Halifax Harbour
Water Quality Monitoring Program
Quarterly Report #20
(March 25 to June 15, 2009**)**

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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 25 March to 15 June 2009 (surveys 180 to 186). 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 twentieth quarter. Every fourth quarterly report includes an annual summary of data and trends over the previous four quarters (see Appendix). 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.

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 twentieth quarter (15 Jun 09) 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 of detection, are now performed only for "supplemental samples".

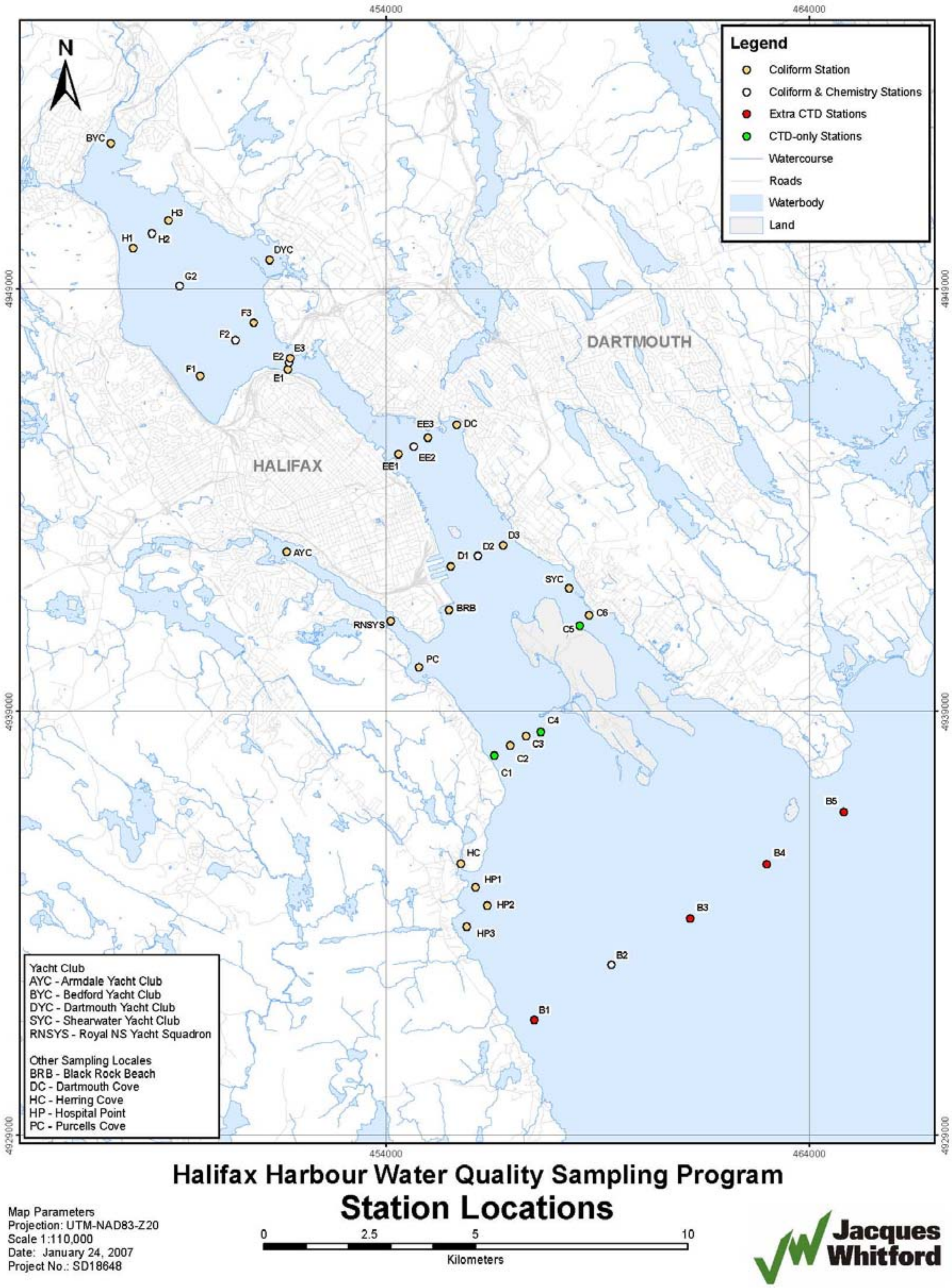


Figure 1. Halifax Inlet sample locations.

Table 1. Summary of measured parameters as of 15 June 2009.

	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		
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 twentieth 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 for each survey. Noteworthy are two surveys (180 and 182) where weather conditions (sea state) precluded operations in the Outer Harbour. In survey 180 the strong north wind also precluded sampling in the south central Bedford Basin.

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 twentieth quarter.

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

Date	25-Mar-09	8-Apr-09	22-Apr-09	5-May-09	19-May-09	2-Jun-09	15-Jun-09
Survey	180	181	182	183	184	185	186
1	BRB	PC	AYC	PC	C2	AYC	PC
2	D1	C2	RNSYS	C2	C1	RNSYS	C2
3	EE1	C1	BRB	C1	HC	BRB	C1
4	E1	HC	D1	HC	HP1	D1	HC
5	E3	HP1	EE1	HP1	HP2	D2	HP1
6	E2	HP2	E2	HP2	HP3	EE1	HP2
7	F1	HP3	E1	HP3	B2	EE2	HP3
8	H1	B2	E2	B2	C3	E3	B2
9	H2	C3	F2	C3	C4	E1	C3
10	BYC	C4	F1	C4	C5	E2	C4
11	H3	C5	G2	C5	C6	F1	C5
12	DYC	C6	H1	C6	SYC	F2	C6
13	F3	SYC	H2	D3	D3	G2	SYC
14	EE3	D3	BYC	D2	D2	H1	D3
15	EE2	EE3	H3	EE3	EE3	H2	EE3
16	D2	F3	DYC	EE2	EE2	BYC	F3
17	D3	DYC	F3	E1	E1	H3	DYC
18	SYC	H3	EE3	E3	E3	DYC	H3
19	C5	BYC	D3	E2	E2	F3	BYC
20	C6	H1	D2	F2	F3	EE3	H1
21	PC	H2	C5	F3	F2	D3	H2
22	RNSYS	G2	C6	DYC	DYC	SYC	G2
23	AYC	F1	PC	H3	H3	C6	F1
24		F2		BYC	H2	C5	F2
25		E1		H1	BYC	C4	E1
26		E3		G2	H1	C3	E3
27		E2		F1	G2	B2	E2
28		EE1		EE1	F1	HP3	EE1
29		EE2		D1	EE1	HP2	EE2
30		D1		BRB	D1	HP1	D2
31		BRB		RNSYS	BRB	HC	D1
32		RNSYS		AYC	PC	C1	BRB
33		AYC			RNSYS	C2	RNSYS
34					AYC	PC	AYC
No data	F2, G2, C1, C2. C3, C4, B2, HC, HP1, HP2, HP3	D2	SYC, C1, C2, C3, C4, B2, HC, HP1, HP2, HP3	SYC			
Supplemental							

Table 3. Quarter twenty data return.

Chemical	Target	Achieved	Percent Return
7 sites			
NH3	98	90	
TSS	98	90	
Metal Suite	98	90	
Mercury	98	90	
Total	**392**	**360**	**92%**

Bacteria	Target	Achieved	
28 sites			
F Coliform	434	366	
Total	**434**	**366**	**84%**

Profiles	Target	Achieved	
31 sites			
C-T	238	205	
Dissolved Oxygen	238	205	
Chlorophyll	238	205	
Total	**714**	**615**	**86%**
All data records	**1540**	**1341**	**87%**

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 twentieth quarter are shown in red. In this figure the sample sites are generally sorted from north to south. There are a few general 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. This quarter all but one survey sampled the Outer Harbour in the morning. Bedford Basin and the Inner Harbour were relatively uniformly sampled.

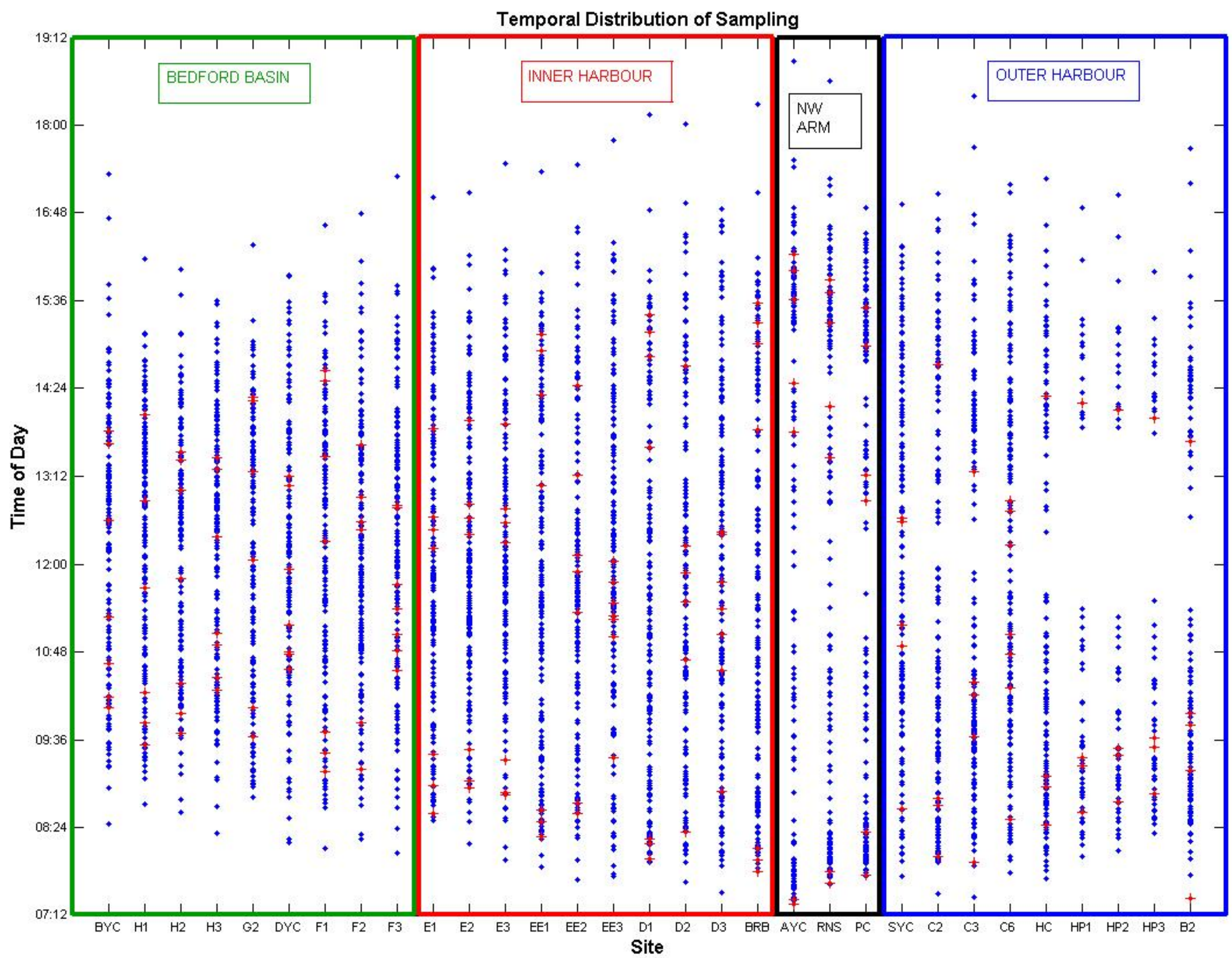


Figure 2. Temporal sampling distribution by site over entire program. Red markers denote points from 25 March to 15 June 2009.

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 2009 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. The range of water levels was relatively well sampled at all sites, but the distribution is poorly represented at some sites.

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.

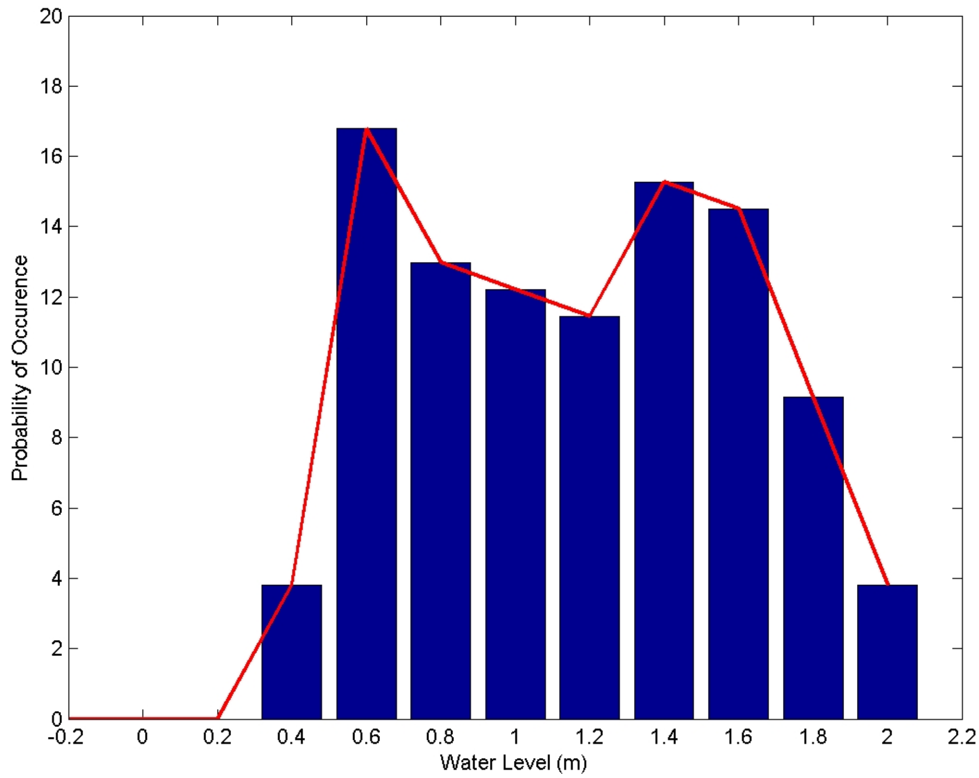


Figure 3. Probability distribution of water levels in Halifax, March to June 2009.

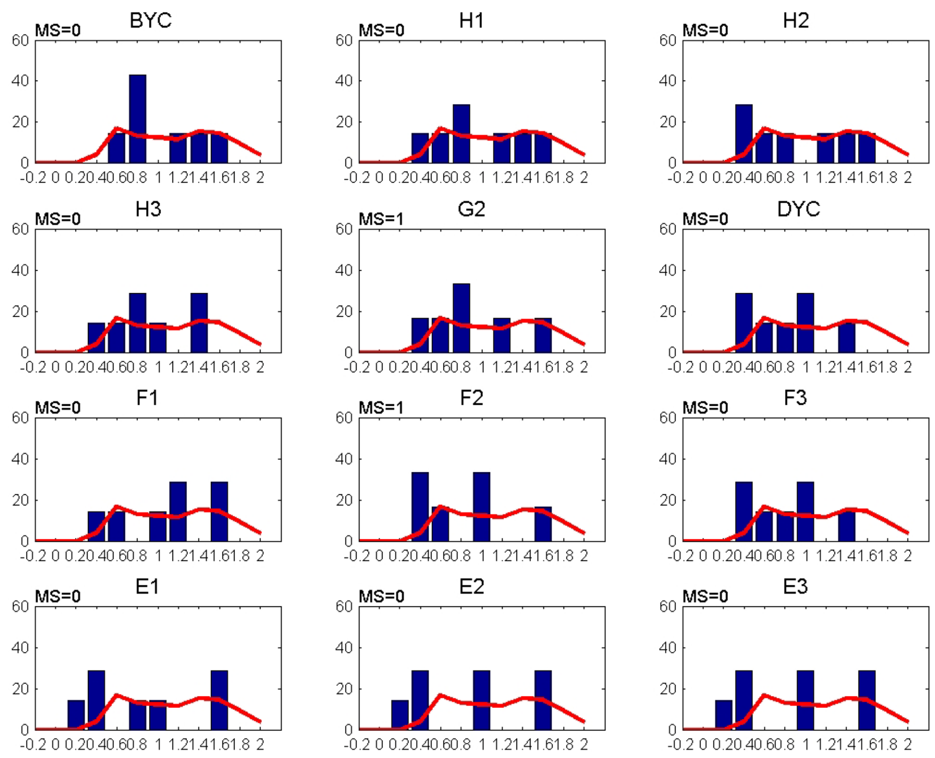


Figure 4a. Water level distribution at each site during sampling 25 March to 15 June 2009. Note: MS = Missed samples.

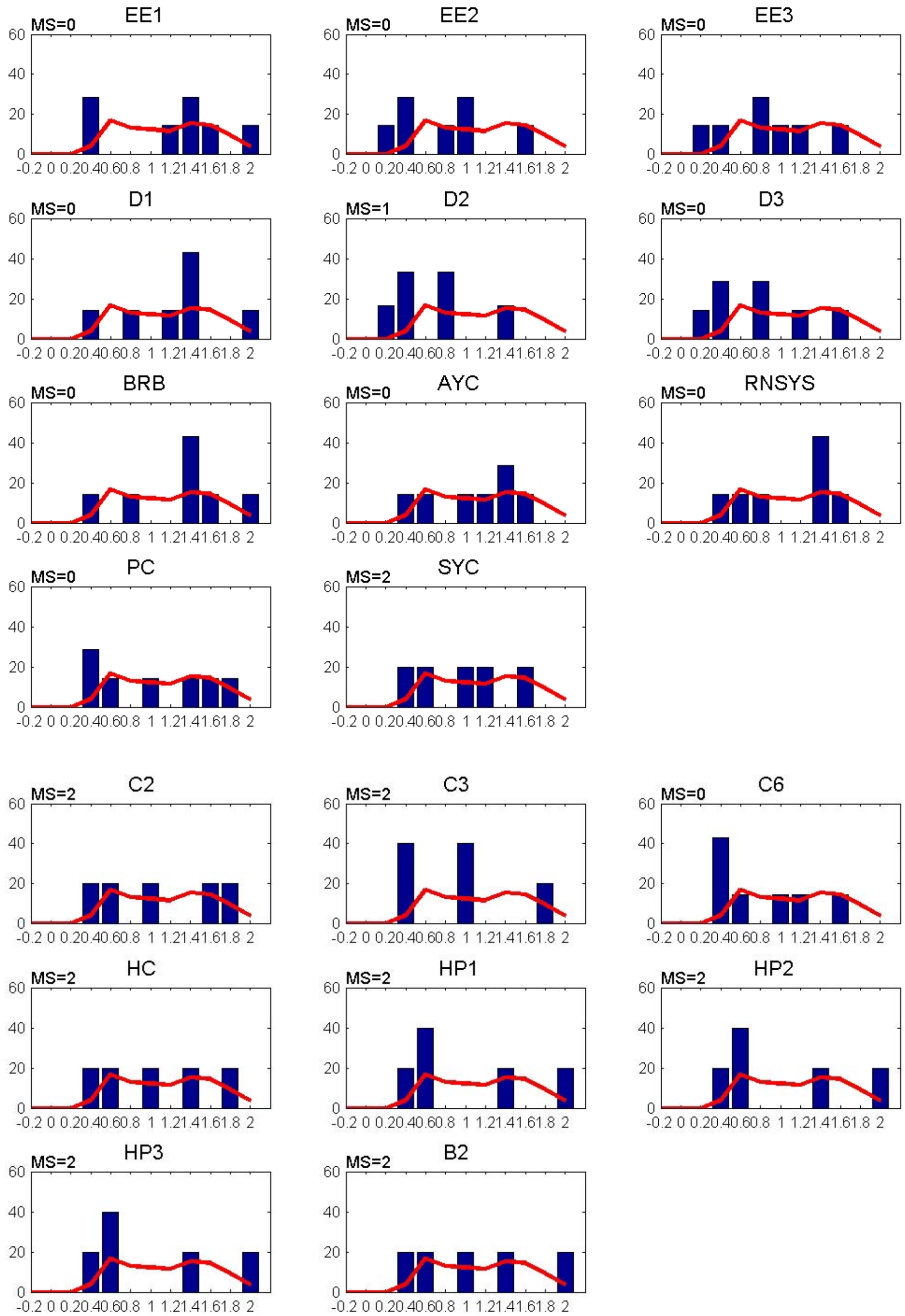


Figure 4b. Water level distribution at each site during sampling 25 March to 15 June 2009. Note: MS = Missed samples.

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 (25 March to 15 June 2009). The blue bars on this plot represent a similar analysis performed for sampling days only. The plot indicates that, given the limited number of surveys, the precipitation distribution was relatively well sampled. There were some higher precipitation events that were not sampled.

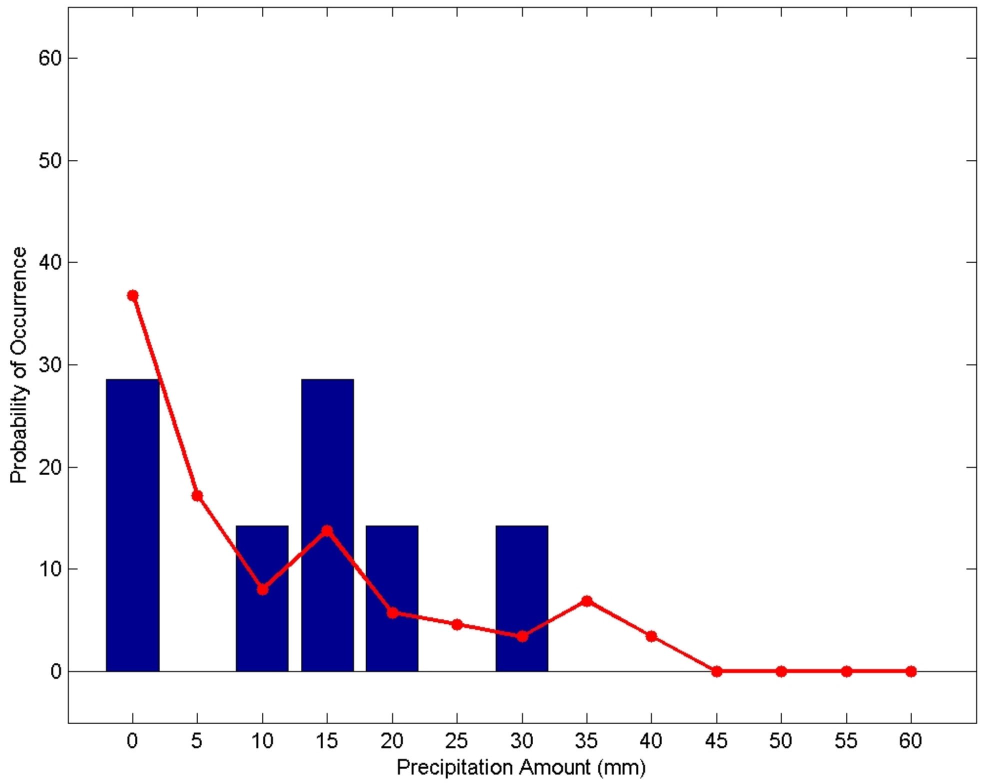


Figure 5. Probability distribution of cumulative 72 hour rainfall, 25 March to 15 June 2009.

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 continued to be out of commission. The sewage effluent was discharging through CSO's along the waterfront and Northwest Arm. The Dartmouth sewage treatment plant was fully functional.

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

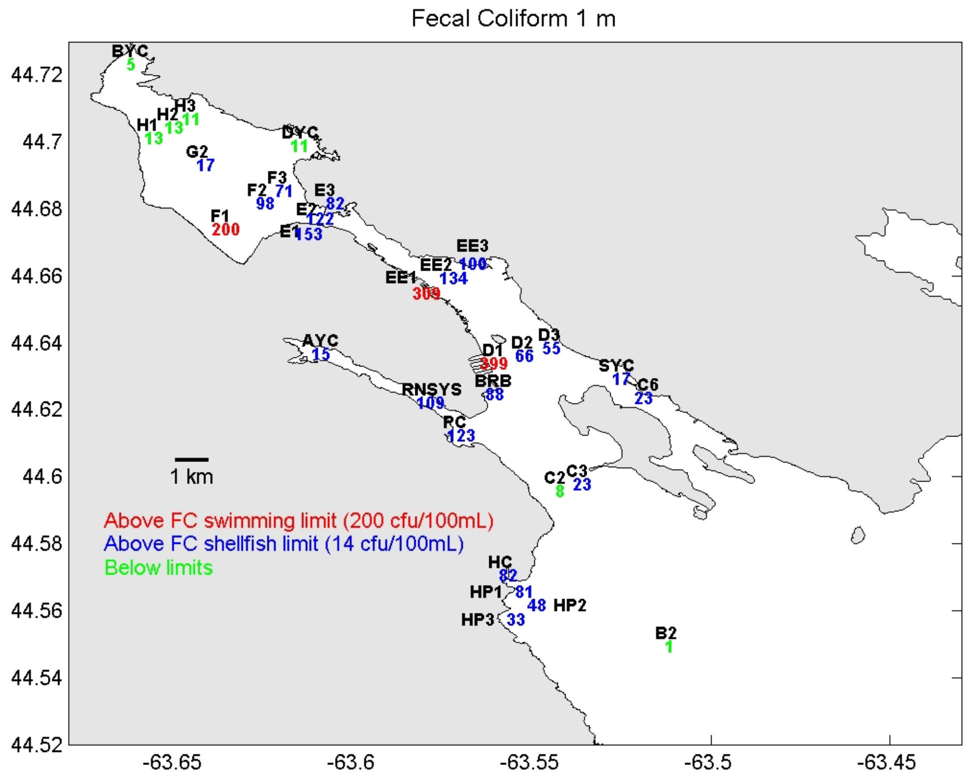
The Guidelines for Canadian Recreational Water Quality (GCRWQ) (Health and Welfare Canada 1992) evaluate the compliance with bacterial water quality criteria based on geometric mean. The geometric mean, G, of n values is defined as:

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

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 twentieth 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.

The geometric mean values exceeding the swimming guidelines are limited to a very few sites. Most are in the Inner Harbour, where there are no Task Force guidelines on bacteria, with only one (F1-1m) outside of the Inner Harbour. There is a tendency for the levels to be higher in the 1m samples in the Inner Harbour and higher in the 10m samples in the Basin but the differences are mostly small and the pattern is not completely consistent. A more rigorous treatment of guideline exceedance follows.



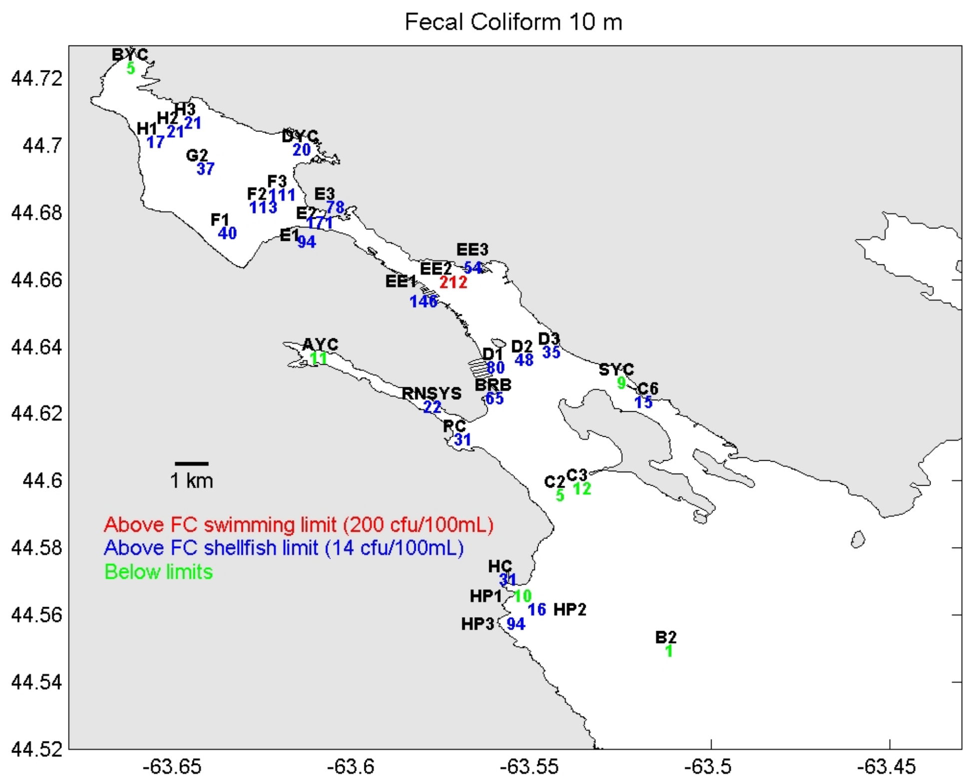


Figure 6. Fecal coliform geometric means (cfu/100mL) at 1m and 10m, 25 March to 15 June 2009.

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.

<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 the failure of the Halifax Sewage treatment plant has resulted in class SB exceedances both North and South of the Inner Harbour. The exceedances are sporadic everywhere with the most persistent being in the Basin at site F1–1m. 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. This quarter HC (Herring Cove) essentially never meets the SA guideline, while the HP sites seldom do. 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
Survey180	1 (2)	159 (2)	467 (2)	209 (2)	133 (2)	10 (2)	62 (2)	70 (3)	99 (3)	57 (3)	17 (3)	13 (3)	316 (3)	699 (3)	135 (3)
Survey181	1 (2)	209 (2)	471 (2)	479 (2)	101 (2)	52 (2)	139 (2)	197 (3)	134 (3)	80 (3)	19 (3)	86 (3)	191 (3)	1613 (3)	166 (3)
Survey182	1 (1)	50 (1)	570 (1)	410 (1)	250 (1)	27 (1)	470 (1)	98 (3)	103 (2)	36 (2)	19 (3)	128 (2)	224 (2)	1620 (2)	85 (3)
Survey183	1 (2)	7 (2)	24 (2)	54 (2)	84 (2)	7 (2)	48 (2)	309 (3)	1635 (2)	28 (2)	19 (3)	1500 (1)	62 (2)	622 (2)	100 (3)
Survey184	1 (2)	21 (2)	17 (2)	29 (2)	75 (2)	19 (2)	21 (2)	127 (3)	476 (2)	10 (2)	5 (3)	42 (1)	93 (2)	315 (2)	39 (3)
Survey185	1 (3)	147 (3)	7 (3)	9 (3)	41 (3)	10 (3)	12 (3)	125 (3)	189 (3)	5 (3)	27 (3)	11 (2)	104 (3)	222 (3)	76 (3)
Survey186	1 (3)	266 (3)	17 (3)	7 (3)	59 (3)	8 (3)	7 (3)	86 (3)	20 (3)	3 (3)	39 (3)	5 (3)	31 (3)	169 (3)	21 (3)

	Inner Harbour							Bedford Basin								
	D3	EE1	EE2	EE3	E1	E2	E3	F1	F2	F3	DYC	G2	H1	H2	H3	BYC
Survey180	66 (3)	214 (3)	223 (3)	213 (3)	172 (3)	85 (3)	94 (3)	109 (3)	71 (2)	29 (3)	2 (2)	118 (2)	17 (3)	13 (3)	19 (3)	3 (3)
Survey181	123 (3)	363 (3)	409 (3)	355 (3)	476 (3)	195 (3)	213 (3)	250 (3)	548 (2)	71 (3)	13 (3)	560 (2)	66 (3)	43 (3)	50 (3)	24 (3)
Survey182	222 (3)	245 (2)	395 (2)	109 (3)	1102 (2)	113 (2)	310 (2)	409 (2)	1200 (1)	204 (3)	56 (3)	560 (1)	95 (2)	36 (2)	84 (2)	24 (2)
Survey183	187 (3)	520 (2)	510 (2)	122 (3)	587 (2)	497 (2)	339 (2)	361 (2)	216 (2)	373 (3)	71 (3)	132 (2)	88 (2)	36 (2)	37 (2)	24 (2)
Survey184	54 (3)	342 (2)	45 (2)	38 (3)	74 (2)	187 (2)	35 (2)	386 (2)	23 (2)	93 (3)	20 (3)	8 (2)	10 (2)	4 (2)	5 (2)	4 (2)
Survey185	33 (3)	383 (3)	90 (3)	58 (3)	81 (3)	121 (3)	38 (3)	240 (3)	64 (3)	37 (3)	10 (3)	4 (3)	5 (3)	6 (3)	3 (3)	2 (3)
Survey186	13 (3)	315 (3)	33 (3)	38 (3)	55 (3)	68 (3)	28 (3)	248 (3)	72 (3)	34 (3)	6 (3)	1 (3)	3 (3)	6 (3)	3 (3)	2 (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
Survey180	1 (2)	5 (2)	5 (2)	9 (2)	57 (2)	3 (2)	61 (2)	66 (3)	13 (3)	22 (3)	34 (3)	19 (3)	237 (3)	148 (3)	135 (3)
Survey181	1 (2)	9 (2)	17 (2)	67 (2)	62 (2)	22 (2)	189 (2)	143 (3)	61 (3)	33 (3)	46 (3)	24 (3)	178 (3)	170 (3)	125 (3)
Survey182	1 (1)	79 (1)	280 (1)	500 (1)	130 (1)	72 (1)	410 (1)	57 (3)	73 (2)	30 (2)	24 (3)	19 (2)	200 (2)	221 (2)	59 (3)
Survey183	1 (2)	15 (2)	78 (2)	300 (2)	52 (2)	15 (2)	35 (2)	47 (3)	128 (2)	53 (2)	26 (3)	53 (1)	106 (2)	254 (2)	89 (3)
Survey184	1 (2)	10 (2)	42 (2)	141 (2)	31 (2)	6 (2)	4 (2)	33 (3)	55 (2)	7 (2)	5 (3)	4 (1)	130 (2)	34 (2)	34 (3)
Survey185	1 (3)	20 (3)	32 (3)	99 (3)	10 (3)	4 (3)	3 (3)	20 (3)	36 (3)	4 (3)	9 (3)	3 (2)	63 (3)	57 (3)	45 (3)
Survey186	1 (3)	14 (3)	12 (3)	205 (3)	14 (3)	3 (3)	2 (3)	9 (3)	12 (3)	2 (3)	4 (3)	2 (3)	13 (3)	20 (3)	9 (3)

	Inner Harbour							Bedford Basin								
	D3	EE1	EE2	EE3	E1	E2	E3	F1	F2	F3	DYC	G2	H1	H2	H3	BYC
Survey180	56 (3)	144 (3)	235 (3)	149 (3)	156 (3)	118 (3)	121 (3)	39 (3)	94 (2)	49 (3)	10 (2)	58 (2)	19 (3)	22 (3)	23 (3)	4 (3)
Survey181	38 (3)	274 (3)	390 (3)	120 (3)	161 (3)	254 (3)	141 (3)	58 (3)	358 (2)	40 (3)	31 (3)	553 (2)	21 (3)	60 (3)	31 (3)	40 (3)
Survey182	86 (3)	790 (2)	445 (2)	60 (3)	241 (2)	226 (2)	305 (2)	40 (2)	800 (1)	121 (3)	49 (3)	1800 (1)	28 (2)	69 (2)	41 (2)	55 (2)
Survey183	70 (3)	849 (2)	672 (2)	96 (3)	141 (2)	529 (2)	232 (2)	86 (2)	410 (2)	260 (3)	76 (3)	281 (2)	35 (2)	134 (2)	117 (2)	67 (2)
Survey184	99 (3)	101 (2)	222 (2)	39 (3)	57 (2)	198 (2)	78 (2)	67 (2)	56 (2)	181 (3)	28 (3)	22 (2)	19 (2)	33 (2)	7 (2)	2 (2)
Survey185	22 (3)	58 (3)	199 (3)	40 (3)	52 (3)	198 (2)	26 (3)	38 (3)	48 (3)	97 (3)	22 (3)	26 (3)	13 (3)	16 (3)	8 (3)	2 (3)
Survey186	11 (3)	46 (3)	88 (3)	11 (3)	44 (3)	96 (2)	24 (3)	25 (3)	54 (3)	109 (3)	9 (3)	7 (3)	10 (3)	6 (3)	6 (3)	2 (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 46% of samples had detectable concentrations. The overall mean concentration was just about 0.5 mg/L, the detection limit. 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
180 (25 Mar 09)	missed	0.06	0.05	0.11	missed	missed	0.06	0.07	0.11
181 (8 Apr 09)	ND	ND	ND	ND	ND	ND	0.09	0.03	0.09
182 (22 Apr 09)	missed	ND	0.06	ND	ND	0.06	ND	0.04	0.06
183 (5 May 09)	0.05	ND	0.07	0.06	0.12	0.08	0.15	0.08	0.15
184 (19 May 09)	ND	ND	ND	ND	ND	ND	ND	ND	ND
185 (2 Jun 09)	ND	ND	ND	ND	ND	ND	ND	ND	ND
186 (15 Jun 09)	ND	ND	0.06	0.07	0.08	0.09	0.14	0.07	0.14
mean	0.03	0.03	0.05	0.05	0.05	0.05	0.07	0.05	
max	0.05	0.06	0.07	0.11	0.12	0.09	0.15		0.15

10m	B2	D2	EE2	E2	F2	G2	H2	mean	max
180 (25 Mar 09)	missed	0.05	0.06	0.07	missed	missed	0.07	0.06	0.07
181 (8 Apr 09)	ND	0.06	0.06	ND	0.06	ND	ND	0.03	0.06
182 (22 Apr 09)	missed	ND	0.05	ND	0.05	ND	ND	0.02	0.05
183 (5 May 09)	0.05	0.11	0.07	ND	0.06	0.08	0.06	0.06	0.11
184 (19 May 09)	ND	ND	ND	0.10	ND	0.05	ND	0.02	0.10
185 (2 Jun 09)	ND	ND	ND	0.06	ND	ND	ND	0.01	0.06
186 (15 Jun 09)	ND	ND	0.07	0.07	0.08	0.08	0.06	0.05	0.08
mean	0.03	0.05	0.05	0.05	0.05	0.05	0.04	0.04	
max	0.05	0.11	0.07	0.10	0.08	0.08	0.07		0.11

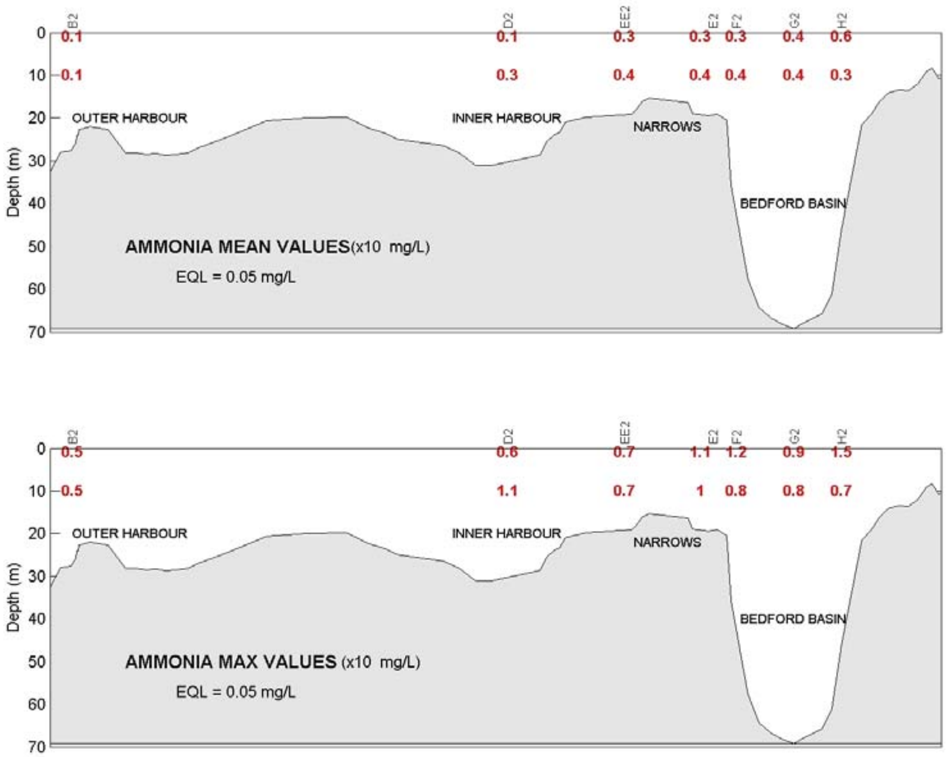


Figure 7. Mean and maximum values of ammonia nitrogen (X10 mg/L) over all twentieth quarter samples.

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 was one sample that below the RDL of 0.5 mg/L. The quarterly mean and max values are plotted by station in Figure 8. This quarter there is strong temporal variability with survey mean values ranging from 1.2 mg/L to 5.9 mg/L, almost a factor of five variances. The overall quarterly mean is 3.4 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.

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

1m	B2	D2	EE2	E2	F2	G2	H2	mean	max
180 (25 Mar 09)	missed	2.3	6.1	2.7	missed	missed	1.7	3.2	6.1
181 (8 Apr 09)	3.0	3.3	8.7	5.9	11	8.7	6.3	6.7	11.0
182 (22 Apr 09)	missed	3.5	2.4	3.0	3.4	2.9	6.5	3.6	6.5
183 (5 May 09)	1.6	1.7	3.1	2.2	2.2	4.0	2.1	2.4	4.0
184 (19 May 09)	2.1	5.5	2.5	2.6	1.1	2.9	2.4	2.7	5.5
185 (2 Jun 09)	ND	6.0	4.0	4.0	5.0	3.0	5.0	3.9	6.0
186 (15 Jun 09)	0.6	1.4	1.0	0.8	1.1	0.9	1.3	1.0	1.4
mean	1.5	3.4	4.0	3.0	4.0	3.7	3.6	3.4	
max	3.0	6.0	8.7	5.9	11.0	8.7	6.5		11.0

10m	B2	D2	EE2	E2	F2	G2	H2	mean	max
180 (25 Mar 09)	missed	5.9	3.2	6.2	missed	missed	2.9	4.6	6.2
181 (8 Apr 09)	3.2	4.3	3.9	7.7	6.8	5.7	4.1	5.1	7.7
182 (22 Apr 09)	missed	2.5	2.5	3.7	2.8	2.1	1.8	2.6	3.7
183 (5 May 09)	1.5	3.5	6.5	2.7	3.7	2.3	1.5	3.1	6.5
184 (19 May 09)	1.2	4.5	2.3	3.9	1.2	2.1	5.6	3.0	5.6
185 (2 Jun 09)	2.5	2.0	2.0	3.0	7.0	2.0	4.0	3.2	7.0
186 (15 Jun 09)	0.7	0.8	1.1	1.7	0.7	2.8	1.7	1.4	2.8
mean	1.8	3.4	3.1	4.1	3.7	2.8	3.1	3.3	
max	3.2	5.9	6.5	7.7	7.0	5.7	5.6		7.7

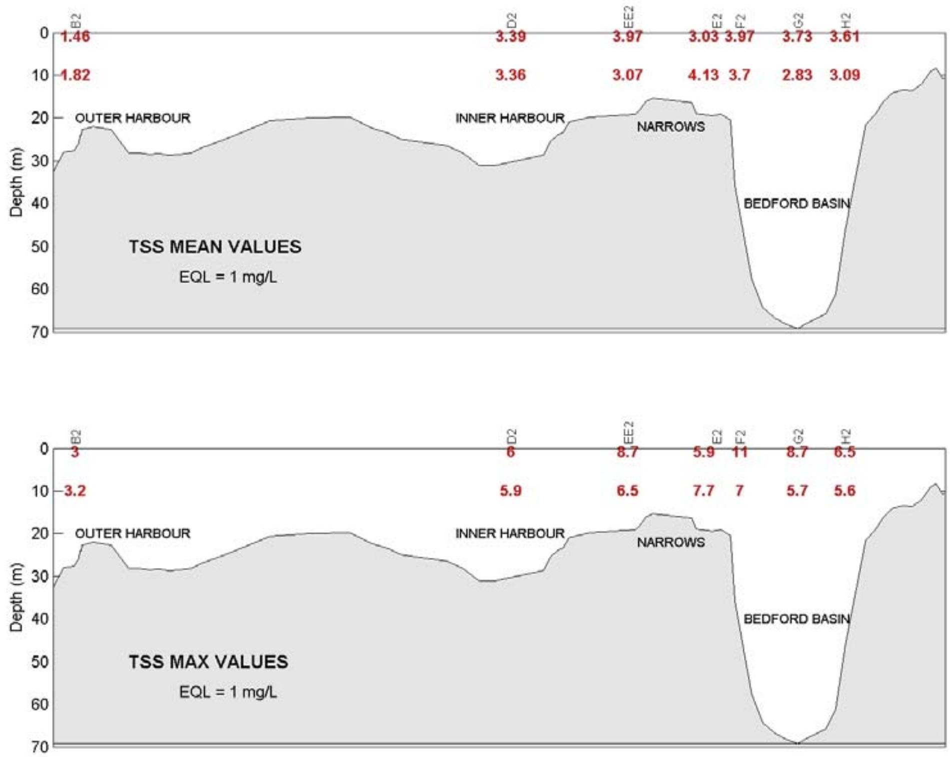


Figure 8. Mean and maximum values of total suspended solids (mg/L) over all twentieth quarter samples.

4.5 Total Oil 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. This quarter there were no guideline exceedances. 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 a mean value under 20% of the guideline. Mercury also has levels approaching the guideline quite often but the detection limit is 40% of the guideline so it is most often below detection.

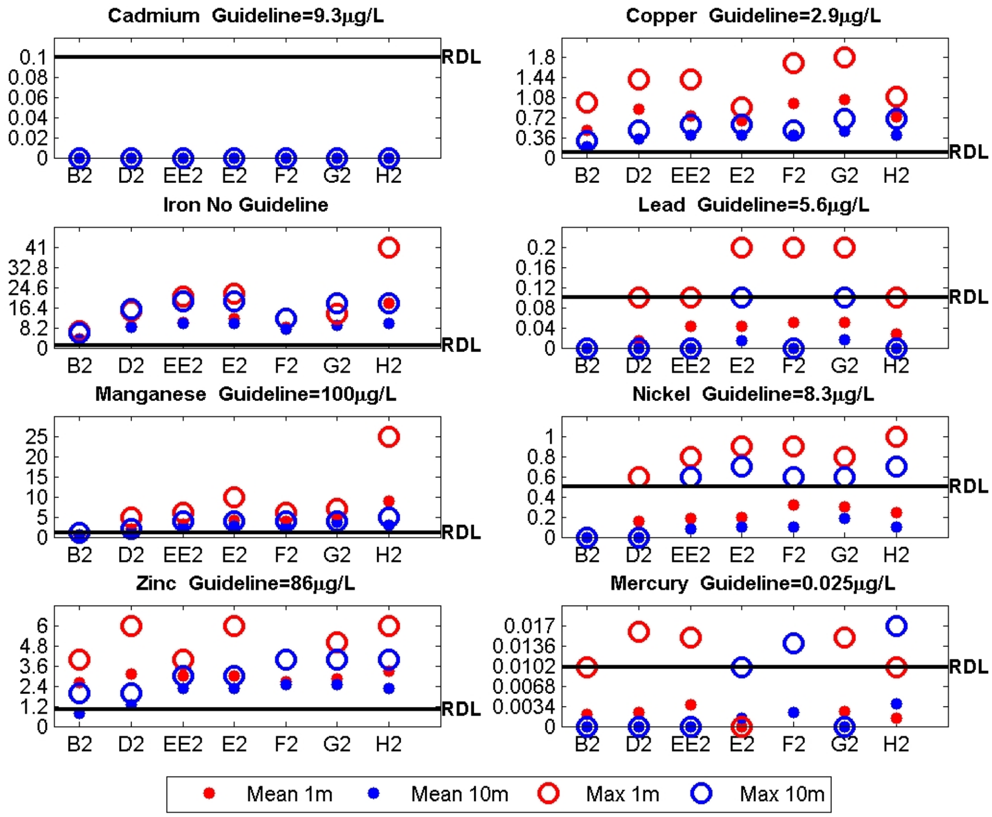


Figure 9. Mean and maximum values of metals (µg/L) over all twentieth quarter samples.

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 (See Appendix).

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, particularly in summer 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 the fluorescence levels were variable, but consistently moderate to high. The survey maximum values ranged from about 20 to 60 mg/m^3. The higher values in May (survey 183) were higher than those observed during spring bloom.

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 08) 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 until the final survey. The Basin bottom water started the quarter well oxygenated. The DO dropped monotonically through the quarter and dropped below the 7.0 mg/L SB guideline by the final survey (survey 186, 15 Jun 09).

4.8 Supplemental Sample

There were no supplemental samples this quarter.

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 Northwest 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

The failure of the Halifax sewage treatment plant has resulted in a return to high fecal coliform values in the Inner Harbour. The elevated values periodically find their way into the class SB (recreational) areas adjacent to the Inner Harbour. While there are elevated bacteria levels in the Inner Harbour they are not as great as pre treatment levels as the Dartmouth Plant is still operating. The conditions in the NW Arm have pretty much returned to pretreatment conditions. RNSYS and PC are affected by the effluent from the chain rock outfall depending on the plume trajectory. In addition to this there are the relatively unrelated elevated levels in the vicinity of the Tribune Head outfall (HC and HP sites). The class SA guideline in the Outer Harbour is generally not met at these sites. The class SA guideline is met generally and throughout this quarter at the B2 site.

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 NW 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. There does seem to be some significant (i.e. greater than random) temporal variability but the reason 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. This quarter the mean concentrations are moderate at about 3.4 mg/L. 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 in general lower in the Outer Harbour at B2.

Changes:
- None

Total Oil and Grease

Based on recommendations in Quarterly Report 5, Total Oil 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. This quarter there were no guideline exceedances. The metal that is consistently closest to exceeding the guideline is copper. In this quarter the mean copper values were less than 20% of the 2.9 µg/L guideline. The current analysis is providing a reasonable assessment of the important metals concentrations in the Harbour.

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, but consistently moderate to high phytoplankton activity.

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 until the last survey of the quarter. The Basin bottom water started the quarter well oxygenated. By the end of the quarter the levels had dropped to just below the 7.0 mg/l guideline. There were no other exceedances.

Changes

- None

References

CCME, 1999. Canadian water quality guidelines for the protection of aquatic life: In: Canadian environmental quality guidelines, 1999, Canadian Council of Ministers of the Environment, Winnipeg.

Dalziel, J.A., P.A. Yeats and D.H. Loring (1989). Dissolved and particulate trace metal distributions in Halifax Harbour, In: H.B. Nicholls (ed.), Investigations of Marine Environmental Quality in Halifax Harbour. Can. Tech. Rep. Fish. Aquat. Sci. 1693.

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

Health and Welfare Canada (1992). Guidelines for Canadian Recreational Water Quality.

Hurlbut, S., A. Isenor, J.M. MacNeil and B. Taylor (1990). Residual Circulation in Halifax Inlet and its Impact on Water Quality, report prepared by ASA Consulting Ltd. for Nova Scotia Department of the Environment.

Jordan, F. (1972), Oceanographic Data of Halifax Inlet", BIO data series, B1-D-72-8.

JWL and COA (2004 – 2005). Halifax Harbour Waster Quality Monitoring Program, Weekly and Quarterly Reports 2004 to 2008, report to the Halifax Regional Municipality, Harbour Solutions Project. http://www.halifax.ca/harboursol/waterqualitydata.html

USEPA (1985). Rates Constants, and Kinetics Formulations in Surface Water Quality Modeling (Second Edition). EPA 600385040.

Halifax Harbour
Water Quality Monitoring Program
Quarterly Report 20

APPENDIX

Annual Summary Year Five

2 July 2008 - 15 June 2009

March 2010

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1 Introduction

The following is a summary of data from year five, from 2 July 2008 through 15 June 2009. It includes information provided in Quarterly Reports 17 through 20. 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

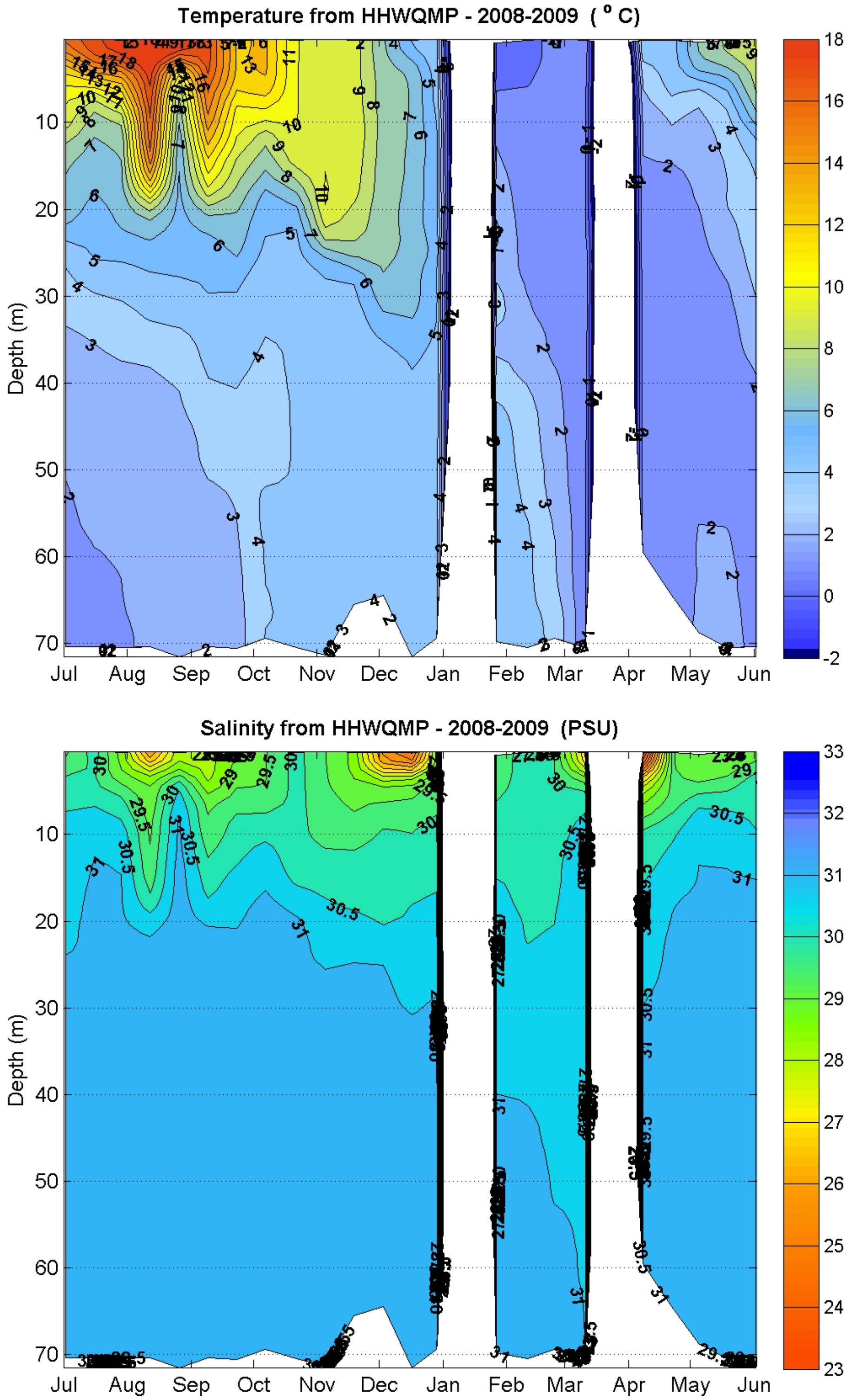


Figure 1. HHWQMP temperature and salinity data from Station G2 (2 July 2008 to 15 June 2009).

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 17, 18, 19 and 20 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 six or seven 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 October.

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 concentrations observed and is representative of the timing of phytoplankton activity in the remainder of the harbour. Note, however, that the maximum values do not always occur at G2. It seems that the wind can displace the maximums to one side of the Basin ore the other. Figure 2 shows the time series of fluorescence profiles in the centre of the Basin (site G2). This shows relatively continuous moderate activity throughout the summer and fall (quarter 17+18). The activity then declines to relatively low levels throughout the winter until the spring bloom in March.

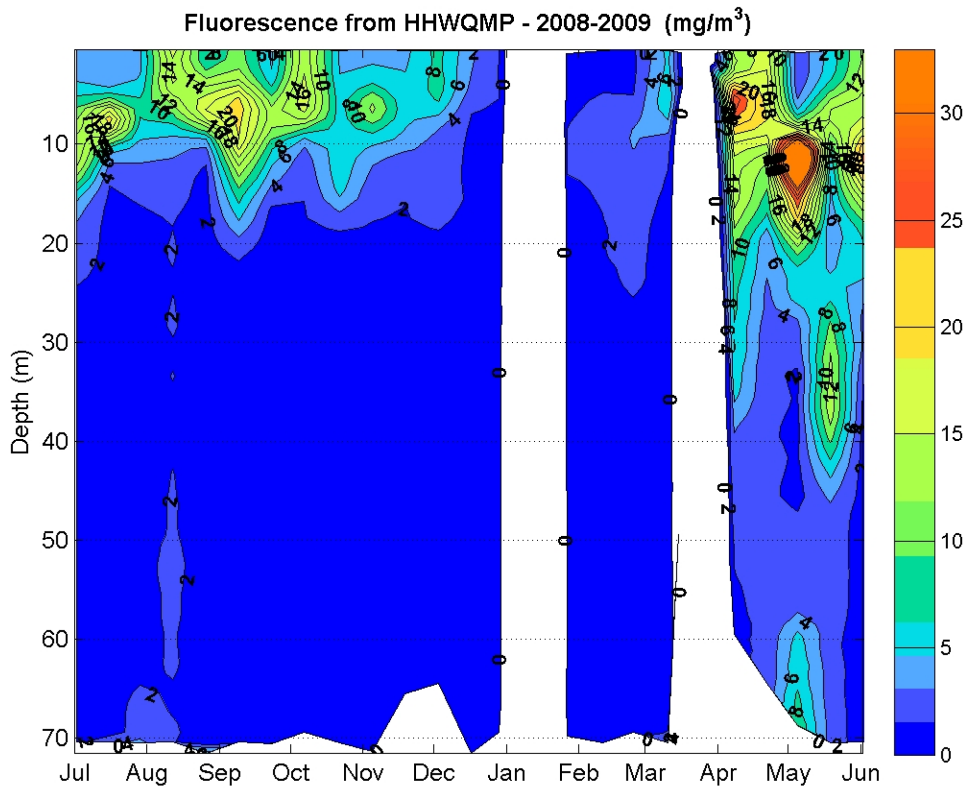


Figure 2. HHWQMP fluorescence data from Station G2 (2 July 2008 to 15 June 2009).

During blooms, 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 previous years 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 there was additional data collected with a YSI handheld dissolved oxygen (DO) meter at selected sites on every survey. In addition, every survey the CTD is 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 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.

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 very significant, but most of the time the spatial variations are small compared to the large-scale temporal variations. 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 relatively well oxygenated but the vertical gradient is quite steep. In the beginning of 2009 the dissolved oxygen increases dramatically and becomes quite uniform in the top 20 m. There is an interruption of this pattern by what may be the surface expression a large intrusion/upwelling event. The resolution of this event is hampered by the data gap. Site G2 at was not sampled due to sea-state during a southerly (down harbour) gale. After this event the near-surface DO soon returns to high relatively uniform values.

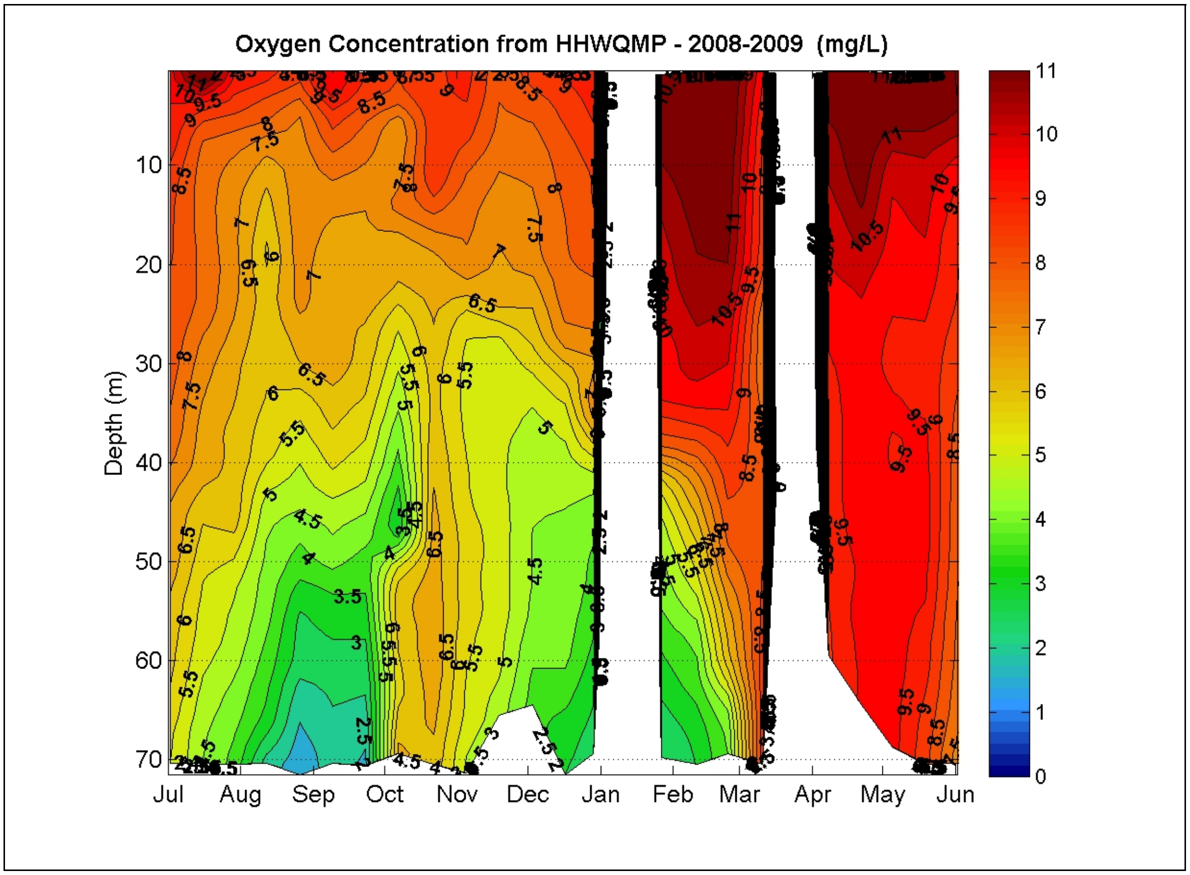


Figure 3. HHWQMP dissolved oxygen data from Station G2 (2 July 2008 to 15 June 2009)

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 4.1). Sometimes, but not always, the signature of a deep 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 a function of state of the upper water column and the magnitude of intrusion. The volume of bottom water is also considerably smaller than the near surface water. An event that has a large effect on bottom water will be "diluted" in its surface signature.

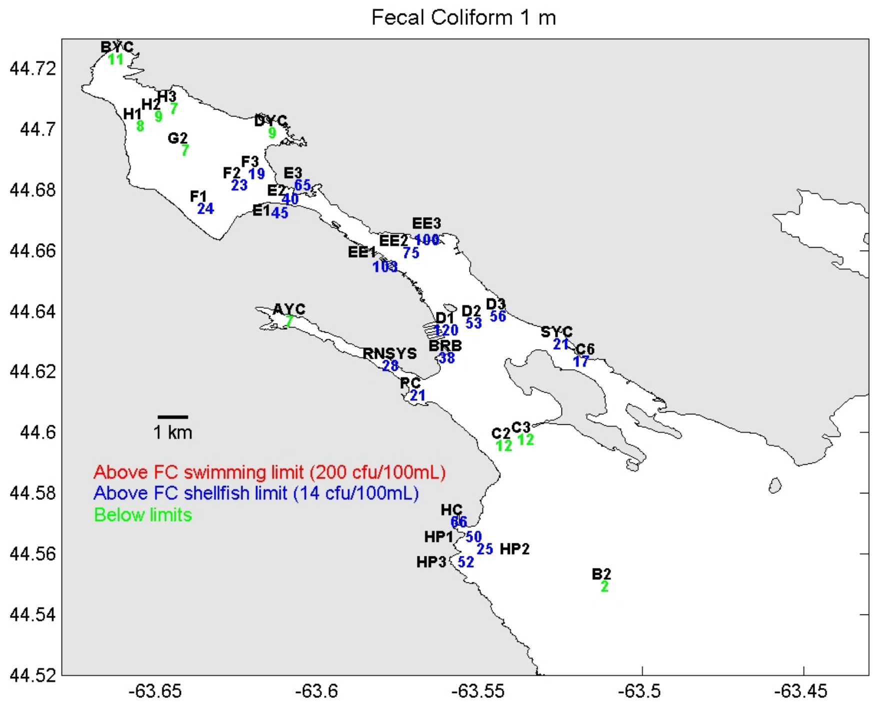
This water does not generally have dissolved oxygen above the class SB guideline (7.0 mg/L). In this period there is one very distinct intrusion at the beginning of October. This raises the DO close to the guideline. The signature dissipates over the next month or two. In November – December a seemingly typical seasonal increase in near surface DO begins and starts making its way into the deeper water. This is interrupted by the event discussed above that results in a remarkably uniform water column. The well-oxygenated deep water persists for the remainder of the year.

5 Fecal Coliform

Geometric Means

At the start of this year the Halifax STP was completely functional. During the first quarter the Dartmouth STP treatment plant was coming on line. At the beginning of the third quarter, in early January, the Halifax STP failed and remained out of commission for the remainder of the period. Maps showing the annual geometric mean fecal coliform concentrations at 1 and 10 m are presented in Figure 4. The pattern that have become recognizable as "normal" have been overridden by the operations of the Halifax and Dartmouth sewage treatment plants. The effect of the treatment plants is immediately obvious in the annual geometric mean bacteria concentrations. Even with the plants being fully functional for only one quarter, the mean concentrations are very low everywhere. Interestingly the concentrations are also quite similar in the 1 and 10m samples most everywhere. This may be due to the submerged diffused outfalls that mix the effluent deeper in the water column. Somewhat surprising is that the effect of the Tribune Head outfall is not more evident.

Within the basic annual pattern there is generally quite a bit of variability in both the magnitude and distribution of the bacteria concentrations in the harbour. These variations are due to interactions of meteorological and oceanographic factors affecting source strength, effluent trajectory and mixing, and bacteria die-off on seasonal, weekly and daily timescales. Maps representing the geometric mean values over all samples for each of the four quarters (seasons) are reproduced from quarterly reports 17 through 20 in Figures 5 through 8. In these figures, 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. In each figure, separate maps are presented for the 1 and 10 m samples. This year the expected seasonal variability is largely overridden by the STP operation. Interestingly the summer concentrations (Fig. 5), with the Dartmouth plant not fully functional, are lower than in the fall, when both plants were operational. Typically, without source strength variations, fall concentrations are higher than summer concentrations. This is likely a factor but it is also likely that there were “debugging” issues with the new Dartmouth plant. More details of plant operation would be required to make any more concrete inference. In the last half of the year, after the failure of the Halifax plant, some geometric mean values > 200 cfu/100 mL occur in the Inner Harbour. These are generally just over 200 cfu/100mL. The concentrations remain significantly lower than with no plant.



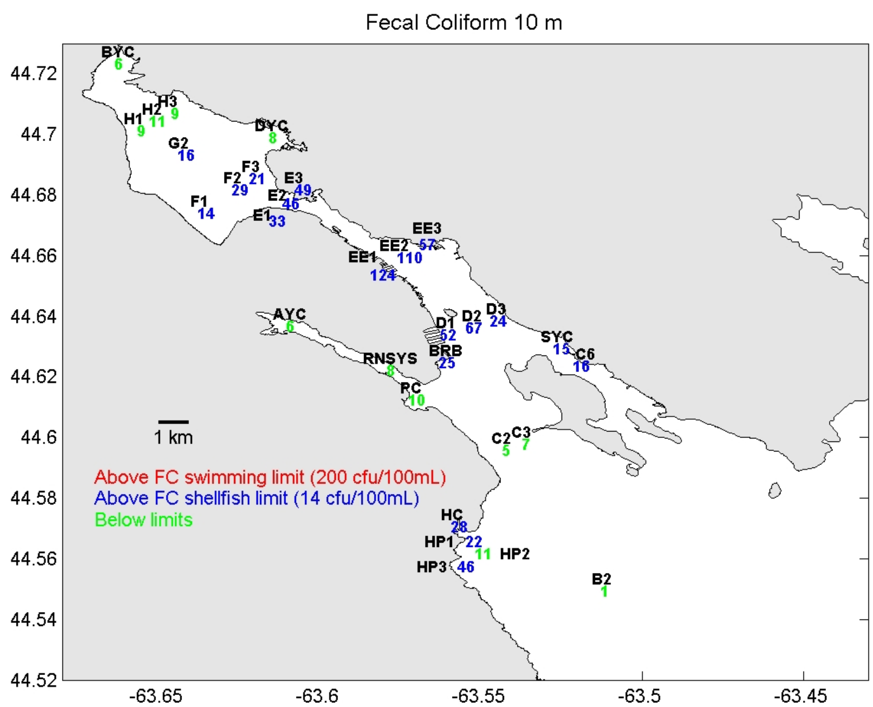
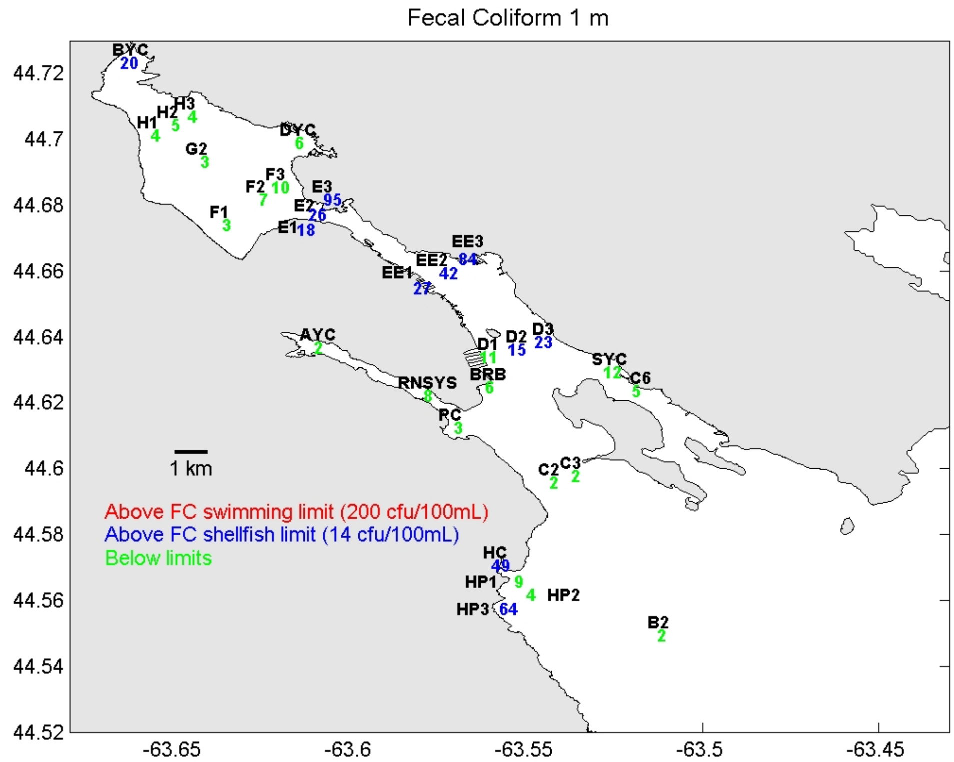


Figure 4. Fecal coliform annual geometric means (cfu/100mL), 2 July 2008 to 15 June 2009.



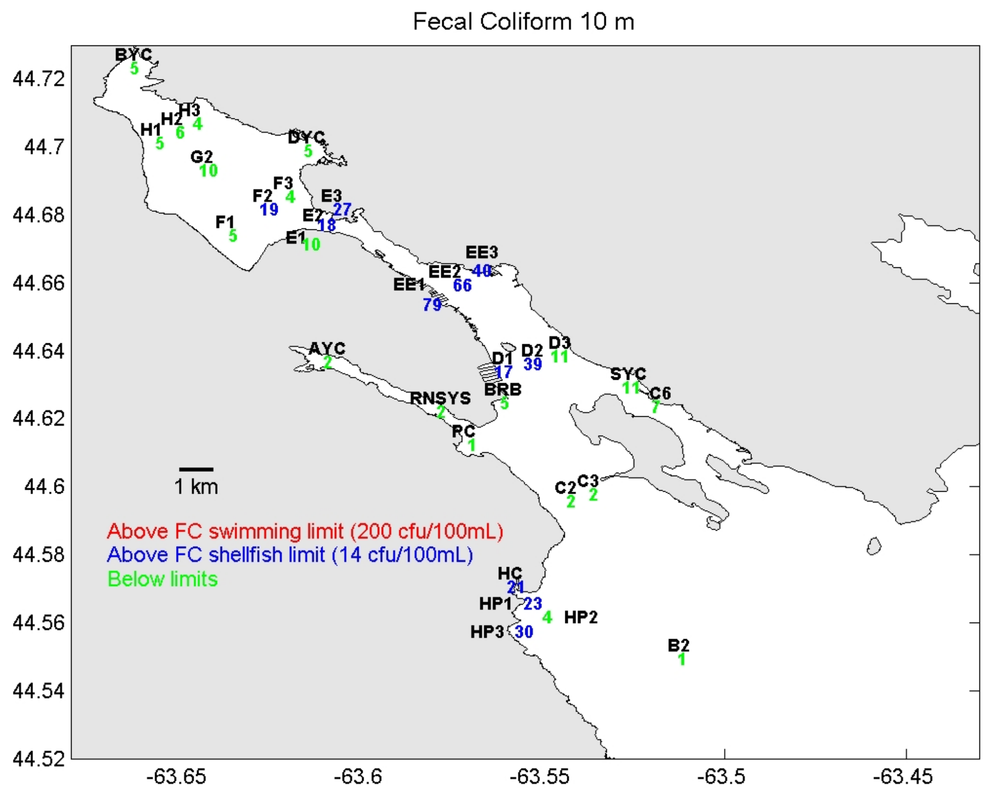


Figure 5. Fecal coliform geometric means (cfu/100mL), summer 2008 (2 July to 9 September 2008).

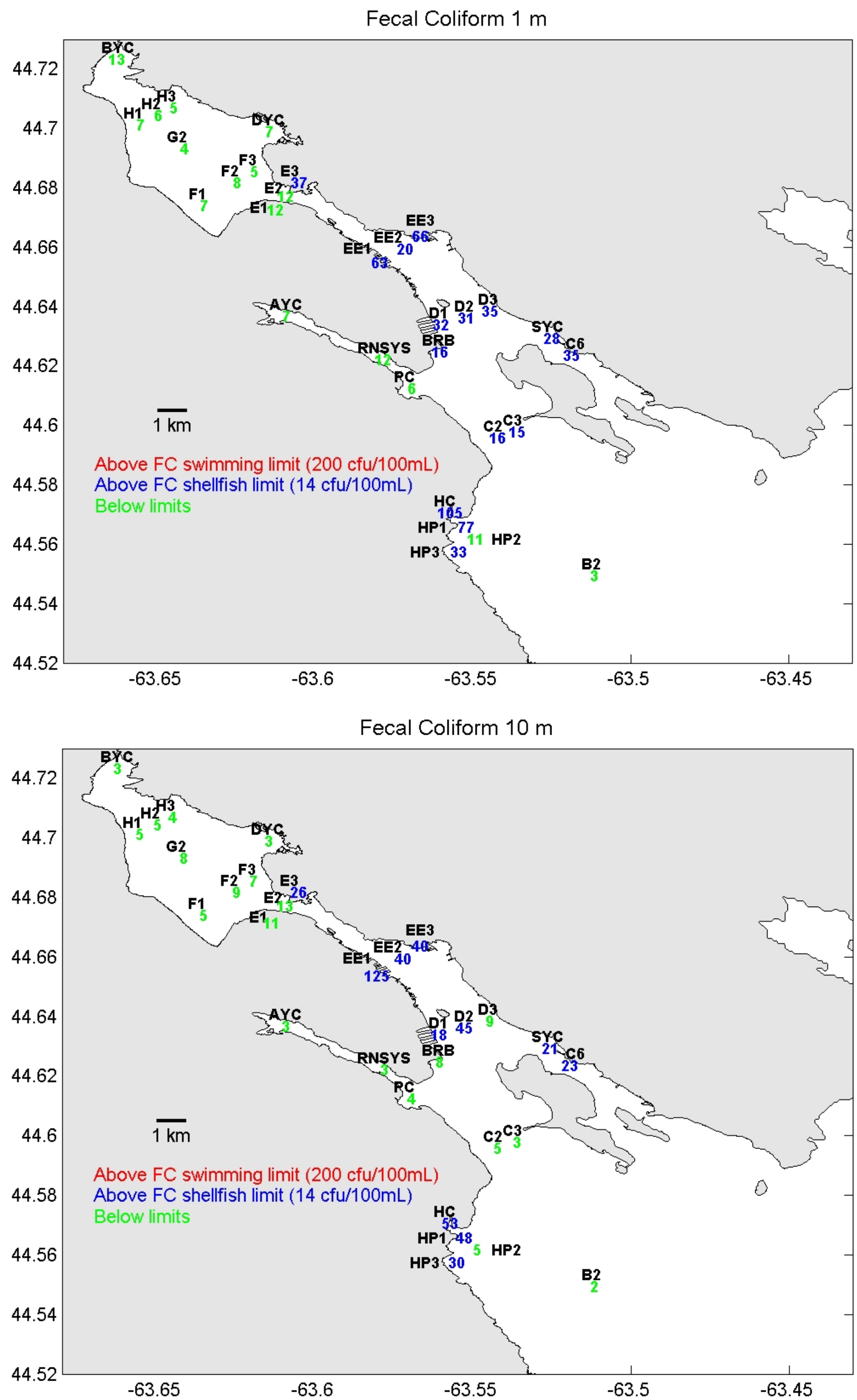


Figure 6. Fecal coliform geometric means (cfu/100mL), fall 2008 (23 September to 17 December 2008).

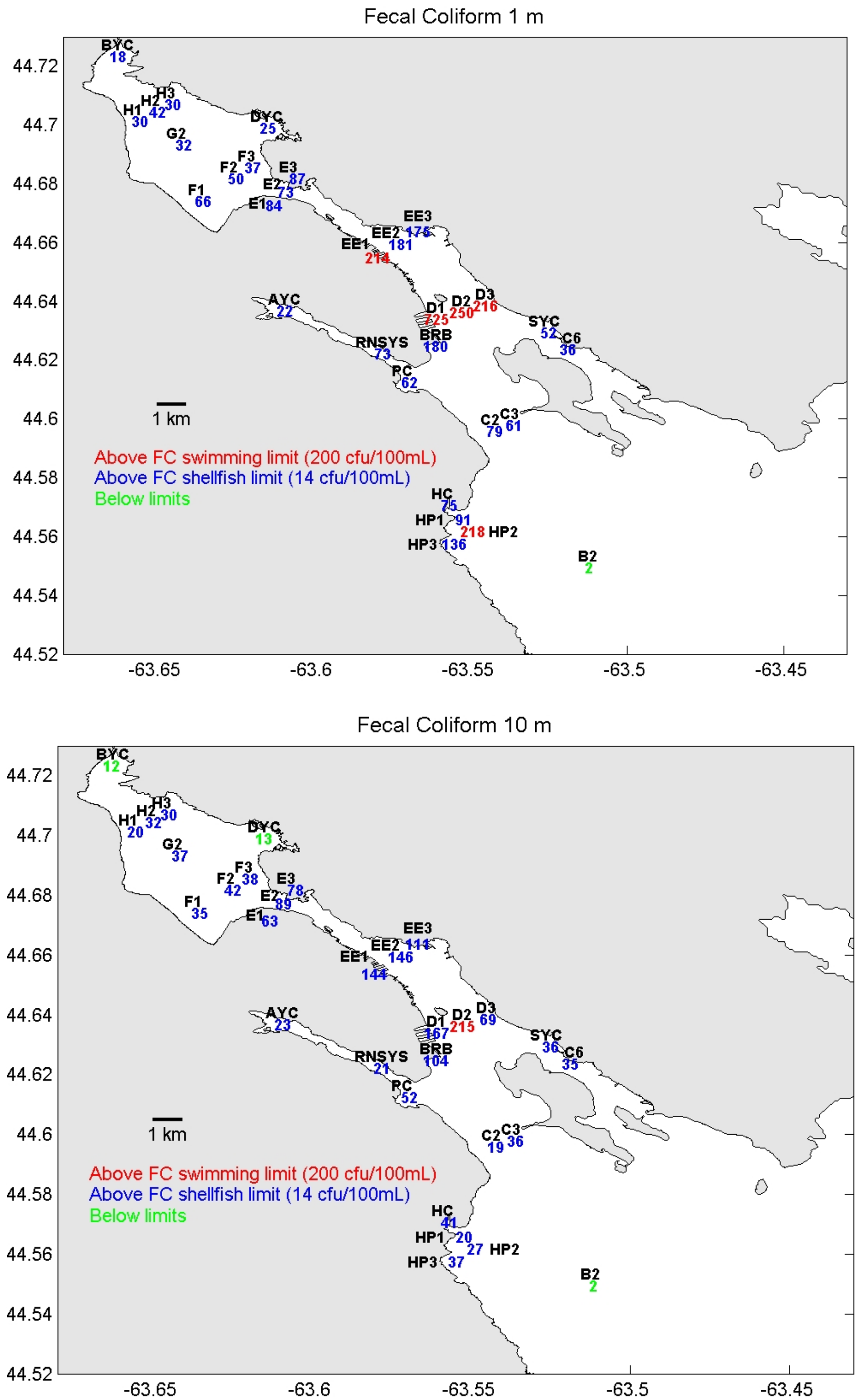


Figure 7. Fecal coliform geometric means (cfu/100mL), winter 2008/2009 (29 December 2008 to 11 March 2009).

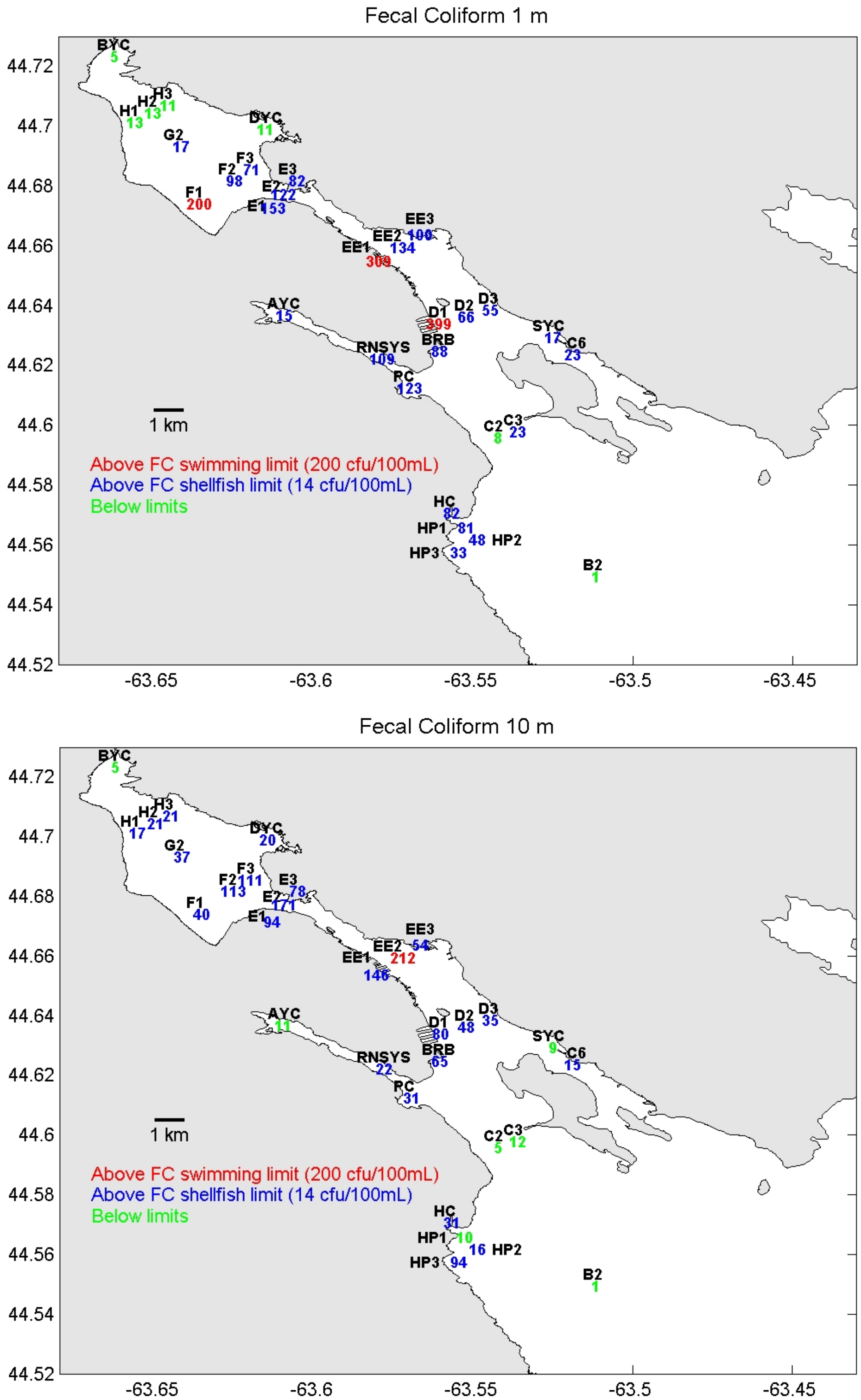


Figure 8. Fecal coliform geometric means (cfu/100mL), spring 2009 (25 March to 15 June 2009).

Thirty Day Floating Means

The thirty-day floating geometric mean, compiled for the entire year are shown in Tables 1 and 2. The most interesting period is the second quarter (surveys 165-171) when both plants were in operation. In this quarter, aside from some “unacceptable” values at HC and HP sites, due to the Tribune Head outfall, there were only four occurrences of “unacceptable” bacteria concentrations. Three occurred at site EE1, the site closest to the Halifax STP outfall, and EE2. Three of the four were at 10m.

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
Survey159	2	8	3	88	19	2	1	4	8	2	3	5	5	4	10
Survey160	2	8	3	112	24	1	1	3	4	2	3	17	7	4	6
Survey161	2	7	1	64	39	1	1	2	3	1	3	8	10	16	17
Survey162	2	9	8	248	47	1	4	3	9	1	2	7	13	55	27
Survey163	2	9	25	120	101	1	4	3	14	3	8	6	4	29	13
Survey164	2	24	9	44	147	4	11	3	11	3	30	28	3	7	15
Survey165	2	14	2	5	269	4	4	2	4	3	53	18	4	6	11
Survey166	3	76	8	3	230	9	16	1	5	3	38	37	6	16	31
Survey167	3	85	24	3	158	5	5	1	3	4	45	14	4	16	6
Survey168	3	490	24	70	50	18	14	3	8	7	32	21	18	49	26
Survey169	1	857	1	700	37	11	6	8	10	6	27	14	21	43	31
Survey170	3	229	5	265	17	70	73	19	27	10	18	27	82	187	166
Survey171	5	61	65	285	77	125	150	35	52	15	25	61	65	113	107
Survey172	3	28	47	104	58	115	94	29	24	14	44	96	110	143	221
Survey173	1	36	209	111	87	78	45	20	15	9	38	88	146	342	244
Survey174	1	13	255	41	47	60	26	12	9	7	49	139	115	719	170
Survey175	1	30	2700	120	66	228	52	85	41	14	16	120	220	2092	187
Survey176		250	160	270	87	267	57	157	101	21	12	66	200	3017	201
Survey177		524	294	139	65	281	57	314	424	21	22	51	351	2587	426
Survey178	1	200	364	115	122	25	45	68	278	22	57	23	260	982	402
Survey179	1	303	490	147	95	31	62	98	410	74	58	20	293	771	380
Survey180	1	159	467	209	133	10	62	70	99	57	17	13	316	699	135
Survey181	1	209	471	479	101	52	139	197	134	80	19	86	191	1613	166
Survey182	1	50	570	410	250	27	470	98	103	36	19	128	224	1620	85
Survey183	1	7	24	54	84	7	48	309	1635	28	19	1500	62	622	100
Survey184	1	21	17	29	75	19	21	127	476	10	5	42	93	315	39
Survey185	1	147	7	9	41	10	12	125	189	5	27	11	104	222	76
Survey186	1	266	17	7	59	8	7	86	20	3	39	5	31	169	21

	Inner Harbour							Bedford Basin								
	D3	EE1	EE2	EE3	E1	E2	E3	F1	F2	F3	DYC	G2	H1	H2	H3	BYC
Survey159	19	9	60	228	11	28	43	1	16	8	1	2	4	7	1	22
Survey160	7	29	33	24	24	21	53	2	14	12	4	7	3	3	3	19
Survey161	5	33	101	49	20	47	140	9	14	27	9	7	4	6	5	53
Survey162	32	103	167	63	153	105	244	19	12	52	32	8	6	7	9	25
Survey163	18	72	54	80	38	26	131	9	3	9	12	3	4	4	4	15
Survey164	42	57	12	49	26	16	143	3	3	5	12	3	3	3	4	15
Survey165	10	18	8	40	2	3	38	1	1	1	6	1	2	2	2	6
Survey166	25	23	18	40	2	3	13	2	1	1	4	1	2	2	2	10
Survey167	7	20	8	50	4	4	9	1	5	1	2	2	2	1	1	4
Survey168	39	110	12	67	9	6	9	3	7	1	1	2	2	1	1	7
Survey169	33	183	20	119	29	22	33	9	17	3	3	5	3	3	3	9
Survey170	139	323	120	146	67	50	53	52	27	18	16	11	19	18	12	20
Survey171	107	127	80	105	98	97	155	97	85	81	59	50	111	84	43	57
Survey172	222	155	128	226	126	176	183	90	131	94	74	65	157	157	53	117
Survey173	217	119	101	297	34	49	106	34	53	30	61	30	36	58	21	38
Survey174	108	106	136	310	35	40	64	25	30	17	72	17	15	43	14	21
Survey175	129	153	158	140	43	32	67	24	20	35		6	3	14	5	4
Survey176	203	186	163	68	72	53	46	22	17	58		5	8	6	39	8
Survey177	704	252	245	76	158	44	71	112	40	29		7	8	9	25	9
Survey178	663	268	218	107	107	35	52	120	29	19		11	12	14	37	4
Survey179	259	555	336	277	165	103	109	252	108	21	1	52	19	32	28	6
Survey180	66	214	223	213	172	85	94	109	71	29	2	118	17	13	19	3
Survey181	123	363	409	355	476	195	213	250	548	71	13	560	66	43	50	24
Survey182	222	245	395	109	1102	113	310	409	1200	204	56	560	95	36	84	24
Survey183	187	520	510	122	587	497	339	361	216	373	71	132	88	36	37	24
Survey184	54	342	45	38	74	187	35	386	23	93	20	8	10	4	5	4
Survey185	33	383	90	58	81	121	38	240	64	37	10	4	5	6	3	2
Survey186	13	315	33	38	55	68	28	248	72	34	6	1	3	6	3	2

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
Survey159	2	12	8	19	5	1	1	1	2	1	1	4	1	9	14
Survey160	2	23	11	14	6	3	1	1	2	1	5	8	7	8	27
Survey161	2	112	27	22	10	5	1	2	2	2	10	8	15	28	43
Survey162	1	22	4	29	38	5	4	2	2	2	18	8	26	43	284
Survey163	1	3	1	118	105	2	4	2	3	5	15	23	9	31	59
Survey164	1	31	1	55	110	1	8	1	2	4	16	18	3	15	37
Survey165	1	90	1	16	52	3	2	1	2	3	44	30	4	11	21
Survey166	2	103	1	13	39	3	3	1	1	1	18	6	5	10	38
Survey167	2	68	1	13	35	3	1	1	2	1	29	10	4	7	31
Survey168	4	25	6	55	36	1	1	2	2	1	21	19	6	25	46
Survey169	4	74	36	17	34	2	1	4	5	2	40	27	8	55	55
Survey170	3	12	20	18	17	20	4	9	6	4	25	24	23	101	104
Survey171	2	48	39	43	93	96	24	26	11	7	13	15	23	23	99
Survey172	2	29	47	110	55	49	23	19	10	12	17	17	37	20	195
Survey173	1	36	87	108	56	16	28	26	12	10	26	26	42	57	195
Survey174	1	19	69	116	21	8	27	14	16	9	59	50	55	211	129
Survey175	1	35	72	19	24	35	70	61	51	21	42	61	91	602	134
Survey176	5	36	72	24	27	59	50	100	98	39	45	46	176	505	166
Survey177	5	38	35	42	25	44	42	254	126	55	51	103	364	622	364
Survey178	2	31	33	25	41	7	28	104	16	38	81	63	304	449	413
Survey179	1	10	8	18	43	6	48	104	16	42	63	60	247	302	385
Survey180	1	5	5	9	57	3	61	66	13	22	34	19	237	148	135
Survey181	1	9	17	67	62	22	189	143	61	33	46	24	178	170	125
Survey182	1	79	280	500	130	72	410	57	73	30	24	19	200	221	59
Survey183	1	15	78	300	52	15	35	47	128	53	26	53	106	254	89
Survey184	1	10	42	141	31	6	4	33	55	7	5	4	130	34	34
Survey185	1	20	32	99	10	4	3	20	36	4	9	3	63	57	45
Survey186	1	14	12	205	14	3	2	9	12	2	4	2	13	20	9

	Inner Harbour							Bedford Basin								
	D3	EE1	EE2	EE3	E1	E2	E3	F1	F2	F3	DYC	G2	H1	H2	H3	BYC
Survey159	9	26	72	54	15	17	51	4	21	8	6	15	17	9	12	2
Survey160	32	90	70	65	6	18	30	4	19	7	7	13	8	13	8	7
Survey161	61	143	133	61	14	42	34	11	21	7	9	9	6	15	9	10
Survey162	57	290	216	63	20	70	34	10	47	5	8	12	3	9	4	20
Survey163	9	221	64	30	14	32	32	7	20	4	4	7	2	4	4	5
Survey164	3	104	27	18	7	13	19	4	12	3	4	7	3	3	3	6
Survey165	1	100	15	26	2	3	7	2	3	3	2	4	3	2	1	3
Survey166	2	38	22	33	5	5	9	3	2	4	2	4	3	2	2	4
Survey167	3	38	17	58	7	5	18	2	3	4	1	5	2	1	1	3
Survey168	14	126	111	49	26	15	48	3	8	8	1	3	2	1	2	2
Survey169	22	271	136	50	32	20	68	5	24	10	4	5	5	5	5	2
Survey170	45	445	400	52	49	86	54	12	33	20	6	9	16	19	13	3
Survey171	45	135	40	49	24	39	51	14	37	16	15	38	21	48	18	6
Survey172	45	74	66	74	40	80	61	16	59	19	14	38	19	37	14	15
Survey173	57	65	79	98	48	70	63	15	40	31	23	33	20	22	14	22
Survey174	45	62	177	127	72	105	55	19	35	32	13	23	22	15	11	37
Survey175	47	193	159	86	79	89	68	22	29	38		18	36	16	22	18
Survey176	74	311	128	70	71	81	95	40	21	33		29	3	39	93	14
Survey177	187	355	190	87	96	82	125	83	27	37		31	10	25	52	18
Survey178	201	343	233	175	77	65	156	81	27	88		27	20	31	87	7
Survey179	113	161	287	226	106	130	109	104	74	74	11	49	31	33	50	8
Survey180	56	144	235	149	156	118	121	39	94	49	10	58	19	22	23	4
Survey181	38	274	390	120	161	254	141	58	358	40	31	553	21	60	31	40
Survey182	86	790	445	60	241	226	305	40	800	121	49	1800	28	69	41	55
Survey183	70	849	672	96	141	529	232	86	410	260	76	281	35	134	117	67
Survey184	99	101	222	39	57	198	78	67	56	181	28	22	19	33	7	2
Survey185	22	58	199	40	52	198	26	38	48	97	22	26	13	16	8	2
Survey186	11	46	88	11	44	96	24	25	54	109	9	7	10	6	6	2

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.

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. As with the mean values the expected seasonal variation is largely overridden by STP operation.

In the Basin (Fig. 9) the minimum concentrations occur in September and October when both plants were functioning, however concentrations increase through December. This is possibly a seasonal effect of cooler water and lower sunlight, but could also be related to STP “debugging”. Interestingly there is not a major spike with the failure of the Halifax STP. However the levels at F2 are definitely higher in the last half of the year. The picture at H2 is not as straight forward. Concentrations decrease going in to spring, again this may be a seasonal effect of warming water and increased sunlight. There is not a consistent vertical pattern at either site; either the 1 or 10m sample may have higher concentrations.

In the Inner Harbour (Fig. 10) the concentrations decrease markedly in the fall with both plants operating. Concentrations increase with the failure of the plant, but remain close to the 100-200 cfu/100 mL level. Again there is not a consistent vertical picture with the concentrations at 1 and 10 m being very similar and the highest concentrations occurring at either depth.

The Northwest Arm (Fig. 11) levels show the most dramatic changes. With treatment, primarily the diversion of the Chain Rock outfall to the Halifax STP, the bacteria levels drop dramatically. With the Halifax plant failure in mid January, conditions returned to essentially the same as before treatment.

In the Outer Harbour (Fig. 12) the picture is quite interesting. The concentrations at B2 are higher (though still low in an absolute sense) in the fall with the plants operating than in the winter. This may partly be a seasonal transport issue. In the summer and fall when the water column is more stratified, there is more two-layer “sloshing” and it may be easier for water from the inner harbour to make it to the outer harbour within the decay time of the bacteria. This is not so evident at C2 that is closer to Inner Harbour sources. At both these sites there is a tendency for the higher values to be in the 1m samples.

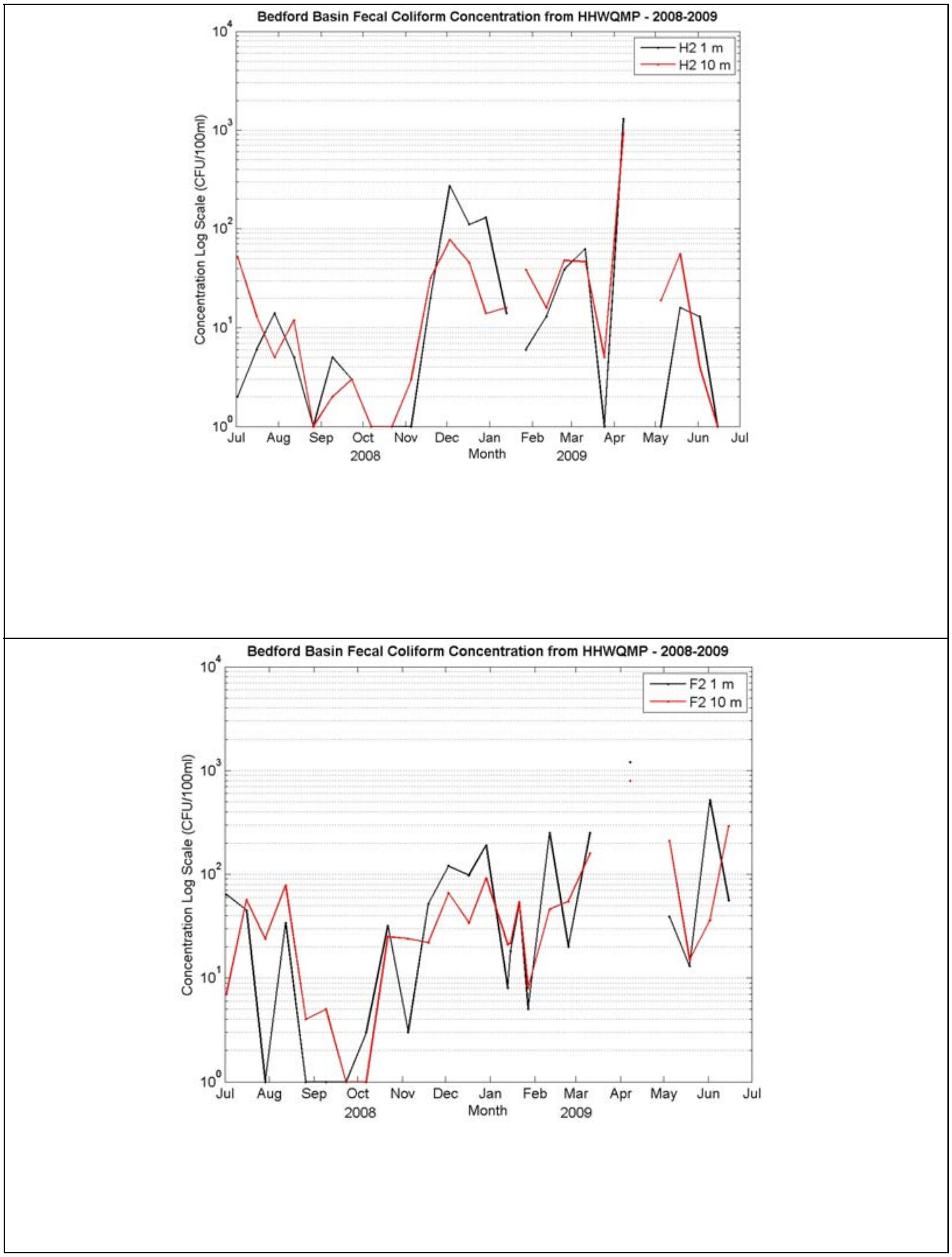


Figure 9. HHWQMP Bedford Basin Fecal Coliform Concentration (2 July 2008 to 15 June 2009).

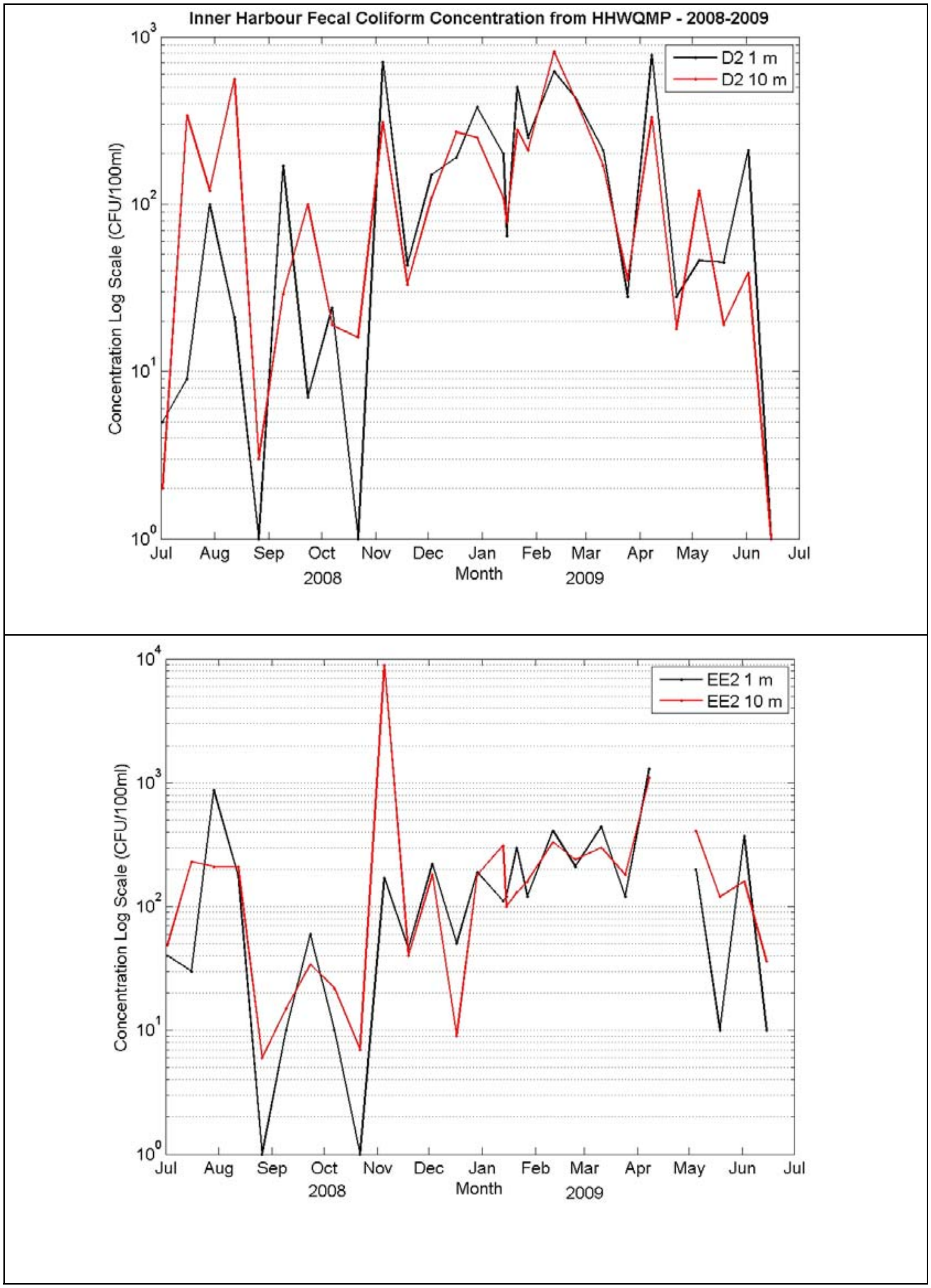


Figure 10. HHWQMP Inner Harbour Fecal Coliform Concentration (2 July 2008 to 15 June 2009).

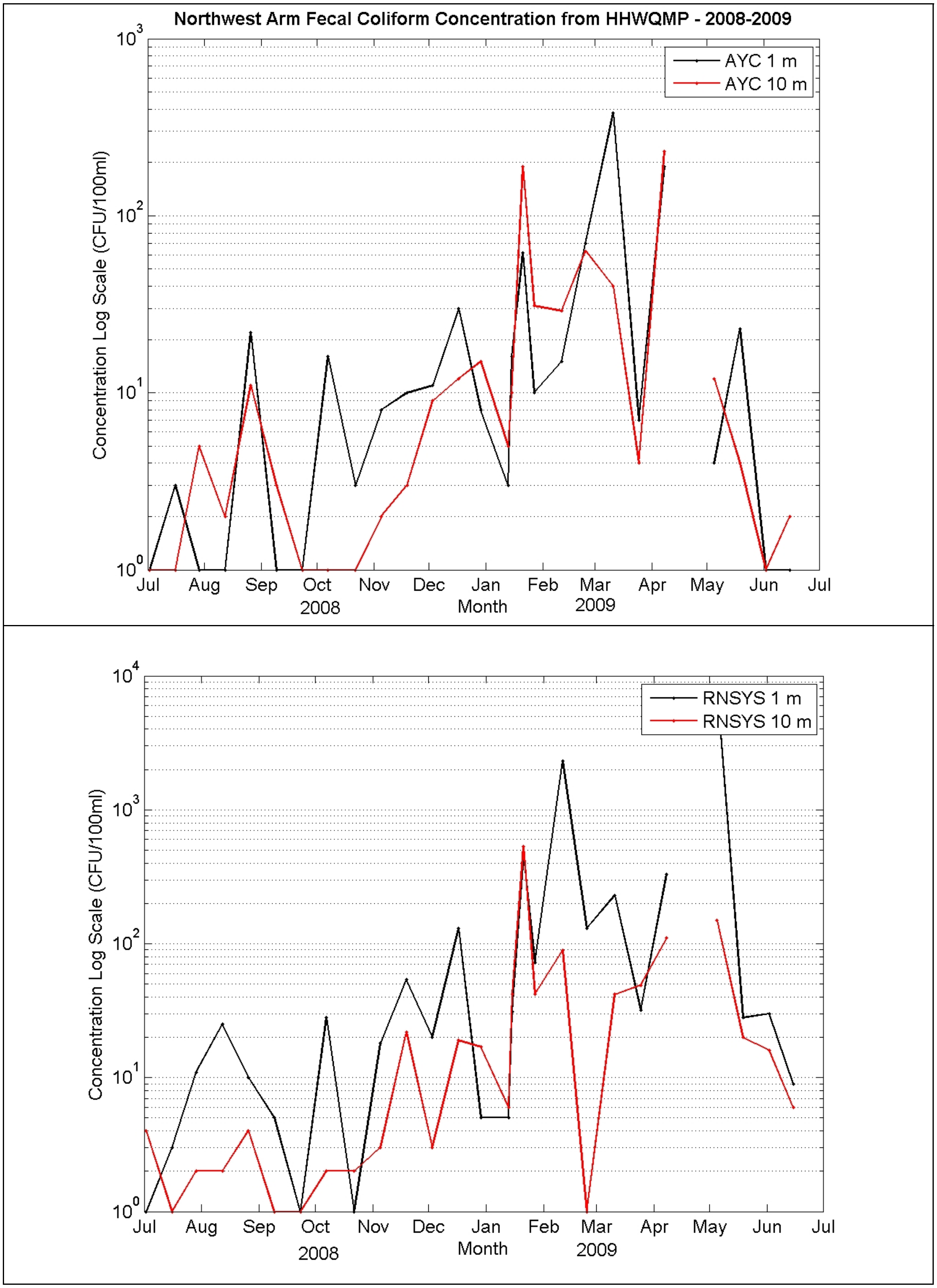


Figure 11. HHWQMP Northwest Arm Fecal Coliform Concentration (2 July 2008 to 15 June 2009).

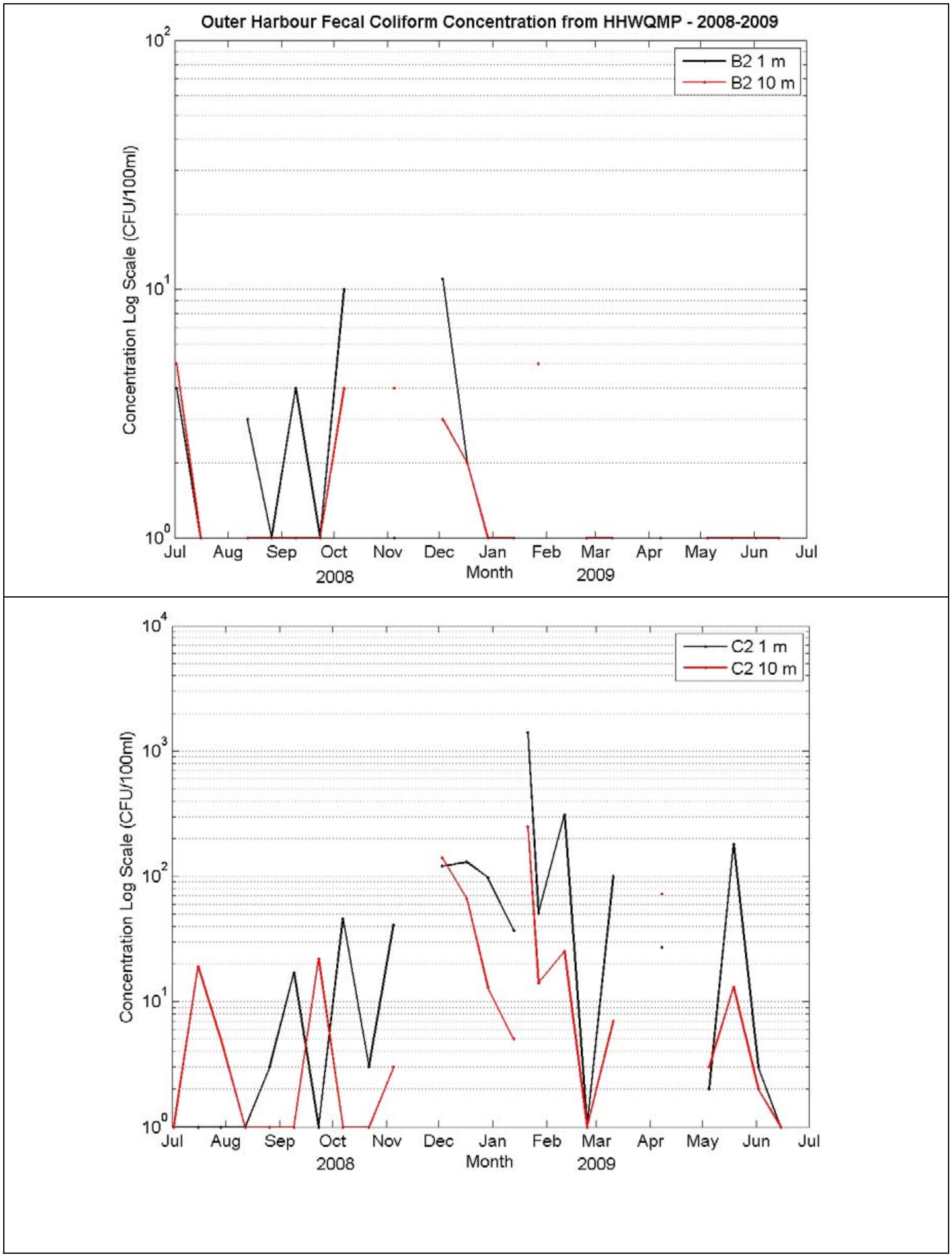


Figure 12. HHWQMP Outer Harbour Fecal Coliform Concentration (2 July 2008 to 15 June 2009).

6 Ammonia Nitrogen

The measured values of ammonia nitrogen at 1 and 10m over the entire fifth 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 0.16 mg/L. The higher survey means are sometimes skewed by single high measurements (up to 0.42 mg/L). 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 wand 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
2-Jul-08	0.06	ND	ND	0.05	0.06	ND	0.10	0.05	0.10
16-Jul-08	0.11	0.06	0.07	0.07	0.06	0.07	0.07	0.07	0.11
29-Jul-08	missed	ND	ND	ND	ND	ND	ND	ND	ND
12-Aug-08	0.07	0.06	0.06	0.07	0.22	0.06	0.06	0.09	0.22
26-Aug-08	0.10	0.11	0.10	0.10	0.08	0.10	0.10	0.10	0.11
9-Sep-08	0.11	0.10	0.09	0.11	0.09	0.08	0.10	0.10	0.11
23-Sep-08	0.11	0.22	0.11	0.07	0.08	0.10	0.10	0.11	0.22
7-Oct-08	ND	ND	0.05	ND	ND	0.06	0.09	0.04	0.09
22-Oct-08	missed	0.10	0.11	0.11	0.13	0.09	0.10	0.11	0.13
5-Nov-08	ND	0.08	0.07	0.07	0.06	0.07	0.12	0.07	0.12
19-Nov-08	missed	ND	ND	ND	0.05	0.06	0.06	0.04	0.06
3-Dec-08	ND	0.08	0.07	0.07	0.06	0.07	0.12	0.07	0.12
17-Dec-08	ND	0.10	0.07	0.11	0.08	0.09	0.10	0.08	0.11
29-Dec-08	ND	0.07	0.12	0.09	0.12	0.06	0.09	0.08	0.12
13-Jan-09	0.05	0.09	0.09	0.10	0.11	0.10	0.13	0.10	0.13
15-Jan-09	missed	0.09	0.07	0.42	0.07	missed	missed	0.16	0.42
21-Jan-09	missed	0.08	0.08	0.09	0.09	missed	missed	0.09	0.09
27-Jan-09	ND	0.07	0.07	0.09	0.09	0.10	0.14	0.08	0.14
11-Feb-09	missed	0.07	0.08	0.09	0.08	0.10	0.10	0.09	0.10
24-Feb-09	ND	0.08	0.09	0.10	0.11	0.09	0.09	0.08	0.11
11-Mar-09	ND	ND	0.09	0.06	0.07	0.09	0.08	0.06	0.09
25-Mar-09	missed	0.06	0.05	0.11	missed	missed	0.06	0.07	0.11
8-Apr-09	ND	ND	ND	ND	ND	ND	0.09	0.03	0.09
22-Apr-09	missed	ND	0.06	ND	ND	0.06	ND	0.04	0.06
5-May-09	0.05	ND	0.07	0.06	0.12	0.08	0.15	0.08	0.15
19-May-09	ND	ND	ND	ND	ND	ND	ND	ND	ND
2-Jun-09	ND	ND	ND	ND	ND	ND	ND	ND	ND
15-Jun-09	ND	ND	0.06	0.07	0.08	0.09	0.14	0.07	0.14
mean	0.05	0.06	0.07	0.08	0.08	0.07	0.09	0.07	
max	0.11	0.22	0.12	0.42	0.22	0.10	0.15		0.42

Table 4. Annual Summary of 10 m Ammonia Nitrogen

10 m	B2	D2	EE2	E2	F2	G2	H2	mean	max
2-Jul-08	ND	ND	ND	ND	ND	0.06	0.05	0.03	0.06
16-Jul-08	0.07	0.08	0.06	0.09	0.07	0.07	0.08	0.07	0.09
29-Jul-08	missed	ND	ND	ND	ND	ND	ND	ND	ND
12-Aug-08	0.06	0.08	0.09	0.09	0.07	0.07	0.09	0.08	0.09
26-Aug-08	0.08	0.12	0.11	0.10	0.10	0.11	0.12	0.11	0.12
9-Sep-08	0.09	0.13	0.13	0.10	0.08	0.09	0.11	0.10	0.13
23-Sep-08	0.23	0.14	0.12	0.11	0.14	0.21	0.11	0.15	0.23
7-Oct-08	ND	ND	ND	ND	ND	0.09	0.08	0.04	0.09
22-Oct-08	missed	0.11	0.10	0.10	0.12	0.09	0.08	0.10	0.12
5-Nov-08	ND	0.11	0.09	0.08	0.07	0.08	0.09	0.08	0.11
19-Nov-08	missed	ND	0.42	0.05	0.06	0.06	0.07	0.11	0.42
3-Dec-08	ND	0.11	0.09	0.08	0.07	0.08	0.09	0.08	0.11
17-Dec-08	ND	0.13	0.05	0.09	0.08	0.06	0.08	0.07	0.13
29-Dec-08	ND	0.06	0.10	0.07	0.08	0.06	0.06	0.07	0.1
13-Jan-09	0.05	0.08	0.14	0.08	0.10	0.12	0.08	0.09	0.14
15-Jan-09	missed	0.09	0.08	0.07	0.07	missed	missed	0.08	0.09
21-Jan-09	missed	0.06	0.07	0.08	0.10	missed	missed	0.08	0.10
27-Jan-09	ND	0.08	0.06	0.08	0.08	0.13	0.09	0.08	0.13
11-Feb-09	missed	0.07	0.06	0.07	0.08	0.08	0.09	0.08	0.09
24-Feb-09	ND	0.14	0.18	0.10	0.10	0.17	0.08	0.11	0.18
11-Mar-09	ND	0.05	0.05	0.05	0.06	0.06	0.05	0.05	0.06
25-Mar-09	missed	0.05	0.06	0.07	missed	missed	0.07	0.06	0.07
8-Apr-09	ND	0.06	0.06	ND	0.06	ND	ND	0.04	0.06
22-Apr-09	missed	ND	0.05	ND	0.05	ND	ND	0.03	0.05
5-May-09	0.05	0.11	0.07	ND	0.06	0.08	0.06	0.07	0.11
19-May-09	ND	ND	ND	0.10	0.025	0.05	ND	0.04	0.10
2-Jun-09	ND	ND	ND	0.06	ND	ND	ND	0.03	0.06
15-Jun-09	ND	ND	0.07	0.07	0.08	0.08	0.06	0.06	0.08
mean	0.05	0.07	0.09	0.07	0.07	0.08	0.07	0.07	
max	0.23	0.14	0.42	0.11	0.14	0.21	0.12		0.42

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 no observations below the detection limit. On average the TSS levels are quite low. The annual mean level is about 3.1 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. Interestingly there is no obvious correlation with the STP operations. This is likely a more subtle effect.

Table 5. Annual summary of 1 m TSS values

1 m	**B2**	**D2**	**EE2**	**E2**	**F2**	**G2**	**H2**	**mean**	**max**
2-Jul-08	2.0	3.7	2.9	3.1	3.5	1.3	3.0	2.8	3.7
16-Jul-08	4.1	3.0	5.0	7.0	4.3	8.0	11.0	6.1	11.0
29-Jul-08	missed	7.0	4.5	4.0	8.9	12.0	6.0	7.1	12.0
12-Aug-08	3.0	2.2	4.9	3.0	11	5.0	4.1	4.7	11.0
26-Aug-08	4.0	3.0	3.0	4.0	4.0	4.0	5.0	3.9	5.0
9-Sep-08	3.0	2.4	4.5	4.5	3.8	4.4	3.4	3.7	4.5
23-Sep-08	1.8	2.9	2.0	1.9	3.6	2.3	6.8	3.0	6.8
7-Oct-08	1.0	2.0	2.0	3.0	3.0	4.0	2.0	2.4	4.0
22-Oct-08	missed	1.0	2.0	2.0	4.0	4.0	5.0	3.0	5.0
5-Nov-08	1.0	1.0	1.0	2.0	3.0	3.0	1.0	1.7	3.0
19-Nov-08	missed	4.2	3.2	4.1	4.4	1.8	3.6	3.6	4.4
3-Dec-08	1.0	1.0	1.0	2.0	3.0	3.0	1.0	1.7	3.0
17-Dec-08	1.1	2.0	2.0	2.3	2.0	5.0	5.0	2.8	5.0
29-Dec-08	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
13-Jan-09	2.0	2.2	5.0	1.9	2.8	4.0	2.0	2.8	5.0
15-Jan-09	missed	3.0	2.0	1.0	1.0	missed	missed	1.8	3.0
21-Jan-09	missed	2.0	3.0	1.0	3.0	missed	missed	2.3	3.0
27-Jan-09	3.0	2.7	1.0	2.0	1.0	1.0	4.0	2.1	4.0
11-Feb-09	0.9	3.3	7.7	1.5	2.2	2.5	4.6	3.2	7.7
24-Feb-09	2.5	4.1	3.6	1.5	2.6	2.4	4.2	3.0	4.2
11-Mar-09	0.9	1.0	5.3	4.9	2.0	2.6	5.3	3.1	5.3
25-Mar-09	missed	2.3	6.1	2.7	missed	missed	1.7	3.2	6.1
8-Apr-09	3.0	3.3	8.7	5.9	11.0	8.7	6.3	6.7	11.0
22-Apr-09	missed	3.5	2.4	3.0	3.4	2.9	6.5	3.6	6.5
5-May-09	1.6	1.7	3.1	2.2	2.2	4.0	2.1	2.4	4.0
19-May-09	2.1	5.5	2.5	2.6	1.1	2.9	2.4	2.7	5.5
2-Jun-09	ND	6.0	4.0	4.0	5.0	3.0	5.0	3.9	6.0
15-Jun-09	0.6	1.4	1.0	0.8	1.1	0.9	1.3	1.0	1.4
mean	1.9	2.8	3.4	2.9	3.7	3.8	4.0	3.2	5.5
max	4.1	7.0	8.7	7.0	11.0	12.0	11.0	7.1	12.0

Table 6. Annual summary of 10 m TSS values

10 m	B2	D2	EE2	E2	F2	G2	H2	mean	max
2-Jul-08	3.1	3.6	4.0	2.2	1.4	2.0	3.0	2.8	4.0
16-Jul-08	3.2	5.0	5.0	8.3	8.0	12.0	6.0	6.8	12.0
29-Jul-08	missed	3.8	3.4	6.0	6.0	9.0	4.0	5.4	9.0
12-Aug-08	2.8	3.0	4.0	2.1	7.3	3.7	8.0	4.4	8.0
26-Aug-08	3.0	3.0	3.0	3.0	5.0	4.0	4.0	3.6	5.0
9-Sep-08	0.7	2.4	4.9	2.6	3.0	11.0	3.0	3.9	11.0
23-Sep-08	4.1	2.0	2.0	1.5	1.5	2.9	4.5	2.6	4.5
7-Oct-08	4.0	3.0	3.0	5.0	2.0	6.0	1.0	3.4	6.0
22-Oct-08	missed	1.0	2.0	2.0	2.0	2.8	4.0	2.3	4.0
5-Nov-08	1.0	2.0	4.0	1.0	1.0	5.0	2.0	2.3	5.0
19-Nov-08	missed	1.5	1.8	2.7	3.0	2.2	2.3	2.3	3.0
3-Dec-08	1.0	2.0	4.0	1.0	1.0	5.0	2.0	2.3	5.0
17-Dec-08	0.9	5.0	1.0	5.0	2.0	2.0	1.0	2.4	5.0
29-Dec-08	2.0	3.0	3.0	3.0	2.0	3.0	2.0	2.6	3.0
13-Jan-09	2.0	3.0	ND	1.4	3.0	2.0	2.0	1.9	3.0
15-Jan-09	missed	2.0	7.0	1.0	1.0	missed	missed	2.8	7.0
21-Jan-09	missed	3.0	2.0	1.0	1.0	missed	missed	1.8	3.0
27-Jan-09	2.0	2.0	3.0	2.0	8.0	2.0	3.0	3.1	8.0
11-Feb-09	0.5	5.7	3.1	1.8	4.6	3.4	3.1	3.2	5.7
24-Feb-09	1.3	2.6	1.4	2.8	1.0	3.6	2.2	2.1	3.6
11-Mar-09	2.0	1.1	1.3	3.2	3.0	4.2	3.7	2.6	4.2
25-Mar-09	missed	5.9	3.2	6.2	missed	missed	2.9	4.6	6.2
8-Apr-09	3.2	4.3	3.9	7.7	6.8	5.7	4.1	5.1	7.7
22-Apr-09	missed	2.5	2.5	3.7	2.8	2.1	1.8	2.6	3.7
5-May-09	1.5	3.5	6.5	2.7	3.7	2.3	1.5	3.1	6.5
19-May-09	1.2	4.5	2.3	3.9	1.2	2.1	5.6	3.0	5.6
2-Jun-09	2.5	2.0	2.0	3.0	7.0	2.0	4.0	3.2	7.0
15-Jun-09	0.7	0.8	1.1	1.7	0.7	2.8	1.7	1.4	2.8
mean	2.0	3.0	3.0	3.1	3.3	4.1	3.2	3.1	5.7
max	4.1	5.9	7.0	8.3	8.0	12.0	8.0	6.8	12.0

8 Metals

A summary of all measured metals concentrations over year five are presented in Figure 13. There are some individual guideline exceedances, notably in mercury and copper, however the mean values for all metals are well below the guideline levels. This quarter there are more sites with mercury exceedances than copper exceedances. The metal that regularly has measured concentrations 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 it would be mostly non-detectable.

This plot shows that of the metals for which guidelines exist copper, manganese and zinc regularly have detectable levels (means are above the detection limit). Lead, nickel and mercury are occasionally detectable, while cadmium is seldom 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.

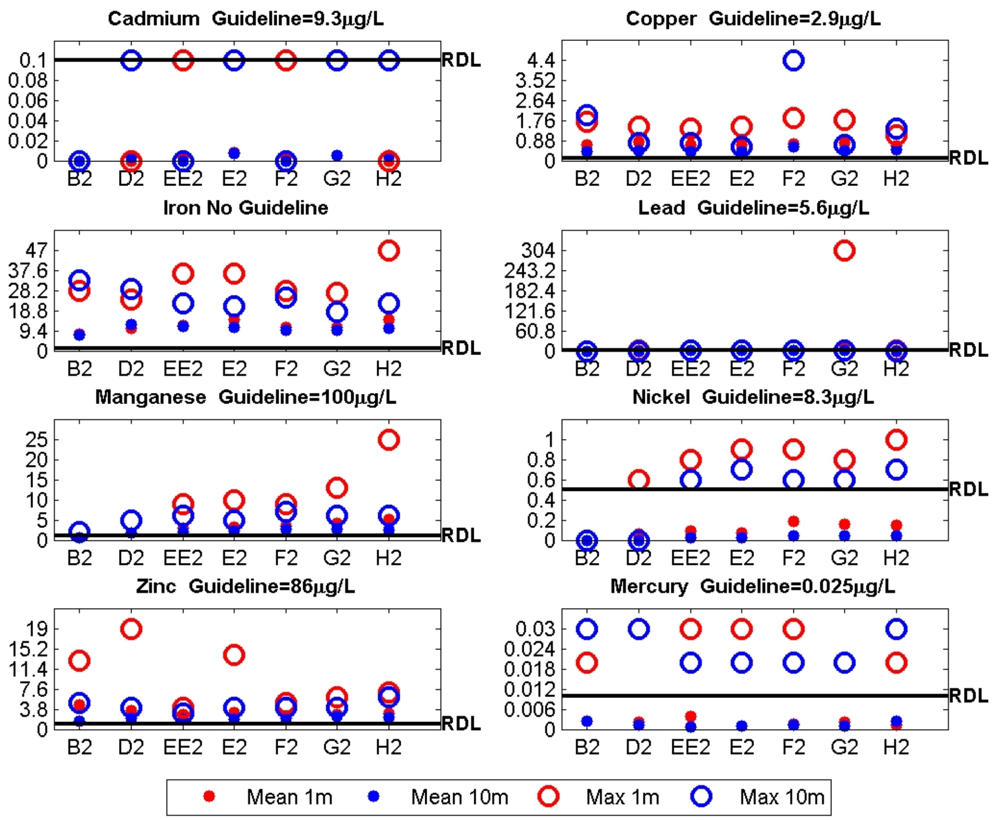


Figure 13. Mean and maximum values of metals (µg/L) over all year five samples.

9 References

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