	C5	C3	C6	BYC	C3
12	C6	C6	C6	C4	SYC	H3	C4
13	D3	SYC	SYC	C5	D3	H2	C5
14	EE3	D3	D3	C6	D2	G2	C6
15	F3	EE3	D2	SYC	EE2	DYC	SYC
16	DYC	F3	EE3	D3	EE3	F3	D3
17	H3	DYC	EE2	D2	E3	F2	D2
18	BYC	H3	E1	EE3	E1	EE3	EE3
19	H2	BYC	E3	EE2	E2	EE2	EE2
20	H1	H1	E2	E3	F2	D3	F3
21	G2	H2	F2	E1	F3	D2	F2
22	F1	G2	F3	E2	H3	SYC	H3
23	F2	F1	DYC	F1	H2	C6	H2
24	E2	F2	H3	G2	BYC	C5	BYC
25	E3	E1	H2	H1	H1	C4	H1
26	E1	E2	BYC	H2	G2	C3	G2
27	EE1	E3	H1	BYC	F1	B2	F1
28	EE2	EE1	G2	H3	EE1	HP3	E1
29	D2	EE2	F1	F3	D1	HP2	E3
30	D1	D2	EE1	F2	BRB	HP1	E2
31	BRB	D1	D1	EE1	PC	HC	PC
32	PC	BRB	BRB	D1	RNSYS	C1	RNSYS
33	RNSYS	RNSYS	RNSYS	BRB	AYC	C2	AYC
34	AYC	AYC	AYC			PC	
No data				DYC	DYC		DYC
Supplemental	F1,F2 ($CBOD_5$)	F1,F2($CBOD_5$)				Fairview Cove	

Table 3. Quarter eleven data return.

Chemical	**Target**	**Achieved**	**Percent Return**
7 sites			
NH3	98	98	
TSS	98	98	
Metal Suite	98	98	
Mercury	98	98	
Total	**392**	**392**	**100%**

Bacteria	**Target**	**Achieved**	
28 sites			
F Coliform	434	428	
Total	**434**	**428**	**99%**

Profiles	**Target**	**Achieved**	
31 sites			
C-T	238	233	
Dissolved Oxygen	238	230	
Chlorophyll	238	233	
Total	**714**	**696**	**97%**
All data records	**1540**	**1516**	**98%**

3.5.1 Time of Day

Sewage flows have significant regular diurnal variations, which can affect the water quality in the Harbour on short timescales. In residential areas there are generally two flow peaks a day, the largest occurring in the morning, and the second in the evening. In systems with relatively short flow distances these generally occur around 0800 – 0900 and 2100. In commercial areas the flows are much more uniform during the day and low at night. In addition to variations in sewage load, the most obvious diurnal variation is in sunlight. Sunlight is perhaps the major contributor to the die off of bacteria, and can have effects on other parameters, particularly chlorophyll (fluorescence) and dissolved oxygen. The short term variation in sewage load is primarily an issue in the Inner Harbour, relatively close to the outfalls, however sunlight affects the entire Harbour. In Halifax there is also a significant diurnal tidal component affecting water levels. This is considered in the subsequent section.

Figure 2 shows the sampling time at each site since the start of the program in June 2004. The data from the eleventh quarter are shown in red. In this figure the sample sites are generally sorted from north to south. There are a few patterns that emerge that have been documented previously. The stations at the north end of Bedford Basin have a smaller

range of sampling times. This is because logistics dictates that the surveys never start or end in the Basin. In general, the range of sampling times increases with distance south, a function of travel time from the Armdale Yacht club in the Northwest Arm. Even if a site is sampled first, it still takes time to travel there. Given that sampling begins at the same time every week, these effects are unavoidable. Given the necessary operational constraints, the sampling scheme this quarter has resulted in a reasonably uniform distribution in the Inner Harbour (Section D through Section E), where diurnal fluctuations would likely be greatest, due to proximity to outfalls. The Northwest Arm has a strong early morning/late afternoon bias. Because of travel time constraints, each survey either begins or ends in the Arm. In this quarter the sampling was balanced between morning and afternoon. The Outer Harbour also shows a morning and afternoon bias for similar reasons discussed in Section 3.3. This quarter weather issues skewed the sampling toward the morning, with the Outer Harbour being sampled in the morning in six of the seven surveys.

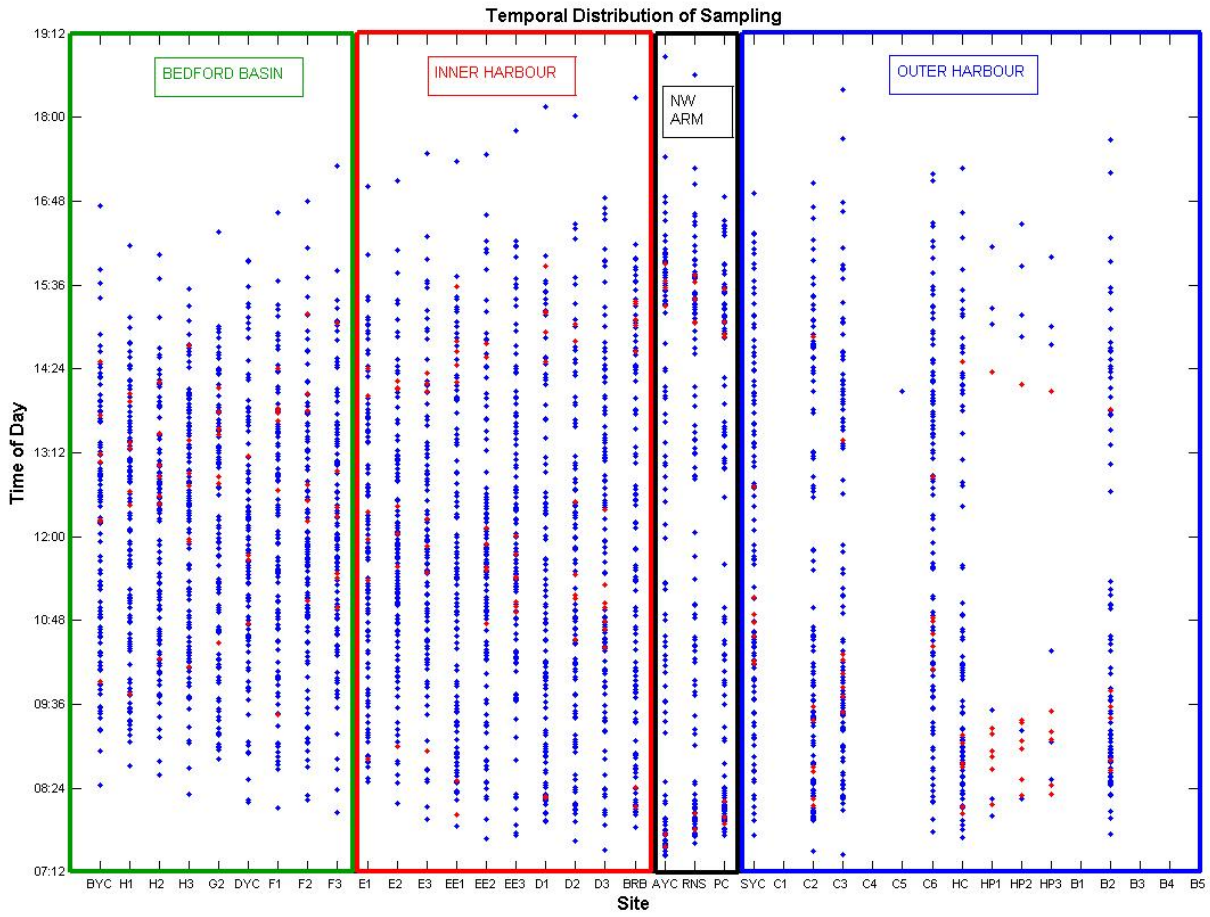

Figure 2. Temporal sampling distribution by site over entire program. Red markers denote points from 20 December 2006 to 13 March 2007.

3.5.2 Water Levels

The water level at the time of sampling can affect sampling results. The two most obvious considerations are whether a particular sample was taken upstream or downstream (based on flood/ebb direction) from the nearest outfall, and the variation in initial dilution, caused by variations in submergence depth, from shallow shoreline outfalls. These are both issues primarily in the Inner Harbour.

Water level variations in the Harbour are caused by the tides and meteorological forcing. The meteorologically-induced changes are mostly of longer period and, except in large storms, are smaller in magnitude than the tides. Because of their longer duration their effect on Harbour flushing can be significant and their impact on water quality may warrant investigation in the future. Note that the tidal currents in the Harbour are, for the most part, not that strong and may be over ridden by local/regional meteorological effects (Hurlbut et al., 1990). This means, for example, that the surface current may not always be going out on a falling tide. However, the occurrence of surges is relatively random and the possibility of inducing a systematic sampling bias is small compared with that of the very regular higher frequency tides. The tides in Halifax Harbour are classified as semidiurnal, meaning that there are two high and two low tides in a day.

There is also a potential bias introduced by regular weekly/biweekly sampling. Sampling that occurs on the same day every second week could occur at the same point in the fortnightly tidal cycle (i.e. the same tidal range). An initial assessment of the tidal signal in Halifax Harbour indicates that the fortnightly cycle is sufficiently irregular (i.e. the tides are sufficiently "mixed"), that this problem is unlikely, particularly given the variation in sampling day (Tuesday or Wednesday, sometimes Thursday). This issue will be monitored and may be revisited more rigorously at a later time.

The probability distribution of water level (above chart datum) as derived from the tide gauge at the Naval Dockyard in Halifax (CHS station 490) for the period December 2006 to March 2007 is shown in Figure 3. The overall water level distribution is slightly bi-modal. The central minimum roughly corresponds to the mean tide level. However the distribution is actually relatively flat, between 0.6 m and 1.6 m. In an ideal situation each site would be sampled in a distribution similar to the overall baseline distribution. The red line connecting the bars is the baseline, recreated in each panel of Figure 4, against which water levels during sampling are compared. With bi-weekly sampling, there are fewer surveys in a quarter and the shape of the sampling distribution will not be as well defined as with the previous weekly sampling.

Figure 4 shows the distribution of water levels at each site at the time of sampling (blue bars) compared to the overall water level distribution for the quarter, as represented by the red line recreated from Figure 3. The sites are arranged roughly north to south. This shows that for this quarter, in the Inner Harbour and Basin (Section D and north) there was a bias towards sampling lower water levels. South of this, and in the Northwest Arm, the distribution is more uniform, and the distribution is reasonably sampled. If more detailed analysis is performed, particularly in the Inner Harbour where water

level/tidal phase is more important, the analysis may have to include the tidal phase explicitly.

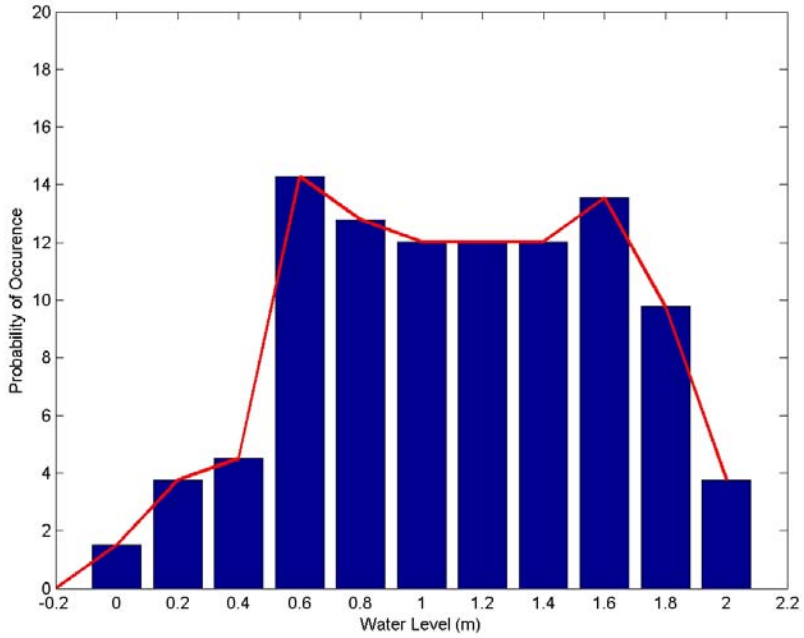

Figure 3. Probability distribution of water levels in Halifax, December 2006 to March 2007.

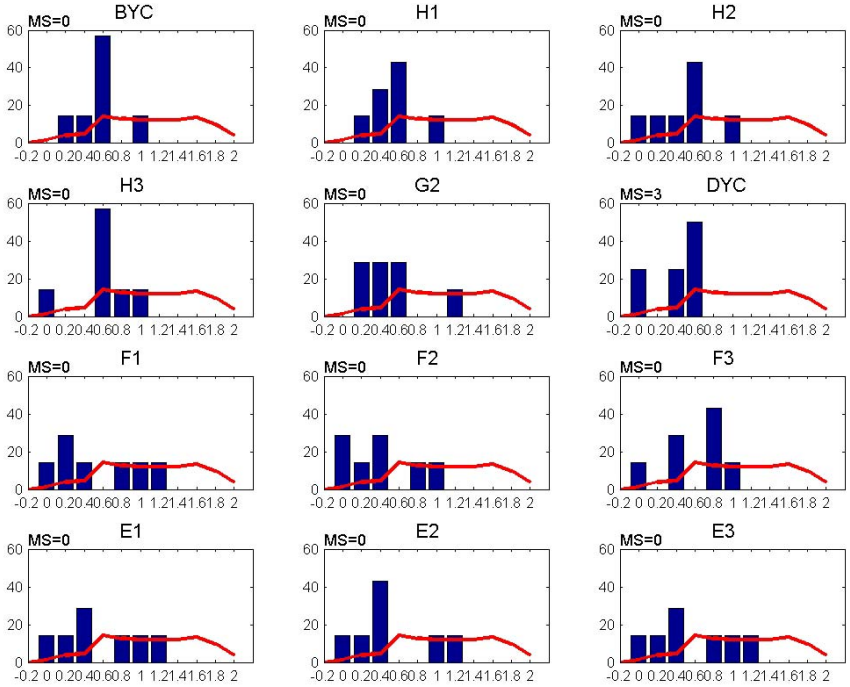

Figure 4a. Water level distribution at each site during sampling 20 December 2006 to 13 March 2007. Note: MS = Missed samples.

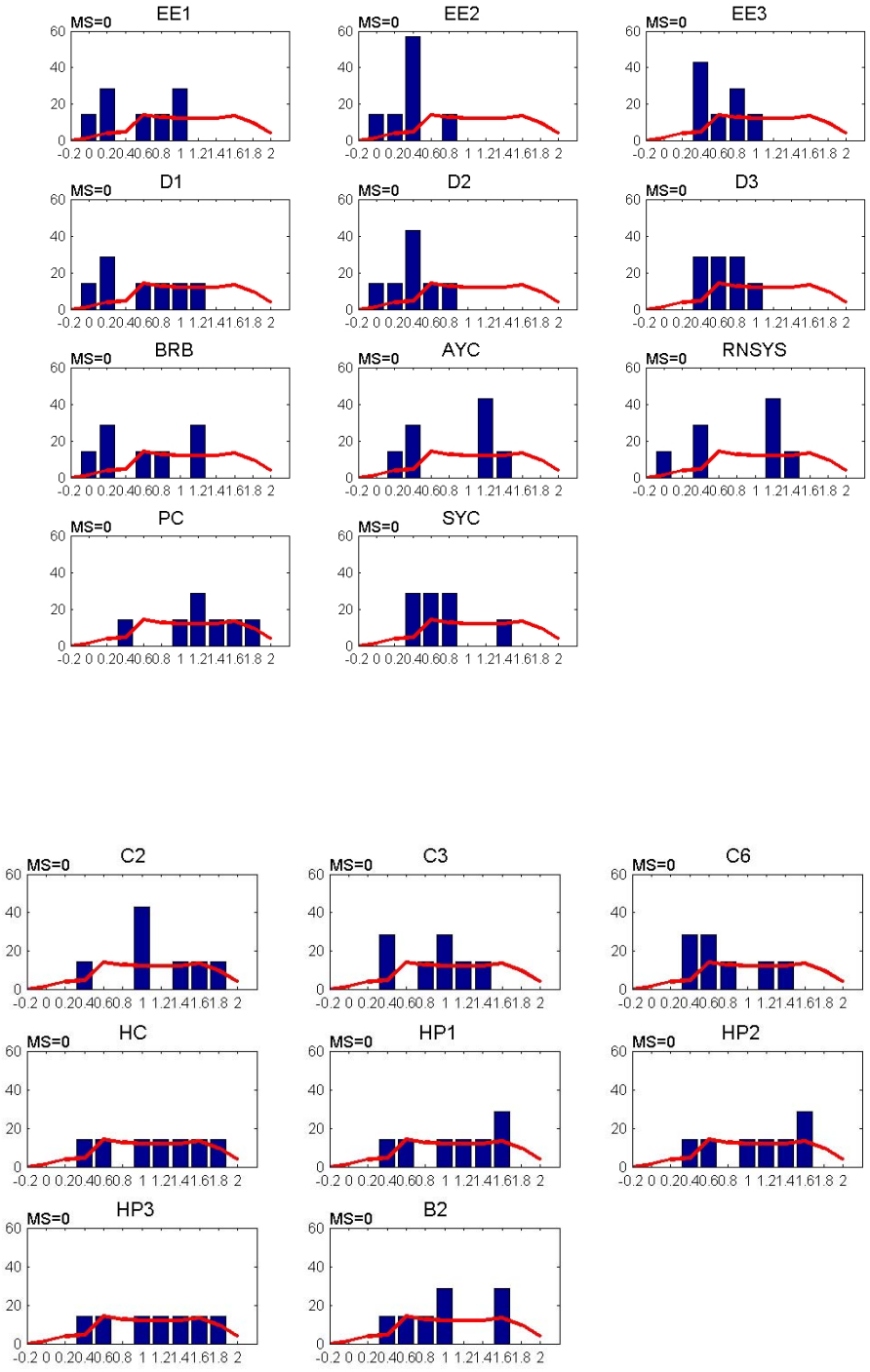

Figure 4b. Water level distribution at each site during sampling 20 December 2006 to 13 March 2007. Note: MS = Missed samples.

3.5.3 Precipitation

Rainfall affects both the sewage loads and the dynamics of the Harbour. In a combined sewer system, like in Halifax, increased flow due to a rainfall event can mobilize material that has collected in the sewer pipes in low flow conditions resulting in quite high loads. Additionally, in response to the increased fresh water input, the harbour can become more stratified, enhancing estuarine circulation. The combination of increased flow and stratification can have a significant effect on the near field behaviour of the plumes from the outfalls. These effects lag the rainfall and persist for a period of time after the rain stops. The duration of the impact, of course, depends on the magnitude of the rain event and the condition of the watershed. For purposes of discussion we have, somewhat arbitrarily, selected a three day (72 hour) precipitation window for our analysis. The red line in Figure 5 depicts the probability distribution of precipitation integrated over the current and previous two days for this quarter (December 20 to March 13, 2007). The blue bars on this plot represent a similar analysis performed for sampling days only. The plot indicates that given the limited number of sampling days our sampling has been reasonably representative with respect to precipitation. There have been some moderate rainfall events missed (35 to 40 mm), but the number of dry days sampled is within a few percent of the overall distribution.

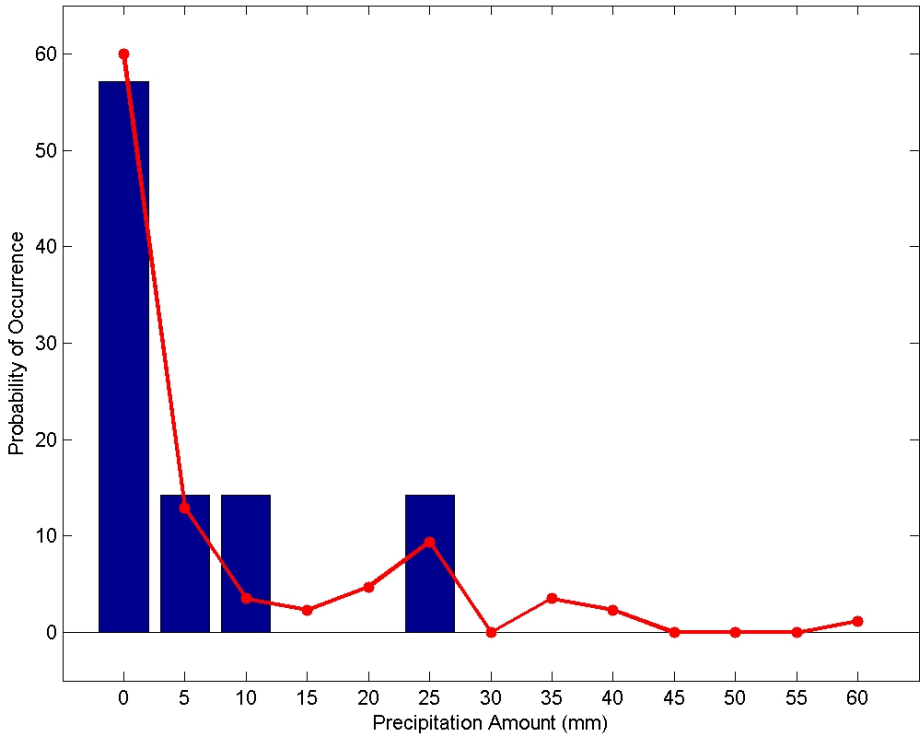

Figure 5. Probability distribution of cumulative 72 hour rainfall, 20 December 2006 to 13 March 2007.

4 Water Quality Results and Discussion

Results of the water quality sampling are discussed in the following sections with emphasis on compliance with water quality guidelines, and any need for modifications to the program.

4.1 Fecal Coliform

4.1.1 Out-of-Range Values

The adaptive lab procedure, using different fecal coliform detection ranges for different sites, developed as a result of previous recommendations, has reduced the number of out-of-range values significantly. For this quarter there are no out of range values in regular samples. The 1m supplementary sample at Fairview Cove was mistakenly analyzed at the normal resolution and resulted in an out-of-range value.

4.1.2 Quarterly Mean Values

The Guidelines for Canadian Recreational Water Quality (GCRWQ) (Health and Welfare Canada 1992) evaluate the compliance with bacterial water quality criteria based on geometric mean. The geometric mean, G, of n values is defined as:

$$G(x_1,x_2,x_3,\ldots,x_n) = (x_1 \cdot x_2 \cdot x_3 \cdot \ldots \cdot x_n)^{1/n}$$

To compute geometric mean, some adjustments to the data are required. Zeros are not valid in the calculation, so ones (1's) are substituted for all zero values. The result of this is that there will be no zero counts reported at any site. An appropriate interpretation of a reported mean value of one, then, is that it is equivalent to "less than or equal to" one. Out of range values are reported by the lab as >10,000 in the units reflective of the resolution of the analysis being performed. For this analysis out of range values are replaced by 10,000.

Maps representing the geometric mean values over all samples for the eleventh quarter are presented in Figure 6. In this figure, values in red exceed swimming guidelines (200 cfu/100 mL); values in blue exceed shellfishing guidelines (14 cfu/100 mL); and values in green indicate suitability for either activity. Separate maps are presented for the 1 and 10m samples.

For the 1 m samples, and to a lesser extent, the 10 m samples, the geometric mean coliform values are high in the Inner Harbour. The center of the spatial distribution at both depths is about the same at a point between sections D and EE. There is no clear indication of the effect of estuarine circulation in this distribution. The centre is relatively far south, particularly given the ongoing diversion of sewage up-harbour to Fairview Cove. The vertical pattern is familiar with the highest values in the 1m samples south of the Narrows. North of the Narrows, in the Bedford Basin, the highest values are generally

in the 10 m sample. This distribution suggests a net "estuarine" flow in the Basin with contaminated Inner Harbour water flowing in a lower layer into the Basin. This pattern is not particularly strong this quarter, with the vertical differences being relatively small. This is likely affected by the temporary diversion of sewage.

The geometric mean values exceeding the swimming guidelines occur in the southern Inner Harbour and Northwest Arm. There were low, but measureable levels all the way out to site B2. A more rigorous discussion of guideline exceedance follows.

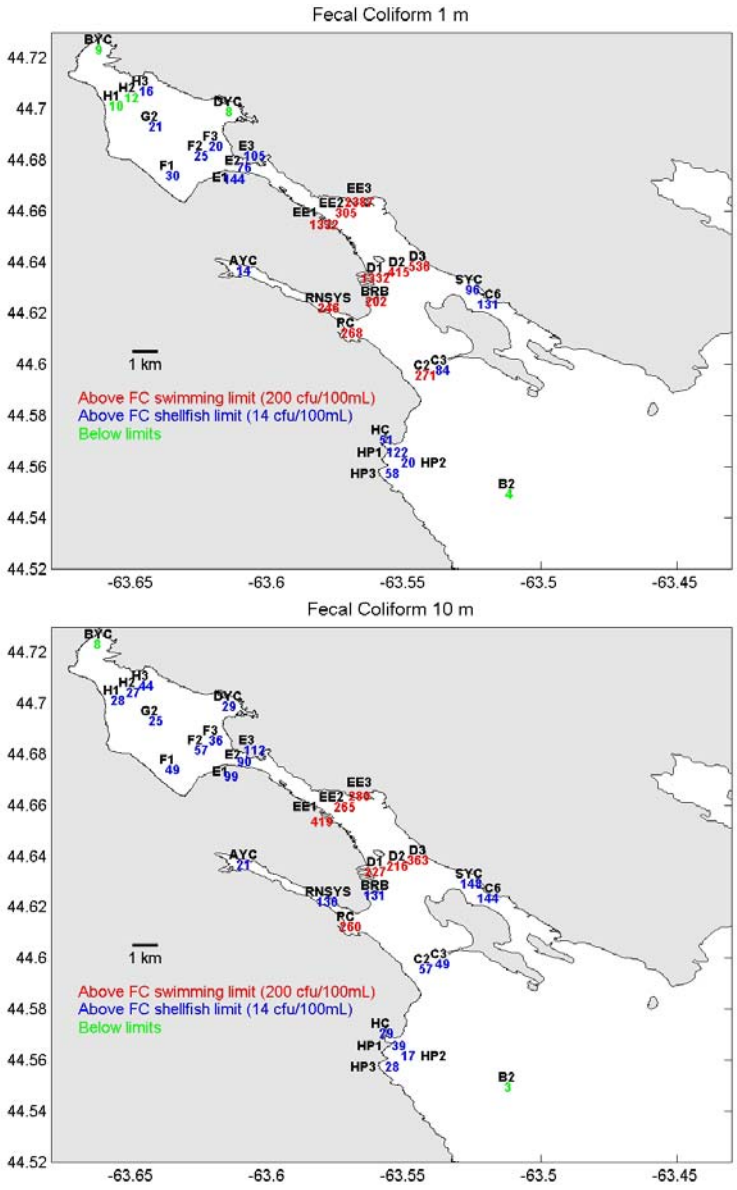

Figure 6. Fecal coliform geometric means (cfu/100mL) at 1m and 10m, 20 December 2006 to 13 March 2007.

4.1.3 Guideline Exceedance

As presented in Quarterly Report 1, the Harbour Task Force fecal coliform guidelines (Harbour Task Force, 1990) are interpreted using the methodology for swimming areas, presented in the Guidelines for Canadian Recreational Water Quality (Health and Welfare Canada, 1992). The recreational guidelines specify that in swimming areas, the geometric mean of at least five fecal coliform values taken within 30 days should not exceed 200 cfu/100mL, and any sample with values >400 cfu/100mL should trigger re-sampling. This strictly applies only to areas classified SB (recreational) by the Task Force (Table 1). The implications for areas classified SA and SC are discussed subsequently. The original weekly sampling regimen resulted in five samples within 30 days and allowed a fairly rigorous application of this analysis. The change to biweekly sampling in quarter nine means that the data do not meet the criteria of five samples within 30 days. The analysis is continued using a three sample floating average to meet the 30 day window but sacrifice the five sample criteria. We feel that the analysis, though no longer a rigorous application of the criteria, remains instructive.

Interpreting this procedure in our context results in a biweekly assessment, at three levels:

1. ACCEPTABLE, defined as a geometric mean <200 cfu/100mL
2. QUESTIONABLE, geometric mean <200 cfu/100mL but one or more samples >400 cfu/100mL
3. UNACCEPTABLE, geometric mean >200 cfu/100mL.

In the following discussion the terms “acceptable”, “questionable” and “unacceptable” will refer to these primary contact levels and not the Harbour Task Force SA, SB and SC guidelines. These guidelines will be discussed subsequently.

Tables 4 and 5 show the results of the analysis for the 1 m and 10 m samples respectively. The tables represent the floating 30 day geometric mean and, in parentheses, the number of samples (max 3) used in the average. The values are colour coded to represent acceptable (green), questionable (yellow) and unacceptable (red) levels.

1 m Samples

For this quarter, the near surface water (1 m) at Section EE and D in the Inner Harbour would be deemed “unacceptable” for primary body contact all of the time. The concentrations in this area are high. Stations just south of these sections, section C, BRB and SYC are “unacceptable” at the beginning of the quarter, but improve in the last half. Interestingly in this quarter, there are no “unacceptable” values at section E and further north. Outside of the Inner Harbour there are sporadic “unacceptable” or “questionable” values in many places. This is largely due to episodic advection of poorly diluted sewage either from the Inner Harbour or local outfalls, e.g.: the Chain Rock outfall and storm overflows in the NW Arm, the Fairview Cove CSO in the Basin, and the Tribune Head outfall near the Herring Cove (HC) and Hospital Point (HP) sites. There is a general decrease in the number of “unacceptable” values through the quarter.

10 m Samples

Referring to Table 5, as with the 1m samples, the floating mean values at sections D and EE are "unacceptable" most of the time. The levels are generally somewhat lower than the 1m means. Also, similar to the 1m means the values just south of the D section tend to be "unacceptable" at the start of the quarter and improve with time. The exception is BRB that shows the opposite trend. Elsewhere, as with the 1m samples, the concentrations are typified by sporadic high values causing "unacceptable "or "questionable" values. The trend toward lower values at the end of the quarter in the 1m samples is not apparent in the 10m data.

Task Force Guidelines

Most of the sites that are regularly deemed unacceptable for swimming are in the Inner Harbour that is classified SC by the Halifax Harbour Task Force. There are no Task Force limits on bacteria in this area. The greatest number of Task Force guideline exceedances, occur in the class SB areas just outside the Inner Harbour; that is, in the southern Basin, Black Rock Beach and the Northwest Arm, particularly the PC and RNSYS sites. This quarter most of the SB guideline exceedances are to the south of the Inner Harbour, rather than in Bedford Basin. The Outer Harbour is the only region classified SA. This has a lower requirement (14 cfu/100 mL) than the swimming criteria. The sites within the Task Force "Outer Harbour" boundaries are B2, HC and the HP section. HC (Herring Cove) never meets the SA criteria. The HP sites sometimes meet the SA guideline, but these sites are periodically visited by the plume of untreated sewage from the Tribune Head Outfall. This quarter, site B2 meets the SA criteria all of the time.

Table 4. 30 day geometric mean (number of samples) of 1 m fecal coliform concentrations (cfu/100 ml).

	Outer Harbour							Northwest Arm			Eastern Pass		Inner Harbour		
	B2	HP1	HP2	HP3	HC	C2	C3	PC	RNSYS	AYC	C6	SYC	BRB	D1	D2
Survey119	8 (3)	282 (3)	64 (3)	225 (3)	97 (3)	476 (3)	177 (3)	296 (3)	180 (3)	54 (3)	258 (3)	384 (3)	476 (3)	3409 (3)	763 (3)
Survey120	5 (3)	251 (3)	27 (3)	48 (3)	110 (3)	309 (3)	248 (3)	438 (3)	200 (3)	103 (3)	165 (3)	314 (3)	680 (3)	2239 (3)	550 (3)
Survey121	2 (3)	487 (3)	14 (3)	9 (3)	188 (3)	359 (3)	154 (3)	669 (3)	69 (3)	33 (3)	161 (3)	282 (3)	508 (3)	1419 (3)	308 (3)
Survey122	5 (3)	237 (3)	7 (3)	7 (3)	83 (3)	334 (3)	142 (3)	555 (3)	60 (3)	21 (3)	157 (3)	237 (3)	192 (3)	1083 (3)	329 (3)
Survey123	5 (3)	106 (3)	18 (3)	31 (3)	64 (3)	181 (3)	47 (3)	626 (3)	192 (3)	6 (3)	175 (3)	118 (3)	159 (3)	918 (3)	386 (3)
Survey124	5 (3)	39 (3)	27 (3)	67 (3)	20 (3)	105 (3)	24 (3)	383 (3)	399 (3)	4 (3)	202 (3)	44 (3)	72 (3)	1448 (3)	292 (3)
Survey125	2 (3)	27 (3)	18 (3)	124 (3)	17 (3)	124 (3)	23 (3)	117 (3)	1381 (3)	3 (3)	56 (3)	10 (3)	90 (3)	640 (3)	285 (3)

	Inner Harbour							Bedford Basin							
	D3	EE1	EE2	EE3	E1	E2	E3	F1	F2	F3	DYC	G2	H1	H2	H3	BYC
Survey119	1649 (2)	1441 (3)	423 (3)	612 (3)	196 (3)	77 (3)	136 (3)	134 (3)	89 (3)	63 (3)	24 (3)	78 (3)	22 (3)	21 (3)	59 (3)	15 (3)
Survey120	1115 (3)	678 (3)	426 (3)	715 (3)	141 (3)	100 (3)	141 (3)	147 (3)	67 (3)	104 (3)	13 (3)	77 (3)	40 (3)	68 (3)	75 (3)	23 (3)
Survey121	776 (3)	700 (3)	483 (3)	2718 (3)	71 (3)	50 (3)	115 (3)	42 (3)	78 (3)	55 (3)	7 (3)	38 (3)	17 (3)	34 (3)	29 (3)	23 (3)
Survey122	479 (3)	637 (3)	322 (3)	2281 (3)	87 (3)	40 (3)	46 (3)	29 (3)	47 (3)	21 (3)	4 (2)	31 (3)	12 (3)	24 (3)	12 (3)	9 (3)
Survey123	304 (3)	1090 (3)	293 (3)	7245 (3)	91 (3)	26 (3)	56 (3)	17 (3)	15 (3)	9 (3)	14 (1)	13 (3)	6 (3)	8 (3)	7 (3)	6 (3)
Survey124	250 (3)	1330 (3)	184 (3)	3527 (3)	101 (3)	53 (3)	73 (3)	23 (3)	5 (3)	7 (3)	1 (1)	9 (3)	6 (3)	7 (3)	5 (3)	3 (3)
Survey125	283 (3)	2573 (3)	208 (3)	9735 (3)	176 (3)	142 (3)	184 (3)	7 (3)	4 (3)	6 (3)	1 (1)	4 (3)	4 (3)	3 (3)	6 (3)	5 (3)

Table 5. 30 day geometric mean (number of samples) of 10 m fecal coliform concentrations (cfu/100 mL).

	Outer Harbour							Northwest Arm			Eastern Pass		Inner Harbour		
	B2	HP1	HP2	HP3	HC	C2	C3	PC	RNSYS	AYC	C6	SYC	BRB	D1	D2
Survey119	5 (3)	66 (3)	57 (3)	59 (3)	22 (3)	99 (3)	67 (3)	176 (3)	82 (3)	169 (3)	271 (3)	447 (3)	79 (3)	144 (3)	261 (3)
Survey120	3 (3)	23 (3)	20 (3)	24 (3)	38 (3)	275 (3)	179 (3)	412 (3)	80 (3)	142 (3)	280 (3)	530 (3)	148 (3)	243 (3)	438 (3)
Survey121	1 (3)	23 (3)	10 (3)	10 (3)	79 (3)	197 (3)	133 (3)	760 (3)	61 (3)	42 (3)	541 (3)	319 (3)	111 (3)	213 (3)	361 (3)
Survey122	3 (3)	16 (3)	6 (3)	8 (3)	88 (3)	128 (3)	136 (3)	492 (3)	73 (3)	17 (3)	541 (3)	247 (3)	196 (3)	262 (3)	405 (3)
Survey123	3 (3)	31 (3)	24 (3)	24 (3)	97 (3)	54 (3)	49 (3)	667 (3)	195 (3)	4 (3)	256 (3)	139 (3)	209 (3)	441 (3)	431 (3)
Survey124	3 (3)	73 (3)	31 (3)	57 (3)	28 (3)	25 (3)	34 (3)	280 (3)	406 (3)	3 (3)	46 (3)	54 (3)	206 (3)	441 (3)	291 (3)
Survey125	2 (3)	56 (3)	14 (3)	45 (3)	12 (3)	15 (3)	13 (3)	205 (3)	366 (3)	3 (3)	20 (3)	30 (3)	143 (3)	312 (3)	96 (3)

	Inner Harbour							Bedford Basin							
	D3	EE1	EE2	EE3	E1	E2	E3	F1	F2	F3	DYC	G2	H1	H2	H3	BYC
Survey119	901 (2)	104 (3)	267 (3)	297 (3)	147 (3)	139 (3)	117 (3)	61 (3)	231 (3)	46 (3)	25 (3)	118 (3)	57 (3)	68 (3)	100 (3)	11 (3)
Survey120	710 (3)	203 (3)	341 (3)	780 (3)	131 (3)	121 (3)	107 (3)	117 (3)	208 (3)	119 (3)	51 (3)	121 (3)	75 (3)	76 (3)	140 (3)	23 (3)
Survey121	429 (3)	157 (3)	389 (3)	471 (3)	65 (3)	73 (3)	109 (3)	110 (3)	113 (3)	61 (3)	28 (3)	45 (3)	38 (3)	40 (3)	63 (3)	20 (3)
Survey122	429 (3)	1017 (3)	608 (3)	352 (3)	60 (3)	61 (3)	78 (3)	76 (3)	43 (3)	37 (3)	52 (2)	29 (3)	39 (3)	60 (3)	67 (3)	16 (3)
Survey123	356 (3)	1261 (3)	374 (3)	242 (3)	69 (3)	60 (3)	83 (3)	42 (3)	15 (3)	13 (3)	28 (1)	13 (3)	23 (3)	26 (3)	24 (3)	9 (3)
Survey124	370 (3)	1316 (3)	231 (3)	287 (3)	94 (3)	56 (3)	77 (3)	29 (3)	10 (3)	17 (3)	12 (1)	8 (3)	13 (3)	13 (3)	14 (3)	5 (3)
Survey125	168 (3)	695 (3)	115 (3)	210 (3)	111 (3)	85 (3)	153 (3)	25 (3)	18 (3)	27 (3)	12 (1)	4 (3)	9 (3)	5 (3)	12 (3)	3 (3)

Note: Red indicates exceedance of swimming criteria (geometric mean >200). Yellow denotes "questionable" water quality, resampling is indicated (mean < 200, but one or more samples >400). Green indicates compliance with criteria.

4.2 Ammonia Nitrogen

Ammonia nitrogen is an important component in the nutrient balance in an estuary, and in high concentrations has potential for toxic effects; however, there is currently no marine water quality guideline for ammonia (CCME, 1999). The values obtained for this period are shown in Table 6. In addition, the quarterly mean and max values are plotted by station in Figure 7. For the purpose of computing statistics, the RDL/2, or 0.025 mg/L was used for values below detection. Missed sample are excluded from the calculations.

Ammonia nitrogen has consistently been present at levels that, on average, are around the detection limit of 0.05 mg/L. Overall, in this quarter, at 1 m 84 % of samples had detectable levels of ammonia and at 10 m 76 % of samples had detectable levels. This is relatively high. The mean values in both the 1m and 10m samples are quite uniform. At both depths the site means have a maximum at E2, but it is not significantly different than other values. The only clear spatial trend is that levels tend to be lower at B2 in the Outer Harbour. Here, 10 of 14 samples were below the detection limit. In general the week to week means do not vary greatly over the quarter. The exception is survey 124 (28 Feb 07) that had the quarterly site maximum values for all but one sample. The survey mean was 0.1 mg/L compared to the overall quarterly mean of 0.06 mg/L. Overall, there does not appear to be a strong correlation between ammonia concentrations and meteorological events/oceanographic conditions, as is seen in the coliform data.

For the supplemental sample at Fairview Cove (survey 124, 28 Feb 07) the levels of ammonia were relatively high 0.33 mg/L at 1 m and 0.12 mg/L at 10 m (see section 4.8).

Table 6. Ammonia nitrogen summary (mg/L).
Note: green highlights indicate values below detection limits (0.05 mg/L). For statistics 0.025 mg/L was used for values below detection

1m	B2	D2	EE2	E2	F2	G2	H2	mean	max
119 (20 Dec 06)	ND	0.06	0.07	0.08	0.08	0.09	0.09	0.07	0.09
120 (3 Jan 07)	ND	0.07	0.07	0.07	0.08	0.08	0.08	0.07	0.10
121 (18 Jan 07)	ND	0.07	0.07	0.08	0.08	0.08	0.08	0.07	0.08
122 (30 Jan 07)	ND	ND	0.06	0.06	0.07	0.06	0.08	0.05	0.08
123 (14 Feb 07)	ND	0.09	0.07	0.07	0.06	0.06	0.08	0.06	0.09
124 (28 Feb 07)	0.06	0.10	0.11	0.15	0.09	0.10	0.16	0.11	0.16
125 (13 Mar 07)	ND	ND	0.08	0.10	0.05	0.07	0.07	0.07	0.10
mean	0.03	0.06	0.08	0.09	0.07	0.08	0.09	0.07	
max	0.06	0.10	0.11	0.15	0.09	0.10	0.16		0.16

10m	B2	D2	EE2	E2	F2	G2	H2	mean	max
119 (20 Dec 06)	ND	ND	ND	0.10	0.06	ND	ND	0.02	0.10
120 (3 Jan 07)	ND	0.06	0.05	0.07	0.07	0.07	0.06	0.05	0.07
121 (18 Jan 07)	0.05	0.07	0.09	0.07	0.06	0.06	0.07	0.07	0.09
122 (30 Jan 07)	ND	0.05	0.05	0.06	0.06	0.06	0.05	0.05	0.06
123 (14 Feb 07)	0.06	0.06	0.05	0.06	0.06	0.06	0.06	0.06	0.06
124 (28 Feb 07)	0.08	0.08	0.08	0.11	0.09	0.10	0.09	0.09	0.11
125 (13 Mar 07)	ND	ND	ND	ND	0.05	ND	0.09	0.07	0.09
mean	0.04	0.05	0.05	0.07	0.06	0.06	0.06	0.06	
max	0.08	0.08	0.09	0.11	0.09	0.10	0.09		0.11

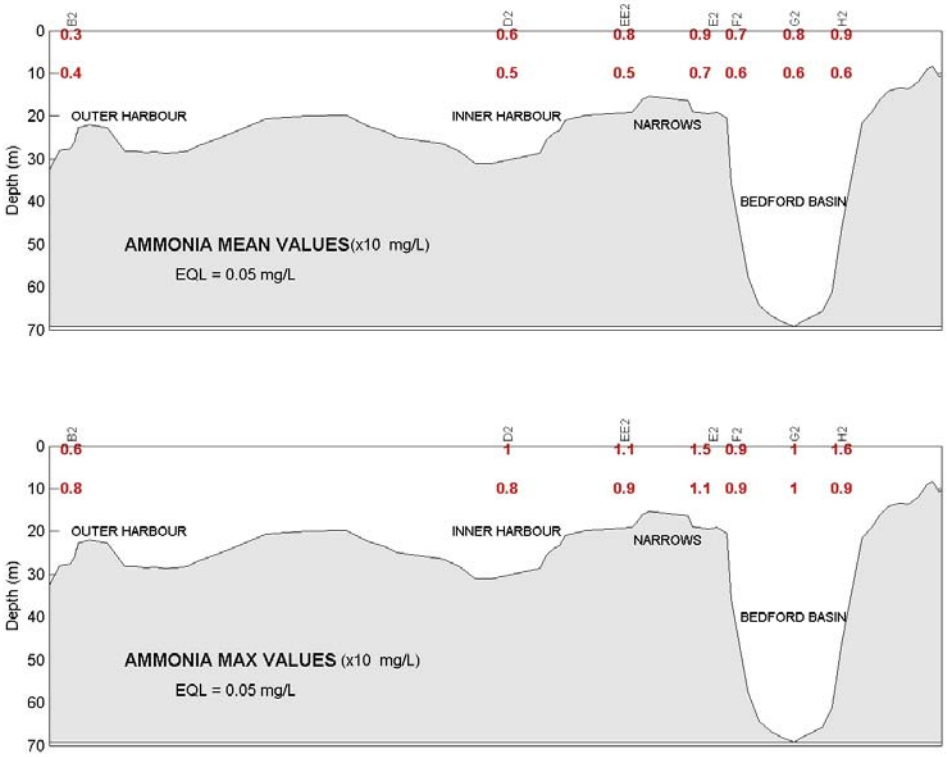

Figure 7. Mean and maximum value of ammonia nitrogen (X10 mg/L) over all eleventh quarter samples

4.3 Carbonaceous Biochemical Oxygen Demand

Further to a recommendation in Quarterly Report 2, $CBOD_5$ analysis for regular samples ceased on 25 May 2005, due to lack of detectable values. $CBOD_5$ analysis continues for supplemental samples, where there have been detectable values. The $CBOD_5$ analysis was performed on surveys 119 (20 Dec 07) and 120 (3 Jan 07) at stations F1 and F2. The levels were below the 5 mg/L RDL.

4.4 Total Suspended Solids

A summary of the TSS values for this quarter is shown in Table 7. Overall there were two samples that were below the RDL of 0.5 mg/L. As with total nitrogen, for samples below the detection limit, a value of one half the RDL (0.25 mg/L) is used for statistical purposes. The quarterly mean and max values are plotted by station in Figure 8. This quarter's values ranged from <0.5-6.8 mg/L at 1 m and <0.5-6.9 mg/L at 10 m. Overall there does not appear to be a clear spatial pattern, except that the Outer Harbour tends to have somewhat lower values. For the most part the values are relatively low this quarter. Survey 125 (13 Mar 07) had consistently higher levels. Quarterly maximum values were recorded in nine of fourteen samples. The mean values this survey were nearly twice the quarterly averaged survey mean. The fluorescence data indicate that the spring bloom is occurring in this survey.

Table 7. Summary of TSS data (mg/L).
Note: green highlights indicate values below detection limits (0.5 mg/L). For statistics 0.25 mg/L was used for values below detection.

1m	B2	D2	EE2	E2	F2	G2	H2	mean	max
119 (20 Dec 06)	1.8	2.8	2.4	4.6	2.0	3.7	6.4	3.4	6.4
120 (3 Jan 07)	2.1	1.4	1.8	1.3	3.3	3.5	2.2	2.2	3.5
121 (18 Jan 07)	0.7	1.5	2.7	3.2	1.4	1.6	1.5	1.8	3.2
122 (30 Jan 07)	1.3	2.4	0.8	1.1	ND	0.7	2.3	1.2	2.4
123 (14 Feb 07)	0.6	3.5	2.2	1.8	2.1	5.1	1.9	2.5	5.1
124 (28 Feb 07)	3.0	2.8	2.0	1.7	3.0	4.0	4.1	2.9	4.1
125 (13 Mar 07)	2.6	2.3	6.8	5.1	3.9	4.5	5.2	4.3	6.8
mean	1.7	2.4	2.7	2.7	2.2	3.3	3.4	2.6	
max	3.0	3.5	6.8	5.1	3.9	5.1	6.4		6.8

10m	B2	D2	EE2	E2	F2	G2	H2	mean	max
119 (20 Dec 06)	1.0	2.9	2.1	1.9	1.5	2.5	1.6	1.9	2.9
120 (3 Jan 07)	ND	0.9	3.0	1.4	3.6	1.0	1.0	1.6	3.6
121 (18 Jan 07)	0.9	2.1	1.3	2.6	1.7	2.7	1.1	1.8	2.7
122 (30 Jan 07)	2.3	2.4	1.4	1.9	1.5	1.3	1.6	1.8	2.4
123 (14 Feb 07)	3.7	5.8	2.2	2.0	5.4	2.4	2.6	3.4	5.8
124 (28 Feb 07)	1.3	1.4	2.0	4.5	3.0	1.6	5.9	2.8	5.9
125 (13 Mar 07)	3.4	6.3	3.7	5.7	6.9	5.8	4.0	5.1	6.9
mean	1.8	3.1	2.2	2.9	3.4	2.5	2.5	2.6	
max	3.7	6.3	3.7	5.7	6.9	5.8	5.9		6.9

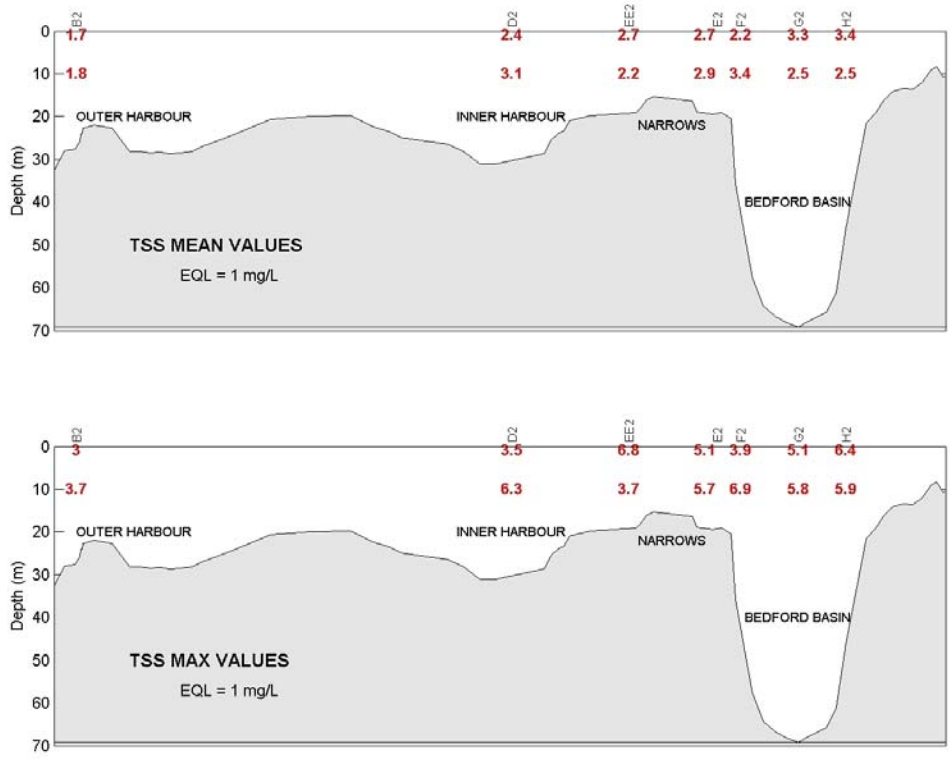

Figure 8. Mean and maximum values of total suspended solids (mg/L) over all eleventh quarter samples.

4.5 Total Oils and Grease

Based on recommendations in Quarterly Report 5 regular sampling for Total Oil and Grease was discontinued in survey 75 (23 Nov 05). The analysis is retained for supplemental samples.

4.6 Metals

The results of the metals analysis are summarized in Figure 9. For this plot the non-detectable values are considered zero. There was one guideline exceedance. In survey 121 (18 Jan 07) a single mercury level of 0.03 µg/L was measured. This exceeds the 0.025 µg/L guideline. In addition, in survey 125 (13 Mar 07) all samples had mercury levels just at the 0.01 µg/L detection limit except for two samples with 0.02 µg/L levels. Aside from mercury, this plot shows that of the metals for which guidelines exist copper, manganese and zinc regularly have detectable levels. Lead and nickel are occasionally detectable, while cadmium was not detected. Iron is regularly detected, but has no guideline. Note that cobalt is also measured but has no guideline and is not regularly detectable, so it is not reported. The metal regularly closest to the exceedance level is copper with a mean value under 20% of the guideline.

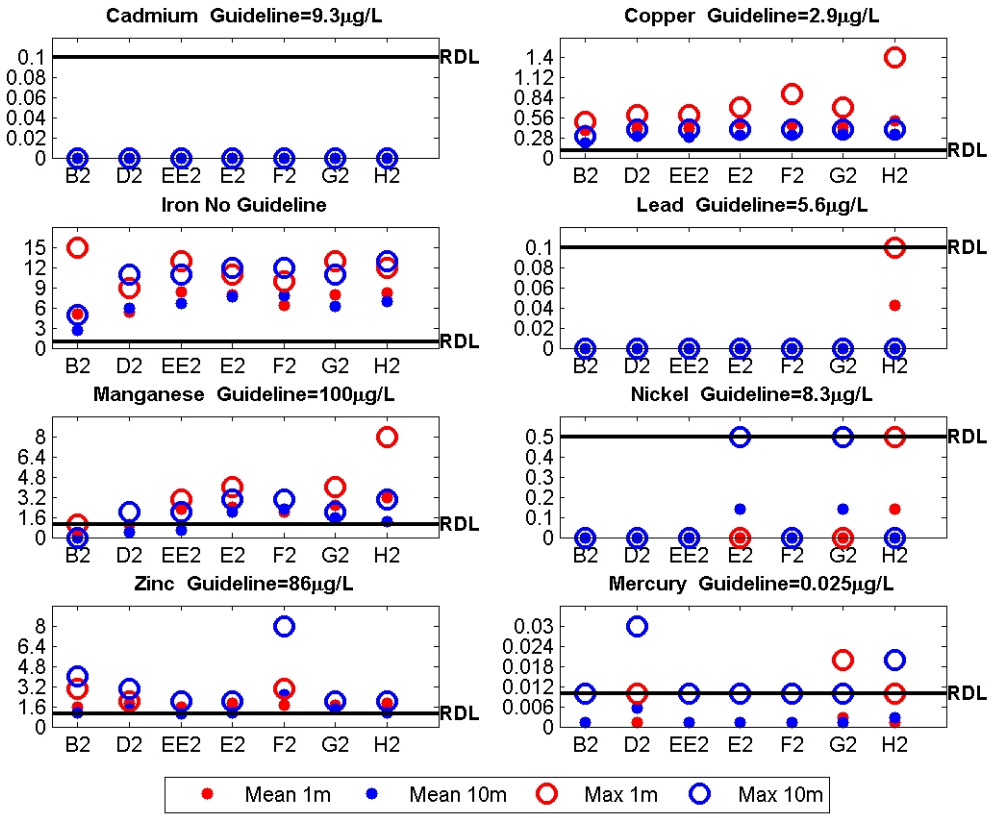

Figure 9. Mean and maximum values of metals (µg/L) over all eleventh quarter samples.

4.7 Profile Data

The CTD used in this program measures continuous profiles of temperature, salinity, fluorescence and dissolved oxygen with depth. In early quarterly reports (up to Quarterly Report 8) the profile data was compared to the BBPMP data from the centre of Bedford Basin. This provided a check on the ranges and quality of the data collected for this survey. BBPMP has discontinued the time series contour plots so this comparison is no longer feasible. However, the contour plots of profile time series are useful in visualizing the longer term variation in the state of the harbour. These plots will be continued in the annual summary section of every fourth quarterly report (12, 16 and 20).

4.7.1 Salinity and Temperature

The temperature, salinity and density (derived from temperature and salinity) profile data provides valuable information on the physical state of the harbour that is very useful in interpreting the water quality data in the weekly surveys. The data is discussed in that context in the survey reports. As time series, the data is useful in characterizing changes in the state of the harbour on meteorological (storms etc) and seasonal timescales. The most interesting point is probably the centre of Bedford Basin as this reflects not only the near surface (upper 20 m) response to wind and rain, but also shows the effects of the periodic intrusion of dense shelf bottom water into the Basin (forced by local and shelf-wide meteorological events). This longer term variation is discussed in the annual summaries.

4.7.2 Fluorescence

The HHWQMP reported values of Chlorophyll *a* are un-calibrated, generated using the default values provided with the Seabird instrument software. As such, though the units are mg/m^3, they are really more of a measure of fluorescence than of a true measure of the mass concentration of phytoplankton. The conversion to biomass is highly dependant on many factors, including species and condition of plankton present, and is approximate even when fully calibrated with water samples. However, the un-calibrated fluorescence values can be useful when considered on a relative basis. This comparison is probably more valid within a survey, where conditions are more likely to be consistent over the harbour, than between surveys which occur under different conditions. The more separated in time and space, the more uncertain the comparison. Nonetheless, due to the large variability in natural plankton concentrations, the data provides useful information on the relative spatial and temporal variability of phytoplankton activity.

The phytoplankton in Halifax Harbour generally exhibit more or less typical estuarine behaviour in the winter. That is, low productivity (<5 mg/m^3) during the winter followed by the strongest bloom of the year (40-80 mg/m^3) as sunlight returns in the spring (typically March). After the spring bloom, when light is plentiful, the behaviour seems to be affected by anthropogenic nutrient input. There are sporadic phytoplankton blooms throughout the summer and into the fall. These blooms can be close to the spring bloom in magnitude (30-40 mg/m^3) and occur until the drop in light levels in late fall and winter. There is a less distinct fall bloom that does not appear to be significantly different in intensity, based on fluorescence, than the blooms occurring throughout the summer. Phytoplankton blooms tend to start in the Basin and migrate outward to the rest of the harbour. The profile maximum values generally decrease in magnitude and occur lower in the water column further out of the harbour. The data in the Basin generally represents the maximum concentrations observed and is representative of the timing of phytoplankton activity in the remainder of the harbour. During this quarter there was minimal phytoplankton activity with maximum levels of < 3 mg/m^3 through most of the quarter. Levels increased slightly in survey 124 (28 Feb07) and spring bloom was occurring in the final survey 125 (13 Mar 07).

4.7.3 Dissolved Oxygen

Comparison between dissolved oxygen determinations by different methods/instruments has proven uncertain. Part of this uncertainty is due to the vagaries of the instruments themselves. Additionally, small variations in processing procedures, particularly with "alignment" procedures, that assign depths to the DO measurements obtained with the CTD, can add uncertainty. The CTD sensors are quite stable, but tend to lose sensitivity with time. Due to the nature of the CTD itself, they cannot be user calibrated. The BBPMP routinely collects water samples for ground truthing their CTD DO measurements. The samples are analyzed with a well calibrated bench top DO meter. This data can be used to adjust the profile data. The BBPMP publishes the weekly profile data on their website. For purposes of comparison the DO values at 1 and 10 m are estimated from the plots, and are compared with corresponding values from the HHWQMP profiles in Table 8, below. Note that the BBPMP station is approximately 125 m east of the HHWQMP site G2 and that BBPMP samples are generally collected on the day following the HHWQMP samples, so direct correspondence is not to be expected.

Table 8. Comparison of HHWQMP and BBPMP dissolved oxygen data.

Survey Number	HHWQMP (mg/L)		BBPMP (mg/L)		Ratio(BBPMP/HHWQMP)	
	1m	10m	1m	10m	1m	10m
119 (20 Dec 06)	6.8	6.20	7.7	6.9	1.13	1.11
120 (3 Jan 07)	7.2	7.00	8.1	7.7	1.13	1.10
121 (18 Jan 07)	7.3	6.80	7.9	7.6	1.08	1.11
122 (30 Jan 07)	7.5	7.30	7.7	7.7	1.03	1.06
123 (14 Feb 07)	7.8	7.80	8.4	8.4	1.08	1.08
124 (28 Feb 07)	7.7	7.70	8.7	8.7	1.13	1.13
125 (13 Mar 07)	8.6	8.40	9.6	9.6	1.11	1.14

The data generally exhibits good correspondence given the uncertainties, including the differences in time and location. The HHWQMP data on average is roughly 10% lower than the BBPMP data.

The Harbour Task Force class SA, SB and SC water use classifications have guidelines for dissolved oxygen of 8.0, 7.0 and 6.0 mg/L respectively. Class SA pertains to the Outer Harbour and class SC pertains to the Narrows and Inner Harbour. The remainder of the Harbour is classified as SB. In general in this quarter the dissolved oxygen levels started out relatively low and increased continuously throughout the quarter. At the start of the quarter, in addition to the usual class SB exceedance in the Basin bottom water, the SB guideline was exceeded in the surface water of the Basin. In the Outer Harbour the DO levels were below the 8.0 mg/L class SA guideline. By survey 121 (18 Jan 07) the only exceedances were the Basin bottom water and the Outer Harbour, that was just below the 8.0 mg/L SA guideline. By survey 124 (28 Feb 07) the only exceedance was in the Basin bottom water. The comparison with BBPMP indicates that our levels may be slightly (10%) low.

4.8 Supplemental Sample

Fairview Cove

During this quarter there was one supplemental sample (survey 124, 28 Feb 07) taken in the visible plume from the Fairview Cove combined sewer overflow. Fairview Cove is quite sheltered and has very low tidal currents. The samples were taken at 09:16 at a site (44° 39.906' N, 63° 37.834' W) about 100 m NNW of the outfall (Fig.10). The tide was close to slack and the wind was light (< 10 km/hr) out of the NNW (into the Cove). The plume was very visible, with a strong odour. The effluent was spreading out over the salt water in a relatively shallow layer. The drift of the boat caused upwelling of deeper water, creating a clear wake (Figure 11). The thickness was difficult to estimate but likely on the order of 1m or less. Both 1 and 10m samples were taken and were analyzed for a full suite of parameters, except that by oversight the samples were not analyzed for $CBOD_5$ and Total Oil and Grease.

Figure 10. Fairview Cove combined sewer overflow (CSO) from sample site.

Figure 11. Clear water in boat wake in plume.

The results of the lab analysis are presented in Table 9. Both the FC (>10,000 cfu/100 mL) and ammonia (0.33 mg/L) are relatively high in the 1m sample. As discussed in section 4.2, in survey 124 the ammonia levels throughout the harbour were the highest measured for the quarter. The 1m value is 2 times greater than the maximum level measured in regular samples, but there were several observations that survey similar or higher than the 10 m value. Given the visual observations, Fig 10, there is a possibility that the 1m sample was taken below the surface feature. In the 10 m sample the TSS value (57 mg/L) is probably the highest measured to date in the program. The field notes indicate that the sample was taken near bottom in less than 10m of water. This raises the possibility that the sample may have been taken in a sediment plume stirred up by the sampler, but it might also be due to flocculated material settling from the surface. The metals concentrations in the 1m sample were the highest measured in the survey but only slightly. In the 10m samples the concentrations were significantly higher than in the 1m samples. There are no exceedances of metals guidelines, but the copper concentration of 2.4 ug/L is very close to the 2.9 ug/L guideline.

Table 9. Supplemental sample lab results.

	UNITS	1m	10m	RDL
BACTERIA				
Fecal Coliform	CFU/100mL	>10,000	66	1
INORGANICS				
Carbonaceous BOD	mg/L	NA	NA	5
Nitrogen (Ammonia Nitrogen)	mg/L	0.33	0.11	0.05
Total Suspended Solids	mg/L	4	57	0.5
OIL & GREASE				
Total Oil & Grease	mg/L	NA	NA	5
METALS WITH GUIDELINES				
Cadmium (Cd)	ug/L	ND	ND	0.1
Copper (Cu)	ug/L	1	2.4	0.1
Lead (Pb)	ug/L	ND	1.1	0.1
Manganese (Mn)	ug/L	8	10	1
Mercury (Hg)	ug/L	ND	ND	0.01
Nickel (Ni)	ug/L	0.5	0.8	0.5
Zinc (Zn)	ug/L	3	11	1
METALS WITH NO GUIDELINES				
Cobalt (Co)	ug/L	ND	0.2	0.1
Iron (Fe)	ug/L	24	197	1

Additional Individual Samples

Sites F1 and F2 were sampled for $CBOD_5$ in surveys 119 (20 Dec 06) and 120 (3 Jan 07). These were investigating the effect of the temporary sewage diversion from Duffus St, to Fairview Cove. This analysis had no detectable values at the 5 mg/L detection limit.

5 Summary

For each item, a brief statement of summary is provided along with any changes that occurred during the quarter and any new or ongoing issues.

5.1 Reporting

Survey Reports

The report analysis/presentation has been refined and is essentially in final form. There may be periodic changes required to accommodate any changes in data collection.

Changes

– None

Quarterly Reports

The Quarterly report discussion is limited to the data of that quarter. Every fourth Quarterly report includes a section reviewing the data over the last year. Each quarterly report contains a discussion of any supplementary samples taken in the quarter. The documentation of sampling/sample handling/lab procedures/ data analysis remains incomplete.

Changes

- None

5.2 Sampling Program

The sampling route selection continues as per the end of the ninth quarter. As of that time the routes were modified to always either start or end in the Northwest Arm, where the survey boat is based. This was done based on travel time considerations and does introduce an early morning /late afternoon bias into the NW Arm data. The morning sampling may coincide with the peak diurnal sewage flows and may result in a bias in water quality samples near the chain rock outfall (e.g. RNSYS, PC). This is also a function of the plume trajectory at the time of sampling. This should be considered in a detailed analysis of RNSYS, and PC water quality data. The sampling sites remain as of the end of quarter 10. The last change has been the addition of the HP sites. The sample analysis remains the same as at the end of quarter nine. The last modification was the addition of the high resolution metals analysis.

Changes

- None

5.3 Water Quality Parameters

Fecal Coliform

In general, the geometric mean coliform values are well above primary contact guidelines in the Inner Harbour. Outside of the Inner Harbour high values are more sporadic. The occurrence of high values outside the Inner Harbour are primarily dependant on oceanographic conditions, that may transport water from the Inner Harbour either up or down harbour, and secondarily dependant on loading events (e.g. storms) that may increase loads thereby raising levels everywhere. Both of these often act together. This quarter, the spatial distribution of fecal coliform seemed shifted down harbour, in both the 1 and 10m samples. The mean values in section E are below 200 cfu/100 mL at both depths. This, in spite of the diversion of sewage north from Duffus St. to the Fairview Cove STP that in the past has seemed to increase fc concentrations in sections E and F.

With respect to compliance with Task Force guidelines the most numerous exceedances are in the class SB rated areas adjacent to the Inner Harbour. This quarter exceedances in the Southern Basin were almost non-existent. There were persistent exceedances to the south at Black Rock Beach, the Northwest Arm and Eastern Passage. In general, the number of sites with SB exceedances decreased throughout the quarter.

Changes
- None

Outstanding item: The current Canadian Environmental Quality Guidelines (ceqg-rcqe.ccme.ca) recommend enterococci over fecal coliform as a tracer of human waste contamination in salt water. There are several practical reasons for continuing to monitor fecal coliform including historical continuity, and consistency with WWTP monitoring procedures. The trend toward enterococci will likely continue and it would be advantageous to future endeavours if the monitoring program could bridge to the use of this tracer. Enterococci is considered to be more specific that fecal coliform in identifying contamination by human waste. In Halifax the overwhelming source of bacterial contamination is sewage. The concentration of fecal coliform in the Harbour would likely correlate very strongly with the more human specific enterococci. Limited sampling of both parameters could allow investigation of this correlation.

Ammonia Nitrogen

Ammonia nitrogen has consistently been present at levels that are at or slightly above the detection limit of 0.05 mg/L. Overall, in this quarter, at 1 m 84 % of samples had detectable levels of ammonia and at 10 m 76 % of samples had detectable levels. The overall mean concentration is 0.06 mg/L. This quarter, the mean values in both the 1m and 10m samples are relatively uniform throughout the Inner Harbour and Basin. The only clear spatial trend is that values are lower in the Outer Harbour. The week to week variability in mean concentration is low except for a single survey (124, 28 February 2007) where concentrations were elevated over the quarterly mean by over 50%. The

supplemental sample (section 4.8) taken in a visible sewage plume had an ammonia level (0.33 mg/L) twice as high as the maximum value measured at regular sample sites.

Changes
- None

$CBOD_5$

Based on recommendations in Quarterly Report 2, $CBOD_5$ was dropped from regular analysis in survey 49 (25 May 2005). Until that time there were an insignificant number of regular samples with detectable $CBOD_5$ at the 5 mg/L level. $CBOD_5$ has been retained as a tracer for the supplemental sampling program.

The $CBOD_5$ analysis was performed at stations F1 and F2 in the first two surveys of this quarter (119, 120). The levels were below the 5 mg/L detection limit.

Changes
- None

Total Suspended Solids

The TSS values in the harbour are generally moderate with no obvious strong correlation in space or time with oceanographic or sewage loading conditions. There are occasional higher values that seem to be associated with more extreme events (e.g. storms, plankton blooms etc). These events are generally identifiable visibly and are usually documented in field notes. This quarter the levels were quite low and uniform in time and space with mean values of about 2.6 mg/L. The exception was survey 125 (13 Mar 07). This survey was associated with increased fluorescence and had mean TSS values nearly twice as high as the overall survey means.

Changes:
- None

Total Oils and Grease

Based on recommendations in Quarterly Report 5, Total Oils and Grease was dropped from regular analysis in survey 75 (23 November 2005), due to lack of detection. It is retained in supplemental sample analysis. This quarter the TOG analysis for the supplemental sample in Fairview Cove was inadvertently omitted.

Changes
- None

Metals

There was a single guideline exceedance of mercury, a metal normally not detected at the 0.01 µg/L detection limit. The measured value was 0.03 µg/L compared to the 0.025 µg/L guideline. Aside from Mercury there were no other guideline exceedances. The present analysis allows good quantification of concentrations of copper, manganese, zinc and lead, for which guidelines exist. The analysis will also allow evaluation of guideline compliance for cadmium, nickel and mercury, though these metals are seldom present in detectable concentrations. The metal that is regularly closest to guideline exceedance is copper: this quarter the mean values were under 20% of the 2.9 µg/L guideline.

Changes:
- None

Fluorescence

Un-calibrated fluorescence provides a relative measure of chlorophyll and hence phytoplankton activity throughout the Harbour. The HHWQMP data allows for the gross identification of phytoplankton activity and is particularly useful in the interpretation of the DO data. The fluorescence data could also be useful to add a spatial interpretation to the detailed phytoplankton analysis at the BBPMP site.

During this quarter the fluorescence generally remained at near background levels (< 3 mg/L). In the final survey (125, 13 March 07) the levels increased, likely due to the spring bloom.

Changes
- None

Dissolved Oxygen

To date, oxygen levels as measured in the program, are generally relatively high in surface waters, and chronically low in the deep water of Bedford Basin. This is consistent with the existing understanding that Bedford Basin is a fjord, in which depressed oxygen in bottom water is typical. At the start of this quarter, in addition to the Basin bottom water there were relatively widespread exceedances in class SA and SB areas of the harbour. This improved relatively regularly with time, until by the end of the quarter the only guideline exceedance was again in the deep water of the Basin. There are continuing issues of DO sensor calibration/ground truth (Section 4.7.3). This quarter comparison with the ground truthed BBPMP DO data indicates relatively good correspondence. The HHWQMP values are on average about 10% below the BBPMP published values.

Changes
- None

6 References

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