Halifax Harbour
Water Quality Monitoring Program
Quarterly Report #16
(March 26 to June 16, 2008**)**

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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 26 March to 16 June 2008 (surveys 152 to 158). The results of the individual surveys are documented in survey reports. In this report, 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 a 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 sixteenth 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 a stand-alone document, there is a significant amount of repetition of background information among the quarterly reports.

2 Reporting

The basic report format for both survey and quarterly reports 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 (See Appendix).

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 is done on a biweekly basis as of July 2006. 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 the sixteenth quarter (16 June 2008) are in Table 1. This table indicates that the biochemical oxygen demand (BOD_5) and total oil and grease (TOG) analyses, discontinued from regular sampling due to lack detection, are now performed only for “supplemental samples”.

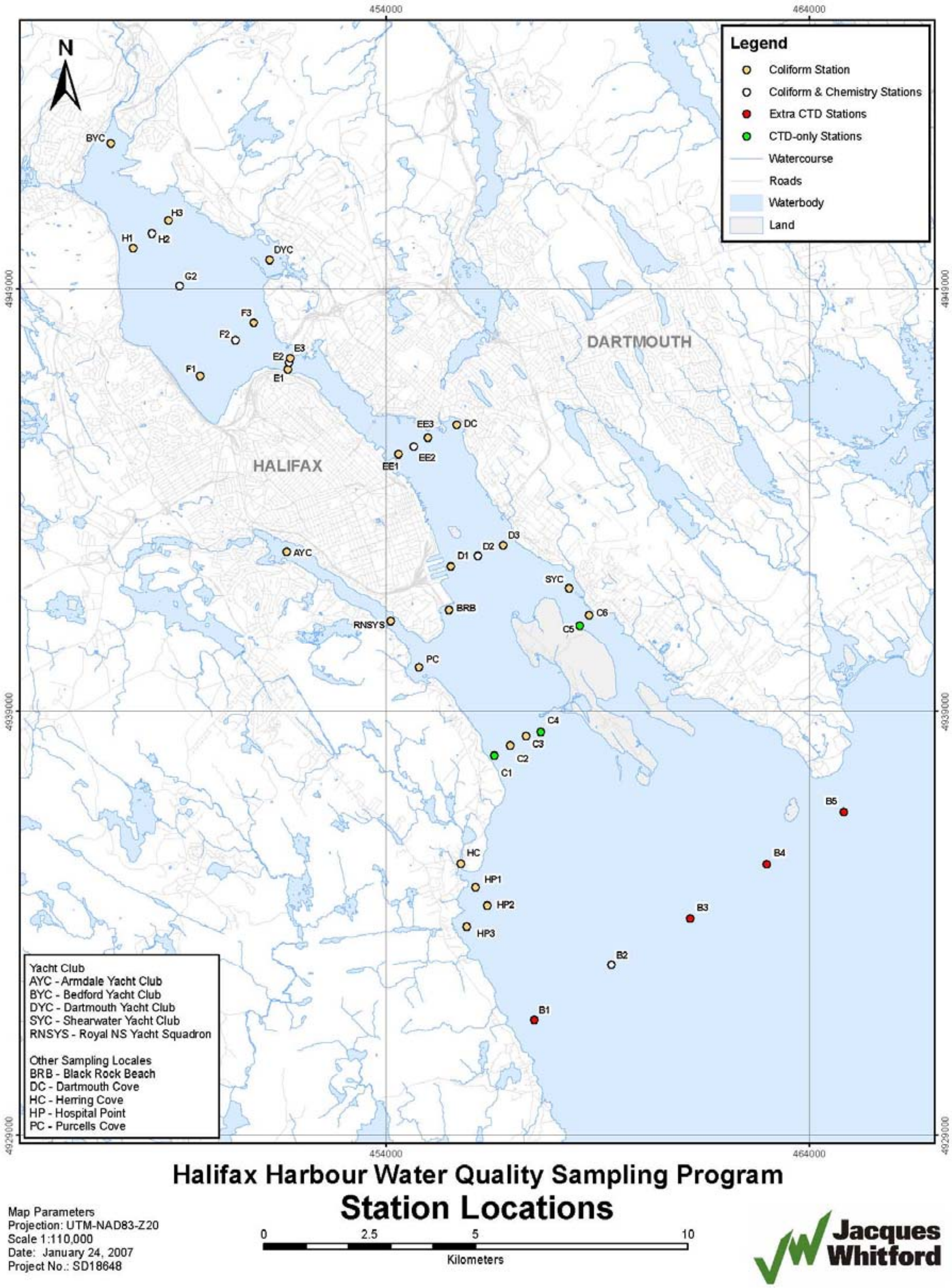

Figure 1. Halifax Inlet sample locations.

Table 1. Summary of measured parameters as of 16 June 2008.

	RDL value	RDL units	Harbour Task Force Guideline	Water Use Category	Sampling Stations (refer to Fig. 1)	Sampling frequency
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		
Dissolved Oxygen	n/a	mg/L	8 7 6	SA SB SC		
Secchi depth	n/a	m	n/a	n/a		
Bacteria Samples					Bacteria + Chemical	biweekly
Fecal Coliform	1	cfu/ 100mL	14 200 none	SA SB SC		
Chemical Samples						
CBOD	5	mg/L	none		Supplemental sites	unscheduled
Ammonia Nitrogen	0.05	mg/L	none		Chemical sites	bi-weekly
TSS	0.5	mg/L	<10% 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 which have been eliminated from normal sampling due to lack of detection.

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 sixteenth quarter is presented in Table 2.

From time to time survey sites are missed. There are many reasons why this might occur, the primary reason is generally weather conditions. The survey details are in the individual survey reports. Table 2 lists the missed stations and any additional samples (described above) for each survey.

3.4 Data Return

In addition to the missed sites detailed above, there were other sporadic data losses generally associated with quality control issues that were discovered during 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 that 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 sixteenth quarter.

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

Date	26-Mar-08	9-Apr-08	22-Apr-08	6-May-08	21-May-08	4-Jun-08	16-Jun-08
Survey	152	153	154	155	156	157	158
1	AYC	AYC	AYC	C5	AYC	C5	AYC
2	RNSYS	RNSYS	RNSYS	C6	RNSYS	C6	RNSYS
3	PC	PC	PC	SYC	PC	SYC	PC
4	BRB	EE3	BRB	D3	BRB	D3	BRB
5	C2	EE2	B2	EE3	C5	EE3	C4
6	C1	D3	HP3	F3	C6	F3	C3
7	B2	D2	HP2	DYC	SYC	DYC	B2
8	HP3	SYC	HP1	H3	D3	H3	HP3
9	HP2	C6	HC	BYC	D2	BYC	HP2
10	HP1	C5	C1	H1	EE3	H1	HP1
11	HC	C4	C2	H2	EE2	H2	HC
12	C3	C3	D1	G2	F3	G2	C1
13	C4	B2	EE1	F1	F2	F1	C2
14	C5	HP3	F1	F2	DYC	F2	D1
15	C6	HP2	G2	E3	G2	E3	D2
16	SYC	HP1	H1	E1	H3	E1	EE1
17	EE3	HC	BYC	E2	H2	E2	EE2
18	F3	C1	H3	EE1	BYC	EE1	E3
19	DYC	C2	H2	EE2	H1	EE2	E1
20	H3	BRB	DYC	D1	F1	D1	E2
21	BYC	D1	F3	D2	E1	D2	F2
22	H1	EE1	F2	BRB	E3	BRB	F1
23	H2	F1	E1	C2	E2	C2	G2
24	G2	G2	E3	C1	EE1	C1	H1
25	F1	H1	E2	HC	D1	HC	H2
26	F2	BYC	EE3	HP1	C4	HP1	BYC
27	E1	H3	EE2	HP2	C3	HP2	H3
28	E3	H2	D3	HP3	HP1	HP3	DYC
29	E2	DYC	D2	B2	HC	B2	F3
30	EE1	F3	SYC	C3	HP2	C3	EE3
31	EE2	F2	C6	C4	HP3	C4	D3
32	D1	E1	C5	PC	C1	PC	SYC
33	D2	E3	C4	RNSYS	C2	RNSYS	C6
34	D3	E2	C3	AYC		AYC	C5
No data					B2		
Supplemental				F2(surface)		DC	DC

Table 3. Quarter sixteen data return.

Chemical	Target	Achieved	Percent Return
7 sites			
NH3	98	96	
TSS	98	96	
Metal Suite	98	96	
Mercury	98	95	
Total	**392**	**383**	**98%**

Bacteria	Target	Achieved	
28 sites			
F Coliform	434	431	
Total	**434**	**431**	**99%**

Profiles	Target	Achieved	
31 sites			
C-T	238	236	
Dissolved Oxygen	238	217	
Chlorophyll	238	236	
Total	**714**	**689**	**96%**
All data records	**1540**	**1503**	**98%**

3.5.1 Time of Day

Sewage flows have significant regular diurnal variations that 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 sixteenth 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. Since each survey either begins or ends in the Northwest Arm there is a built in early morning/late afternoon bias there. The procedure for selecting routes based on weather conditions also introduces a morning/afternoon bias in the Outer Harbour.

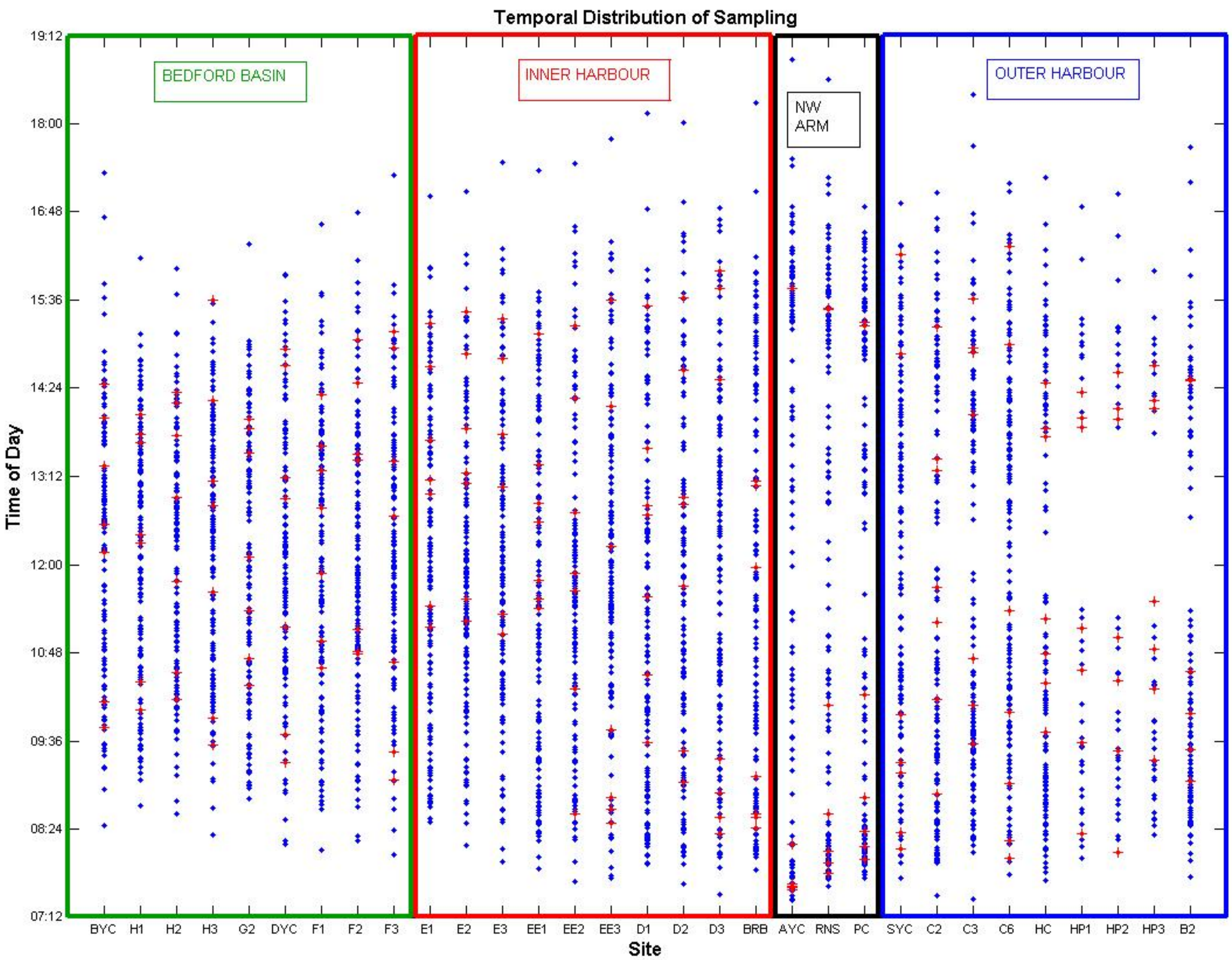

Figure 2. Temporal sampling distribution by site over entire program. Red markers denote points from 26 March to 16 June 2008.

3.5.2 Water Levels

The water level at the time of sampling can affect the 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 much 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 overridden 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 March to June 2008 is shown in Figure 3. In an ideal situation each site would be sampled in a distribution similar to the overall baseline distribution. 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.

Because sampling has been switched to bi-weekly, the number of samples in a quarter has been roughly halved. Therefore a somewhat deteriorated representation of the water level range is inevitable. 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.

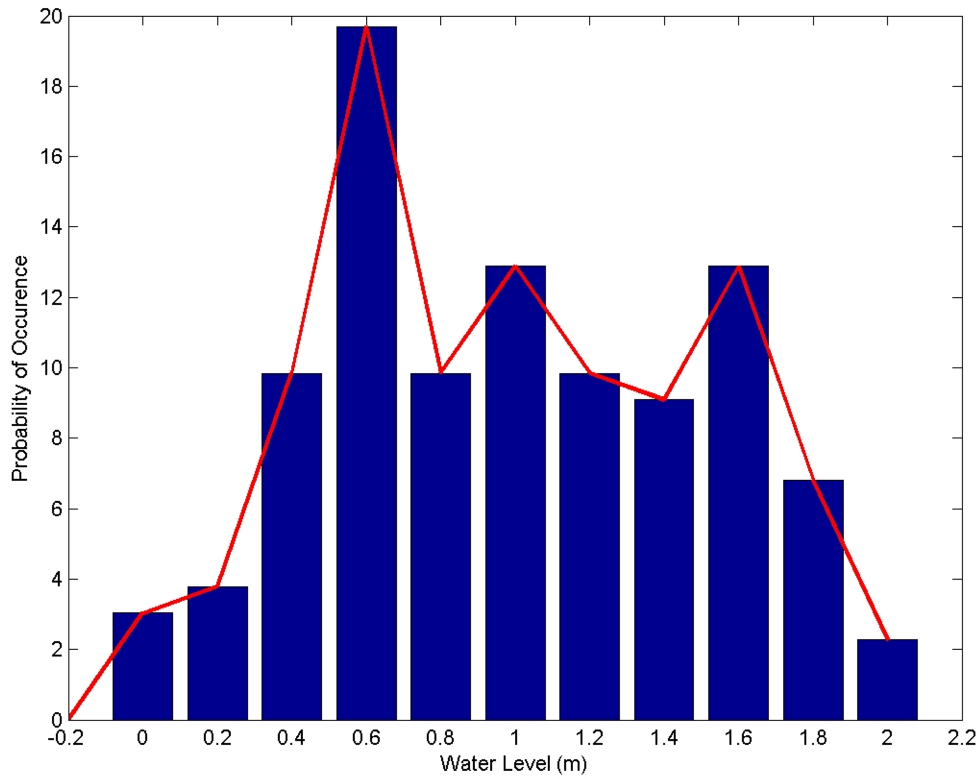

Figure 3. Probability distribution of water levels in Halifax, March to June 2008.

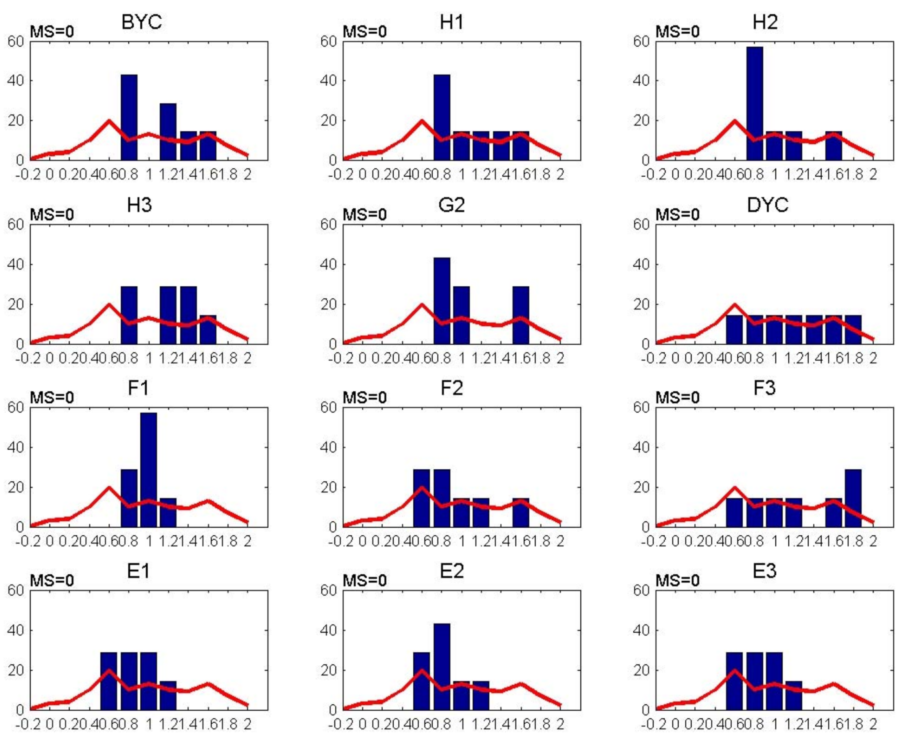

Figure 4a. Water level distribution at each site during sampling 26 March to 16 June 2008.

Note: MS = Missed samples.

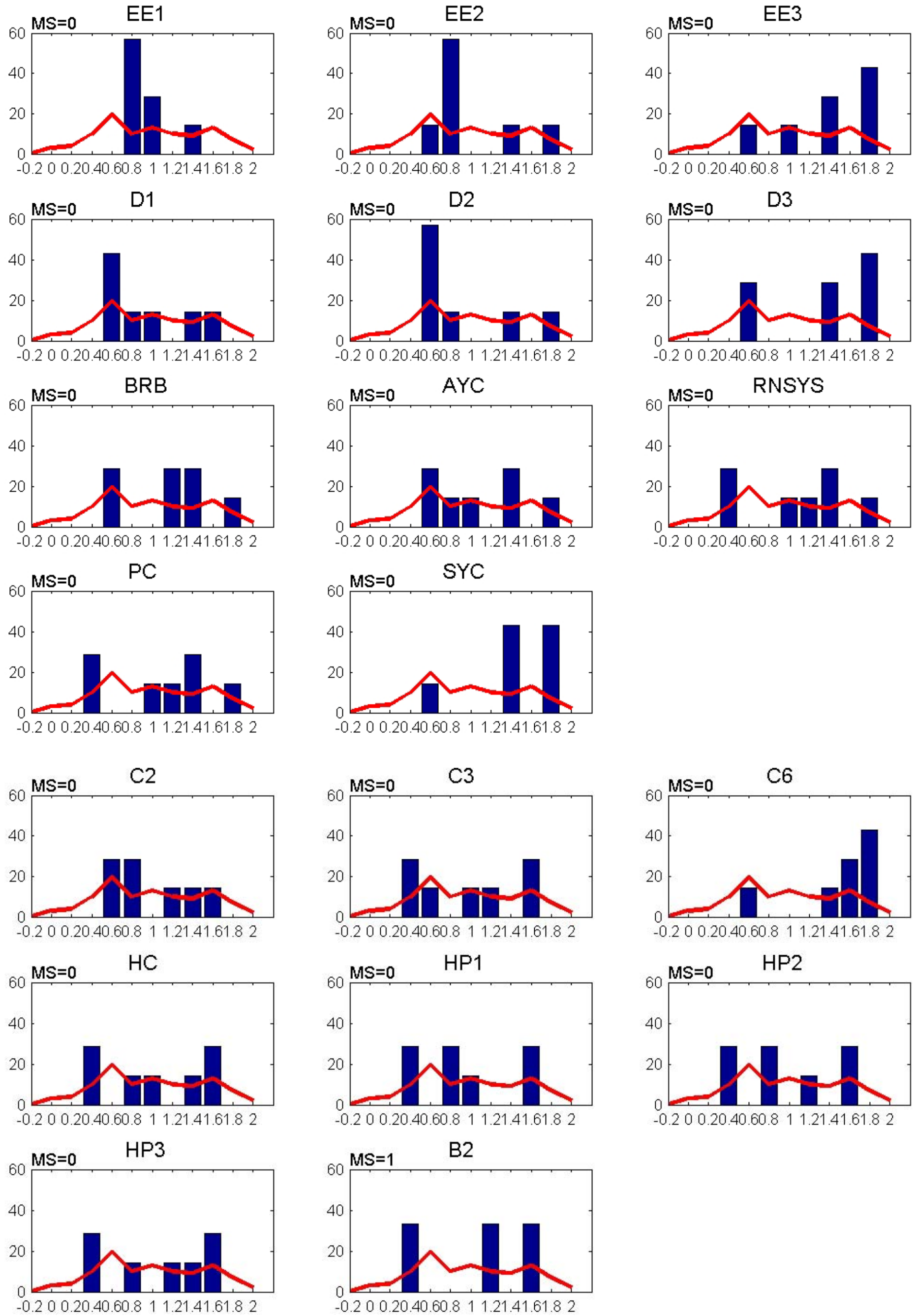

Figure 4b. Water level distribution at each site during sampling 26 March to 16 June 2008. Note: MS = Missed samples.

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 (26 March to 16 June, 2008). The blue bars on this plot represent a similar analysis performed for sampling days only. The plot indicates a fair weather bias this quarter, with most larger rainfall events (>20 mm) being missed. Significant bypass of sewage to combined sewage overflows (CSOs) starts at about 30 mm of rainfall.

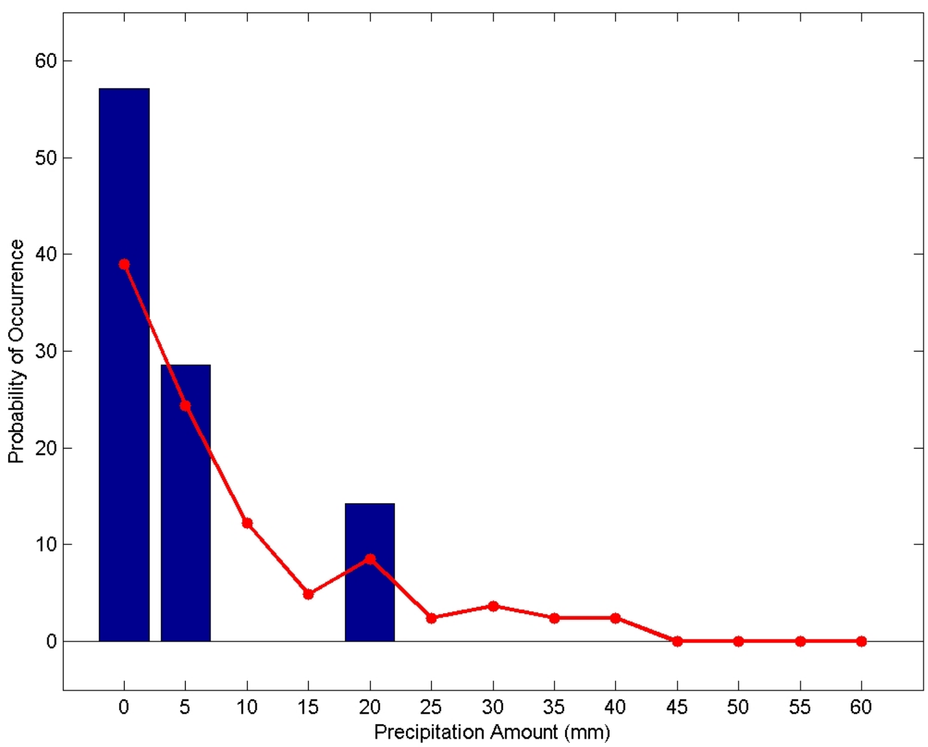

Figure 5. Probability distribution of cumulative 72 hour rainfall, 26 March to 16 June 2008.

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. The Halifax sewage treatment plant is operating at full capacity and after the first survey the UV disinfection system is fully operational.

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.

4.1.2 Quarterly Means

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 sixteenth 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.

Remarkably, the only site with a geometric mean greater than 200 cfu/100 mL is site EE3 at 1 m. This site is the closest site to the Peace Pavilion outfall in Dartmouth. Outside of the Inner Harbour most of the sites have geometric means less than 14 cfu/100 mL. The exceptions are the 10m sample in the centre of the Basin that are slightly higher and the HP sites that are still affected by the Tribune Head outfall.

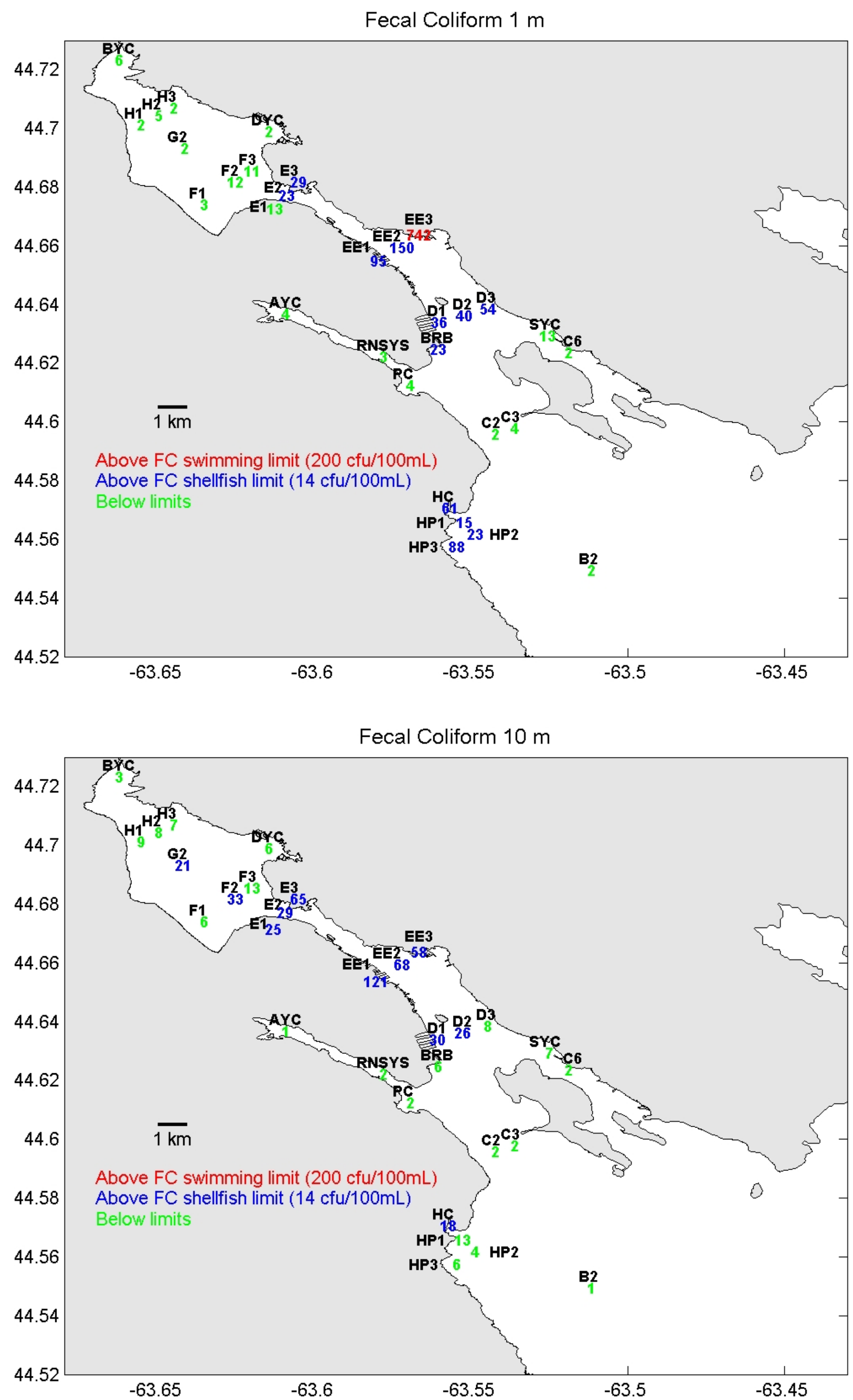

Figure 6. Fecal coliform geometric means (cfu/100mL) at 1m and 10m, 26 March to 16 June 2008.

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. The results are remarkable in that after the first survey, except at site EE3, there are hardly any occurrences of “unacceptable” water quality

<u>Task Force Guidelines</u>

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, normally 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 there is only a single class SB guideline exceedance at BRB. 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) virtually never meets the SA guideline and the HP sites seldom meet the SA guideline. The plume from the Tribune Head outfall periodically affects these sites. 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
Survey152	4 (3)	26 (3)	51 (3)	57 (3)	69 (3)	6 (2)	44 (3)	6 (3)	4 (3)	2 (3)	6 (2)	87 (2)	210 (3)	98 (3)	102 (3)
Survey153	4 (3)	29 (3)	283 (3)	79 (3)	126 (3)	6 (2)	28 (3)	4 (3)	2 (3)	8 (3)	2 (2)	4 (2)	108 (3)	87 (3)	93 (3)
Survey154	1 (3)	19 (3)	216 (3)	171 (3)	93 (3)	3 (3)	4 (3)	2 (3)	2 (3)	10 (3)	3 (3)	13 (3)	16 (3)	20 (3)	32 (3)
Survey155	1 (3)	18 (3)	29 (3)	136 (3)	115 (3)	1 (3)	1 (3)	1 (3)	1 (3)	5 (3)	3 (3)	8 (3)	6 (3)	22 (3)	29 (3)
Survey156	1 (2)	42 (3)	8 (3)	146 (3)	141 (3)	1 (3)	1 (3)	1 (3)	1 (3)	2 (3)	2 (3)	10 (3)	4 (3)	23 (3)	21 (3)
Survey157	1 (2)	8 (3)	3 (3)	67 (3)	67 (3)	2 (3)	1 (3)	3 (3)	3 (3)	3 (3)	1 (3)	2 (3)	13 (3)	103 (3)	40 (3)
Survey158	1 (2)	7 (3)	8 (3)	86 (3)	29 (3)	2 (3)	1 (3)	5 (3)	8 (3)	4 (3)	1 (3)	6 (3)	9 (3)	21 (3)	21 (3)

	Inner Harbour							Bedford Basin								
	D3	EE1	EE2	EE3	E1	E2	E3	F1	F2	F3	DYC	G2	H1	H2	H3	BYC
Survey152	227 (3)	286 (3)	314 (3)	3153 (3)	28 (3)	25 (3)	19 (3)	13 (3)	7 (3)	6 (3)	6 (2)	6 (3)	2 (2)	6 (3)	3 (3)	15 (3)
Survey153	60 (3)	143 (3)	300 (3)	503 (3)	6 (3)	20 (3)	26 (3)	7 (3)	9 (3)	7 (3)	3 (3)	6 (3)	2 (2)	6 (3)	3 (3)	9 (3)
Survey154	7 (3)	81 (3)	121 (3)	1058 (3)	4 (3)	16 (3)	32 (3)	2 (3)	5 (3)	11 (3)	1 (3)	2 (3)	2 (3)	1 (3)	1 (3)	2 (3)
Survey155	10 (3)	77 (3)	80 (3)	189 (3)	3 (3)	12 (3)	22 (3)	1 (3)	6 (3)	12 (3)	1 (3)	1 (3)	1 (3)	1 (3)	1 (3)	1 (3)
Survey156	13 (3)	196 (3)	65 (3)	462 (3)	15 (3)	26 (3)	51 (3)	1 (3)	33 (3)	27 (3)	1 (3)	1 (3)	2 (3)	4 (3)	1 (3)	4 (3)
Survey157	94 (3)	53 (3)	118 (3)	686 (3)	10 (3)	35 (3)	65 (3)	1 (3)	84 (3)	23 (3)	2 (3)	1 (3)	5 (3)	15 (3)	2 (3)	8 (3)
Survey158	67 (3)	39 (3)	135 (3)	686 (3)	20 (3)	38 (3)	61 (3)	1 (3)	40 (3)	16 (3)	2 (3)	1 (3)	5 (3)	15 (3)	2 (3)	17 (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.

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
Survey152	2 (3)	40 (3)	2 (3)	2 (3)	27 (3)	3 (2)	11 (3)	8 (3)	6 (3)	2 (3)	6 (2)	12 (2)	44 (3)	71 (3)	22 (3)
Survey153	1 (3)	3 (3)	3 (3)	3 (3)	49 (3)	3 (2)	7 (3)	4 (3)	4 (3)	2 (3)	5 (2)	11 (2)	25 (3)	58 (3)	55 (3)
Survey154	1 (3)	8 (3)	2 (3)	3 (3)	25 (3)	2 (3)	3 (3)	2 (3)	2 (3)	1 (3)	4 (3)	9 (3)	12 (3)	77 (3)	31 (3)
Survey155	1 (3)	9 (3)	5 (3)	8 (3)	34 (3)	1 (3)	1 (3)	1 (3)	1 (3)	1 (3)	2 (3)	4 (3)	3 (3)	36 (3)	26 (3)
Survey156	1 (2)	22 (3)	5 (3)	15 (3)	20 (3)	1 (3)	1 (3)	1 (3)	1 (3)	1 (3)	2 (3)	3 (3)	3 (3)	32 (3)	12 (3)
Survey157	1 (2)	15 (3)	10 (3)	37 (3)	21 (3)	1 (3)	1 (3)	1 (3)	1 (3)	1 (3)	1 (3)	4 (3)	2 (3)	26 (3)	25 (3)
Survey158	1 (2)	6 (3)	6 (3)	16 (3)	6 (3)	1 (3)	1 (3)	1 (3)	1 (3)	1 (3)	1 (3)	8 (3)	2 (3)	11 (3)	31 (3)

	Inner Harbour							Bedford Basin								
	D3	EE1	EE2	EE3	E1	E2	E3	F1	F2	F3	DYC	G2	H1	H2	H3	BYC
Survey152	16 (3)	450 (3)	25 (3)	157 (3)	32 (3)	23 (3)	53 (3)	23 (3)	14 (3)	19 (3)	12 (2)	14 (3)	6 (2)	15 (3)	25 (3)	11 (3)
Survey153	31 (3)	336 (3)	97 (3)	93 (3)	28 (3)	14 (2)	54 (3)	18 (3)	39 (3)	12 (3)	5 (3)	19 (3)	6 (2)	5 (3)	8 (3)	9 (3)
Survey154	24 (3)	172 (3)	77 (3)	41 (3)	13 (3)	10 (2)	50 (3)	6 (3)	20 (3)	12 (3)	3 (3)	13 (3)	8 (3)	4 (3)	2 (3)	3 (3)
Survey155	8 (3)	81 (3)	93 (3)	20 (3)	23 (3)	72 (2)	128 (3)	3 (3)	62 (3)	19 (3)	3 (3)	49 (3)	8 (3)	7 (3)	2 (3)	2 (3)
Survey156	2 (3)	92 (3)	76 (3)	29 (3)	28 (3)	88 (3)	136 (3)	2 (3)	44 (3)	25 (3)	9 (3)	28 (3)	11 (3)	13 (3)	6 (3)	1 (3)
Survey157	2 (3)	48 (3)	264 (3)	55 (3)	111 (3)	96 (3)	110 (3)	3 (3)	81 (3)	11 (3)	7 (3)	34 (3)	11 (3)	7 (3)	8 (3)	1 (3)
Survey158	4 (3)	49 (3)	135 (3)	60 (3)	22 (3)	20 (3)	41 (3)	3 (3)	41 (3)	6 (3)	6 (3)	13 (3)	10 (3)	4 (3)	7 (3)	1 (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. The laboratory "reportable detection limit" (RDL) for ammonia nitrogen is 0.05 mg/L. For the purpose of computing statistics, the RDL/2, or 0.025 mg/L was used for values below detection. Missed samples are excluded from the calculations.

Ammonia nitrogen has consistently been present at levels that are around the detection limit of 0.05 mg/L. This quarter 60% of samples had detectable concentrations. Overall, there does not appear to be a simple correlation between ammonia concentrations and meteorological events/oceanographic conditions, as is seen in the coliform data.

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
152 (26 Mar 08)	ND	ND	ND	ND	ND	0.05	ND	0.03	0.06
153 (9 Apr 08)	ND	0.06	0.07	ND	0.05	0.06	ND	0.05	0.07
154 (22 Apr 08)	0.06	0.05	0.06	0.06	0.05	0.05	0.06	0.06	0.06
155 (6 May 08)	0.06	0.05	0.06	0.06	0.05	0.05	0.06	0.06	0.06
156 (21 May 08)	missed	0.09	0.08	ND	0.07	0.07	0.14	0.08	0.14
157 (4 Jun 08)	ND	0.06	0.14	0.06	ND	ND	0.07	0.06	0.14
158 (16 Jun 08)	ND	ND	ND	ND	ND	ND	ND	ND	ND
mean	0.04	0.05	0.07	0.04	0.04	0.05	0.06	0.05	
max	0.06	0.09	0.14	0.06	0.07	0.07	0.14		0.14

10m	B2	D2	EE2	E2	F2	G2	H2	mean	max
152 (26 Mar 08)	ND	ND	0.06	ND	ND	0.05	ND	0.03	0.06
153 (9 Apr 08)	ND	0.06	0.07	ND	0.05	0.06	0.06	0.05	0.07
154 (22 Apr 08)	0.06	0.06	0.06	0.06	0.06	0.06	0.05	0.06	0.06
155 (6 May 08)	0.06	0.06	0.06	0.06	0.06	0.06	0.05	0.06	0.06
156 (21 May 08)	missed	0.08	0.09	ND	ND	0.07	ND	0.05	0.09
157 (4 Jun 08)	0.06	0.08	0.07	ND	0.05	0.07	0.07	0.06	0.08
158 (16 Jun 08)	ND	ND	ND	ND	ND	ND	ND	ND	ND
mean	0.04	0.06	0.06	0.04	0.04	0.06	0.04	0.05	
max	0.06	0.08	0.09	0.06	0.06	0.07	0.07		0.09

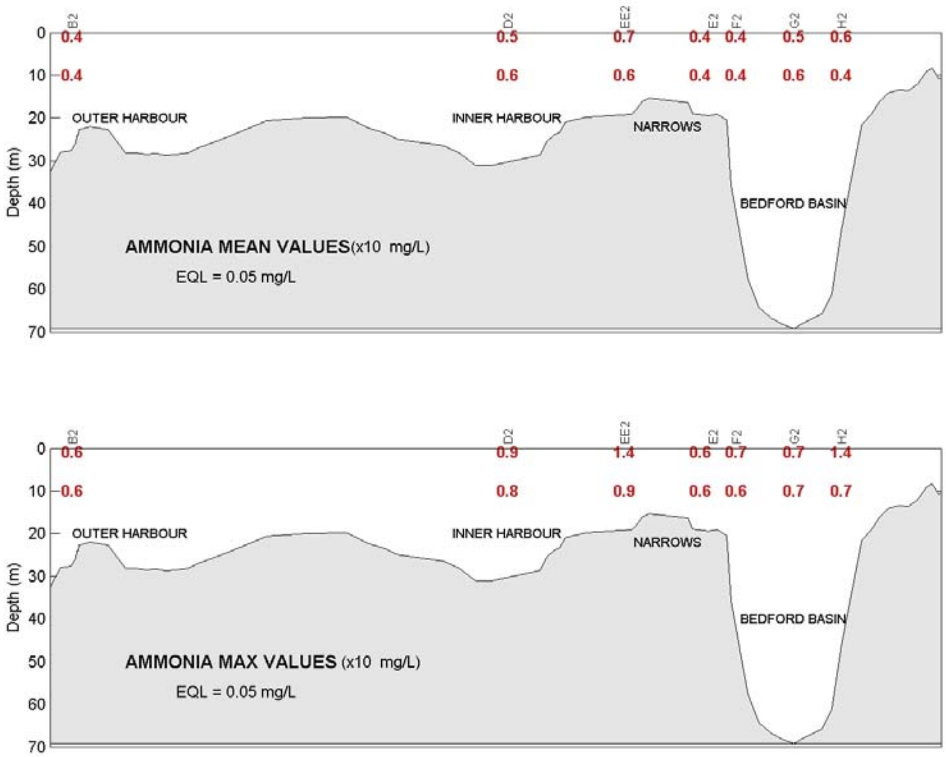

Figure 7. Mean and maximum values of ammonia nitrogen (X10 mg/L) over all sixteenth quarter samples

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. There has been no $CBOD_5$ analysis this quarter.

4.4 Total Suspended Solids

A summary of the TSS values for this quarter is shown in Table 7. There were no samples that were below the RDL of 0.5 mg/L. The quarterly mean and max values are plotted by station in Figure 8. There is some temporal variability; about a factor of two or more in survey mean values. Overall, as with ammonia, there does not appear to be a simple correlation between TSS concentrations and meteorological events/oceanographic 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 visually and are usually documented in field notes.

Table 7. Summary of TSS data (mg/L).

1m	B2	D2	EE2	E2	F2	G2	H2	mean	max
152 (26 Mar 08)	1.0	5.0	3.7	2.0	2.6	3.0	4.0	3.0	5.0
153 (9 Apr 08)	1.0	4.4	3.4	2.7	2.7	3.5	4.0	3.1	4.4
154 (22 Apr 08)	5.6	3.7	9.1	6.5	5.4	6.0	5.9	6.0	9.1
155 (6 May 08)	5.6	3.7	9.1	6.5	5.4	6.0	5.9	6.0	9.1
156 (21 May 08)	missed	2.8	0.5	2.0	2.0	2.0	2.1	1.9	2.8
157 (4 Jun 08)	4.0	3.0	3.0	5.0	9.0	3.0	4.0	4.4	9.0
158 (16 Jun 08)	2.3	1.1	2.1	3.2	5.5	2.7	4.7	3.1	5.5
mean	3.3	3.4	4.4	4.0	4.7	3.7	4.4	3.9	
max	5.6	5.0	9.1	6.5	9.0	6.0	5.9		9.1

10m	B2	D2	EE2	E2	F2	G2	H2	mean	max
152 (26 Mar 08)	2.6	3.0	2.0	4.0	3.6	4.3	4.0	3.4	4.3
153 (9 Apr 08)	1.7	4.0	4.0	4.0	4.0	4.0	4.5	3.7	4.5
154 (22 Apr 08)	6.0	3.8	3.1	4.0	6.7	7.1	4.6	5.0	7.1
155 (6 May 08)	6.0	3.8	3.1	4.0	6.7	7.1	4.6	5.0	7.1
156 (21 May 08)	missed	3.0	4.0	2.0	2.0	1.7	1.1	2.3	4.0
157 (4 Jun 08)	5.0	5.0	3.9	6.0	4.0	5.4	8.6	5.4	8.6
158 (16 Jun 08)	1.1	2.4	4.0	2.8	3.3	5.7	3.0	3.2	5.7
mean	3.7	3.6	3.4	3.8	4.3	5.0	4.3	4.0	
max	6.0	5.0	4.0	6.0	6.7	7.1	8.6		8.6

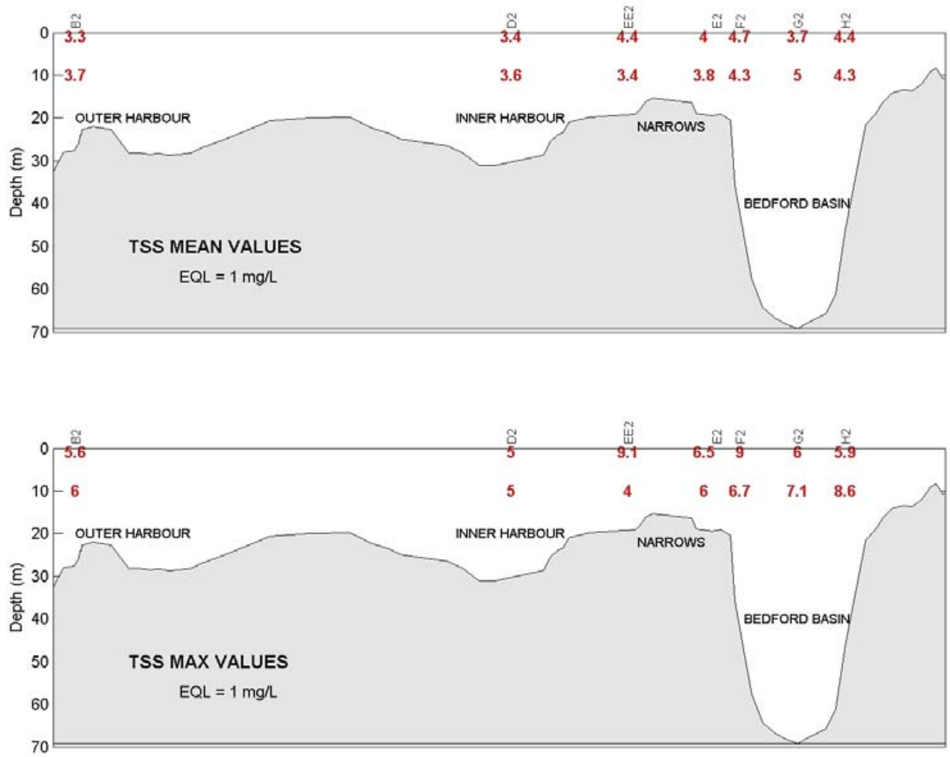

Figure 8. Mean and maximum values of total suspended solids (mg/L) over all sixteenth quarter samples.

4.5 Total Oils and Grease

Based on recommendations in Quarterly Report 5 regular sampling for total oil and grease was discontinued in, survey 73 (23 Nov 06). The analysis is retained for supplemental samples. This quarter there has been no total oil and grease analysis.

4.6 Metals

The results of the metals analysis are summarized in Figure 9. For this plot the non-detectable values are considered zero. Through the whole quarter there were no guideline exceedances in regular samples. The guidelines for copper, lead and mercury were exceeded in the supplemental surface sample at F2. There was a concentration of copper equal to the guideline in one of the extra samples taken in Dartmouth Cove (DC). Aside from these samples this plot shows that of the metals for which guidelines exist copper, manganese and zinc regularly have detectable levels. Lead, nickel and mercury 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 typical mean values under 20% of the guideline.

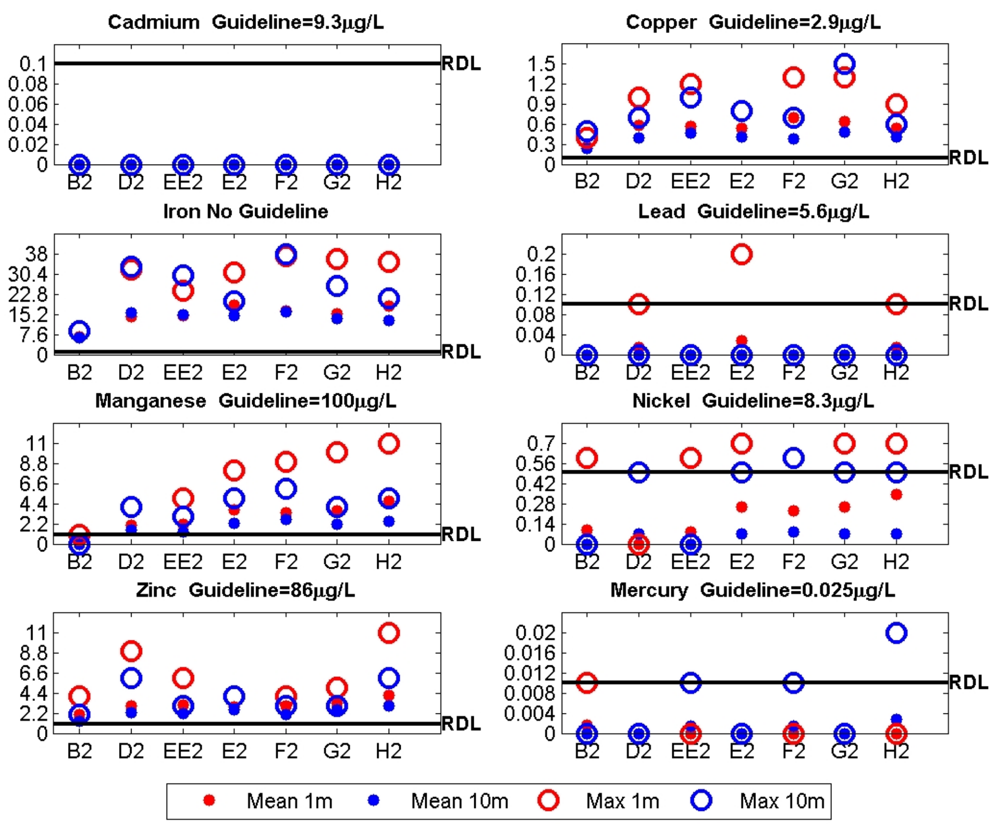

Figure 9. Mean and maximum values of metals (µg/L) over all sixteenth quarter samples.

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 are continued in the annual summary section of every fourth quarterly report (12, 16 and 20). See the Appendix of this report.

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 variable moderate phytoplankton activity (max values 10-20 mg/m^3) punctuated by a relatively intense bloom documented in survey 153 (9 Apr 08). This had maximum values of approximately 60 mg/m^3.

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. Starting with survey 151 (11 Mar 2008) near surface DO concentrations have been measured using a handheld, easily calibrated, YSI DO meter. This data combined with available data from the BBPMP and the LOBO data buoy in the NW Arm, are used to calculate a scale factor for the CTD data. The YSI data and the scale factor computation are included in the individual survey reports.

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. Based on the appropriately scaled HHWQMP data; there were no guideline exceedances this quarter. Unusually the Basin bottom water started the quarter with well oxygenated bottom water. The levels dropped throughout the quarter but remained just above the 7.0 mg/L guideline by the end of the quarter.

4.8 Supplemental Sample

F2

On survey 155 (6 May 08) a supplementary sample was taken in the southern Basin at the regular F2 survey site. This was a surface (dip) sample of a particularly dirty surface feature (Figs 9 -12). The feature appeared to be a linear front where near surface material was collecting. It was a relatively large feature stretching for at least 100m. The nature of most of the material was difficult to determine, but there was definitely both marine and land based detritus. There were seemingly dead or dying jellyfish (aurelius) just under the surface. The lab results are shown in Table 8. The sample had extremely high TSS and high ammonia and metals. All metals had detectable levels and there were three guideline exceedances: copper (5 x guideline), lead (1.3 x guideline) and mercury (1.6 x guideline). There is no guideline for Iron, but the value was 50 - 100 times the concentration in the regular samples.

Figure 10. Surface feature at site F2

Figure 11. Close up #1, surface feature at F2.

Figure 12. Close up #2, surface feature at F2.

Figure 13. Close up #3, surface feature at F2.

Table 8. Lab results for the F2 surface sample.

	UNITS	F2 surface	RDL
BACTERIA			
Fecal Coliform	cfu/100mL	120	1
INORGANICS			
Nitrogen (Ammonia Nitrogen)	mg/L	0.19	0.05
Total Suspended Solids	mg/L	120	0.5
METALS WITH GUIDELINES			
Cadmium (Cd)	ug/L	0.2	0.1
Copper (Cu)	ug/L	14.4	0.1
Lead (Pb)	ug/L	7.3	0.1
Manganese (Mn)	ug/L	43	1
Mercury (Hg)	ug/L	0.04	0.01
Nickel (Ni)	ug/L	1.6	0.5
Zinc (Zn)	ug/L	33	1
METALS WITH NO GUIDELINES			
Cobalt (Co)	ug/L	0.3	0.1
Iron (Fe)	ug/L	580	1

Dartmouth Cove

Extra samples were taken at the DC site during surveys 157 (4 Jun 08) and 158 (16 Jun 08). There was a temporary sewage diversion into the Cove. Both samples showed considerably reduced water quality. The sample in survey 157 had the highest observed ammonia and TSS concentrations in the survey. The concentrations of mercury, and iron were the highest in the survey, but there was no guideline exceedance. The fecal coliform concentration, though generally modest, was very high in a survey with relatively low values everywhere. The sample in survey 158 was even more remarkable. The ammonia concentration was very high, particularly since it was the only sample with a detectable concentration in the survey. The TSS concentration was not particularly high, but was the highest observed in the survey. The copper, iron, manganese and mercury concentrations were the highest observed, with copper just at the 2.9 ug/L guideline. The out of range (>10,000 cfu/100 mL) coliform concentration stands out in a survey where there were no other values in excess of 200 cfu/100 mL.

Table 9. Lab results for Dartmouth Cove.

	UNITS	04-Jun-08 08:58 ADT	16-Jun-08 15:45 ADT	RDL
BACTERIA				
Fecal Coliform	cfu/100mL	410	>10,000	1
INORGANICS				
Nitrogen (Ammonia Nitrogen)	mg/L	0.17	1.4	0.05
Total Suspended Solids	mg/L	14	7	0.5
METALS WITH GUIDELINES				
Cadmium (Cd)	ug/L	ND	ND	0.1
Copper (Cu)	ug/L	0.7	2.9	0.1
Lead (Pb)	ug/L	ND	ND	0.1
Manganese (Mn)	ug/L	8	7	1
Mercury (Hg)	ug/L	0.02	0.02	0.01
Nickel (Ni)	ug/L	0.6	ND	0.5
Zinc (Zn)	ug/L	3	7	1
METALS WITH NO GUIDELINES				
Cobalt (Co)	ug/L	0.1	ND	0.1
Iron (Fe)	ug/L	43	23	1

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.

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. Starting at the end of quarter 15, near-surface DO measurements have been made using a handheld YSI DO meter. This is used to ground truth the CTD DO sensor. The sampling sites remain as at 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 this quarter the Halifax Sewage Treatment Plant, probably aided by the natural fecal coliform (sunlight) variability and possibly a dry weather bias to sampling, has resulted in very (relatively) low fecal coliform values. There is only one site in the Inner Harbour with geometric mean fecal coliform concentrations greater than 200 cfu/100 mL. The only real guideline exceedance is the class SA guideline near the Tribune Head outfall in the Outer Harbour.

As of quarter 10, there has been periodic additional bacteria monitoring initiated in the Northwest Arm. The purpose is to establish storm-induced transients in the Arm. This is not strictly part of this project and the data is reported under separate cover. However, the monitoring includes surface samples for both fecal coliform and enterococci. This data will allow a comparison of the two tracers and if desired to evaluate the use of fecal coliform for a proxy for enterococci in the Harbour. 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.

Changes

- None

Ammonia Nitrogen

Ammonia nitrogen has consistently been present at levels that are around the detection limit of 0.05 mg/L. The reason for the temporal variability is not clear. There does not seem to be a simple correlation between ammonia concentrations and meteorological/oceanographic conditions, as is evident in the coliform data.

Ammonia nitrogen is an attractive tracer as it is routinely monitored in sewage treatment facilities and, therefore, has quantifiable source strength in sewage. Recognizing nitrogen as the key nutrient in marine systems, and the potential importance that nutrients have in the Harbour oxygen dynamics, additional species of nitrogen should continue to be considered for monitoring.

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. There was no $CBOD_5$ monitoring this quarter.

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 at times higher values that seem to be associated with more extreme events (e.g. storms, plankton blooms etc). These events are generally identifiable visually and are usually documented in field notes. The only clear spatial pattern is that the TSS is generally lower in the outer harbour at B2.

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 Nov 05), due to lack of detection. It is retained in supplemental sample analysis. There was no TOG monitoring this quarter.

Changes
- None

Metals

In general the metals with guidelines are present at levels well below the guidelines. The metal that is consistently closest to exceeding the guideline is copper. In this quarter the mean copper values are less than 20% of the 2.9 µg/L guideline. There were no guideline exceedances in regular samples. There were guideline exceedances in the supplemental samples taken in the southern Basin and Dartmouth Cove.

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 there was variable phytoplankton activity. In one survey there was a relatively intense bloom. Other than this, the fluorescence levels were variable and moderate.

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. The appropriately scaled HHWQMP data indicates that there were no exceedances of applicable guidelines this quarter, even in the Basin bottom water.

Changes

- None

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Halifax Harbour
Water Quality Monitoring Program
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APPENDIX

Annual Summary Year Four

4 July 2007 - 16 June 2008

March 2010

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1 Introduction

The following is a summary of data from year four, from 4 July 2007 through 16 June 2008. It includes information provided in Quarterly Reports 13 through 16. There is a very large amount of information in this data bearing on oceanographic and water quality processes in the Harbour. The detailed process-oriented analysis of this data is beyond the scope of a monitoring program, but some discussion of these processes is included. The focus of this summary is with the compliance/exceedance of existing water quality guidelines as developed by the Halifax Harbour Task Force (1990).

2 Hydrographic Data

The temperature and salinity data reflect the dynamic state of the harbour and therefore represent a base from which to interpret the water quality data. To some extent the temperature and salinity, and resultant density stratification, in Halifax Harbour vary predictably on seasonal timescales. The surface water generally warms in spring and summer, reaching a maximum in late August or early September, and cools in fall and winter (minimum late February early March). The surface salinity is low with spring freshet in the Sackville River and other tributaries. On top of the seasonal signal is a large amount of variability, mostly on a meteorological timescale (days to weeks). Large rainfall events cause freshening of the harbour similar in magnitude to the freshet anytime throughout the year. Wind forcing directly on the harbour can push surface water either up or down harbour for days at a time resulting in local upwelling or downwelling and enhanced vertical mixing. On a larger scale, the passage of weather systems/storms on the continental shelf can cause larger scale upwelling or downwelling along the coast. Upwelling pushes colder saltier bottom water into the harbour forcing the warmer fresher harbour water out of the harbour in a surface layer. Downwelling is the reverse. These two layer events are very effective in exchanging harbour water and can result in rapid changes in water properties.

Perhaps the most oceanographically interesting feature of the Halifax Harbour is Bedford Basin. The Basin is a fiord. The near surface water (<20-30 m) exchanges freely with the remainder of the harbour and to a large extent reflects conditions there. The deep water (up to 70m) is relatively isolated by a sill (20-25 m) in the Narrows and is only renewed periodically by the upwelling of dense continental shelf bottom water over the sill. This water displaces and/or mixes with the existing bottom water. As a result of this mechanism, the bottom water in the Basin is normally denser than any water in the remainder of the harbour, reflecting its origins in deeper continental shelf water. These renewals can be seen in the salinity and temperature data, but often the most telling signature of this phenomenon is the dissolved oxygen of the deep bottom water. Under normal conditions, the dissolved oxygen in this water drops as oxygen is consumed by decomposing organic matter, present in the sediments and "raining" down from the surface water. With time, the dissolved oxygen can become very low. The water in an intrusion is generally well oxygenated and dramatically increases the DO. The DO therefore tends to reflect the time since the previous renewal. Between intrusions vertical diffusion slowly decreases the bottom water density by mixing with less dense overlying water. Historical information (i.e. The BBPMP) indicates that these events occur on average once or twice a year in Bedford Basin. Less intense upwelling can occur more often, resulting in intrusion at intermediate depth in the Basin. All intrusions can have surface signatures as the deeper, generally colder, more saline, water is displaced upward and flushed out in the surface layer.

The salinity and temperature data from station B2 in the centre of Bedford Basin, for the year including quarters 13, 14, 15 and 16 are shown in Figure 1. The temperature data shows the seasonal temperature trend in the surface water with a maximum temperature of about 18º C at the end of August and a minimum of less than 2º C in the beginning of March. There are five upper water column “freshening” events, due to precipitation /snowmelt evident in the salinity data.

In both data sets the effects of intrusions, characterized by abrupt changes in water properties, is apparent. Particularly evident in the salinity data is the large intrusion of very saline water in mid December.

3 Fluorescence

The fluorescence data collected by the CTD is a proxy for chlorophyll and can be used to get a relative sense of primary productivity (See Section 4.8 in the main report). The units of the values discussed here are mg/m^3 as generated by the CTD data processing software, but should not be interpreted strictly as biomass measurements.

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 fluorescence observed (though not always at G2) and is representative of the timing of phytoplankton activity in the remainder of the harbour. Figure 2 shows the time series of fluorescence profiles in the centre of the Basin (site G2). This shows relatively continuous moderate to high activity throughout the summer and into the fall (quarters 13 and 14). There is a relatively intense bloom at the beginning of November followed by a decline and relatively low levels throughout the winter until the spring bloom begins in March.

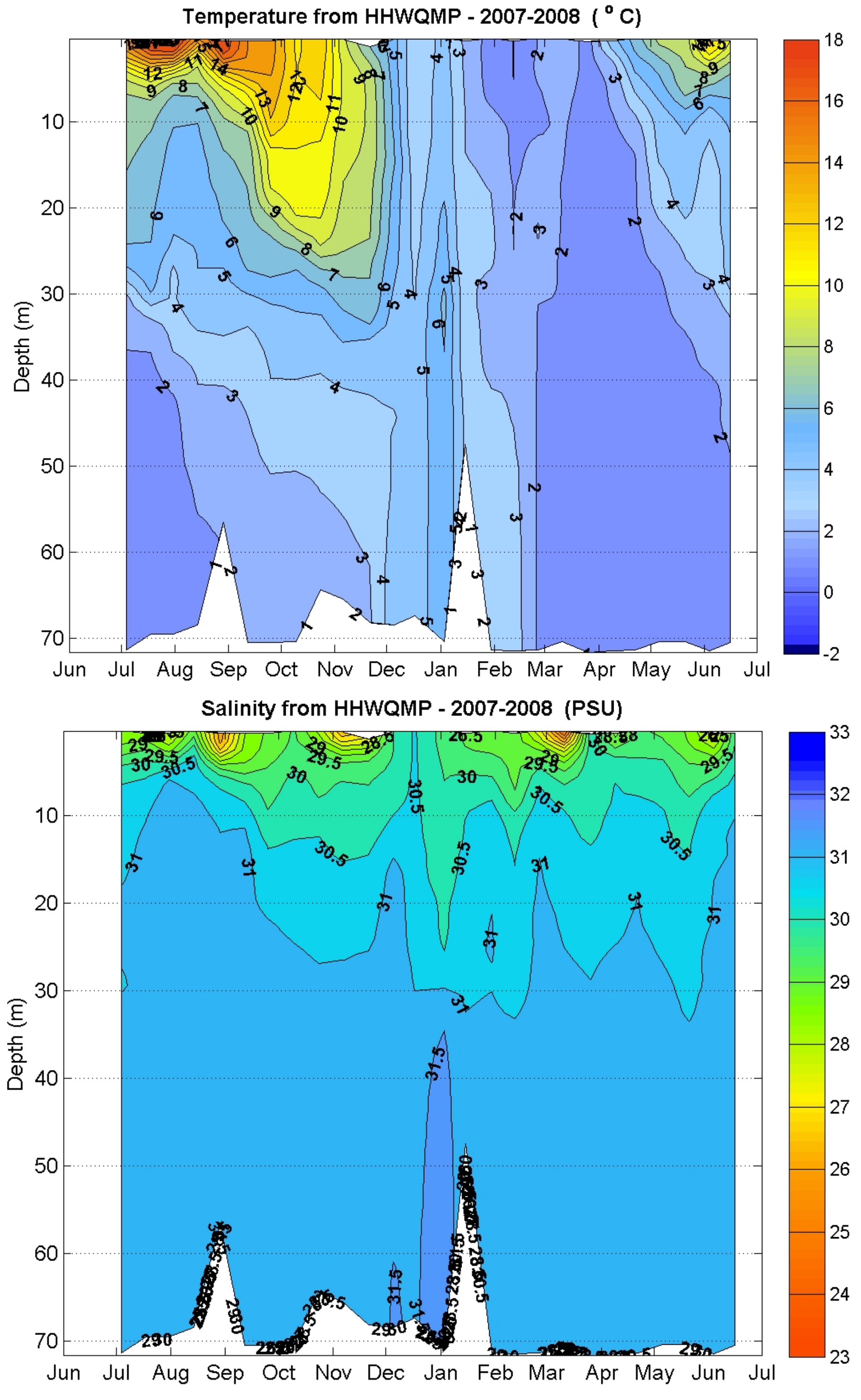

Figure 1. HHWQMP temperature and salinity data from Station G2 (4 July 2007 to 16 June 2008).

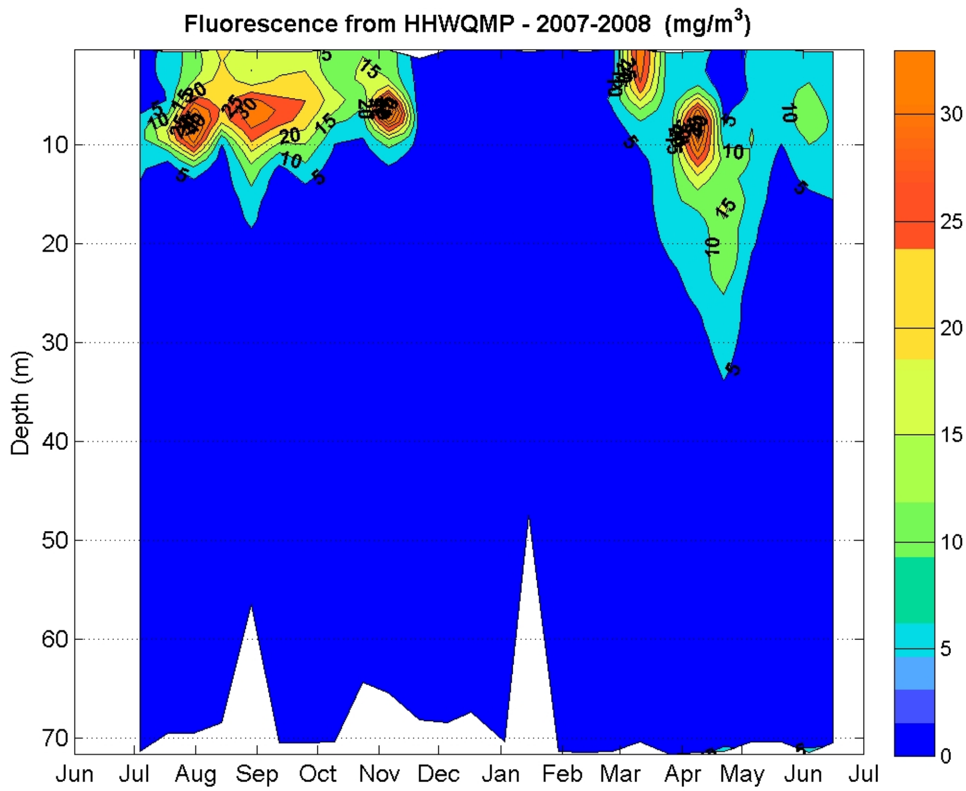

Figure 2. HHWQMP fluorescence data from Station G2 (4 July 2007 to 16 June 2008).

During blooms, particularly in summer, maximum concentrations generally occur in Bedford Basin. In the Inner Harbour, the typical profile maximum values are about half those in the Basin. In the Outer Harbour the profile maximum values are lower still, usually 3-4 mg/ m^3. Consistent with the previous year it appears that, while there is a definite spring bloom, phytoplankton activity continues sporadically throughout the spring, summer and fall, until activity ceases due to lack of light in the late fall and winter.

4 Dissolved Oxygen

During this period the regular collection of additional surface dissolved oxygen (DO) levels began. Starting in survey 151 (11 Mar 08) DO measurements were made with a YSI handheld dissolved oxygen (DO) meter at selected sites on every survey. In addition, every survey the CTD was deployed adjacent to the LOBO data buoy in the Northwest Arm. The real-time and archived LOBO data is available on-line (lobo.satlantic.com). Throughout the program the DO data at station G2 has been compared to that at the nearby BBPMP site (discussed in all quarterly reports). The data from these three sources is used to ground truth /verify the Seabird CTD DO every survey. The results are quite good; with the computed corrections, it appears that the Seabird values are generally equal to or slightly lower than the BBPMP deep-water value. The DO in this water generally changes more slowly than elsewhere, serving to minimize the effect of slight variations in location and timing of sampling.

There are several issues to consider in the interpretation of the DO data in Figure3. The most obvious is the three survey gap in the DO profiles (survey 147, 15 Jan 08, through survey 149, 12 Feb 08). During this period the CTD DO senor failed and required unscheduled maintenance. Surface DO measurements were made but there were no profiles. In addition, prior to survey 151 (11Mar 08) the DO data is un-scaled. Comparison with supplemental data suggests that this data should be scaled by approximately 1.3. As of survey the data is scaled by the formally computed weekly scale factors presented in the survey reports. This results in the apparent discontinuity in early March.

4.1 Harbour and Basin Surface Water

There are spatial variations in dissolved oxygen in any survey. These patterns vary from survey to survey depending on the dynamic state of the Harbour. Sometimes these patterns are significant, but most of the time the spatial variations are small compared to the large-scale temporal variations. The general trends can be seen in the upper portion (top 20-25 m) of the Basin time series contours in Figure 3. The general trends throughout the harbour are therefore reflected in the upper portion (top 20-25 m) of the Basin time series contours in Figure 3. This plot shows that July through December the surface water was well oxygenated but the vertical gradient is quite steep. The discontinuity in scaling makes the plot a bit difficult to interpret; however by April-May the top 10m are uniform and essentially saturated.

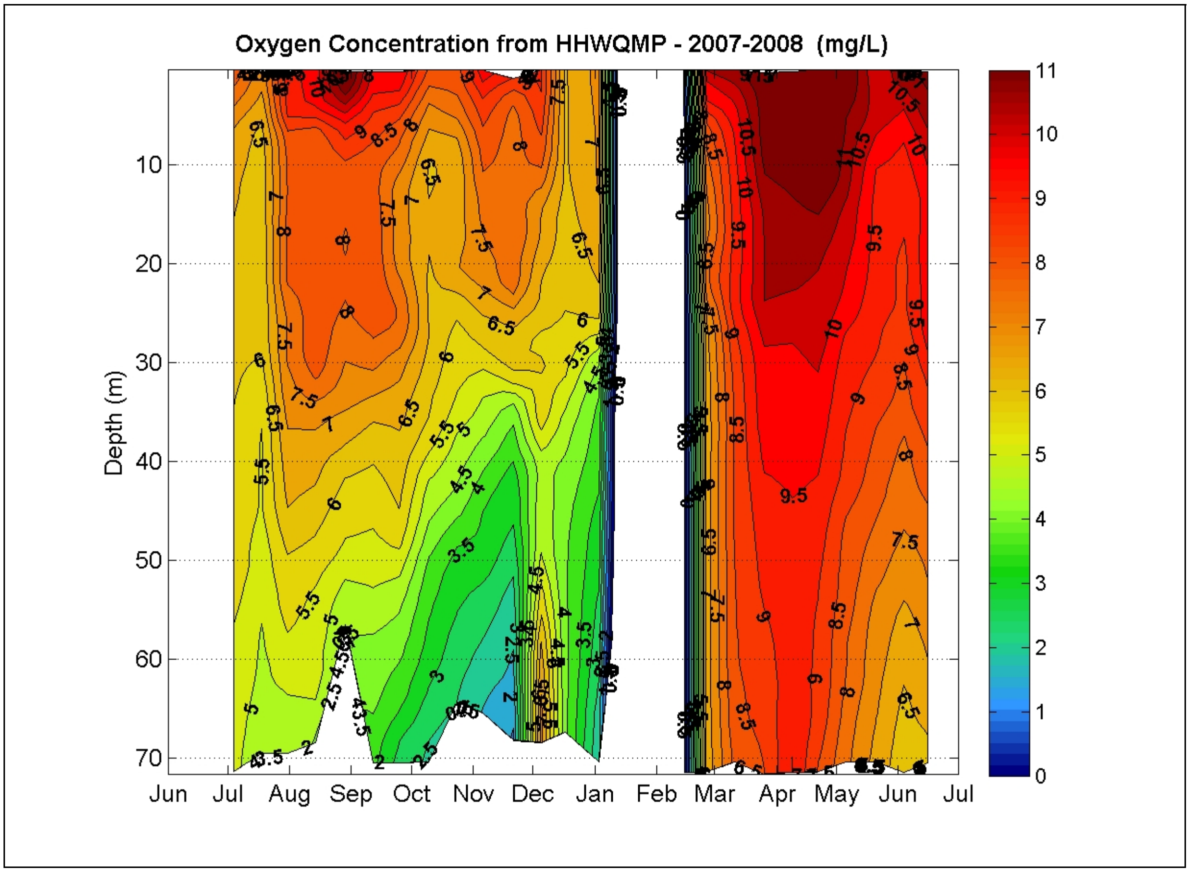

Figure 3. HHWQMP dissolved oxygen data from Station G2 (4 July 2007 to 16 June 2008).

4.2 Bedford Basin Bottom Water

The dissolved oxygen in the Bedford Basin bottom water (Figure 3) generally responds to different processes than the surface water (Section 5.1). On occasion, but not always, the signature of an intrusion can be seen in the near-surface water as the oxygen depleted bottom water is displaced upward and flushed out of the harbour. The reason this is not always seen is likely due to mixing with the larger volume of surface water.

This water only rarely has dissolved oxygen above the Class SB guideline (7.0 mg/L). At the beginning of this period the DO monotonically decreases over time until early December. At this time an intrusion briefly brings the DO (scaled by 1.3) up above the 7.0 mg/L level. In the spring, the DO throughout the water column becomes quite high and, unusually, the bottom water remains above the 7.0 mg/L level from mid-February through mid-May.

5 Fecal Coliform

5.1 Geometric Means

During this year the Halifax STP was brought on-line. At the beginning of the period there was a diversion of sewage from the Duffus St. outfall to the Fairview Cove CSO. This flow was directed to the plant by 1 November 2007. Connections continued until the final connections that diverted the flow from Chain Rock outfall to the plant was completed in mid-February 2008. The UV disinfection system was in sporadic operation until it was brought fully on-line in April 2009. These events created large variations in the sewage load (magnitude and distribution) masking many of the more subtle processes usually evident in the data. Maps showing the annual geometric mean fecal coliform concentrations at 1 and 10 m are presented in Figure 4. The key characteristics of the distribution are that the highest concentrations are in the Inner Harbour, specifically the EE section, in both the 1 and 10 m samples. This is consistent with the distribution of outfalls in the Harbour. Even with the modifications underway the seasonal variation remains relatively consistent with previous years, that is, the concentrations tend to be greater in the fall and winter. The trend for lower values in the spring is obviously emphasized by the UV system coming on line. The resulting concentrations are remarkably low.

The familiar vertical pattern of higher values in the 10m in the Basin and in the 1m samples in the Inner Harbour seems to have been disrupted to large degree, This may have to do with the diffused outfall at the STP putting more effluent into the lower water column.

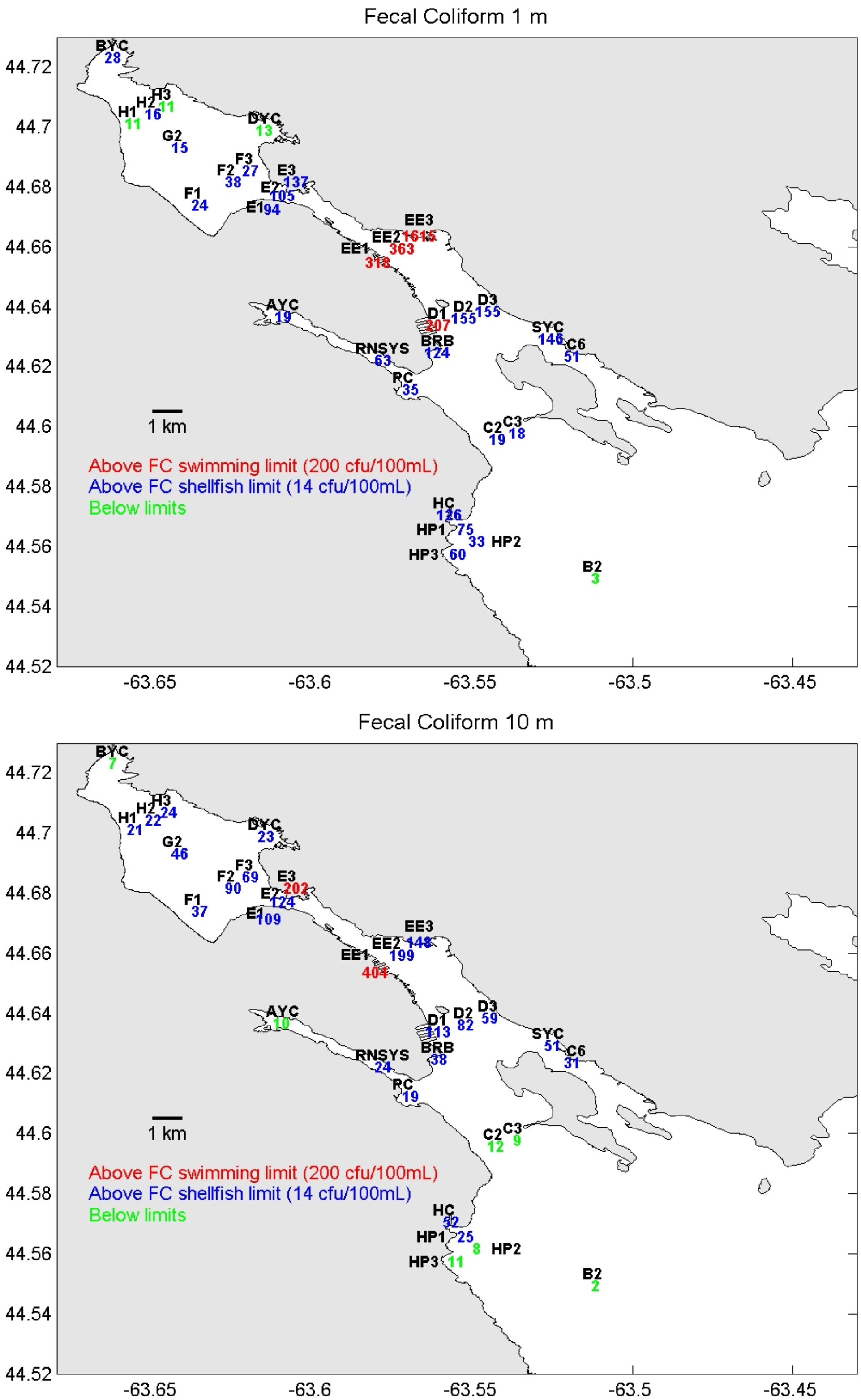

Figure 4. Fecal coliform annual geometric means (cfu/100mL), 4 July 2007 to 16 June 2008.

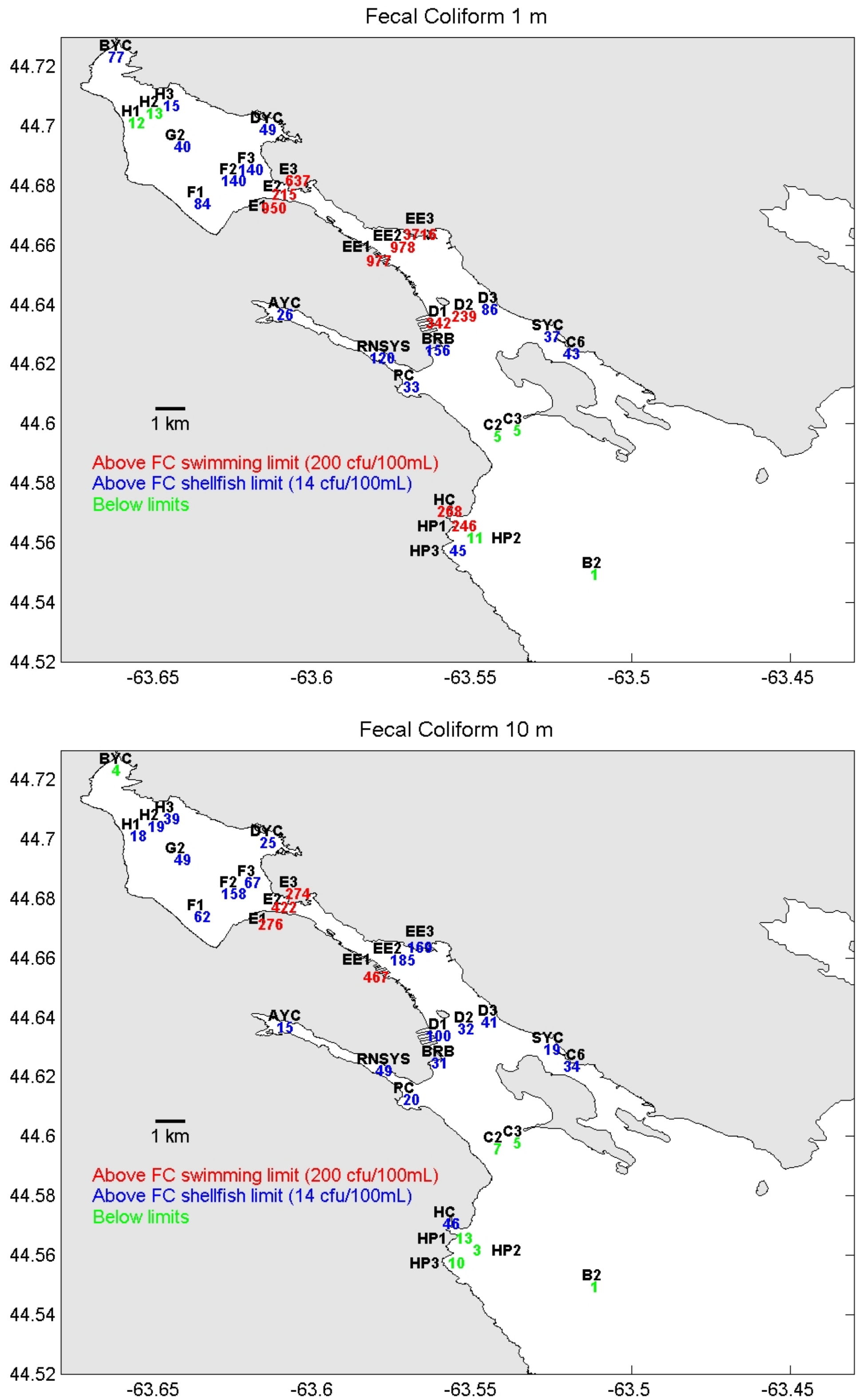

Figure 5. Fecal coliform geometric means (cfu/100mL), summer 2007 (4 July to 12 September 2007).

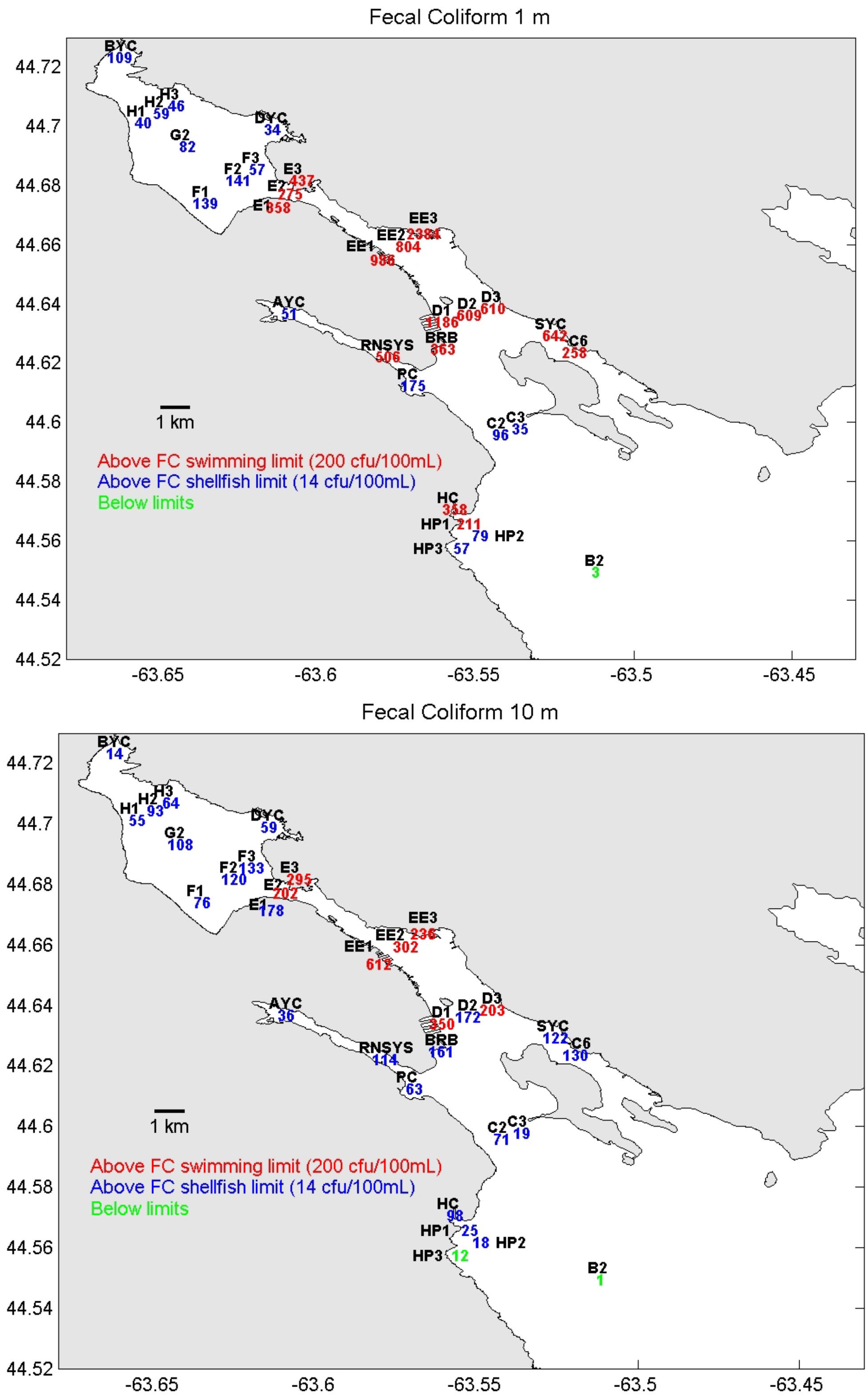

Figure 6. Fecal coliform geometric means (cfu/100mL), fall 2007 (25 September to 17 December 2007).

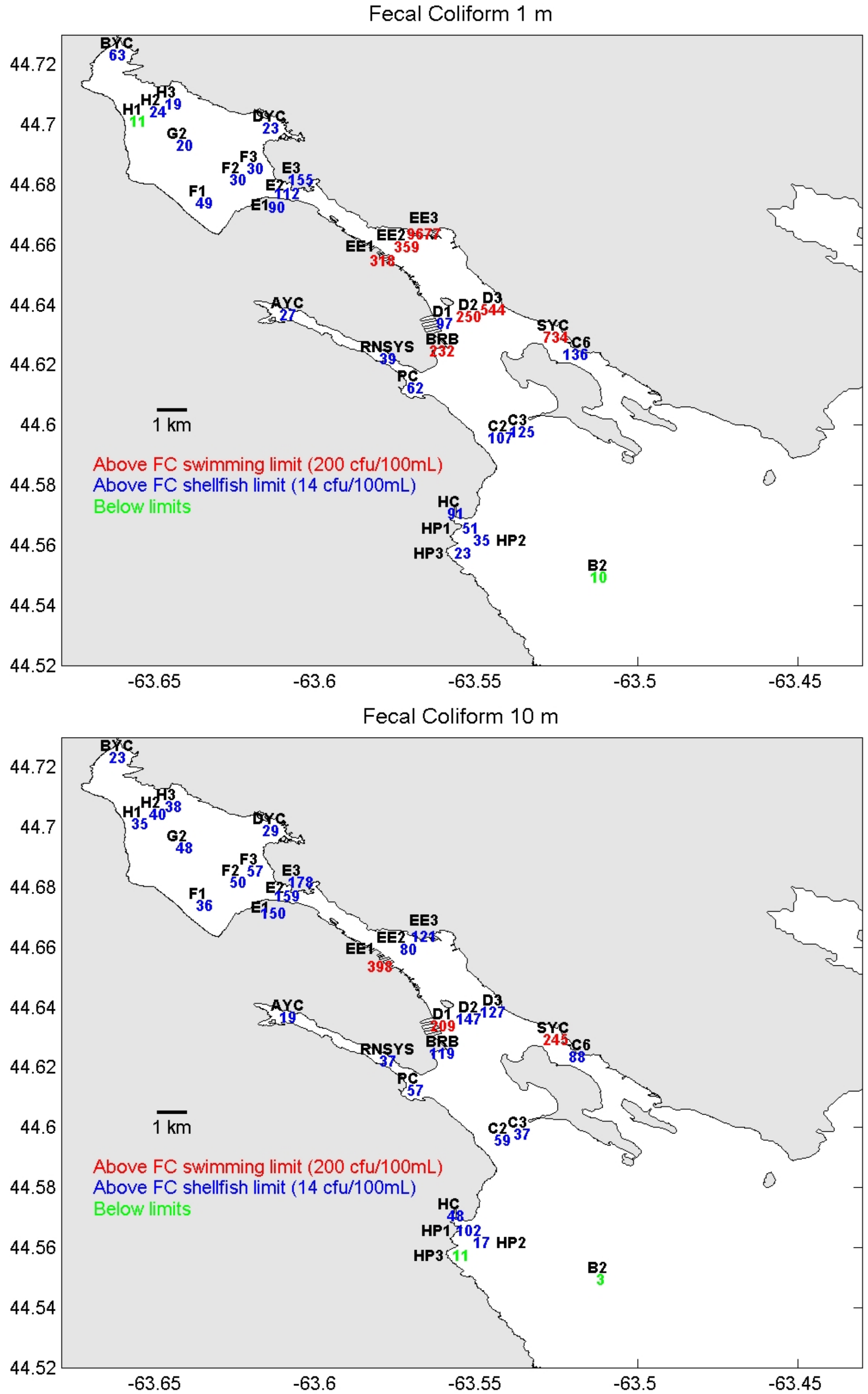

Figure 7. Fecal coliform geometric means (cfu/100mL), winter 2008 (3 January to 11 March 2008).

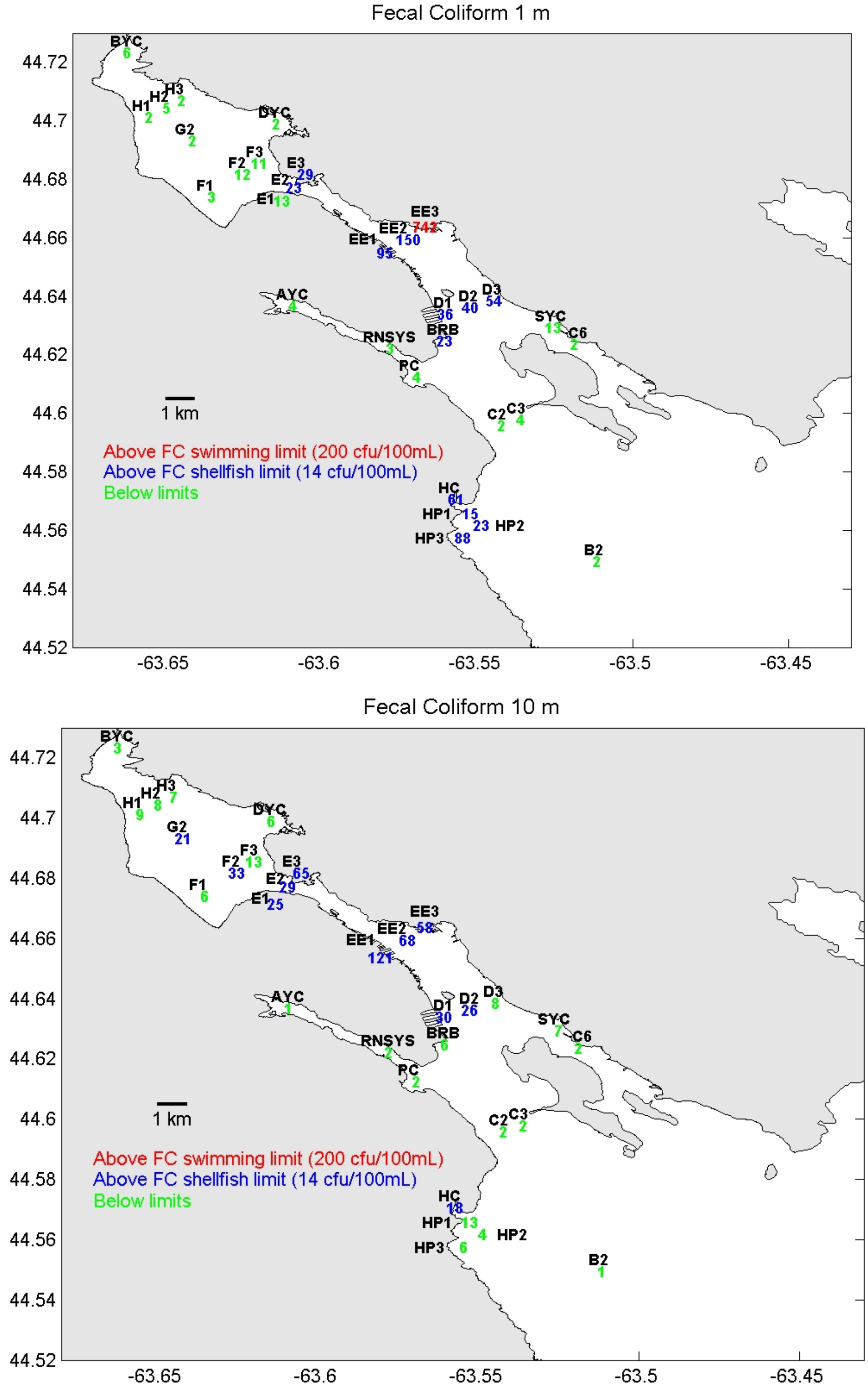

Figure 8. Fecal coliform geometric means (cfu/100mL), spring 2008 (26 March to 16 June 2008).

5.2 Thirty Day Floating Means

These seasonal trends are also evident in the floating thirty-day geometric mean, compiled for the entire year here in Tables 1 and 2. Particularly notable is the increase in bacteria concentration in the fall and winter. There is also significant survey to survey variability in the bacteria concentrations. This is likely mostly due to the higher frequency variability in harbour flushing on the meteorological timescale (3-5 days).

Table 1. 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
Survey133	1	271	5	18	165	4	11	12	40	6	59	270	347	465	69
Survey134	1	65	4	9	89	7	17	117	104	10	23	201	63	586	65
Survey135	12	224	18	21	72	5	33	120	192	95	80	99	188	186	121
Survey136	40	254	18	85	155	10	15	174	1243	163	396	88	158	572	124
Survey137	40	341	17	350	234	14	10	33	416	32	175	59	255	1362	166
Survey138	1	258	7	116	278	9	2	26	219	21	11	23	72	2265	191
Survey139	1	208	20	50	497	8	4	19	266	20	18	48	156	1076	373
Survey140	1	451	49	53	281	10	4	65	1635	56	137	326	311	3628	589
Survey141	4	139	361	74	373	72	28	419	1546	38	1777	1678	651	2608	1528
Survey142	2	171	616	314	373	322	94	958	2260	41	2363	5400	687	2216	1560
Survey143	4	211	469	239	506	963	522	1110	773	82	1097	1916	728	1110	2080
Survey144	19	551	34	121	511	701	246	656	1080	115	467	979	575	737	690
Survey145	19	266	40	12	251	332	120	287	216	155	396	429	447	699	389
Survey146	21	62	35	9	201	253	86	157	205	196	217	321	295	255	176
Survey147	3	28	114	21	148	254	142	109	147	116	308	1024	266	202	201
Survey148	12	69	110	72	163	347	220	149	151	126	71	1129	236	202	263
Survey149	5	60	56	56	47	216	264	89	42	26	139	1322	191	35	468
Survey150	5	24	28	29	20	27	79	47	18	9	56	811	165	31	316
Survey151	5	21	16	22	23	7	82	16	4	2	140	822	158	22	271
Survey152	4	26	51	57	69	6	44	6	4	2	6	87	210	98	102
Survey153	4	29	283	79	126	6	28	4	2	8	2	4	108	87	93
Survey154	1	19	216	171	93	3	4	2	2	10	3	13	16	20	32
Survey155	1	18	29	136	115	1	1	1	1	5	3	8	6	22	29
Survey156	1	42	8	146	141	1	1	1	1	2	2	10	4	23	21
Survey157	1	8	3	67	67	2	1	3	3	3	1	2	13	103	40
Survey158	1	7	8	86	29	2	1	5	8	4	1	6	9	21	21

	Inner Harbour							Bedford Basin								
	D3	EE1	EE2	EE3	E1	E2	E3	F1	F2	F3	DYC	G2	H1	H2	H3	BYC
Survey133	27	351	373	5138	175	97	242	32	19	14	7	3	5	4	4	6
Survey134	53	252	310	820	35	15	56	13	9	14	11	3	4	2	2	6
Survey135	23	384	363	216	214	44	61	16	8	18	55	12	6	7	9	3
Survey136	87	405	554	135	397	288	121	33	39	98	86	102	10	14	21	38
Survey137	173	392	701	323	1594	791	178	73	81	156	94	386	13	38	50	66
Survey138	206	448	939	131	2725	842	416	189	403	156	59	475	24	29	37	558
Survey139	443	432	1297	254	2644	492	836	147	427	86	80	155	47	42	54	128
Survey140	264	948	1297	401	885	298	718	71	194	29	39	95	86	45	60	102
Survey141	1048	2609	2715	15251	510	315	544	70	227	69	27	62	67	55	32	55
Survey142	752	5260	2272	8953	251	305	362	225	151	95	31	155	130	130	61	152
Survey143	989	2737	933	3544	154	524	297	193	156	100	31	100	89	180	85	186
Survey144	537	497	195	2486	59	157	264	195	58	38	19	46	47	75	66	117
Survey145	680	422	176	5963	70	138	276	81	43	26	15	23	11	37	30	66
Survey146	432	224	199	13986	78	134	462	95	39	27	15	21	10	28	25	60
Survey147	598	365	354	12633	102	470	241	49	45	40	19	32	12	43	24	96
Survey148	441	315	291	13904	111	477	226	40	32	44	29	30	22	34	30	106
Survey149	546	363	427	14637	110	196	210	45	54	69	30	37	23	38	29	120
Survey150	596	642	511	19281	126	93	111	24	19	29	31	11	8	9	11	41
Survey151	616	355	566	5006	70	50	45	30	19	19	17	13	5	15	10	35
Survey152	227	286	314	3153	28	25	19	13	7	6	6	6	2	6	3	15
Survey153	60	143	300	503	6	20	26	7	9	7	3	6	2	6	3	9
Survey154	7	81	121	1058	4	16	32	2	5	11	1	2	2	1	1	2
Survey155	10	77	80	189	3	12	22	1	6	12	1	1	1	1	1	1
Survey156	13	196	65	462	15	26	51	1	33	27	1	1	2	4	1	4
Survey157	94	53	118	686	10	35	65	1	84	23	2	1	5	15	2	8
Survey158	67	39	135	686	20	38	61	1	40	16	2	1	5	15	2	17

Note: Red indicates exceedance of swimming criteria (mean >200), yellow denotes "questionable" water quality, (mean < 200, but one or more samples >400), and green indicates compliance with criteria.

Table 2. 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
Survey133	1	18	3	6	69	2	6	28	89	22	48	294	33	58	70
Survey134	1	45	9	20	39	5	6	36	86	18	34	166	31	99	58
Survey135	4	39	6	15	139	3	3	24	44	17	22	30	10	51	24
Survey136	8	26	6	42	175	8	6	31	64	12	60	14	17	130	95
Survey137	8	11	2	11	113	5	7	14	88	6	85	16	11	76	38
Survey138	1	5	2	5	20	16	5	10	87	10	46	16	27	163	59
Survey139	1	3	2	2	50	34	13	17	72	17	53	16	50	124	21
Survey140	1	5	3	2	71	77	9	105	123	38	80	51	218	371	163
Survey141	3	25	13	6	184	67	9	155	138	36	159	110	371	473	492
Survey142	2	53	51	17	176	77	9	231	189	50	147	176	415	682	675
Survey143	3	106	111	35	214	125	28	103	114	56	181	219	221	434	488
Survey144	1	91	55	92	265	175	76	155	166	81	192	402	223	407	338
Survey145	1	97	60	44	106	138	65	65	108	53	279	661	204	504	354
Survey146	3	51	34	32	58	161	48	89	205	64	180	512	321	537	293
Survey147	3	70	38	15	37	104	57	50	118	50	199	494	201	329	278
Survey148	5	171	59	38	82	75	76	117	93	44	67	271	171	244	149
Survey149	3	225	26	13	60	58	93	112	21	17	100	311	133	257	265
Survey150	4	588	17	4	31	22	28	85	11	6	35	82	65	147	96
Survey151	3	84	3	1	17	15	14	25	6	3	48	70	41	72	63
Survey152	2	40	2	2	27	3	11	8	6	2	6	12	44	71	22
Survey153	1	3	3	3	49	3	7	4	4	2	5	11	25	58	55
Survey154	1	8	2	3	25	2	3	2	2	1	4	9	12	77	31
Survey155	1	9	5	8	34	1	1	1	1	1	2	4	3	36	26
Survey156	1	22	5	15	20	1	1	1	1	1	2	3	3	32	12
Survey157	1	15	10	37	21	1	1	1	1	1	1	4	2	26	25
Survey158	1	6	6	16	6	1	1	1	1	1	1	8	2	11	31

	Inner Harbour							Bedford Basin								
	D3	EE1	EE2	EE3	E1	E2	E3	F1	F2	F3	DYC	G2	H1	H2	H3	BYC
Survey133	81	878	161	90	317	884	691	77	315	98	14	63	12	25	40	4
Survey134	50	397	164	56	118	179	222	47	189	35	9	26	24	9	17	3
Survey135	32	438	359	565	47	89	512	66	355	108	35	19	10	4	9	3
Survey136	152	1738	1080	909	128	33	482	463	401	626	60	24	10	4	19	7
Survey137	95	2739	738	843	56	20	464	248	200	699	95	28	5	5	18	7
Survey138	61	1546	383	424	116	135	164	596	104	433	89	62	36	56	66	5
Survey139	35	1169	361	276	238	166	243	87	92	117	75	189	45	88	79	3
Survey140	119	1059	792	733	616	446	385	221	208	216	80	366	61	391	118	4
Survey141	216	1277	1889	943	655	286	567	110	290	452	90	297	31	155	72	14
Survey142	281	609	800	690	244	261	447	155	327	586	132	136	62	157	88	33
Survey143	328	615	497	216	198	254	447	95	141	250	109	82	92	63	76	60
Survey144	579	208	82	61	71	113	148	52	67	47	42	59	70	55	51	38
Survey145	865	322	54	69	97	189	237	33	57	34	21	48	60	58	37	28
Survey146	440	223	61	123	296	188	315	28	44	32	19	38	49	46	33	28
Survey147	197	787	338	158	682	455	430	35	53	85	17	34	49	31	32	24
Survey148	112	527	269	106	502	251	194	32	42	79	24	43	30	28	26	18
Survey149	186	690	361	132	188	215	184	53	92	151	36	73	45	35	31	23
Survey150	84	360	97	170	116	130	131	48	42	71	39	55	21	31	32	20
Survey151	38	360	40	175	67	111	127	43	44	57	61	55	26	44	61	26
Survey152	16	450	25	157	32	23	53	23	14	19	12	14	6	15	25	11
Survey153	31	336	97	93	28	14	54	18	39	12	5	19	6	5	8	9
Survey154	24	172	77	41	13	10	50	6	20	12	3	13	8	4	2	3
Survey155	8	81	93	20	23	72	128	3	62	19	3	49	8	7	2	2
Survey156	2	92	76	29	28	88	136	2	44	25	9	28	11	13	6	1
Survey157	2	48	264	55	111	96	110	3	81	11	7	34	11	7	8	1
Survey158	4	49	135	60	22	20	41	3	41	6	6	13	10	4	7	1

Note: Red indicates exceedance of swimming criteria (mean >200), yellow denotes "questionable" water quality, (mean < 200, but one or more samples >400), and green indicates compliance with criteria.

5.3 Time Series

Figures 9 through 12 show time series of the fecal coliform concentrations at representative sites in the Outer Harbour, NW Arm, Inner Harbour and Bedford Basin. The mean patterns discussed above can be seen as trends in the time series data, namely:

- values are highest in the Inner Harbour
- values tend to be highest in the fall and winter
- The vertical distribution that has become familiar (high at 1m in the Inner Harbour and high at 10 m in the Basin) seems much less robust.

As discussed in quarterly and various weekly reports, the significant week-to-week variations in FC levels and distribution appear to correlate, at least qualitatively, with observed meteorological and oceanographic phenomena. Variations in circulation can displace high bacteria counts either up or down harbour as well as increase or decrease vertical differences and increase or decrease overall concentrations (periods of low or high flushing). The easiest place to see this is in the Outer Harbour at site B2 (Figure 12). The concentrations here are generally <10 cfu/100 mL, but wind/intrusion events that move the surface water out of the harbour are occasionally strong enough to result in quite high concentrations here. In addition to advection and dispersion, cloud cover can reduce bacteria decay rate causing increased concentrations. The seasonal variation is less obvious at sites close to outfalls where the concentration depends more on source strength than mixing/decay.

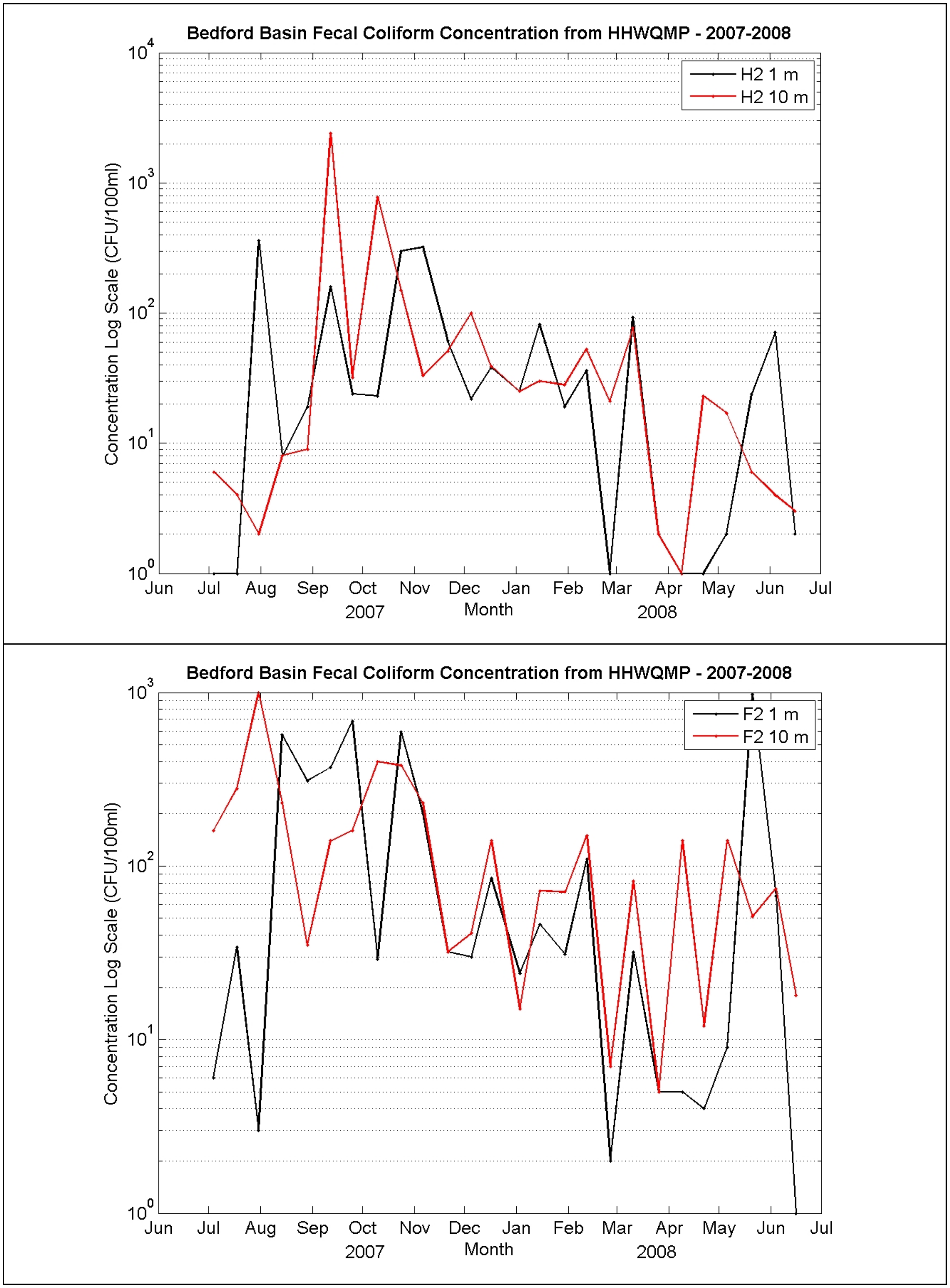

Figure 9. HHWQMP Bedford Basin Fecal Coliform Concentration (4 July 2007 to 16 June 2008).

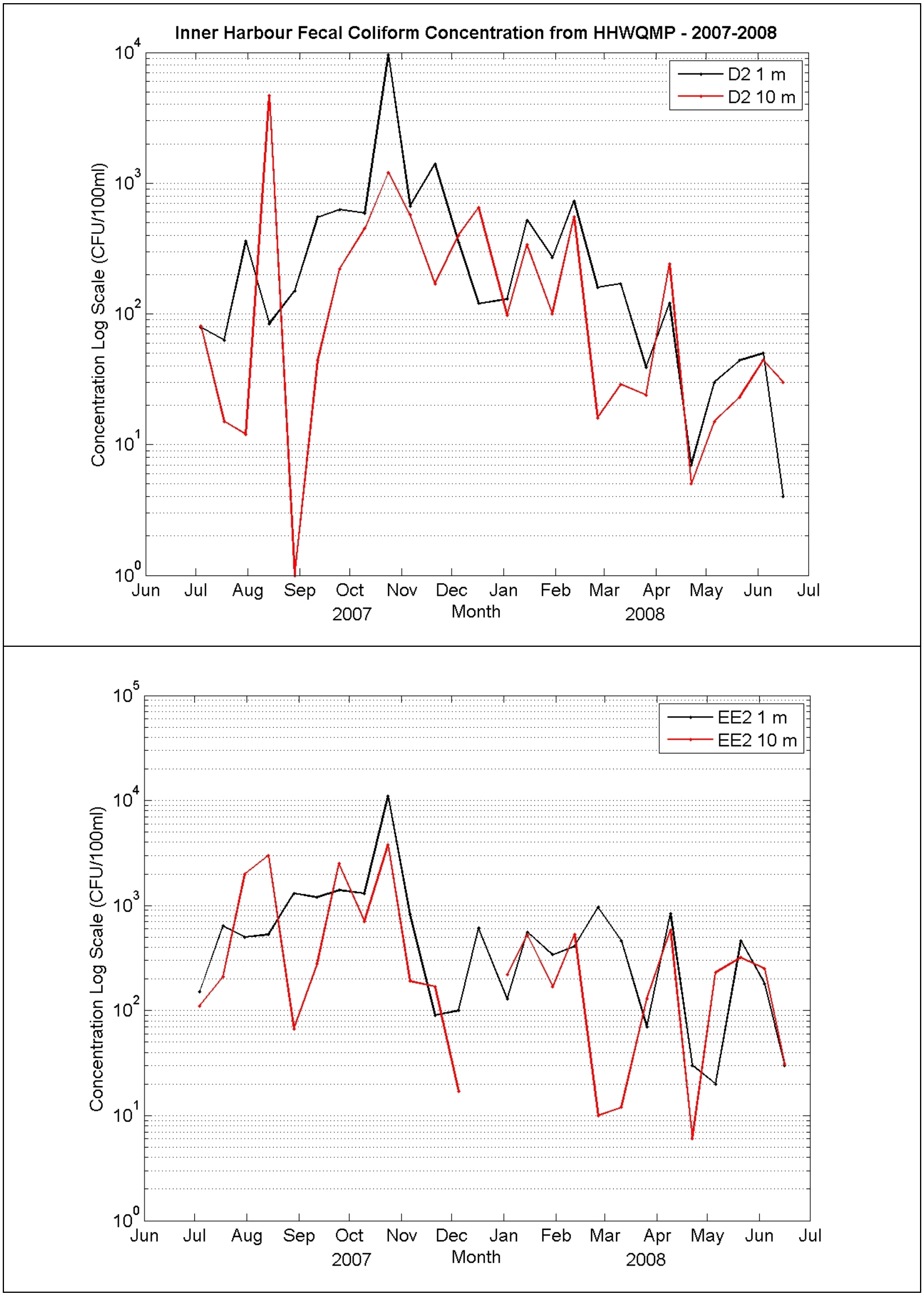

Figure 10. HHWQMP Inner Harbour Fecal Coliform Concentration (4 July 2007 to 16 June 2008).

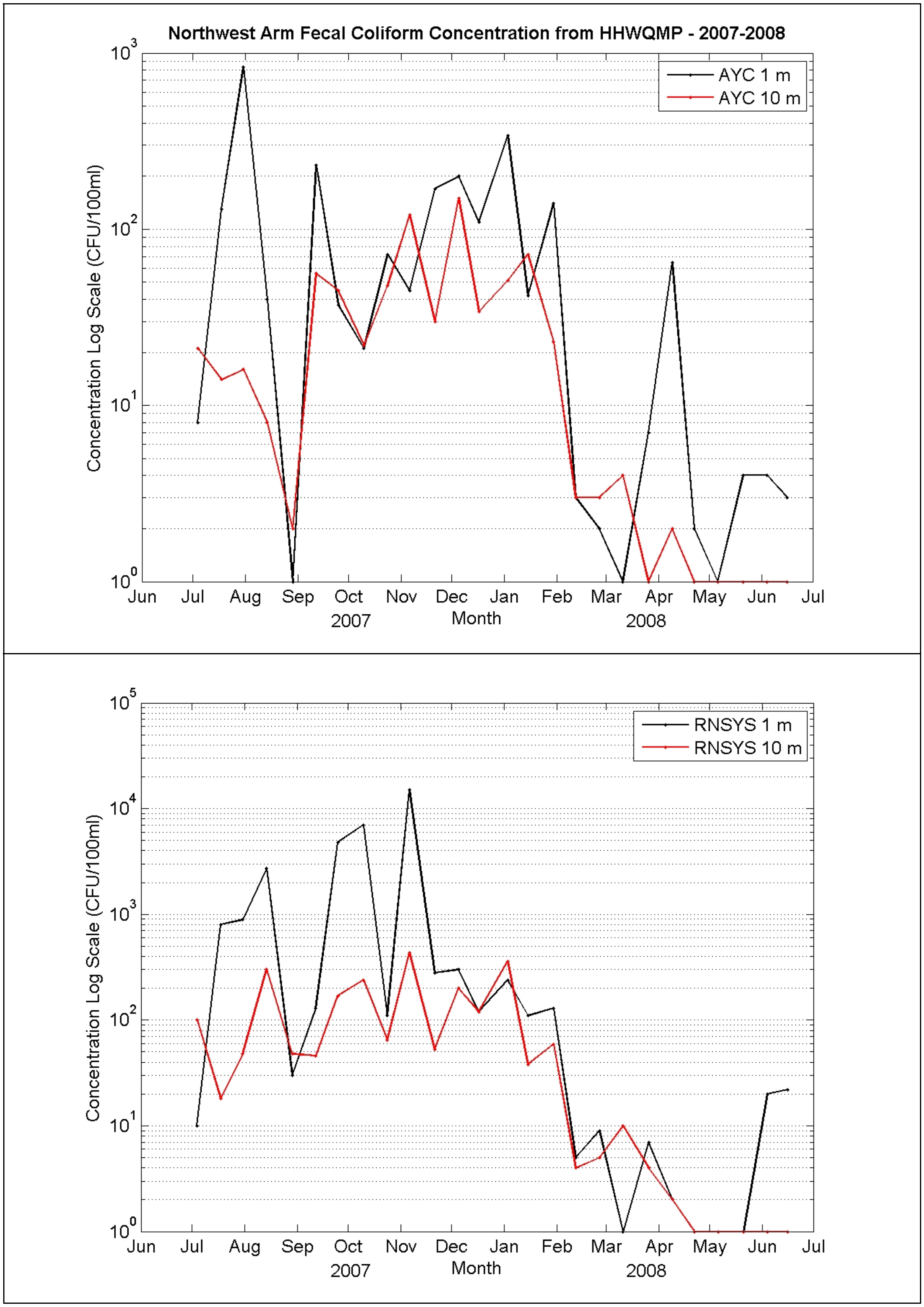

Figure 11. HHWQMP Northwest Arm Fecal Coliform Concentration (4 July 2007 to 16 June 2008).

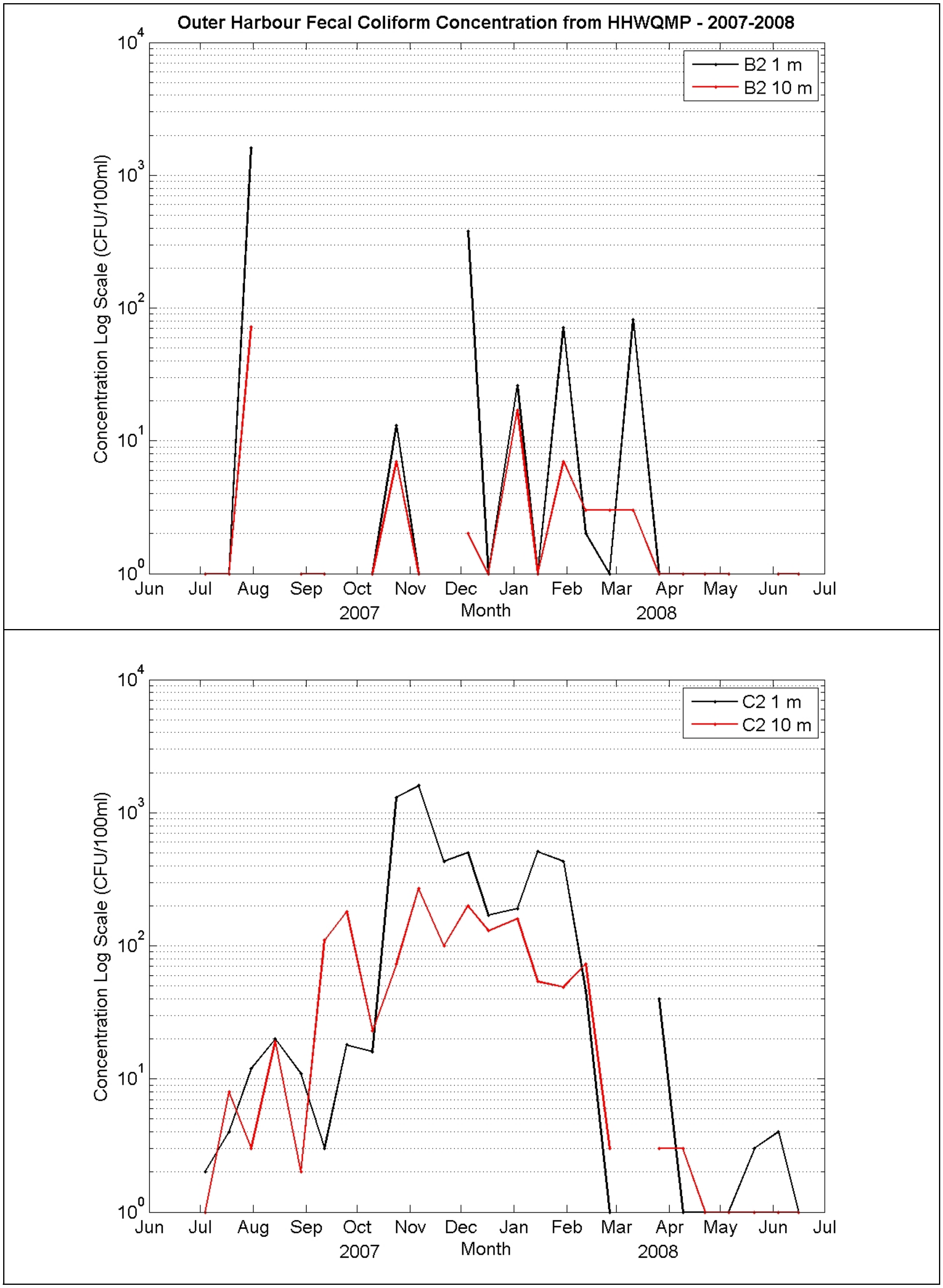

Figure 12. HHWQMP Outer Harbour Fecal Coliform Concentration (4 July 2007 to 16 June 2008).

6 Ammonia Nitrogen

The measured values of ammonia nitrogen at 1 and 10m over the entire fourth year are presented in Tables 3 and 4. Samples that were below the RDL of 0.05 mg/L have been assigned values of 0.025 (RDL/2) for statistical purposes, and are shaded green. Ammonia Nitrogen has consistently been present at levels that are around the detection limit of 0.05 mg/L. The overall mean concentration over the entire year was about 0.07 mg/L. While there are spatial (site to site) variations, there is not a readily discernable pattern, except that the concentrations at B2 (Outer Harbour) are lowest of any site.

There is temporal variability, the survey mean concentrations vary from <0.05 to 0.12 mg/L. There is a single survey (10 Oct) with a mean of about 0.3, but this is skewed by a single high value (2.0 mg/L at B2-1m). Overall, there does not appear to be a simple correlation between ammonia concentrations and meteorological events/oceanographic conditions, as is seen in the coliform data. There does appear to be seasonal component with ammonia concentrations being somewhat higher in the fall and winter. This may be inversely related to phytoplankton activity (fluorescence).

Table 3. Annual Summary of 1 m Ammonia Nitrogen

1 m	B2	D2	EE2	E2	F2	G2	H2	mean	max
4-Jul-07	ND	0.06	ND	0.06	ND	ND	ND	0.04	0.06
18-Jul-07	ND	ND	ND	ND	ND	ND	ND	ND	ND
31-Jul-07	missed	ND	0.06	0.09	0.08	ND	ND	0.05	0.09
14-Aug-07	missed	ND	0.06	0.05	0.09	0.1	0.1	0.07	0.10
29-Aug-07	0.06	0.09	0.05	0.08	0.06	0.07	ND	0.06	0.09
12-Sep-07	0.06	ND	0.07	ND	ND	ND	0.06	0.04	0.07
25-Sep-07	ND	ND	ND	ND	ND	ND	0.06	0.03	0.06
10-Oct-07	2	0.19	0.07	0.81	0.2	0.05	0.07	0.48	2.00
24-Oct-07	0.09	0.1	0.1	0.14	0.09	0.1	0.07	0.10	0.14
6-Nov-07	0.18	0.08	0.08	0.15	0.13	0.07	0.11	0.11	0.18
21-Nov-07	ND	0.09	0.13	0.09	0.11	0.11	0.09	0.09	0.13
5-Dec-07	0.12	0.07	0.08	0.08	0.08	0.08	0.11	0.09	0.12
17-Dec-07	ND	0.07	0.07	0.06	0.06	0.06	0.07	0.06	0.07
3-Jan-08	ND	0.06	0.08	0.07	0.07	0.07	0.08	0.07	0.08
15-Jan-08	ND	0.08	0.17	0.11	0.06	0.09	0.08	0.09	0.17
30-Jan-08	ND	0.07	0.09	0.08	0.07	0.08	0.08	0.07	0.09
12-Feb-08	ND	ND	0.08	0.06	0.06	0.07	0.11	0.06	0.11
26-Feb-08	ND	0.06	0.12	0.05	0.05	0.06	0.07	0.06	0.12
11-Mar-08	ND	ND	ND	ND	ND	ND	ND	ND	ND
26-Mar-08	ND	ND	ND	ND	ND	0.05	ND	0.03	0.05
9-Apr-08	ND	0.06	0.07	ND	0.05	0.06	ND	0.05	0.07
22-Apr-08	0.06	0.05	0.06	0.06	0.05	0.05	0.06	0.06	0.06
6-May-08	0.06	0.05	0.06	0.06	0.05	0.05	0.06	0.06	0.06
21-May-08	missed	0.09	0.08	ND	0.07	0.07	0.14	0.08	0.14
4-Jun-08	ND	0.06	0.14	0.06	ND	ND	0.07	0.06	0.14
16-Jun-08	ND	ND	ND	ND	ND	ND	ND	ND	ND
mean	0.13	0.06	0.07	0.09	0.06	0.06	0.07	0.08	
max	2.00	0.19	0.17	0.81	0.20	0.11	0.14		2.00

Table 4. Annual Summary of 10 m Ammonia Nitrogen

10 m	B2	D2	EE2	E2	F2	G2	H2	mean	max
4-Jul-07	ND	ND	ND	0.025	ND	0.05	0.08	0.04	0.08
18-Jul-07	ND	ND	ND	0.07	ND	0.06	0.07	0.04	0.07
31-Jul-07	missed	0.08	0.06	0.07	0.11	0.1	0.15	0.10	0.15
14-Aug-07	missed	ND	ND	0.1	ND	0.12	ND	0.05	0.12
29-Aug-07	0.06	0.07	0.05	0.08	0.08	0.1	0.11	0.08	0.11
12-Sep-07	ND	ND	ND	0.06	0.09	0.09	0.06	0.05	0.09
25-Sep-07	0.07	0.05	ND	0.06	ND	ND	ND	0.04	0.07
10-Oct-07	ND	0.16	0.12	0.1	0.08	0.33	0.1	0.13	0.33
24-Oct-07	0.08	0.11	0.13	0.12	0.12	0.11	0.12	0.11	0.13
6-Nov-07	ND	0.08	0.08	0.19	0.08	0.07	0.08	0.09	0.19
21-Nov-07	ND	0.06	0.07	0.06	0.11	0.07	0.07	0.07	0.11
5-Dec-07	ND	ND	0.05	0.08	0.08	0.08	0.06	0.06	0.08
17-Dec-07	ND	0.06	0.06	0.12	0.06	0.05	ND	0.06	0.12
3-Jan-08	ND	0.06	0.06	0.08	0.07	0.07	0.07	0.06	0.08
15-Jan-08	ND	0.07	0.06	0.09	0.1	0.08	0.06	0.07	0.10
30-Jan-08	0.08	ND	ND	ND	0.11	0.06	0.06	0.06	0.11
12-Feb-08	ND	0.06	0.05	0.025	0.08	0.07	0.13	0.06	0.13
26-Feb-08	ND	ND	ND	ND	ND	ND	ND	ND	ND
11-Mar-08	ND	ND	0.025	ND	0.025	0.05	ND	0.03	0.06
26-Mar-08	ND	ND	0.06	ND	ND	0.05	ND	0.03	0.06
9-Apr-08	ND	0.06	0.07	ND	0.05	0.06	0.06	0.05	0.07
22-Apr-08	0.06	0.06	0.06	0.06	0.06	0.06	0.05	0.06	0.06
6-May-08	0.06	0.06	0.06	0.06	0.06	0.06	0.05	0.06	0.06
21-May-08	missed	0.08	0.09	ND	ND	0.07	ND	0.05	0.09
4-Jun-08	0.06	0.08	0.07	ND	0.05	0.07	0.07	0.06	0.08
16-Jun-08	ND	ND	ND	ND	ND	ND	ND	ND	ND
mean	0.04	0.06	0.06	0.06	0.06	0.08	0.06	0.06	
max	0.08	0.16	0.13	0.19	0.12	0.33	0.15		0.33

7 Total Suspended Solids

The measured values of TSS at 1 and 10 m over the entire year are presented in Tables 5 and 6. The RDL for the analysis is 0.5 mg/L. There were four observations below the detection limit. . Samples that were below the RDL of 0.5 mg/L have been assigned values of 0.25 (RDL/2) for statistical purposes, and are shaded green. On average the TSS levels are quite low. The annual mean level is about 3.7 mg/L. There is no appreciable difference in the 1 and 10 m samples. There is survey to survey variability with survey means ranging from a low of 1.2 to a high of 7.1 mg/L. Overall, as with ammonia, there does not appear to be a simple correlation between TSS concentrations and meteorological events/oceanographic 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 visually and are usually documented in field notes. The only easily identified spatial variation is that TSS tends on average to be lower at B2 in the Outer Harbour.

Table 5. Annual summary of 1 m TSS values

1 m	B2	D2	EE2	E2	F2	G2	H2	mean	max
4-Jul-07	0.5	2.3	7.7	2.7	4.4	3.0	5.0	3.7	7.7
18-Jul-07	2.1	2.7	3.8	4.9	3.1	2.3	8.4	3.9	8.4
31-Jul-07	missed	3.0	3.8	6.4	3.6	2.0	4.8	3.9	6.4
14-Aug-07	missed	2.2	2.0	3.0	3.0	1.0	0.9	2.0	3.0
29-Aug-07	0.6	2.5	3.0	3.1	3.2	2.8	3.5	2.7	3.5
12-Sep-07	0.5	1.5	4.6	5.8	4.7	3.1	6.7	3.8	6.7
25-Sep-07	ND	3.6	6.0	7.4	3.1	4.4	9.0	4.8	9.0
10-Oct-07	1.4	6.2	4.1	2.0	7.2	4.9	12	5.4	12.0
24-Oct-07	1.5	3.6	2.9	3.9	1.4	3.3	14	4.4	14.0
6-Nov-07	2.0	4.3	3.0	4.8	4.5	8.8	2.4	4.3	8.8
21-Nov-07	5.0	4.0	2.0	2.0	1.0	1.0	3.0	2.6	5.0
5-Dec-07	4.7	2.3	2.9	1.3	1.9	1.8	1.6	2.4	4.7
17-Dec-07	2.0	2.0	2.0	0.7	0.9	ND	1.6	1.4	2.0
3-Jan-08	4.0	3.1	6.7	4.0	6.3	2.8	4.4	4.5	6.7
15-Jan-08	5.0	1.0	7.7	3.0	2.8	2.0	2.4	3.4	7.7
30-Jan-08	12.0	10.0	4.7	5.4	8.0	8.2	4.0	7.5	12.0
12-Feb-08	4.1	1.6	4.0	3.2	4.8	3.1	3.0	3.4	4.8
26-Feb-08	3.0	2.9	3.0	6.2	5.0	2.0	5.0	3.9	6.2
11-Mar-08	2.6	3.6	3.4	4.0	4.0	6.2	6.1	4.3	6.2
26-Mar-08	1.0	5.0	3.7	2.0	2.6	3.0	4.0	3.0	5.0
9-Apr-08	1.0	4.4	3.4	2.7	2.7	3.5	4.0	3.1	4.4
22-Apr-08	5.6	3.7	9.1	6.5	5.4	6.0	5.9	6.0	9.1
6-May-08	5.6	3.7	9.1	6.5	5.4	6.0	5.9	6.0	9.1
21-May-08	missed	2.8	0.5	2.0	2.0	2.0	2.1	1.9	2.8
4-Jun-08	4.0	3.0	3.0	5.0	9.0	3.0	4.0	4.4	9.0
16-Jun-08	2.3	1.1	2.1	3.2	5.5	2.7	4.7	3.1	5.5
mean	3.1	3.3	4.2	3.9	4.1	3.4	4.9	3.8	
max	12.0	10.0	9.1	7.4	9.0	8.8	14.0		14.0

Table 6. Annual summary of 10 m TSS values

10 m	B2	D2	EE2	E2	F2	G2	H2	mean	max
4-Jul-07	0.9	2.0	2.1	2.3	4.3	7.0	2.3	3.0	7.0
18-Jul-07	2.0	2.5	5.0	2.6	3.3	5.0	3.1	3.4	5.0
31-Jul-07	missed	1.0	4.6	1.7	6.3	5.6	2.0	3.5	6.3
14-Aug-07	missed	2.6	4.0	2.0	3.8	3.0	3.0	3.1	4.0
29-Aug-07	1.2	2.8	5.7	1.9	1.8	1.6	5.9	3.0	5.9
12-Sep-07	1.0	1.8	2.0	2.7	2.3	5.8	7.1	3.2	7.1
25-Sep-07	1.0	1.8	2.4	4.2	8.8	7.6	4.0	4.3	8.8
10-Oct-07	4.0	3.6	5.0	2.8	4.9	4.0	1.8	3.7	5.0
24-Oct-07	3.3	3.0	3.7	5.1	5.7	4.1	4.5	4.2	5.7
6-Nov-07	1.5	5.7	2.7	1.9	3.5	5.9	2.6	3.4	5.9
21-Nov-07	3.0	15.0	2.0	3.0	3.0	7.0	4.0	5.3	15.0
5-Dec-07	2.2	1.1	1.4	1.2	1.8	1.5	3.4	1.8	3.4
17-Dec-07	2.3	2.0	2.0	0.6	ND	ND	1.5	1.3	2.3
3-Jan-08	2.0	3.0	7.2	2.0	2.3	5.9	1.2	3.4	7.2
15-Jan-08	3.3	7.0	3.1	2.7	3.0	6.1	2.3	3.9	7.0
30-Jan-08	6.0	3.2	7.0	12.0	6.2	7.0	6.0	6.8	12.0
12-Feb-08	2.0	2.0	1.9	5.0	2.2	2.8	5.9	3.1	5.9
26-Feb-08	2.2	5.3	3.3	6.0	2.2	2.9	2.6	3.5	6.0
11-Mar-08	3.0	3.8	6.1	3.8	3.4	4.1	2.0	3.7	6.1
26-Mar-08	2.6	3.0	2.0	4.0	3.6	4.3	4.0	3.4	4.3
9-Apr-08	1.7	4.0	4.0	4.0	4.0	4.0	4.5	3.7	4.5
22-Apr-08	6.0	3.8	3.1	4.0	6.7	7.1	4.6	5.0	7.1
6-May-08	6.0	3.8	3.1	4.0	6.7	7.1	4.6	5.0	7.1
21-May-08	missed	3.0	4.0	2.0	2.0	1.7	1.1	2.3	4.0
4-Jun-08	5.0	5.0	3.9	6.0	4.0	5.4	8.6	5.4	8.6
16-Jun-08	1.1	2.4	4.0	2.8	3.3	5.7	3.0	3.2	5.7
mean	2.8	3.6	3.7	3.5	3.8	4.7	3.7	3.7	
max	6.0	15.0	7.2	12.0	8.8	7.6	8.6		15.0

8 Metals

A summary of all measured metals concentrations over year four are presented in Figure 13. There are some individual guideline exceedances, notably in copper and mercury, however the mean values for all metals are well below the guideline levels. The metal regularly closest to the exceedance level is copper with a mean value under 20% of the guideline. This may be somewhat misleading as mercury also has levels approaching the guideline occasionally but the detection limit is 40% of the guideline. If mercury were regularly at 20% of the guideline, similar to copper, it would still be mostly non-detectable.

This plot shows that of the metals for which guidelines exist copper, manganese and zinc regularly have detectable levels. Lead, nickel and mercury 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.

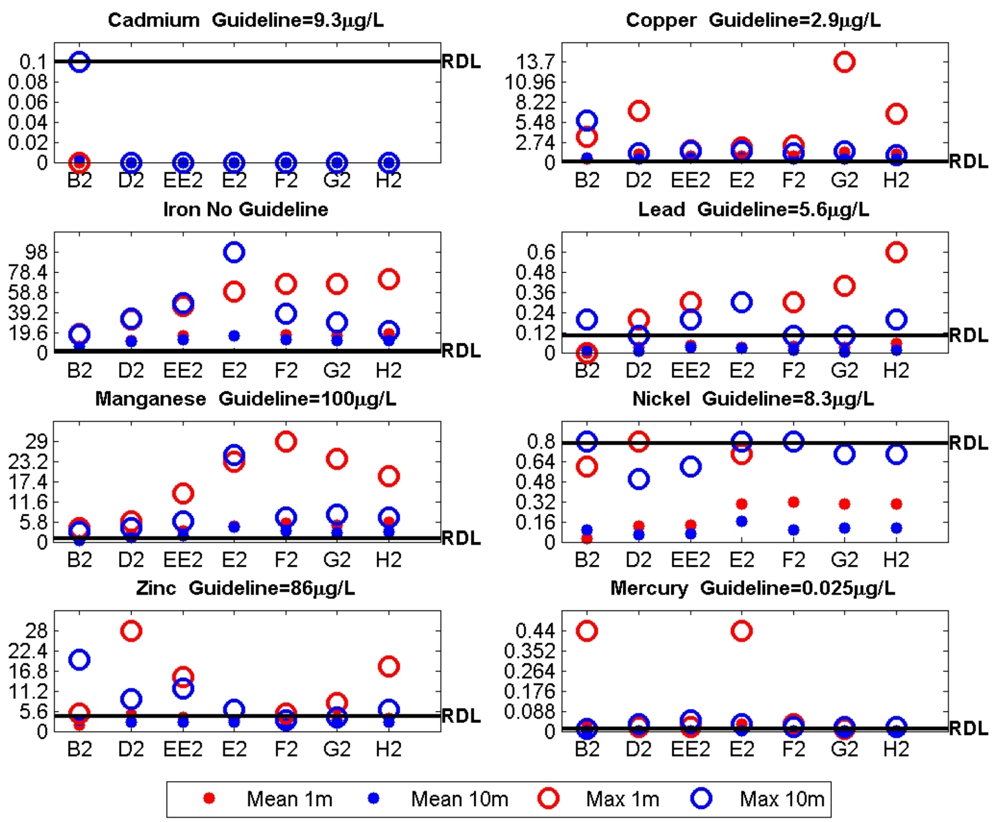

Figure 13. Mean and maximum values of metals (µg/L) over all year four samples.

9 References

Halifax Harbour Task Force. (1990). Halifax Harbour Task Force Final Report. Prepared for Nova Scotia Department of Environment, R. Fournier ed.