Halifax Harbour
Water Quality Monitoring Program
Quarterly Report #4

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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 weekly sampling at over 30 sites located from the Bedford Basin to the Outer Halifax Harbour. Water samples taken at 1m and 10m depths are analyzed for a range of parameters. In addition, continuous profiles of basic hydrographic properties (salinity, temperature and density), dissolved oxygen and chlorophyll *a* are collected. The sample and profile data are presented in weekly reports along with ancillary data including water level, wind, rainfall and other parameters. The weekly reports are generated as inserts into a binder (JWEL and COA, 2004). The detailed datasets are also archived to CD and delivered on a weekly basis with the reports. A detailed description of the program is contained in the introduction section of the report binder.

The weekly data sets are reviewed on a quarterly basis (13 weeks). The main objective of the quarterly reports is to summarize and evaluate the weekly 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.

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 will be 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 22 March to 14 June 2005. The analysis presented here is an evolving presentation of the data. 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. The 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 which can occur as the project proceeds. In this report, the data from the center of Bedford Basin (Our Station G2) is compared with data collected at the same site by the Bedford Basin Phytoplankton Monitoring Program conducted by scientists with the Department of Fisheries and Oceans at Bedford Institute of Oceanography. Since this is the fourth quarterly report, an annual summary of data and trends over the first four quarters is also included.

2 Weekly Reporting

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

From time to time errors are discovered in the weekly reports after they have been issued. In addition, the sampling program is modified periodically, necessitating changes in the weekly reports. An Errata/Changes section is included in the Introduction section of the report binder and is updated on a quarterly basis. This documents any issues which could affect the interpretation of the data, as well as documenting changes in the data collection or analysis.

3 Sampling Program

Survey sampling is conducted on a weekly basis from one of two vessels based at the Armdale Yacht Club (AYC). The details of the sampling program are discussed in the introduction section of the project report binder and QR#1. The locations of the 34 sampling sites are included for reference in Figure 1. Sampling involves the collection of continuous profile data and discrete water samples at 1 and 10m water depth. The level of analysis varies from site to site. The Levels are: CTD sites (CTD only), Bacteria (CTD and coliform bacteria) and Chem (CTD, Bacteria, and additional contaminant analysis). The additional sampling at the Chem sites occurs on a bi-weekly basis. A summary of the sampling and analysis schedules and relevant established criteria are reiterated in Table 1. In addition, a "supplemental sample" procedure is in place. This allows water samples to be taken at additional sites, based on visual observations, at the discretion of the field team. During this quarter, there were two supplemental samples taken. The results are discussed in Section 3. The laboratory analysis on these supplementary samples is made possible using funds saved from missed samples during the regular program. During this quarter there were six missed Chem stations, both 1 and 10 m samples for a total of 12 samples, and 26 missed Bacteria stations or 52 missed samples. These stations were missed due to ice, environmental conditions or conflicting harbour activities (e.g. diving operations). The missed stations are described in the weekly reports.

3.1 Sampling Order

Sampling generally occurs on Tuesday, with Wednesday and Thursday as contingency days. Every week 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 QR#1. The sampling order for each week in the fourth quarter is presented in Table 2.

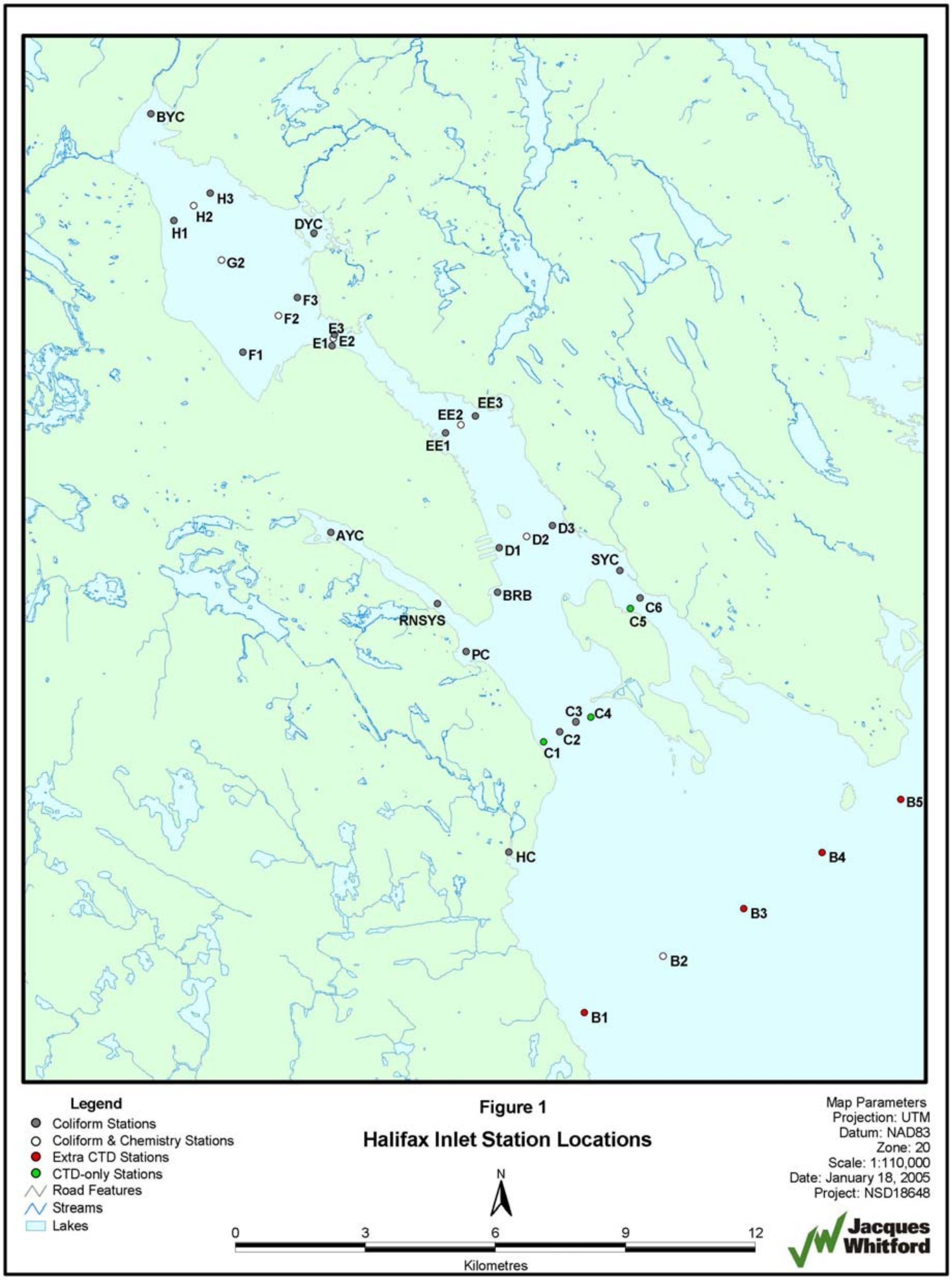


Figure 1. Halifax Inlet Sample Locations

Table 1. Summary of measured parameters

	EQL		Harbour Task Force Guideline	Water Use Category	Sampling Stations (refer to Fig. 1)	Sampling frequency
	value	units				
Profile Data					All	weekly
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	weekly
Fecal Coliform	0	cfu/100ml	14 200	SA SB		
Chemical Samples					Chemical sites	bi-weekly
CBOD	5	mg/L	none			
Ammonia Nitrogen	0.05	mg/L	none			
TSS	0.5	mg/L	<10% background	all		
Total Oil and Grease	5	mg/L	10	all		
Metal scan					Chemical sites	bi-weekly
Cadmium	3	ug/L	9.3	all		
Chromium	20	ug/L	50.0	all		
Copper	20	ug/L	2.9	all		
Lead	5	ug/L	5.6	all		
Manganese	20	ug/L	100.0	all		
Nickel	20	ug/L	8.3	all		
Zinc	50	ug/L	86.0	all		
Aluminum	100	ug/L	none			
Antimony	20	ug/L	none			
Arsenic	20	ug/L	none			
Barium	50	ug/L	none			
Beryllium	20	ug/L	none			
Bismuth	20	ug/L	none			
Boron	500	ug/L	none			
Cobalt	10	ug/L	none			
Lithium	20	ug/L	none			
Iron	500	ug/L	none			
Molybdenum	20	ug/L	none			
Selenium	50	ug/L	none			
Strontium	50	ug/L	none			
Thallium	1	ug/L	none			
Tin	20	ug/L	none			
Titanium	20	ug/L	none			
Uranium	1	ug/L	none			
Vanadium	20	ug/L	none			

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

Date	22-Mar-04	31-Mar-05	5-Apr-05	12-Apr-05	19-Apr-05	27-Apr-05	3-May-05	10-May-05	17-May-05	25-May-05	31-May-05	8-Jun-05	14-Jun-05
Survey	40	41	42	43	44	45	46	47	48	49	50	51	52
code	b4	a19b	a19b	b1	a16b	a1	a3	a16b	a10	b2	ad hoc	a4	a18b
1	AYC	AYC	AYC	AYC	D2	AYC	C2	D2	D1	BRB	C5	B2	EE1
2	RNSYS	RNSYS	RNSYS	RNSYS	D3	RNSYS	C1	D3	EE1	D1	C6	HC	E1
3	PC	PC	PC	PC	SYC	PC	HC	SYC	E1	D2	SYC	C1	F1
4	BRB	D1	D1	C2	C6	C1	B2	C6	F1	EE2	D3	C2	G2
5	D1	BRB	BRB	C1	C5	C2	C3	C5	G2	EE1	D2	PC	H1
6	D2	C2	C2	HC	C4	HC	C4	C4	H1	E2	EE3	RNSYS	BYC
7	EE2	C1	C1	B2	C3	B2	C5	C3	BYC	E1	EE2	AYC	H2
8	EE1	HC	HC	C3	B2	C3	C6	B2	H2	F2	E3	BRB	H3
9	E2	B2	B2	C4	HC	C4	SYC	HC	H3	F1	E2	D1	DYC
10	E1	C3	C3	C5	C1	C6	D3	C1	DYC	G2	F2	EE1	F3
11	F2	C4	C4	C6	C2	C5	D2	C2	F3	H1	F3	E1	F2
12	F1	C5	C5	SYC	BRB	SYC	EE3	BRB	F2	H2	DYC	F1	E2
13	G2	C6	C6	D3	D1	D3	EE2	D1	E2	BYC	H3	G2	E3
14	H1	SYC	SYC	EE3	EE1	D2	E3	EE1	E3	H3	H2	H1	EE2
15	H2	D3	D3	E3	E1	EE3	E2	E1	EE2	DYC	BYC	BYC	EE3
16	BYC	D2	D2	F3	F1	EE2	F2	F1	EE3	F3	H1	H2	D2
17	H3	EE3	EE3	DYC	G2	E3	F3	G2	D2	E3	G2	H3	D3
18	DYC	EE2	EE2	H3	H1	E2	DYC	H1	D3	EE3	F1	DYC	SYC
19	F3	E3	E3	BYC	BYC	F3	H3	BYC	SYC	D3	E1	F3	C6
20	E3	E2	E2	H2	H2	F2	H2	H2	C6	SYC	EE1	F2	C5
21	EE3	F2	F2	H1	H3	DYC	BYC	H3	C5	C6	D1	E2	C4
22	D3	F3	F3	G2	DYC	H3	H1	DYC	C4	C5	BRB	E3	C3
23	SYC	DYC	DYC	F1	F3	H2	G2	F3	C3	C4	C4	EE2	B2
24	C6	H3	H3	F2	F2	BYC	F1	F2	B2	C3	C3	EE3	HC
25	C5	H2	H2	E1	E2	H1	E1	E2	HC	B2	C2	D2	C1
26	C4	BYC	BYC	E2	E3	G2	EE1	E3	C1	HC	B2	D3	C2
27	C3	H1	H1	EE1	EE2	F1	D1	EE2	C2	C1	HC	SYC	BRB
28	B2	G2	G2	EE2	EE3	E1	BRB	EE3	BRB	C2	C1	C6	D1
29	HC	F1	F1	D2	PC	EE1	PC	PC	PC	PC	PC	C5	PC
30	C1	E1	E1	D1	RNSYS	D1	RNSYS	RNSYS	RNSYS	RNSYS	RNSYS	C4	RNSYS
31	C2	EE1	EE1	BRB	AYC	BRB	AYC	AYC	AYC	AYC	AYC	C3	AYC

3.2 Sampling Bias

There are two issues regarding potential bias in the dataset. The first is the relative bias between sites. That is, whether the statistics from one site can be compared with those from another site. The second is the absolute bias with respect to the environmental forcing, or how well the dataset represents typical conditions in the harbour. Our sampling has operational constraints which introduce a morning/early afternoon bias to the entire dataset. It is impractical to address this fully, except to document it.

The following section is a first look at potential bias with respect to time of day, water level, and rainfall during the fourth quarter.

3.2.1 Time of Day

Sewage flows have significant regular diurnal variations, which can affect the water quality in the harbour on short timescales. 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 *a* and dissolved oxygen. The short term variation in sewage load is primarily an issue in the Inner Harbour, relatively close to the outfalls, while sunlight affects the entire harbour.

Figure 2 represents the sampling time at each site since the start of the program in June 2004. The data from the fourth quarter are shown in red. The sites are generally sorted from north to south. There are a few patterns which emerge. 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. This is a function of travel time from the Armdale Yacht club in the Northwest Arm. Even if a site is sampled first, it still takes time to travel there. Given that sampling begins at the same time every week, these effects are unavoidable. Given the necessary operational constraints, the sampling scheme has resulted in a reasonably uniform distribution in the Inner Harbour (Section D through Section E), where diurnal fluctuations would likely be greatest. The diagram indicates that there is an early morning bias in the Outer Harbour Stations. This is a result of weather considerations.

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. Wind, waves and visibility can limit operations in the Outer Harbour and since the wind and wave conditions tend to be worse in the afternoon, a morning bias is introduced. The diurnal variations in conditions in the Outer Harbour are expected to be the least of any harbour region, so this bias is probably not significant.

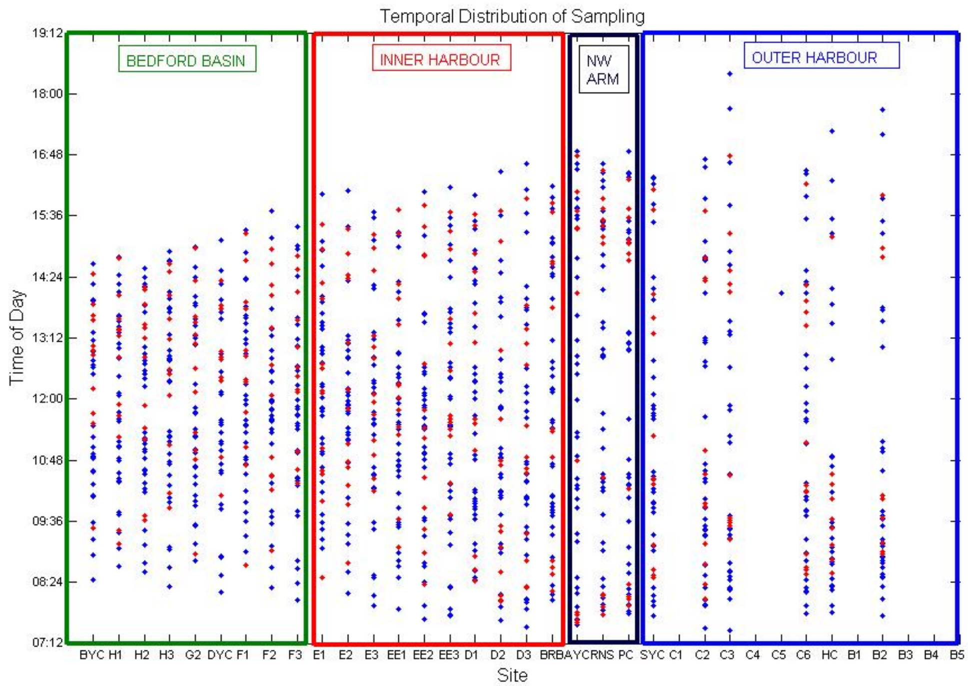


Figure 2. Temporal sampling distribution by site

3.2.2 Water Levels

The water level at the time of sampling can affect the results. The two most obvious effects are expected to be whether a particular sample was taken upstream or downstream (based on tide direction) from the nearest outfall, and the variation in initial dilution from shallow outfalls. These are both issues primarily in the Inner Harbour. In the many shallow outfalls that currently exist in the harbour, the tidal change in water depth can be a significant part of the total depth of water over the outfall. This can have a major effect on initial dilution and can affect whether a discrete plume or "pool" of effluent can exist at a sample site.

Water level variations in the Harbour are caused by the tides and meteorological forcing. The meteorologically-induced changes are of longer period and, except in extreme storms, are much smaller than the tides. Their effect on Harbour flushing can be significant and their impact on water quality may warrant investigation in the future. However, the occurrence of surges is 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 sampling. Sampling which occurs on the same day every second week (the chemical sampling) 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.

A preliminary assessment of water level during sampling follows. 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 June 2004 to June 2005 is shown in Figure 3**.** The red line is the baseline against which water levels during sampling will be compared. The overall water level distribution is slightly bi-modal. The minimum probability roughly corresponds to the mean tide level. However the distribution is actually relatively flat, between 0.6 m and 1.8 m. In an ideal situation each site would be sampled in a distribution similar to the overall distribution.

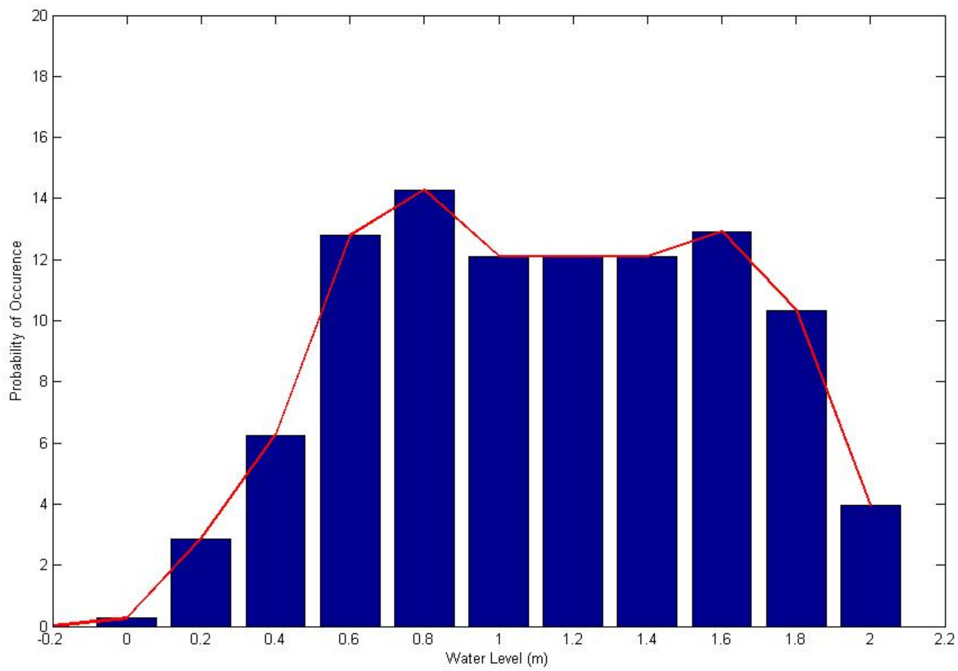


Figure 3. Probability distribution of water levels in Halifax, June 2004 to June 2005

Figure 4 shows the distribution of water levels at the time of sampling compared to the overall water level distribution since the start of sampling in June 04. The sampling distributions show that a relatively full range of water levels has been sampled at each site. If anything the higher water levels appears to be under-sampled at some stations, particularly in Bedford Basin. The reason for this is uncertain, but it is unlikely an issue as tidal currents in the Basin are very low (tidal excursions are small) and large shallow water outfalls do not exist there.

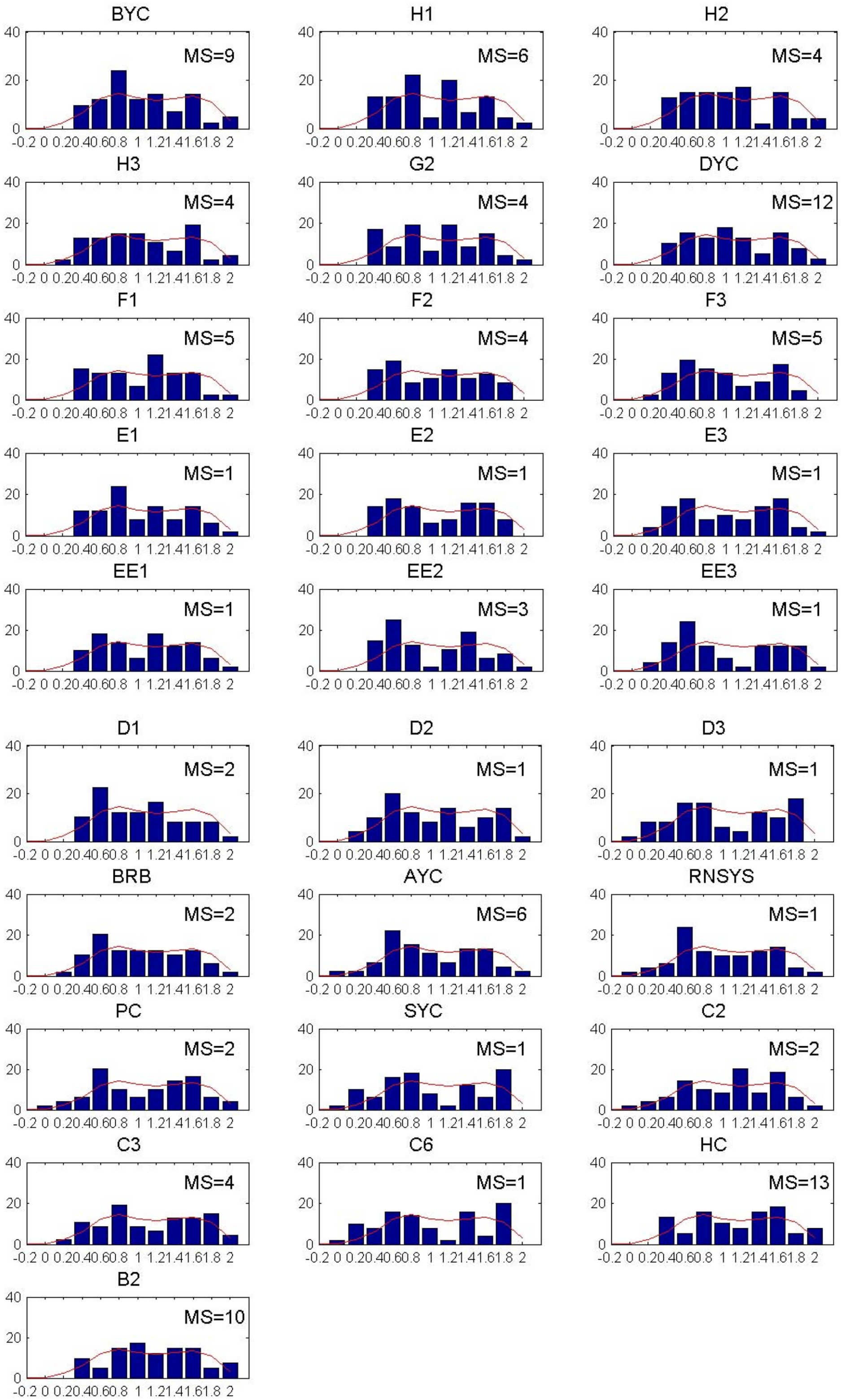


Figure 4. Water level distribution at each site during sampling June 2004 to June 2005.
Note: MS = Missed samples

3.2.3 Precipitation

Rainfall affects both the sewage loads and the dynamics of the harbour. Following a rain event, effluent flow increases in a combined sewage system; collected material in the sewage pipes can be flushed; and the harbour, in response to the increased fresh water input, can become more stratified, enhancing estuarine circulation. The combination of increased flow and stratification can have a great effect on the near field behaviour of the plumes from the outfalls. These effects lag the rainfall by some time and persist for some period 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 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 the entire program period (23 June 04 to 14 June 05). The blue bars on this plot represent a similar analysis performed for sampling days only. The plot indicates that our sampling is relatively unbiased with respect to precipitation. Over the entire twelve month period about 45 % of days had precipitation less than 5 mm in the 72 hour window. The sampling day distribution includes 44% of these "dry days". On the other end, we generally have a good match given the limited number of samples.

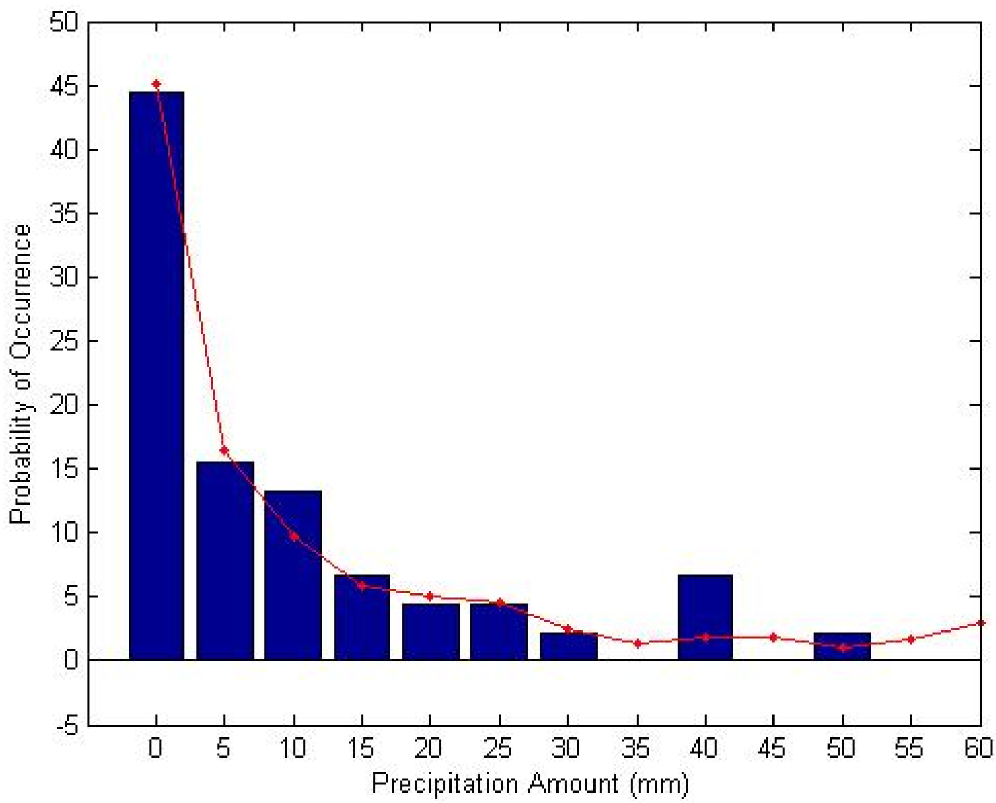


Figure 5. Probability distribution of cumulative 72 hour rainfall, June 2004 through June 2005

3.3 Program Changes

Based on recommendations from QR#3, and subsequent discussions, two changes were made to the program this quarter:

1. On 10 May, the total oil and grease samples at 1 and 10 m were replaced by a single "surface" sample.
2. On 25 May 05, the five day Carbonaceous Biochemical Oxygen Demand ($CBOD_5$) analysis was eliminated.

These changes were made in consideration of there being virtually no detectable values for either Total Oil and Grease or $CBOD_5$ in normal samples (i.e. 1 and 2 detectable values, respectively). The analyses are retained for the Supplemental Samples (below), where detection is expected to be more likely.

3.4 Supplemental Samples

Based on recommendations from QR#2, a supplemental sample protocol to take opportunistic samples of visible water quality features in the Harbour has been instituted. These samples are acquired on a discretionary and exploratory basis when an interesting feature, such as a visible front or plume, 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. During this quarter two such samples, SS#2 and SS#3, were obtained. Sample SS#2 was taken in the visible boil from the outfall off the Peace Pavilion in Dartmouth on 12 Apr 05 (week 43). Sample SS#3 was taken in a visible plume near Pier A in Halifax on 21 Apr 05 (week 45). The laboratory results for these samples are reported in Section 4.10.

3.5 Sampling Protocol

Sampling protocol has been dictated by experience and lab directions. CTD casts are performed according to the manufacturer’s recommendation. These protocols will be documented and added to the project binder with weekly and quarterly reports.

4 Water Quality Results and Discussion

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

4.1 Fecal Coliform

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

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

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 (see Lab Resolution section below and in QR#1). For statistical purposes, these values are, relatively arbitrarily, replaced by 14,999. This is simply a number >10,000 which is easily identified.

Maps representing the geometric mean values over all samples for the fourth 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 black indicate suitability for either activity. Separate maps are presented for the 1 and 10m samples. In the following discussion it is helpful to refer to the station map (Figure 1.)

For both the 1m and 10m samples, the coliform values are highest in the Inner Harbour. The maximum values at both depths occur in the EE section, where the 1m means are higher than the 10m means. The trend of higher 1m means is also the case for all areas south of section EE, whereas north of section EE, higher means tend to be in the 10m samples. From week to week there is considerable variability in this, due to source strength, stratification, water levels, and circulation patterns. This week to week variability is discussed in the weekly reports for this spring quarter. The mean displacement of fecal coliform levels around the harbour is consistent with typical estuarine circulation, with fresher water flowing out at the surface and a deeper return flow of more saline water.

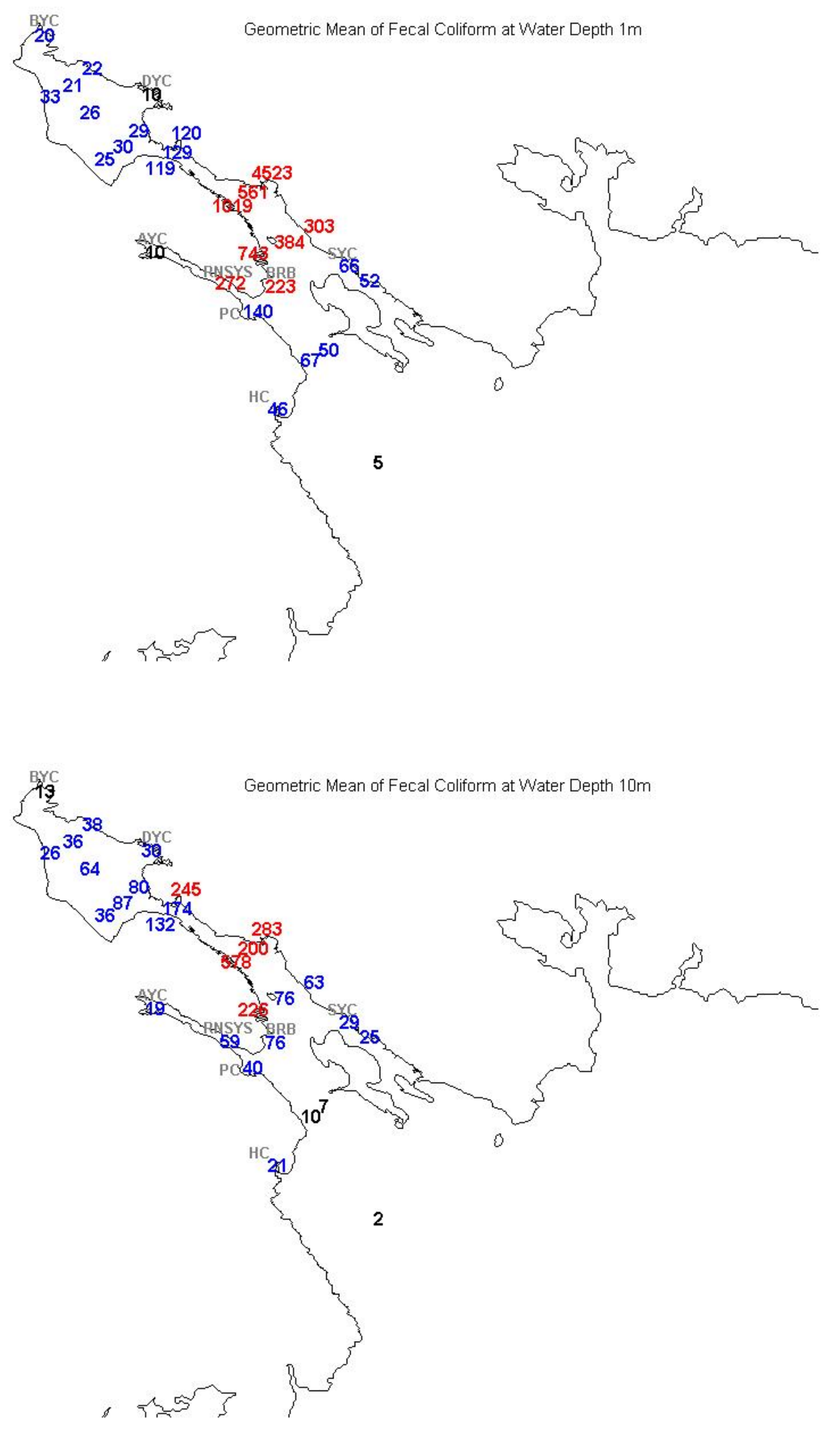


Figure 6. Fecal coliform geometric means (cfu/100mL), 22 March to 14 June 2005.

4.1.1 Guideline Exceedance

As presented in QR#1, the Harbour Task Force fecal coliform guidelines (Harbour Task Force, 1990) are interpreted using the methodology presented in the Guidelines for Canadian Recreational Water Quality (Health and Welfare Canada, 1992). The 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. Our weekly sampling regime generally meets the criteria of five samples within 30 days.

Interpreting this procedure in our context results in a weekly 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.

If there are missed samples within the 30 day period, the analysis uses a reduced number of samples, rather than extending the time beyond thirty days. Tables 3 and 4 show the results of the analysis for the 1m and 10 m samples respectively. The tables represent the floating 30 day geometric mean and, in parentheses, the number of samples (max 5) used in the average.

As seen in the tables below, for this quarter, the surface water in the inner harbour would almost universally be deemed unacceptable for primary body contact. The southern end of the Northwest Arm (PC and RNSYS) is unacceptable about half the time and generally questionable. Almost all sites in the harbour experienced periodic high values that cause the water to be questionable for primary body contact. Values tend to be lower in the 10m samples throughout most of the area. The exception is in the north end of the narrows and Bedford Basin where values are more often higher in the 10m samples.

It is difficult to see trends over this period, as they are masked by an extremely wet May. The total precipitation at Shearwater Airport for May 2005 was 274.5mm, 2.4 times the average monthly precipitation (113.5 mm) between 1971 and 2000. In particular, there were three large rainfall events at week 46 (3 May), week 47 (10 May), and week 49 (25 May). In each of these weeks, between 80 and 100 mm of rain fell in the five days preceding the survey. These events resulted in very high coliform values throughout the harbour, which affected the floating means and triggered "questionable" classifications (values over 400) at many sites. In the first week of the quarter, the split among the three categories, acceptable, questionable and unacceptable, in the 1m samples is 15/3/9 (plus 1 missing site – BYC, 5 week exclusion due to ice). In the final week, the split is 8/12/8. This represents mostly a shift from acceptable to questionable, due to the weather events in May. The 10 m stations exhibit no particular trend, with the split being 19/5/3 (A/Q/U) at the start of the quarter, and 19/4/5 at the end.

Table 3. 30 day geometric mean (number of samples) of 1m fecal coliform concentrations (#/100 ml).

	Outer Harbour				Eastern Passage			Inner Harbour								
	B2	HC	C2	C3	C6	SYC	BRB	D1	D2	D3	EE1	EE2	EE3	E1	E2	E3
Survey40	1 (3)	5 (1)	62 (5)	61 (5)	131 (5)	65 (5)	228 (5)	943 (5)	403 (5)	435 (5)	746 (5)	689 (5)	6574 (5)	46 (5)	40 (5)	50 (5)
Survey41	1 (2)	5 (1)	53 (4)	48 (4)	81 (5)	82 (5)	293 (5)	1037 (5)	417 (5)	592 (5)	985 (5)	569 (5)	7019 (5)	31 (5)	46 (5)	43 (5)
Survey42	2 (3)	17 (2)	109 (4)	60 (4)	60 (5)	39 (5)	367 (5)	1292 (5)	410 (5)	609 (5)	1080 (5)	648 (5)	5053 (5)	42 (5)	54 (5)	59 (5)
Survey43	5 (4)	21 (3)	169 (4)	64 (4)	38 (5)	30 (5)	410 (5)	1744 (5)	346 (5)	425 (5)	931 (5)	651 (5)	1890 (5)	26 (5)	30 (5)	28 (5)
Survey44	7 (4)	29 (4)	190 (4)	54 (4)	19 (5)	21 (5)	348 (5)	1977 (5)	419 (5)	390 (5)	1089 (5)	287 (5)	1686 (5)	20 (5)	35 (5)	52 (5)
Survey45	15 (3)	25 (4)	114 (4)	48 (4)	22 (5)	41 (5)	260 (5)	1078 (5)	357 (5)	227 (5)	999 (5)	290 (5)	3122 (5)	61 (5)	151 (5)	143 (5)
Survey46	16 (4)	31 (5)	137 (5)	66 (5)	29 (5)	63 (5)	161 (5)	633 (5)	560 (5)	353 (5)	982 (5)	392 (5)	2996 (5)	54 (5)	124 (5)	122 (5)
Survey47	9 (4)	42 (5)	139 (5)	98 (5)	41 (5)	147 (5)	229 (5)	660 (5)	739 (5)	332 (5)	712 (5)	427 (5)	3912 (5)	54 (5)	109 (5)	89 (5)
Survey48	3 (4)	37 (5)	88 (5)	39 (5)	26 (5)	163 (4)	369 (5)	1444 (5)	1104 (5)	378 (5)	999 (5)	453 (5)	18121 (5)	90 (5)	255 (5)	143 (5)
Survey49	3 (3)	32 (4)	59 (5)	32 (4)	112 (5)	179 (4)	489 (5)	837 (5)	724 (5)	276 (5)	1074 (5)	802 (5)	17055 (5)	303 (5)	499 (5)	158 (5)
Survey50	3 (4)	91 (4)	102 (5)	94 (4)	186 (5)	567 (4)	581 (5)	1029 (5)	1079 (5)	693 (5)	1486 (5)	1126 (5)	9987 (5)	408 (5)	315 (5)	130 (5)
Survey51	3 (4)	132 (4)	82 (5)	73 (4)	74 (5)	144 (4)	784 (5)	2045 (5)	825 (5)	475 (5)	1596 (5)	888 (5)	8540 (5)	251 (5)	236 (5)	150 (5)
Survey52	4 (3)	100 (3)	25 (5)	12 (4)	22 (5)	34 (4)	171 (5)	528 (5)	177 (5)	135 (5)	2079 (5)	554 (5)	3974 (5)	349 (5)	324 (5)	231 (5)

	Bedford Basin									Northwest Arm		
	F1	F2	F3	DYC	G2	H1	H2	H3	BYC	PC	RNSYS	AYC
Survey40	5 (3)	9 (4)	6 (4)	1 (1)	4 (4)	8 (3)	4 (4)	17 (4)	3 (2)	294 (5)	639 (5)	
Survey41	5 (3)	6 (3)	5 (3)	1 (1)	5 (3)	8 (3)	6 (3)	7 (3)	3 (2)	406 (5)	317 (5)	110 (1)
Survey42	4 (3)	5 (3)	8 (3)	6 (2)	8 (3)	20 (3)	13 (3)	13 (3)	8 (3)	362 (5)	124 (5)	101 (2)
Survey43	3 (4)	4 (4)	5 (4)	3 (3)	7 (4)	12 (4)	11 (4)	12 (4)	9 (4)	333 (5)	37 (5)	22 (3)
Survey44	2 (4)	3 (4)	4 (4)	2 (4)	5 (4)	6 (4)	6 (4)	6 (4)	5 (4)	237 (5)	29 (5)	13 (4)
Survey45	5 (4)	7 (4)	12 (4)	2 (4)	11 (4)	17 (4)	10 (4)	6 (4)	11 (4)	156 (5)	48 (5)	8 (5)
Survey46	10 (5)	11 (5)	19 (5)	5 (5)	17 (5)	20 (5)	12 (5)	9 (5)	18 (5)	100 (5)	97 (5)	5 (5)
Survey47	22 (5)	16 (5)	25 (5)	3 (4)	28 (5)	23 (5)	16 (5)	13 (5)	29 (5)	92 (5)	324 (5)	4 (5)
Survey48	37 (5)	37 (5)	39 (5)	4 (4)	46 (5)	29 (5)	19 (5)	20 (5)	17 (5)	152 (5)	424 (5)	7 (5)
Survey49	131 (5)	136 (5)	109 (5)	13 (4)	142 (5)	102 (5)	61 (5)	66 (5)	55 (5)	229 (5)	1531 (5)	11 (5)
Survey50	150 (5)	114 (5)	84 (5)	32 (4)	138 (5)	88 (5)	105 (5)	106 (5)	58 (5)	138 (5)	804 (5)	14 (5)
Survey51	111 (5)	98 (5)	86 (5)	26 (4)	157 (5)	133 (5)	153 (5)	101 (5)	40 (5)	228 (5)	527 (5)	21 (5)
Survey52	85 (5)	156 (5)	89 (5)	32 (5)	99 (5)	79 (5)	71 (5)	43 (5)	24 (5)	79 (5)	245 (5)	11 (5)

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 4. 30 day geometric mean (number of samples) of 10m fecal coliform concentrations (#/100 ml).

	Outer Harbour				Eastern Passage			Inner Harbour								
	B2	HC	C2	C3	C6	SYC	BRB	D1	D2	D3	EE1	EE2	EE3	E1	E2	E3
Survey40	5 (3)	3 (1)	65 (5)	21 (5)	23 (5)	49 (5)	108 (5)	432 (5)	69 (5)	70 (5)	454 (5)	178 (5)	115 (5)	92 (5)	162 (5)	372 (5)
Survey41	1 (2)	3 (1)	77 (4)	17 (4)	27 (5)	48 (5)	136 (5)	367 (5)	96 (5)	76 (5)	325 (5)	168 (5)	137 (5)	114 (5)	259 (5)	354 (5)
Survey42	1 (3)	6 (2)	59 (4)	13 (4)	31 (5)	33 (5)	125 (5)	354 (5)	80 (5)	84 (5)	232 (5)	135 (5)	181 (5)	120 (5)	253 (5)	268 (5)
Survey43	2 (4)	8 (3)	22 (4)	11 (4)	13 (5)	19 (5)	124 (5)	238 (5)	94 (5)	50 (5)	186 (5)	114 (5)	297 (5)	74 (5)	229 (5)	159 (5)
Survey44	2 (4)	10 (4)	14 (4)	6 (4)	10 (5)	14 (5)	94 (5)	241 (5)	104 (5)	46 (5)	163 (5)	128 (5)	295 (5)	67 (5)	208 (5)	154 (5)
Survey45	3 (3)	29 (4)	4 (4)	5 (4)	12 (5)	18 (5)	110 (5)	253 (5)	143 (5)	55 (5)	319 (5)	161 (5)	633 (5)	82 (5)	286 (5)	172 (5)
Survey46	3 (4)	27 (5)	5 (5)	7 (5)	10 (5)	12 (5)	90 (5)	140 (5)	103 (5)	57 (5)	558 (5)	143 (5)	394 (5)	81 (5)	207 (5)	133 (5)
Survey47	3 (4)	41 (5)	7 (5)	9 (5)	17 (5)	21 (5)	94 (5)	140 (5)	126 (5)	45 (5)	1799 (5)	145 (5)	383 (5)	69 (5)	175 (5)	109 (5)
Survey48	1 (4)	36 (5)	5 (5)	6 (5)	29 (5)	24 (4)	88 (5)	230 (5)	106 (5)	72 (5)	2488 (5)	159 (5)	315 (5)	149 (5)	175 (5)	224 (5)
Survey49	2 (3)	40 (4)	5 (5)	6 (4)	75 (5)	36 (4)	122 (5)	221 (5)	102 (5)	81 (5)	3348 (5)	212 (5)	355 (5)	343 (5)	187 (5)	197 (5)
Survey50	1 (4)	19 (4)	8 (5)	7 (4)	90 (5)	40 (4)	90 (5)	174 (5)	84 (5)	92 (5)	1899 (5)	256 (5)	286 (5)	278 (5)	119 (5)	152 (5)
Survey51	1 (4)	26 (4)	6 (5)	3 (4)	72 (5)	36 (4)	73 (5)	249 (5)	93 (5)	64 (5)	920 (5)	339 (5)	367 (5)	206 (5)	108 (5)	200 (5)
Survey52	1 (3)	17 (3)	3 (5)	1 (4)	33 (5)	21 (4)	35 (5)	136 (5)	39 (5)	45 (5)	361 (5)	287 (5)	332 (5)	226 (5)	133 (5)	323 (5)

	Bedford Basin									Northwest Arm		
	F1	F2	F3	DYC	G2	H1	H2	H3	BYC	PC	RNSYS	AYC
Survey40	9 (3)	20 (4)	74 (4)	2 (1)	34 (4)	10 (3)	11 (4)	14 (4)	8 (2)	125 (5)	159 (5)	
Survey41	9 (3)	31 (3)	121 (3)	2 (1)	16 (3)	10 (3)	11 (3)	17 (3)	8 (2)	169 (5)	124 (5)	83 (1)
Survey42	34 (3)	58 (3)	154 (3)	20 (2)	38 (3)	28 (3)	27 (3)	38 (3)	19 (3)	92 (5)	64 (5)	42 (2)
Survey43	27 (4)	76 (4)	44 (4)	7 (3)	34 (4)	14 (4)	25 (4)	15 (4)	14 (4)	55 (5)	24 (5)	12 (3)
Survey44	19 (4)	36 (4)	26 (4)	9 (4)	29 (4)	9 (4)	15 (4)	11 (4)	10 (4)	34 (5)	20 (5)	9 (4)
Survey45	35 (4)	100 (4)	48 (4)	22 (4)	83 (4)	13 (4)	60 (4)	27 (4)	24 (4)	19 (5)	25 (5)	13 (5)
Survey46	51 (5)	115 (5)	63 (5)	34 (5)	109 (5)	22 (5)	76 (5)	40 (5)	27 (5)	15 (5)	22 (5)	12 (5)
Survey47	35 (5)	97 (5)	50 (5)	21 (4)	92 (5)	18 (5)	62 (5)	37 (5)	28 (5)	18 (5)	25 (5)	15 (5)
Survey48	39 (5)	100 (5)	122 (5)	62 (4)	106 (5)	36 (5)	69 (5)	108 (5)	23 (5)	37 (5)	34 (5)	30 (5)
Survey49	100 (5)	264 (5)	186 (5)	106 (4)	201 (5)	70 (5)	140 (5)	222 (5)	37 (5)	47 (5)	57 (5)	58 (5)
Survey50	88 (5)	175 (5)	110 (5)	83 (4)	127 (5)	108 (5)	105 (5)	173 (5)	26 (5)	47 (5)	49 (5)	30 (5)
Survey51	64 (5)	121 (5)	102 (5)	62 (4)	74 (5)	76 (5)	83 (5)	139 (5)	12 (5)	48 (5)	62 (5)	22 (5)
Survey52	52 (5)	198 (5)	102 (5)	48 (5)	49 (5)	36 (5)	34 (5)	57 (5)	5 (5)	25 (5)	58 (5)	17 (5)

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.

4.1.2 Out-of-Range Values

The adapted lab procedure for detecting fecal coliform, developed as a result of previous recommendations, has reduced the number of out-of-range values significantly. During this quarter there were three samples out of range: one at D1-1m, and two at EE1-10m. Out-of-range samples have previously occurred at the D1-1m site, and analysis of this quarter further supports the QR#3 recommendation that the testing resolution be decreased to cfu/10ml at this site. This is the first quarter that there have been out-of-range values at the EE1-10m site. Reviewing all data at this site indicates that to date, there have been only two values less than 100 cfu/100ml and none less than 10 cfu/100ml. Based on this, a reduction in testing resolution from cfu/100mL to cfu/10mL would likely result in fewer out-of-range values at this site.

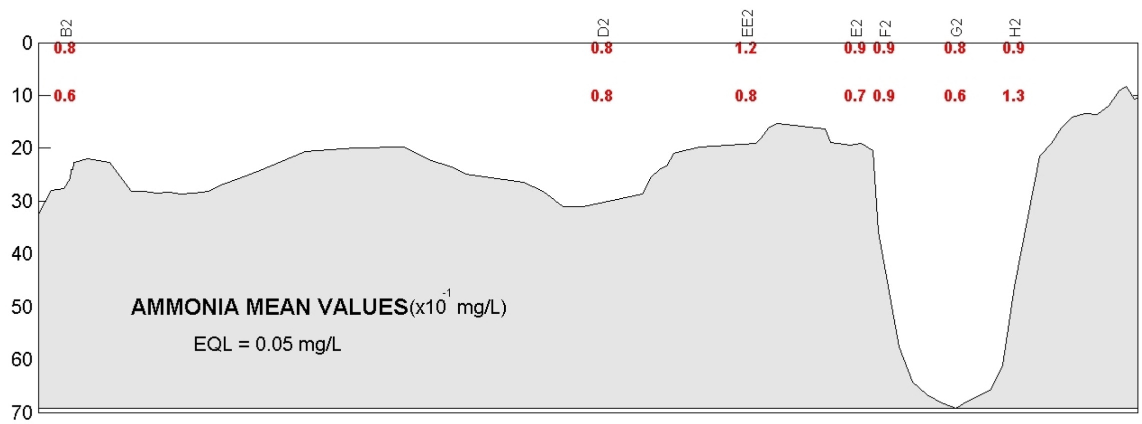
4.2 Ammonia Nitrogen

The values obtained for this period are shown in Table 5. The laboratory "estimated quantification level" (EQL) for ammonia nitrogen is 0.05 mg/L. For the purpose of computing statistics, the EQL value was used for values below detection. Overall, in this quarter, 58% of samples had detectable levels of ammonium. There appears to be no systematic variation with depth, with all mean and variation of values in the 1 and 10 m samples being essentially the same. In this quarter, while there is week to week variability, there appears to be no definite temporal trend, and no strong correlation with meteorological events, as is seen in the coliform data. There is some spatial variability, for example the EE2–1m sample has two of the three samples above 0.20 mg/L for the quarter. The values are also slightly higher in the H2-10m samples. This spatial pattern can be seen in Figure 9, where the average and maximum values are plotted over a centerline section of the harbour. The baseline is too small to say whether this is significant and will be looked at further in the annual summary (Section 5).

Table 5. Ammonia Nitrogen summary (mg/L)
Note: green highlights indicate values below detection limits (0.05 mg/L)

	B2	D2	EE2	E2	F2	G2	H2	mean	max
05-Mar-31		0.05	0.05	0.05				0.05	0.05
05-Apr-12	0.15	0.05	0.09	0.05	0.05	0.05	0.09	0.08	0.15
05-Apr-27		0.11	0.07	0.06	0.05	0.09	0.09	0.08	0.11
05-May-10	0.05	0.05	0.22	0.05	0.12	0.05	0.06	0.09	0.22
05-May-25		0.05	0.05	0.16	0.05	0.05	0.05	0.07	0.16
05-Jun-08	0.05	0.15	0.26	0.17	0.16	0.14	0.16	0.16	0.26
mean	0.08	0.08	0.12	0.09	0.09	0.08	0.09	0.09	
max	0.15	0.15	0.26	0.17	0.16	0.14	0.16		0.26

	B2	D2	EE2	E2	F2	G2	H2	mean	max
05-Mar-31		0.05	0.10	0.05				0.07	0.10
05-Apr-12	0.06	0.06	0.05	0.08	0.10	0.07	0.16	0.08	0.16
05-Apr-27		0.07	0.05	0.05	0.05	0.05	0.05	0.05	0.07
05-May-10	0.05	0.10	0.05	0.05	0.19	0.05	0.26	0.11	0.26
05-May-25		0.05	0.05	0.05	0.05	0.05	0.08	0.06	0.08
05-Jun-08	0.06	0.15	0.17	0.12	0.07	0.08	0.08	0.10	0.17
mean	0.06	0.08	0.08	0.07	0.09	0.06	0.13	0.08	
max	0.06	0.15	0.17	0.12	0.19	0.08	0.26		0.26



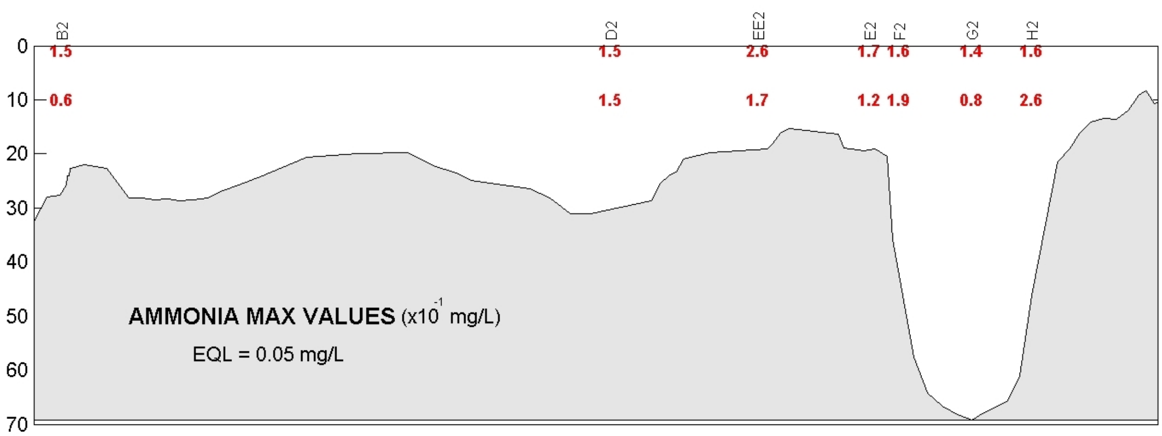


Figure 7. Mean and maximum value of ammonia nitrogen over all fourth quarter samples

4.3 Carbonaceous Biochemical Oxygen Demand

No detectable values were observed in the regular samples for this quarter. Further to a recommendation in QR#2, $CBOD_5$ analysis ceased on 25 May 05, near the end of the reporting period for this report. $CBOD_5$ analysis will continue for supplemental samples.

4.4 Total Suspended Solids

A summary of the TSS values for this quarter is shown in Table 6. For this quarter there were no samples below the detection limit. The mean value over all surveys is approximately 11 mg/L, the highest for any quarter to date (see Section 5). There is significant week to week variability that generally corresponds to variations in phytoplankton activity and/or meteorological events. The spring phytoplankton bloom was occurring in the beginning of the quarter. The highest values observed were at E2-1m, (40 mg/L on 12 Apr 05, and 41 mg/L on 25 May 05), were associated with strong fresh water signal at that site. The first involved a lens of fresher water in the narrows, likely from sewers and storm overflows in the area (see weekly report #44). The second, involved fresher water from the Sackville River, where the E section represented a transition between the stratified water of the Basin and the well-mixed water of the Harbour (see weekly report #49).

Table 6. Summary of TSS Data (mg/L)

	B2	D2	EE2	E2	F2	G2	H2	mean	max
05-Mar-31		29.00	11.00	4.60				14.87	29.00
05-Apr-12	21.00	8.40	9.10	40.00	10.00	9.80	19.00	16.76	40.00
05-Apr-27		9.20	9.80	7.50	10.00	3.90	9.90	8.38	10.00
05-May-10	13.00	7.60	9.80	15.00	8.00	7.80	7.00	9.74	15.00
05-May-25		9.20	3.40	41.00	10.00	7.90	8.50	13.33	41.00
05-Jun-08	4.90	3.40	10.00	9.60	5.90	12.00	5.90	7.39	12.00
mean	12.97	11.13	8.85	19.62	8.78	8.28	10.06	11.38	
max	21.00	29.00	11.00	41.00	10.00	12.00	19.00		41.00

	B2	D2	EE2	E2	F2	G2	H2	mean	max
05-Mar-31		23.00	5.40	5.20				11.20	23.00
05-Apr-12	11.00	8.70	15.00	8.10	13.00	12.00	16.00	11.97	16.00
05-Apr-27		9.50	8.50	9.00	6.60	12.00	8.70	9.05	12.00
05-May-10	14.00	11.00	6.00	11.00	6.40	6.30	34.00	12.67	34.00
05-May-25		6.30	3.00	19.00	9.50	9.80	14.00	10.27	19.00
05-Jun-08	4.40	6.90	4.90	13.00	11.00	9.90	10.00	8.59	13.00
mean	9.80	10.90	7.13	10.88	9.30	10.00	16.54	10.65	
max	14.00	23.00	15.00	19.00	13.00	12.00	34.00		34.00

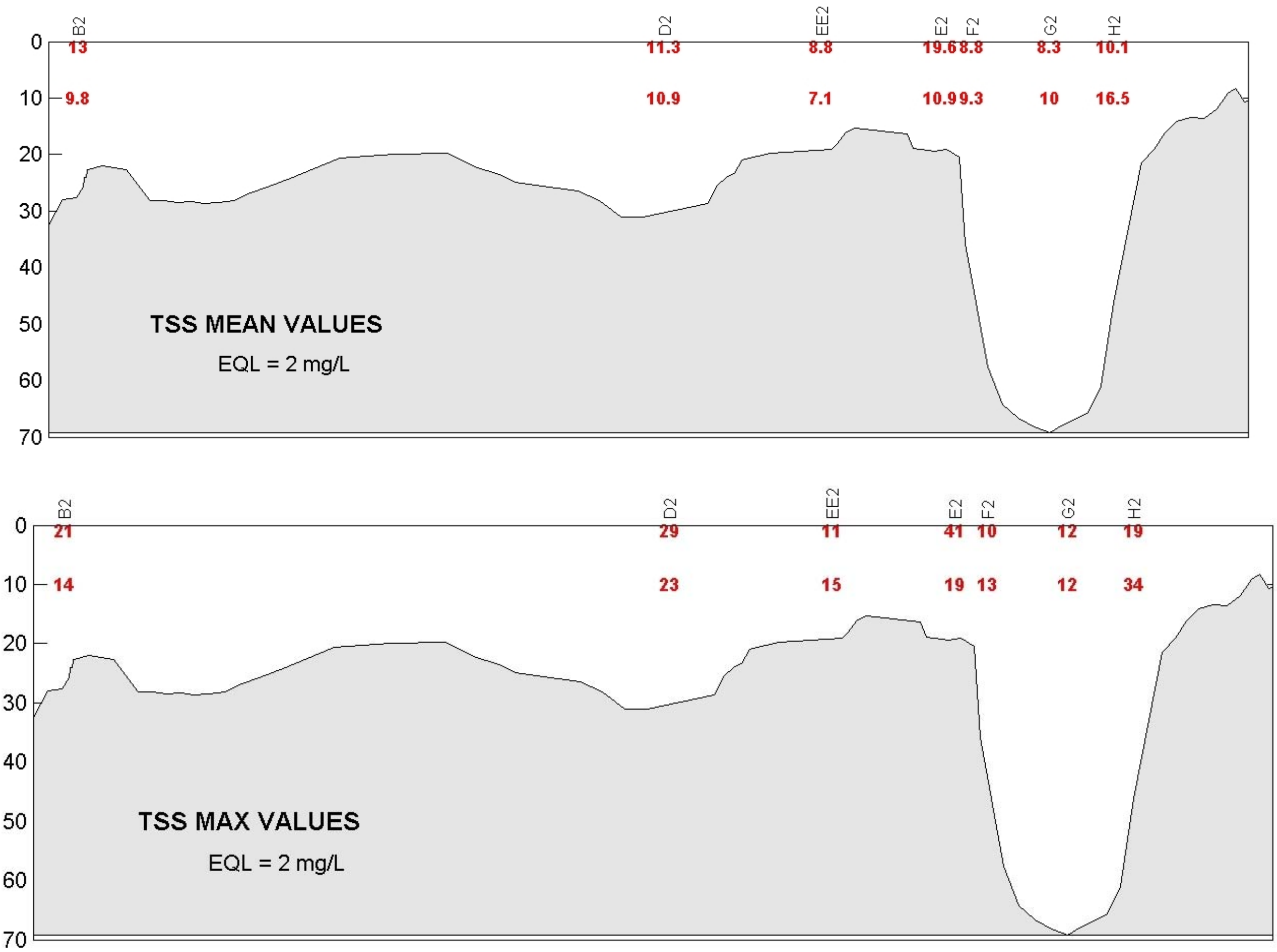


Figure 8. Mean and maximum values of total suspended solids (mg/L) over all fourth quarter samples

4.5 Total Oils and Grease

There have been no detectable levels of total oil and grease in any of the samples in this quarter.

4.6 Metals

In the fourth quarter there have been thirteen independent measurements of metals of interest, that is metals for which water quality guidelines exist, in excess of laboratory EQL's. In the quarter there were a total of 504 measurements (seven sites x two depths x six surveys x seven metals, discounting six missed stations or twelve missed samples.). This equates overall to approximately 2.6% detectable values, or, conversely, greater than 97% non-detectable values. In addition to the regular samples, there were two QA/QC samples with detectable values, which verify the reference values and are not independent.

The relevant fourth quarter metals values are summarized in Table 7. Manganese was present at detectable levels (>20 μg/L) on 4 out of 6 surveys, or in a total of 10 samples. Manganese has the best data recovery of any of the metals analyzed, being detectable in nearly 14% of samples taken. Manganese concentrations ranged from 20 (EQL) to 38 μg/L. In no case was the guideline value of 100 μg/L exceeded. In all cases where manganese was detected, it was in the 1m samples. Additionally, all detectable values were associated with a strong freshwater signal and all, except one, were at sites from the Narrows north to the head of the Basin. These points taken together, as discussed in weekly reports 47, and 49, hint at the Sackville River as being a source for manganese.

Table 7. Summary of metal values >EQL from 22 March through 14 June 2005

Manganese EQL= 20 μg/L Guideline=100 μg/L

Survey Date	Value (μg/L)	Site	Depth (m)
12-Apr-05	29	E2	1
	23	F2	1
	28	G2	1
10-May-05	36	E2	1
	36	F2	1
	34	F2(QA/QC)	1
	33	G2	1
	38	H2	1
25-May-05	35	H2	1
	35	H2(QA/QC)	1
8-Jun-05	20	EE2	1
	21	H2	1

Zinc EQL = 50 μg/L Guideline = 86 μg/L

Survey Date	Value(μg/L)	Site	Depth (m)
31-Mar-05	78	D2	10
8-Jun-05	75	F2	1
	140	G2	1

There were also two surveys, and a total of three samples, in which detectable concentrations of zinc occurred. This is a data recovery rate for zinc analysis of nearly 4%. Of these three samples, one had a zinc concentration of 140 μg/L which exceeds the 86 μg/L guideline. This is the only metals guideline that is exceeded for the quarter.

The resolution of metals concentrations in the harbour is an issue. Options for modifying the program were discussed and recommendations made in previous reports. The implications of these recommendations are currently under consideration.

4.7 Temperature and Salinity

The Bedford Basin Plankton Monitoring Program (BBPMP) is a long standing program conducted by the Department of Fisheries and Oceans at the Bedford Institute of Oceanography. As part of the program, oceanographic profiles from the centre of Bedford Basin (near station G2) are collected on a weekly basis. The data consist of (among other parameters) temperature, salinity, temperature, chlorophyll *a*, and dissolved oxygen, which duplicates HHWQMP observations, and provides an opportunity to crosscheck observations of these parameters. Although not sharing the exact same coordinates, both sample sites are located near the deepest part of the Basin. Both programs are sampled weekly; the HHWQMP being each Tuesday, with contingency on Wednesday or sometimes Thursday; and the BBPMP usually sampling on Wednesday.

The HHWQMP and BBPMP temperature and salinity data from 1 Jan 05 until the end of the fourth quarter are presented in Figures 9 and 10. The temperature data for each of the two programs show a very close correspondence. Minor differences are almost universally explained by missing data from one program or the other.

The salinity data also shows high degree of correspondence. Some of the fine detail varies, but these can also generally be reconciled by missed data. As discussed in QR#3, the largest discrepancy, shown as the upward "spike" in the BBPMP salinity contours in January, is not present in the HHWQMP data due to missed profiles. There appears to be no missed temperature or salinity data in the BBPMP dataset during January. In this quarter (day 81 to day 165) the correspondence is very close. Evident in both data sets is the intrusion of saline "shelf" water into the bottom of the Basin, which was noted in the first week of the quarter (week 40, day 81). Also evident in both data sets is the effect of the very wet weather in May (day 120 through day 151). There are two periods where the surface salinity is below the plotting range minimum of 26 PSU. The data indicate that the surface salinity on 10 May was 18 PSU, and on 25 May was 22 PSU.

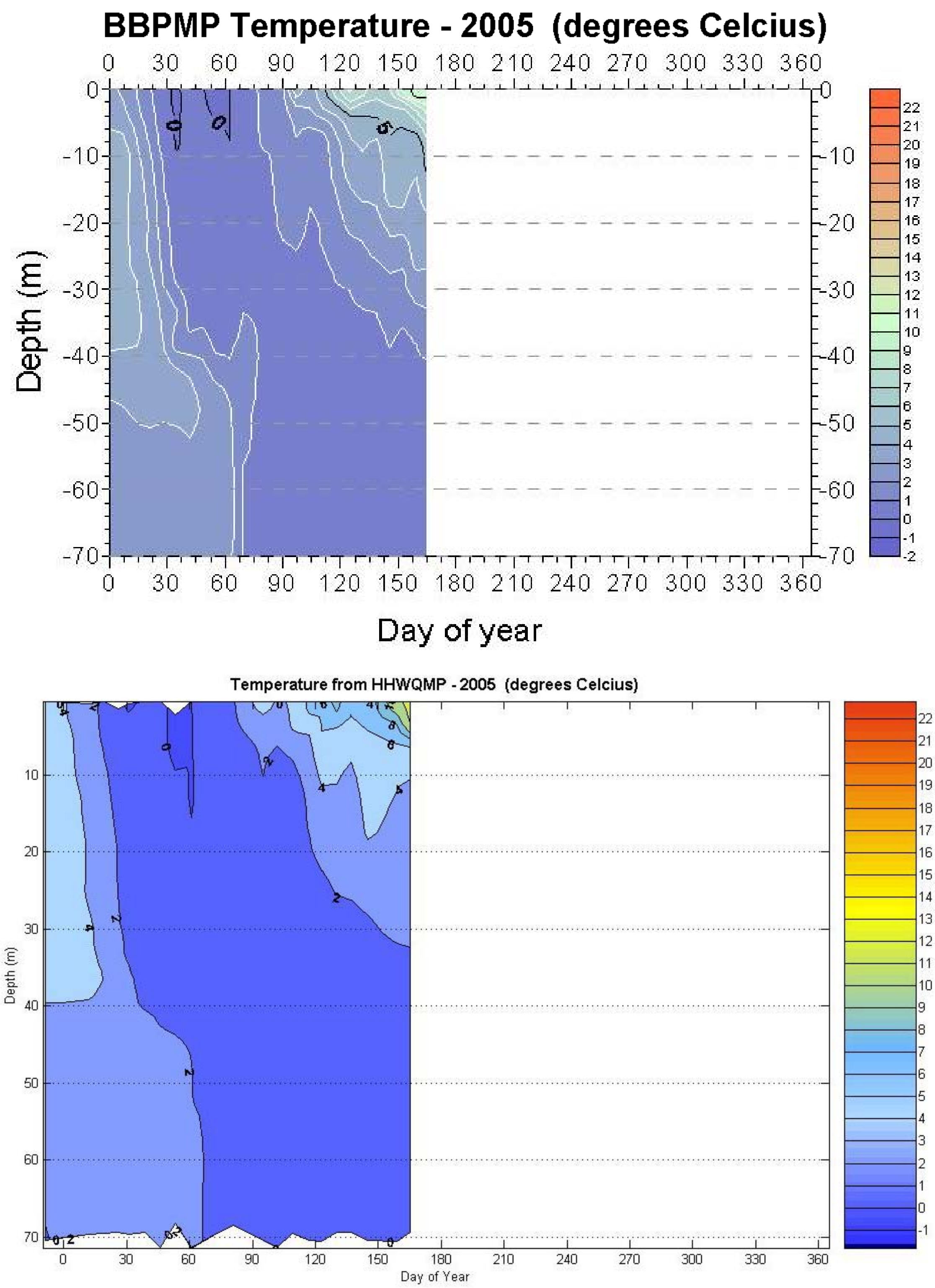
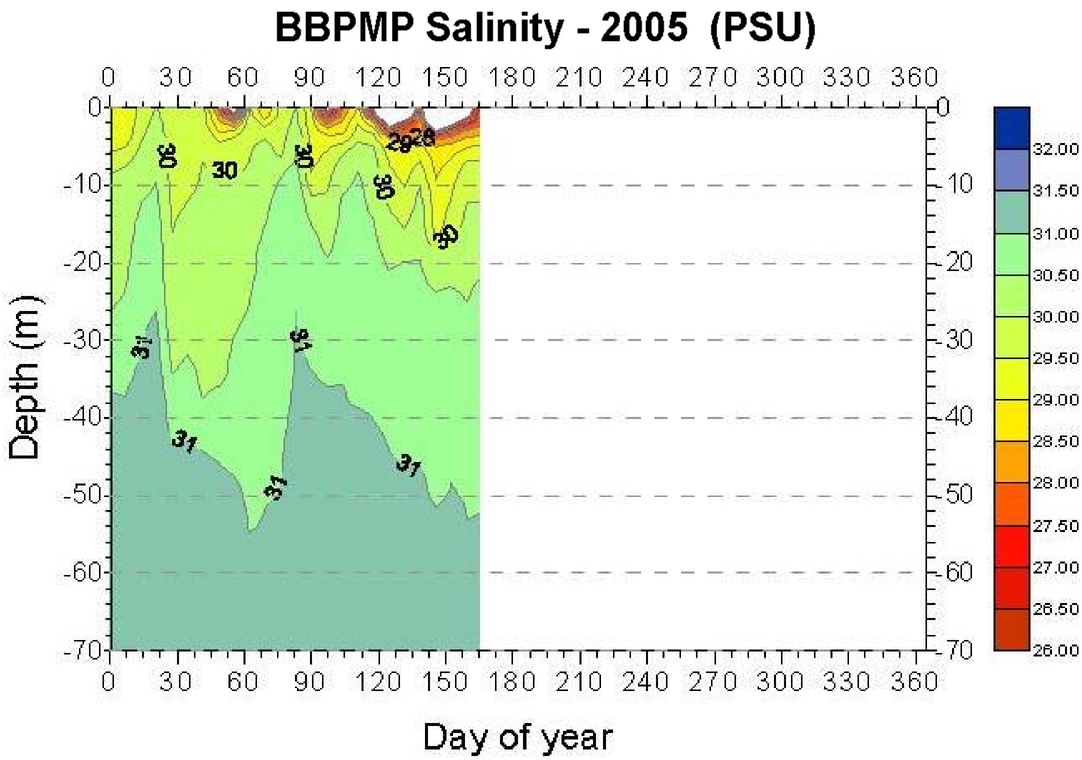


Figure 9. Comparison of BBPMP and HHWQMP temperature data from Station G2 (1 Jan to 14 Jun 2005).



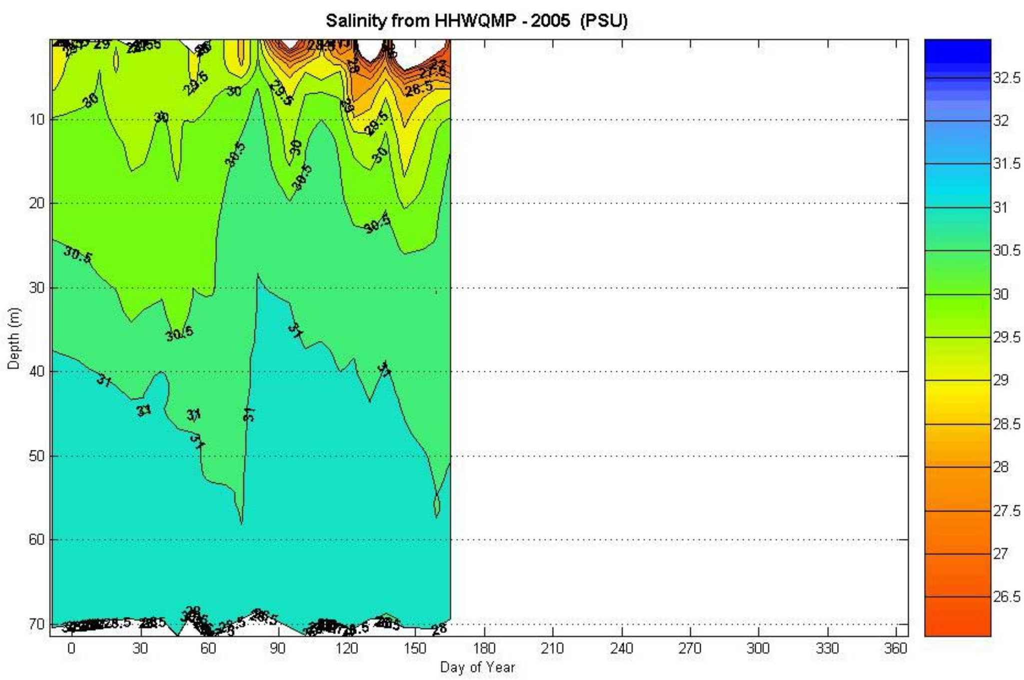


Figure 10. Comparison of BBPMP and HHWQMP salinity data from Station G2 (1 Jan to 14 Jun 2005)

4.8 Fluorescence

The 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. The 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, 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.

A comparison of HHWQMP fluorescence data with that of the BBPMP is presented in Figure 13. Note that BBPMP data is relative fluorescence presented without dimensions. Also, the BBPMP is presented on a variable scale, while the HHWQMP data is presented on a linear scale. These two factors dictate that the units and figure colours are not directly comparable. The general trends in the two data sets, however, are very similar. As discussed in QR#3 the data sets indicate a period of low activity, followed by the beginning of the spring bloom at the end of the third quarter. The spring bloom continues into the fourth quarter (days 81 to 165). The maximum bloom begins at around day 81 and continues in the top 10m (maximums at 5-10m) for about three weeks. At this time the plankton sinks with the maximums at day 109 occurring at 12-15m and the following week at day 116 at 35m. At these times elevated fluorescence is evident all the way to the deep Basin. There are a few differences in the patterns in the two data sets. There is a small maximum at around day 130 in the HHWQMP which appears more prominent than the same feature in the BBPMP data. There is no obvious explanation except for the previously stated scale issues and that the sampling occurred on consecutive days. There is a short (single week) but intense feature at about day 150 in the BBPMP data. This feature is not seen on the HHWQMP plot as the data is missing due to sampling errors at that site. However, this event is evident at other sites in the Basin on that day. Finally, there is a high value in the last week of the HHWQMP data that is not seen in the BBPMP plot as the data for that week is missing. This represents a single week event, as well.

Interesting is spatial variation not captured in BBPMP data. The maximum fluorescence values during spring bloom generally occur in Bedford Basin but not usually at the G2 site. There can be quite a lot of spatial variability. The bloom maximum value varies in location around the Basin. It seems that the distribution varies quite smoothly and coherently among the Basin sites, apparently in response to oceanographic conditions (particularly stratification and estuarine and wind driven circulation). The maximum fluorescence values were observed, on different weeks, in the south, west and north of the

Basin. The value at G2 was representative of the overall maximum value on only one week, when conditions were relatively uniform throughout the Basin. In other weeks the maximum value was up to twice that observed at G2.

In addition to the CTD profiles, the BBPMP collects water samples and does a rigorous analysis of the weekly plankton and nutrient conditions at their site. As discussed in previous reports it is possible that coordination with this program could be mutually advantageous. This might result in adding utility to the HHWQMP data at negligible cost and should be pursued.

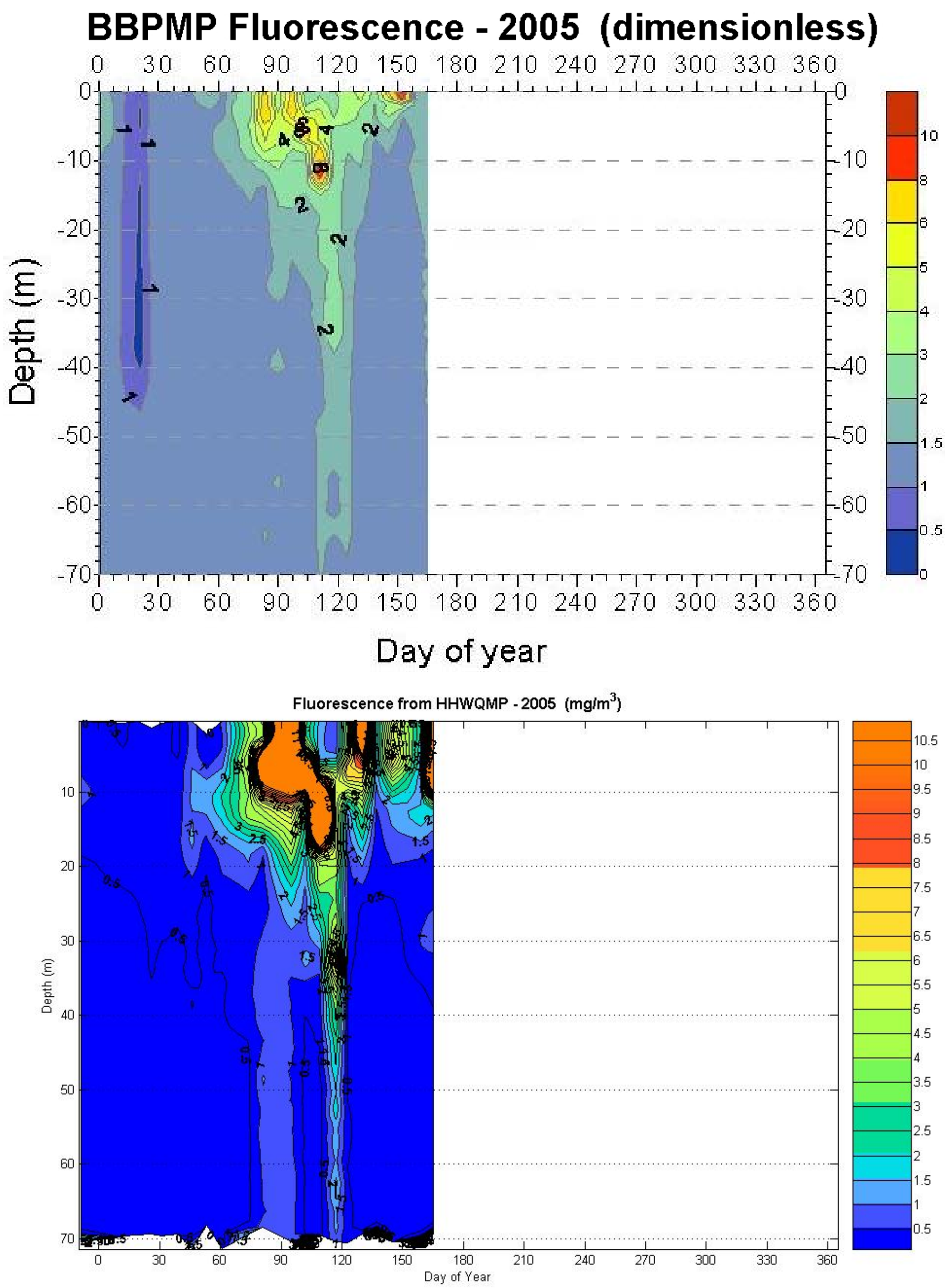


Figure 11. Comparison of BBPMP and HHWQMP fluorescence data from Station G2 (1 Jan to 14 Jun 2005).

4.9 Dissolved Oxygen

The dissolved oxygen data for this quarter are generally above the applicable use-specific (SA, SB and SC) guidelines. There are two exceptions. The first is a one-time observation of a profile minimum of 7.9 mg/L at site B2 (week 42, 5 Apr 05), which is just below the 8.0 mg/L SA guideline. The second is in the Basin bottom water that starts the quarter well oxygenated, due to a shelf water intrusion, but drops below the 7.0 mg/L class SB guideline by week 49 (25 May 05). The dissolved oxygen concentration in the Basin bottom water continued to drop and at the end of the quarter is < 6.0 mg/L. While the data do not indicate that the DO concentrations are below the applicable guidelines, the values are below saturation much of the time. This is counter to the impression given by historical data that, in general, outside the near field of outfalls, the surface water in the harbour is near saturation most of the time. At times, some of the lower values measured seem counterintuitive, causing the values to be questioned.

Figure 14 represents a comparison of HHWQMP oxygen data with the BBPMP oxygen data from the beginning of the year to the end of this quarter (14 Jun 05). Note that the units for the HHWQMP plot are mL/L, rather than the mg/L which is used in the weekly reports. These units correspond to the units of the published BBPMP data. The conversion factor from mg/L to mL/L is approximately 0.7.

The data show similar trends but have discrepancies in magnitude. The data variations prior to day 81 have been discussed in QR#3. In summary, most of the variations in shape in the third quarter can be explained by missing data from one data set or the other. In the forth quarter, there were 3 weeks (days 88, 102 and 151) of missed DO data in the HHWQMP and one week (day 166) of missed data in the BBPMP. It appears that the trends correspond quite closely in this quarter (after day 81). In both data sets, there is evidence of an increase in DO in the surface water which accompanies the spring bloom, and the increase in bottom dissolved oxygen due to the intrusion of shelf water (both commencing just before the start of the quarter). The gradual depletion of the DO in the bottom water, after the intrusion, is also evident. However, there are discrepancies in the magnitude of the data. The data seem to correspond quite closely at lower values but the HHWQMP data tends to be relatively higher at higher values. This suggests a proportional variation, i.e. the HHWQMP data is x% higher than the BBPMP data. Since both programs use similar, if not identical DO sensors, the results of the data comparison give limited comfort with the DO data. It should be mentioned that neither data set is ground-truthed, and that dissolved oxygen sensors are "finicky" sensors, which could result in some of the discrepancies. The nature of the instrument configuration makes regular calibration impractical. While the instruments are inherently stable over long periods, contamination of the sensor can affect sensitivity. Improved data quality can be achieved by adjusting the data a posteriori with independently determined dissolved oxygen values. The BBPMP collects water samples for this purpose and analyzes them in the lab, however the published data presented here has not been adjusted. They are in the process of adjusting this data and have suggested that their data can be made available to HHWQMP for at least qualitative QAQC on DO data.

The importance of this data set has been discussed in previous reports. It is important that the data be appropriately quality controlled, either by cooperation with other investigators or by instituting a ground truthing protocol for HHWQMP. This continues to be investigated.

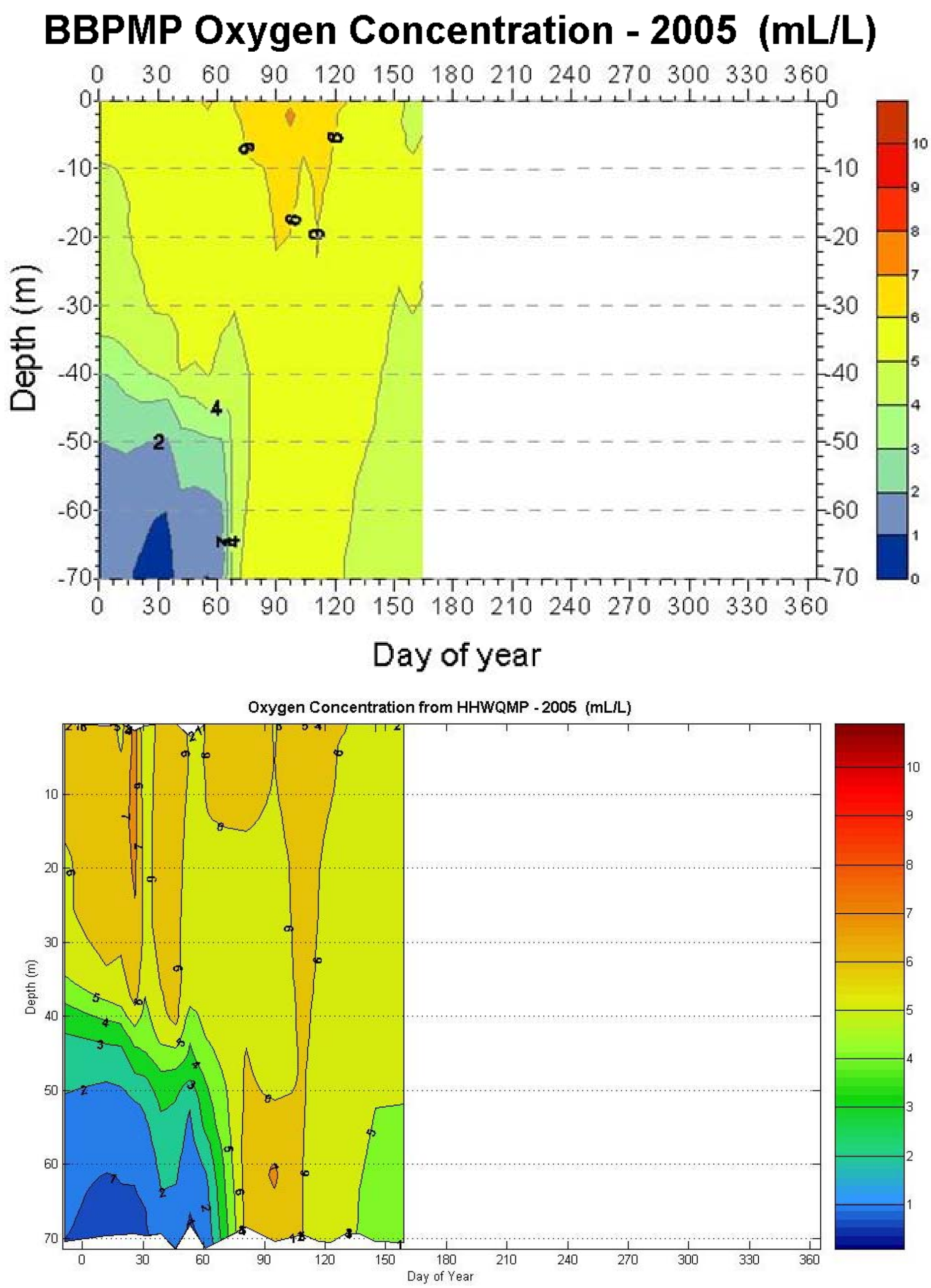


Figure 12. Comparison of BBPMP and HHWQMP dissolved oxygen data from Station G2 (1 Jan to 14 Jun 2005).

4.10 Supplemental Samples

Two supplemental samples were taken this quarter. The location of these samples is shown in Figure 13. Sample SS#2 was taken directly in the "boil" of the outfall off the Peace Pavilion Park in Dartmouth (44º 39.600´ N, 63º 34.200´ W, NAD 83). This is a persistent feature that is almost always visible. The sample was taken at around 11:40 on 12 Apr 05, a time when it was particularly evident. This feature is characterized by a concentration of gulls and ducks (Figure 14) and a visible turbulent boil (Figure 15). There is often a visible turbid plume extending away from the outfall with the prevailing current.

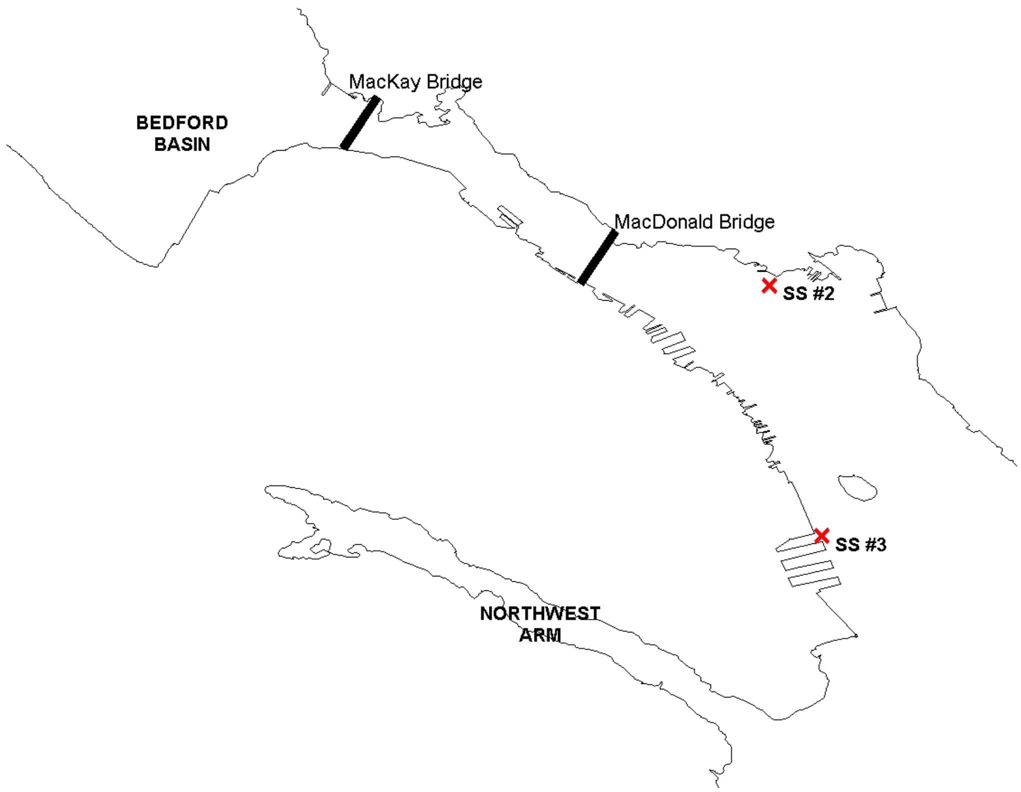


Figure 13. Locations of supplemental sample sites SS#2 and SS#3

Figure 14. Congregation of birds at the outfall off Peace Pavilion Park in Dartmouth (12 Apr 05)

Figure 15. Typical turbulent "boil" over the outfall off Peace Pavilion Park in Dartmouth (picture not taken on sample date)

Sample SS#3 was obtained at approximately 15:30 on 21 Apr 05, inside a visible surface feature in the vicinity of Pier A (44º 38.177´N, 63°38.177´W, NAD 83). This is a commonly visible feature, a result of the large outfall between Pier A and Pier 21, and the storm overflow at the end of Pier A. It is characterized from a distance by a damping of capillary waves. On the day of the supplementary sample, the plume was particularly large, extending from between the piers past Georges Island. There was a congregation of birds by the storm overflow. The water was visibly turbid inside the feature with large, easily visible particulates. Figure 16 is a photo from inside the plume looking north. The birds over the storm overflow are visible on the left. The Northern edge of the plume is visible in the capillary waves.

Figure 16. View looking north from inside a surface feature off Pier A.

The results of the lab analysis for these samples are shown in Table 8. The fecal coliform samples were processed with the standard resolution (CFU/100 ml), which resulted in out-of-range values. The other detectable parameters were also relatively high. The ammonia values are about a factor of three times the maximum value observed in the regular samples. The $CBOD_5$ (EQL= 5 mg/L) values imply a dilution of raw sewage at the sample point of perhaps 10 to 20. The TSS value for SS#2 is similar to or lower than several regular sample sites that week. The several samples with high values that week may be related to the ongoing phytoplankton bloom. The TSS value for SS#3 is the highest observed that week but is not significantly higher than the maximum value observed at a regular station (12 mg/L). The implication is that the visibility of these features has more to do with the nature of the particulates than the absolute concentration.

Table 8. Detectable parameters measured in SS#2 and SS#3

Parameter	**Units**	**Value**	
		SS02	**SS03**
Fecal Coliform	CFU/100mL	>10,000	>10,000
Ammonia (N)	mg/L	0.41	0.32
$CBOD_5$	mg/L	6.4	6.2
TSS	mg/L	17	15

5 Annual Summary

The following section is a summary of information provided in the first three annual reports, combined with information in the previous sections of this report. 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. However, there are summary analyses under development, particularly with the CTD data, which will be instituted as they are developed. These will be useful in directing further analysis if and when required.

5.1 Fecal Coliform

Maps representing the geometric mean values over all samples for each of the four quarters to date are presented in Figures 6 through 9. 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 black indicate suitability for either activity. In each figure, separate maps are presented for the 1 and 10m samples. It is helpful to refer to the station map (Figure 1) in the following discussion.

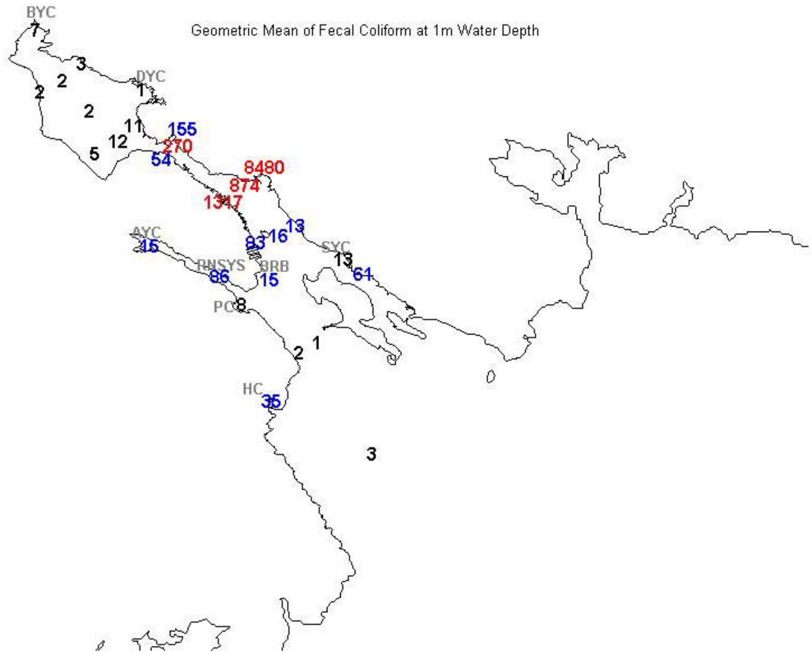
Overall, the coliform levels were lowest in the first quarter (summer), highest in the second quarter (autumn), and intermediate in the third quarter (winter) and fourth quarter (spring). The differences are quite dramatic. In summer, of a total of 56 sample sites (28 stations at two depths), only four had geometric means >200 CFU/100mL, and thirty-three had geometric means < 14 CFU/100mL. This compares to the second quarter, when twenty-six sites had geometric means in excess 200 CFU/100mL, and only three had less than 14 CFU/ 100 mL. These variations are due to complex interactions of meteorological and oceanographic factors affecting source strength, effluent trajectory and mixing, and bacteria die-off. An important factor is the die off of bacteria. Cooler water and reduced sunlight both increase bacterial survival times, resulting in higher concentrations in cold and dark or cloudy conditions.

In all four quarters, both the 1 m and 10 m coliform values were highest in the Inner Harbour, in the vicinity of the majority of large outfalls. Within this basic pattern there was quite a bit of variability. In the summer (Quarter 1), the concentration distribution was centered on sections EE (highest values), and E (second highest values) for both the 1 and 10m samples. This pattern seems consistent with the distribution of major outfalls in the harbour and suggests that, at least in summer, there is little significant residual flow in the Inner Harbour. This is consistent with summer current observations in the harbour (Hurlbut et al. 1990, ASA 1991). In autumn (Quarter 2), the centre of the distribution seems to be displaced slightly down-harbour in the 1 m samples (highest values at EE, but second highest at D), and up harbour in the 10m samples (highest values at E section). In the winter (Quarter 3), this trend was similar, with the highest concentrations in the 1 m samples being centered on section D, and the higher concentrations in the 10m samples centered up harbour near section EE. The displacement is consistent with typical estuarine circulation, with fresher water flowing out at the surface and a deeper return flow of more saline water.

There is a persistent pattern in the vertical fecal coliform distribution which spans all quarters. The 1m values were higher than the 10m values in the southern part of the Inner Harbour (south of section EE) and the Outer Harbour, while the reverse was true in Bedford Basin. The transition point between these two regimes varies between quarters. In the first quarter, the transition is between the Narrows (section E) and the Basin (section F); in the second quarter, sections E and F exhibit similar concentrations top and bottom. In the third quarter, the transition was all the way down to section EE and in the forth quarter it shifted back up-harbour, between sections EE and E.

The water density (salinity and temperature) data indicates that in the Basin, the higher coliform values are usually associated with a deeper layer consisting of water with density similar to that of the near surface water in the Inner Harbour, while the 1 m sample generally occurs in a less dense layer likely resulting from freshwater runoff into the Basin. Therefore, the Inner Harbour is likely to be the major source of bacteria over much of the Basin, rather than a local source, such as the Mill Cove sewage treatment plant (STP) or Sackville River. The Basin, and the northern Basin in particular, always exhibits some degree of vertical density stratification. It is possible that the effluent from the submerged outfall of the Mill Cove STP generally stays submerged below the pycnocline and contributes somewhat to the coliform concentration in this lower layer. South of the Basin, the density stratification and the degree to which the harbour acts as an estuary, is much less consistent, being greatly affected by sporadic meteorological events (rain and snowmelt). It is likely that the variation in the location of this transition in the vertical coliform distribution is a function of the variation in the degree to which the harbour acts like an estuary.

As discussed in previous quarterly reports, and in various weekly reports (JWL and COA, 2004), the significant week to week variations in FC levels and distribution appear to correlate, at least qualitatively, with meteorological and oceanographic phenomena.



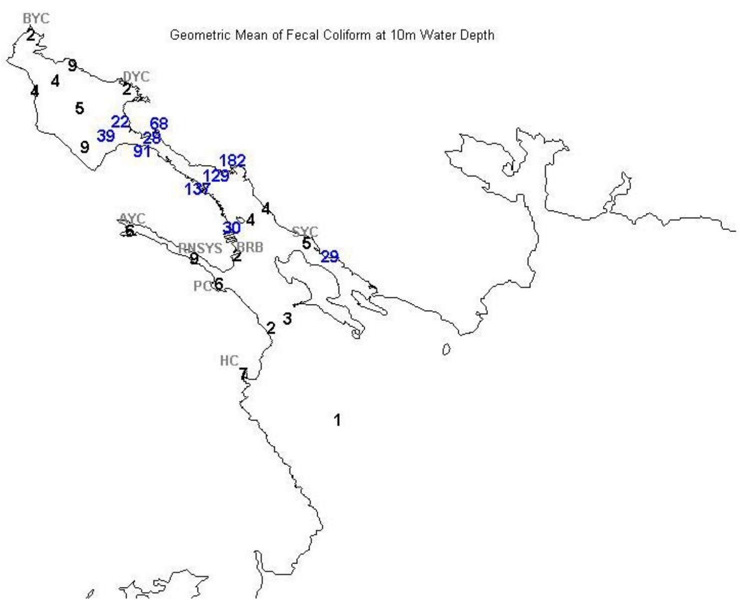
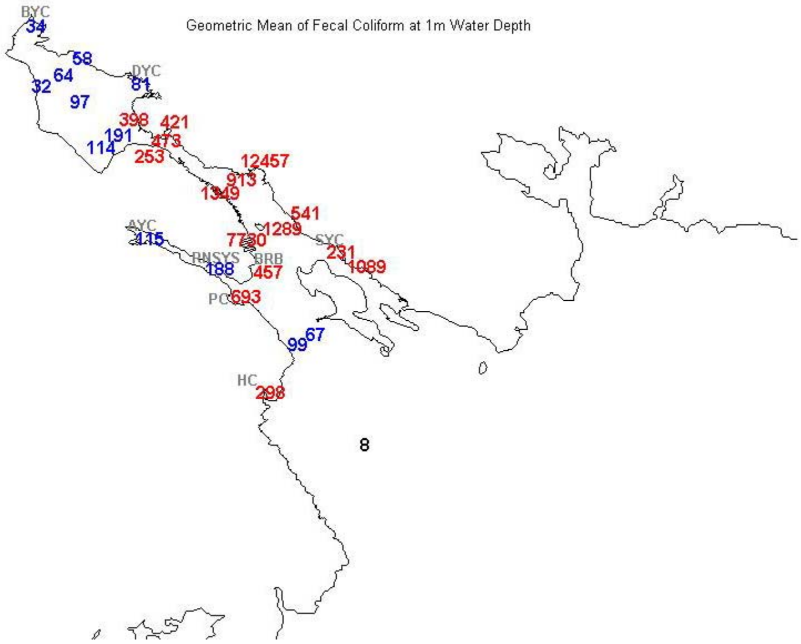


Figure 17. Fecal coliform geometric means (cfu/100mL), 23 June thru 14 Sept. 2004



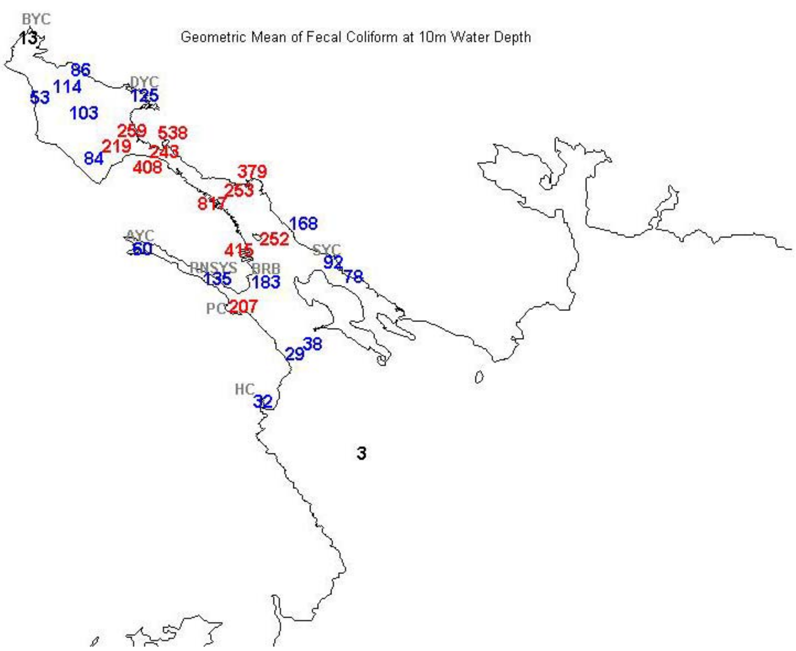
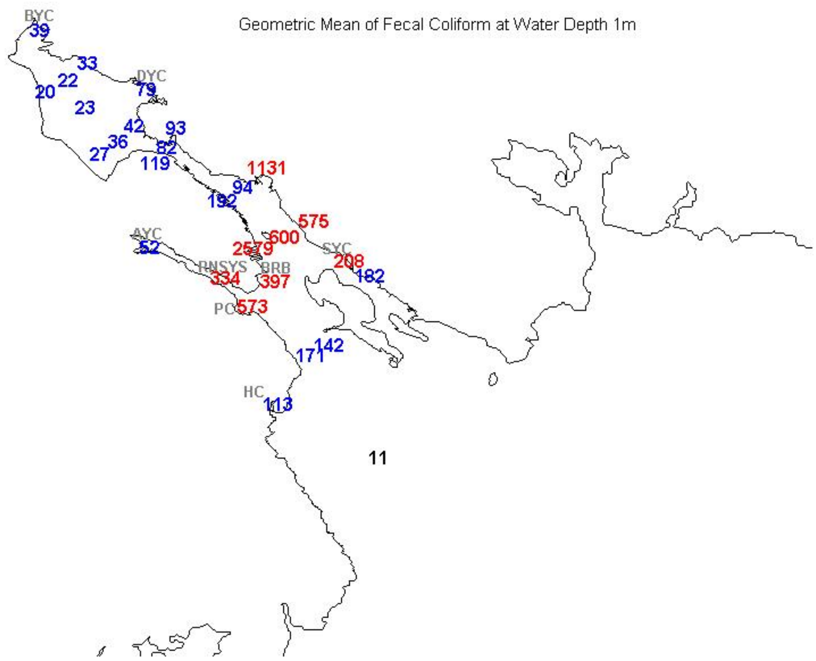


Figure 18. Fecal coliform geometric means (cfu/100mL) 22 Sept. thru 14 Dec. 2004



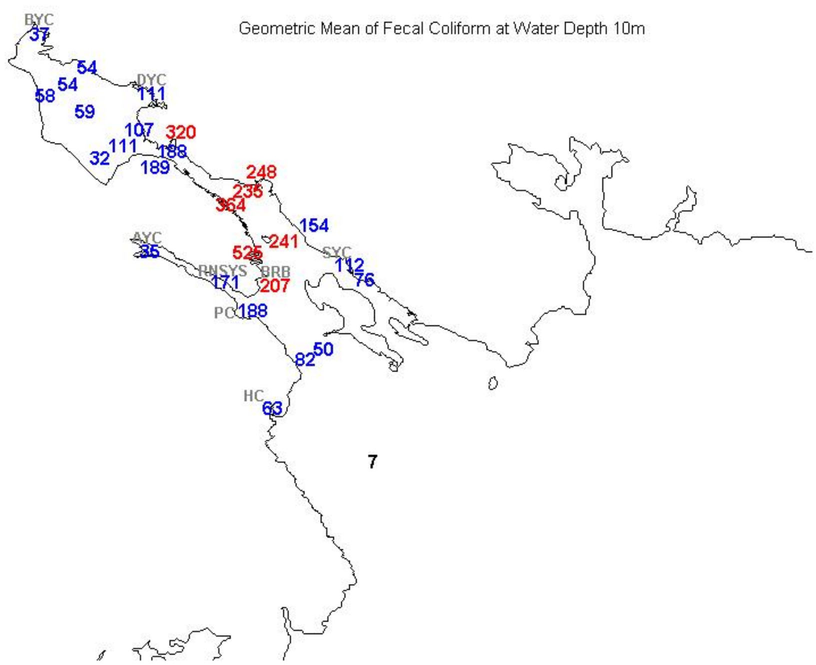
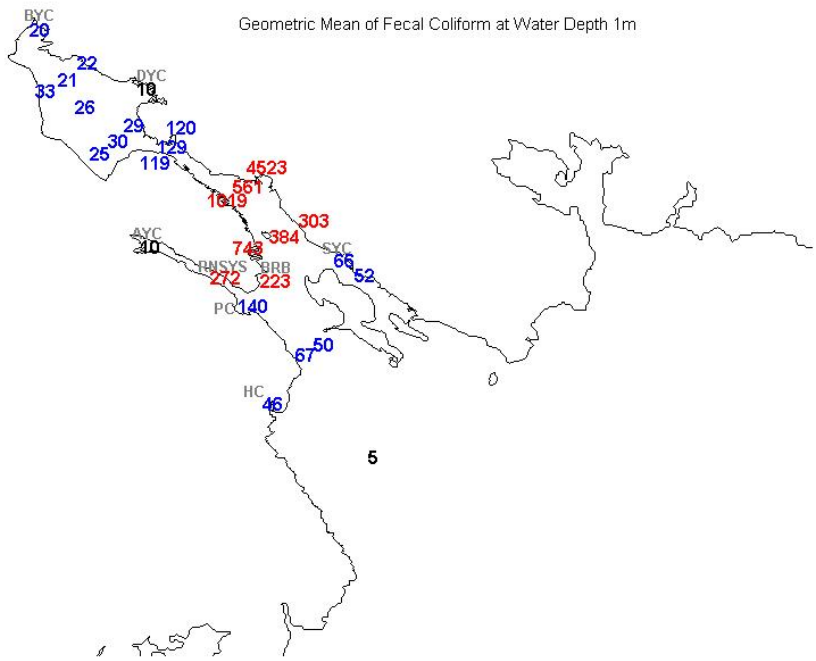


Figure 19. Fecal coliform geometric means (cfu/100mL) , 21 Dec 2004 thru 15 March



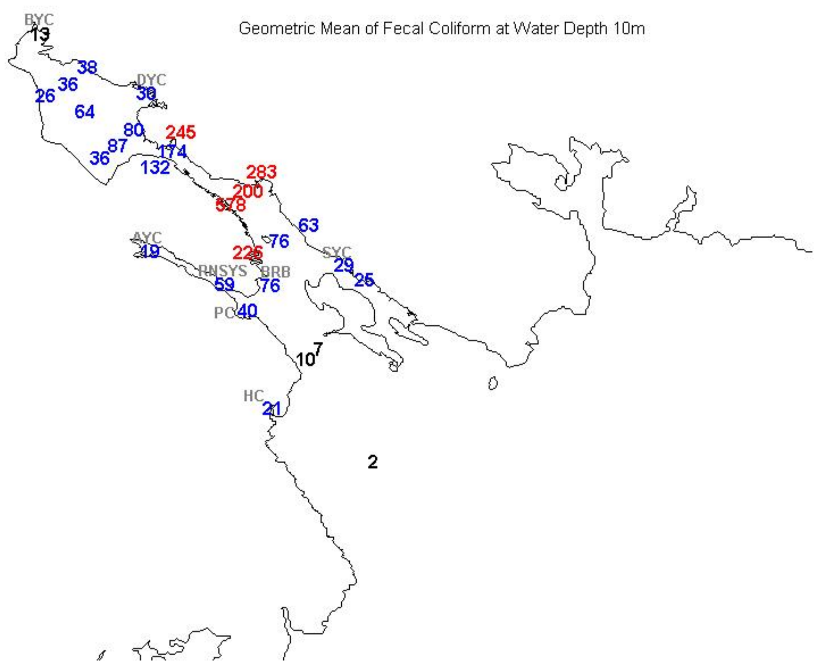


Figure 20. Fecal coliform geometric means (cfu/100 mL), 22 March to 14 June 2005

5.2 Ammonia Nitrogen

The measured values of ammonia nitrogen over the entire year are presented in Tables 9 and 10. Samples which were below the EQL of 0.05 mg/L have been assigned values of 0.025 (EQL/2), and are shaded green. Overall there were 340 samples analyzed of which 179 (53%) had detectable values of ammonia nitrogen. The values cover a relatively limited range with most values less than 0.10 mg/L and only 5 above 0.20 mg/L. There were somewhat more detectable values in the 10 m samples (95) than in the 1 m samples (84). While there are spatial (site to site) variations, there is not a readily discernable pattern. In the 10m sample, the site with the most detectable values is F2 (75%) and the least is at EE2 (35%). There is less variability in the 1m samples with the maximum number of detectable samples at EE2 (58%). The minimum number of detectable values of the 1m samples occurs at B2 (20%), the "reference" site.

There is temporal variability, which appears to be event related. The weeks of 13 Oct (week 17) and 8 Jun (week 51) were remarkable in that they have the highest and next-to-highest mean values in both the 1 and 10m samples. Between these two weeks, there was only one value below EQL, that being at B2 (reference). These surveys were both associated with wet weather, but not large storms. The fecal coliform values on these dates were also high, particularly on 13 Oct. In both cases, the water quality data, taken together with the wind and water level data, hint that harbour flushing may have been inhibited somewhat during these surveys allowing for a buildup of contaminants.

Table 9. Annual Summary of 1m Ammonia Nitrogen

AMMONIA- 1m

1 M	B2	D2	EE2	E2	F2	G2	H2	Mean	Max
23-Jun-04	0.025	0.025	0.025	0.140	0.025	0.025	0.025	0.04	0.14
7-Jul-04	0.025	0.090	0.025	0.090	0.025	0.060	0.050	0.05	0.09
22-Jul-04	0.025	0.025	0.110	0.025	0.025	0.025	0.025	0.04	0.11
3-Aug-04	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.03	0.03
18-Aug-04	0.025	0.050	0.050	0.060	0.070	0.025	0.100	0.05	0.10
31-Aug-04	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.03	0.03
14-Sep-04	0.050	0.050	0.070	0.025	0.025	0.025	0.025	0.04	0.07
28-Sep-04	0.025	0.060	0.025	0.025	0.050	0.025	0.025	0.03	0.06
13-Oct-04	0.050	0.120	0.120	0.130	0.110	0.100	0.150	0.11	0.15
26-Oct-04		0.080	0.060	0.080	0.060	0.080	0.230	0.10	0.23
9-Nov-04	0.025	0.060	0.050	0.060	0.080	0.080	0.080	0.06	0.08
24-Nov-04	0.025	0.060	0.080	0.050	0.060	0.025	0.080	0.05	0.08
9-Dec-04	0.025	0.050	0.025	0.110				0.05	0.11
21-Dec-04	0.025	0.025	0.050	0.025	0.025	0.025	0.025	0.03	0.05
5-Jan-05	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.03	0.03
19-Jan-05	0.025	0.025	0.025	0.025	0.025	0.060	0.080	0.04	0.08
31-Jan-05	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.03	0.03
15-Feb-05		0.060	0.100	0.090	0.090	0.060	0.070	0.08	0.10
2-Mar-05		0.060	0.080	0.090	0.060	0.080	0.110	0.08	0.11
15-Mar-05	0.060	0.070	0.025	0.070	0.080	0.080	0.080	0.07	0.08
31-Mar-05		0.025	0.025	0.025				0.03	0.03
12-Apr-05	0.150	0.025	0.090	0.025	0.050	0.050	0.090	0.07	0.15
27-Apr-05		0.110	0.070	0.060	0.025	0.090	0.090	0.07	0.11
10-May-05	0.025	0.025	0.220	0.025	0.120	0.025	0.060	0.07	0.22
25-May-05		0.025	0.050	0.160	0.025	0.025	0.025	0.05	0.16
8-Jun-05	0.025	0.150	0.260	0.170	0.160	0.140	0.160	0.15	0.26
Mean	**0.04**	**0.05**	**0.07**	**0.06**	**0.05**	**0.05**	**0.07**	**0.06**	**0.10**
Max	**0.15**	**0.15**	**0.26**	**0.17**	**0.16**	**0.14**	**0.23**	**0.15**	**0.26**

Table 10. Annual Summary of 10m Ammonia Nitrogen

AMMONIA- 10m

10 M	B2	D2	EE2	E2	F2	G2	H2	Mean	Max
23-Jun-04	0.025	0.025	0.025	0.025	0.220	0.025	0.025	0.05	0.22
7-Jul-04	0.080	0.060	0.090	0.110	0.090	0.070	0.025	0.08	0.11
22-Jul-04	0.025	0.025	0.070	0.140	0.025	0.025	0.060	0.05	0.14
3-Aug-04	0.050	0.025	0.025	0.050	0.260	0.070	0.070	0.08	0.26
18-Aug-04	0.070	0.025	0.025	0.080	0.080	0.120	0.090	0.07	0.12
31-Aug-04	0.025	0.025	0.070	0.060	0.025	0.025	0.025	0.04	0.07
14-Sep-04	0.060	0.050	0.025	0.060	0.060	0.070	0.060	0.06	0.07
28-Sep-04	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.03	0.03
13-Oct-04	0.070	0.090	0.090	0.110	0.120	0.100	0.130	0.10	0.13
26-Oct-04		0.050	0.025	0.070	0.180	0.070	0.080	0.08	0.18
9-Nov-04	0.060	0.080	0.050	0.090	0.090	0.080	0.070	0.07	0.09
24-Nov-04	0.025	0.080	0.025	0.025	0.050	0.050	0.070	0.05	0.08
9-Dec-04	0.025	0.025	0.025	0.050				0.03	0.05
21-Dec-04	0.025	0.025	0.025	0.025	0.025	0.025	0.025	0.03	0.03
5-Jan-05	0.025	0.070	0.025	0.025	0.110	0.025	0.025	0.04	0.11
19-Jan-05	0.025	0.150	0.025	0.025	0.025	0.025	0.025	0.04	0.15
31-Jan-05	0.050	0.025	0.025	0.025	0.025	0.090	0.050	0.04	0.09
15-Feb-05		0.070	0.025	0.060	0.060	0.025	0.060	0.05	0.07
2-Mar-05		0.090	0.050	0.100	0.100	0.060	0.025	0.07	0.10
15-Mar-05	0.070	0.050	0.100	0.060	0.080	0.070	0.170	0.09	0.17
31-Mar-05		0.025	0.100	0.025				0.05	0.10
12-Apr-05	0.060	0.060	0.025	0.080	0.100	0.070	0.160	0.08	0.16
27-Apr-05		0.070	0.025	0.025	0.050	0.025	0.025	0.04	0.07
10-May-05	0.025	0.100	0.025	0.025	0.190	0.025	0.260	0.09	0.26
25-May-05		0.025	0.025	0.025	0.050	0.025	0.080	0.04	0.08
8-Jun-05	0.060	0.150	0.170	0.120	0.070	0.080	0.080	0.10	0.17
Mean	**0.04**	**0.06**	**0.05**	**0.06**	**0.09**	**0.05**	**0.07**	**0.06**	**0.12**
Max	**0.08**	**0.15**	**0.17**	**0.14**	**0.26**	**0.12**	**0.26**	**0.10**	**0.26**

5.3 Carbonaceous Biochemical Oxygen Demand

The laboratory EQL for carbonaceous biochemical oxygen demand ($CBOD_5$) is 5 mg/L. Values exceeding the EQL in regular samples have occurred twice, both in the second quarter, at station B2 (6 mg/L) on 13 Oct 05, and D2 – 1m (5 mg/L) on 26 Oct 05. The 13 Oct survey is notable in that it exhibited high values of several parameters including ammonia nitrogen and metals. There have been three supplemental samples, all of which had $CBOD_5$ values of 5-7 mg/L. $CBOD_5$ is a parameter regularly monitored in STP effluent. Typical levels in raw sewage are on the order of 100 mg/L, while the regulated end of pipe value for the Advanced Primary STPs designed for the Harbour Solutions Project is 50 mg/L. A relatively low level of dilution is required to reduce the $CBOD_5$ in raw sewage to levels below the EQL. While most of the existing outfalls in the harbour are very low dilution outfalls, the plumes from these outfalls are unlikely to make it to the sample stations in the center of the harbour without $CBOD_5$ being diluted below detectible levels. With the high dilution outfalls designed for the STP's, the discharge of treated effluent would be unlikely to exceed the EQL anywhere even under worst case situations. Based on these arguments and experience to date, $CBOD_5$ analysis was discontinued on 25 May 05, close to the end of the fourth quarter. $CBOD_5$ analysis will continue for supplemental samples.

5.4 Total Suspended Solids

The measured values of TSS over the entire year are presented in Tables 11 and 12. The EQL for the analysis is 1 mg/L (or sometimes 2 mg/L if the sample is split in the lab for duplicate analysis). Samples which were below the EQL have been assigned values of (EQL/2), either 0.5 or 1.0 as appropriate), and are shaded green. There were 17 of 340 samples which were below EQL. Overall, the TSS values increases from quarter to quarter. The mean over all samples in the first quarter was approximately 2.6 mg/L, which compares to approximately 4.5 mg/L in the second quarter, 6 mg/L in the third quarter, and 11 mg/L in the fourth quarter. The high values in the fourth quarter (spring) are likely due to the spring phytoplankton bloom, and large amount of freshwater input in a very wet spring. The intermediate values in the fall (Quarter 2) and winter (Quarter 3) are likely due to the fall phytoplankton bloom and passing storms. The lowest values in the summer may represent a relative lack of major storms, although the phytoplankton activity remains quite low (Section 15.7). Within the seasonal trend there is quite a bit of week to week variability. The mean values typically vary by a factor of two from one week to another within each quarter. There is very little evidence of coherent spatial variability. The site mean values indicate that site E2 has the highest values in the 1 m samples and H2 in the 10 m samples. This is misleading in that the mean at both sites is influenced by several high values in the fourth quarter, during the spring bloom. In fact, half of the measured concentrations at E2 are above the weekly mean value and half are below. The survey maximum values have occurred at every site except B2. On average, the concentrations are lower at B2, but there are weeks where the B2 values are amongst the highest in the survey. A preliminary look suggests that high values at B2 may be associated with wind events.

Table 11. Annual summary of 1 m TSS values

TSS- 1m

1 M	B2	D2	EE2	E2	F2	G2	H2	Mean	Max
23-Jun-04	2.00	2.00	1.80	2.90	0.50	13.80	2.60	3.66	13.80
7-Jul-04	1.60	2.40	1.60	1.20	1.00	2.60	1.20	1.66	2.60
22-Jul-04	0.50	2.80	2.40	1.20	1.60	2.60	2.00	1.87	2.80
3-Aug-04	3.40	1.60	2.40	1.60	2.40	3.80	6.40	3.09	6.40
18-Aug-04	1.40	1.40	2.00	3.20	4.00	3.80	4.80	2.94	4.80
31-Aug-04	0.50	3.70	4.00	4.40	3.60	3.30	4.40	3.41	4.40
14-Sep-04	1.40	3.20	3.60	5.80	4.00	4.20	6.00	4.03	6.00
28-Sep-04	1.00	1.00	1.20	2.20	2.40	1.60	4.20	1.94	4.20
13-Oct-04	3.00	3.80	1.60	2.80	3.00	2.60	4.40	3.03	4.40
26-Oct-04		11.10	5.10	6.90	4.40	3.60	4.00	5.85	11.10
9-Nov-04	3.60	4.40	2.20	2.20	2.80	4.20	1.00	2.91	4.40
24-Nov-04	1.00	4.90	4.90	4.40	9.50	4.20	6.70	5.09	9.50
9-Dec-04	3.10	5.10	4.00	10.50				5.68	10.50
21-Dec-04	5.60	4.00	3.30	3.30	3.60	3.60	5.80	4.17	5.80
5-Jan-05	7.60	4.40	8.40	6.00	5.80	3.60	1.00	5.26	8.40
19-Jan-05	4.00	2.90	7.30	6.20	7.40	13.80	5.80	6.77	13.80
31-Jan-05	4.20	12.00	7.10	4.20	15.00	2.40	5.60	7.21	15.00
15-Feb-05		5.80	7.60	5.10	6.00	5.80	6.70	6.17	7.60
2-Mar-05		4.00	3.80	3.80	5.10	6.70	3.60	4.50	6.70
15-Mar-05	3.40	2.20	16.00	11.00	8.00	6.30	3.20	7.16	16.00
31-Mar-05		29.00	11.00	4.60				14.87	29.00
12-Apr-05	21.00	8.40	9.10	40.00	10.00	9.80	19.00	16.76	40.00
27-Apr-05		9.20	9.80	7.50	10.00	3.90	9.90	8.38	10.00
10-May-05	13.00	7.60	9.80	15.00	8.00	7.80	7.00	9.74	15.00
25-May-05		9.20	3.40	41.00	10.00	7.90	8.50	13.33	41.00
8-Jun-05	4.90	3.40	10.00	9.60	5.90	12.00	5.90	7.39	12.00
Mean	**4.31**	**5.75**	**5.52**	**7.95**	**5.58**	**5.58**	**5.40**	**6.03**	**11.74**
Max	**21.00**	**29.00**	**16.00**	**41.00**	**15.00**	**13.80**	**19.00**	**16.76**	**41.00**

Table 12. Annual summary of 10 m TSS values

TSS- 10m

10 M	B2	D2	EE2	E2	F2	G2	H2	Mean	Max
23-Jun-04	1.60	2.80	2.40	3.00	1.40	5.80	3.10	2.87	5.80
7-Jul-04	1.20	0.50	2.80	1.80	3.40	1.20	0.50	1.63	3.40
22-Jul-04	0.50	1.80	1.60	2.00	0.50	3.00	0.50	1.41	3.00
3-Aug-04	2.20	0.50	1.60	2.80	0.50	1.40	1.60	1.51	2.80
18-Aug-04	1.00	2.20	2.40	1.80	1.00	3.00	1.40	1.83	3.00
31-Aug-04	2.60	2.20	2.40	3.30	0.50	3.70	4.50	2.74	4.50
14-Sep-04	2.00	2.00	2.60	3.20	4.60	3.60	3.80	3.11	4.60
28-Sep-04	2.20	1.40	1.60	3.20	3.20	3.80	4.20	2.80	4.20
13-Oct-04	2.00	1.80	1.80	2.80	9.80	2.00	2.00	3.17	9.80
26-Oct-04		5.60	9.30	10.20	4.90	5.30	3.10	6.40	10.20
9-Nov-04	4.70	3.20	3.80	6.40	2.90	4.00	1.00	3.71	6.40
24-Nov-04	1.00	2.70	2.20	3.60	6.00	5.30	9.50	4.33	9.50
9-Dec-04	4.40	14.20	7.10	8.50				8.55	14.20
21-Dec-04	2.90	5.10	3.80	4.90	2.70	2.20	2.40	3.43	5.10
5-Jan-05	7.30	4.00	4.70	6.90	8.70	6.00	6.40	6.29	8.70
19-Jan-05	3.80	11.80	5.30	6.40	6.90	2.90	2.90	5.71	11.80
31-Jan-05	8.40	8.90	11.00	5.80	4.00	7.30	4.00	7.06	11.00
15-Feb-05		6.00	5.30	2.20	7.30	6.20	7.10	5.68	7.30
2-Mar-05		4.20	2.70	6.70	3.30	5.60	7.80	5.05	7.80
15-Mar-05	2.60	7.60	12.00	8.00	6.80	16.00	5.30	8.33	16.00
31-Mar-05		23.00	5.40	5.20				11.20	23.00
12-Apr-05	11.00	8.70	15.00	8.10	13.00	12.00	16.00	11.97	16.00
27-Apr-05		9.50	8.50	9.00	6.60	12.00	8.70	9.05	12.00
10-May-05	14.00	11.00	6.00	11.00	6.40	6.30	34.00	12.67	34.00
25-May-05		6.30	3.00	19.00	9.50	9.80	14.00	10.27	19.00
8-Jun-05	4.40	6.90	4.90	13.00	11.00	9.90	10.00	8.59	13.00
Mean	**3.99**	**5.92**	**4.97**	**6.11**	**5.20**	**5.76**	**6.41**	**5.75**	**10.23**
Max	**14.00**	**23.00**	**15.00**	**19.00**	**13.00**	**16.00**	**34.00**	**12.67**	**34.00**

5.5 Total Oil and Grease

Total Oil and Grease (TOG) is another value typically measured in sewage and STP effluent. TOG also has a task force guideline of 100 mg/L. The EQL for TOG is 5 mg/L. Counter to discussions in QR#3 there has been a single value of TOG measured at the detection limit in the H2-1m sample on 21 Dec 04. Starting on 10 May 05, based on recommendations of previous reports, this analysis has been performed only in a surface grab sample, rather than at the 1 and 10m sample depths.

5.6 Metals

The metal scan analysis includes a suite of 25 metals (Table 1). There are eight of these with guidelines established by the Halifax Harbour Task Force. Mercury has a HHTF guideline but is not measured in the metal scan. In addition, two of the seven metals, copper (EQL 20µg/L, guideline 2.9 µg/L) and nickel (EQL 20 µg/L, guideline 8.3 µg/L) have EQL values greater than the guidelines so concentrations in excess of the guidelines could go undetected.

Of these seven metals, there are four: manganese, zinc, lead, and copper, which have been detected in samples taken in the first four quarters. These results are presented in Tables 13 through 16. Any value which exceeds the guideline in the tables is highlighted in red. Over the year, there have been 364 possible metal samples. In this time, 12 sites (24 samples) have been missed, primarily due to weather. There have therefore been 340 samples analyzed. Overall, there have been 12 – 15 samples (including QA/QC and laboratory duplicates) with detectable metal species in each quarter. In terms of independent determinations (not counting QA/QC samples and laboratory duplicates), there have been a total of 44 values above detection limits, out of a possible 2380 determinations, for an overall data return of < 2%.

The most frequently detected metal is manganese (Table 13), which has an EQL of 20 µg/L. There have been 26 independent determinations of manganese out of 340 samples, or in 7.6% of samples. These occurrences are distributed 10, 3, 3, and 10 among quarters. There seems to be a slight trend for higher values in the Basin. Interestingly, 11 of the 16 detectable values in the first three quarters (before 31 Mar 05) were in 10 m samples, while all 10 occurrences after that date were in the 1m samples. The three Basin sites (of 7) account for 16 of the 26 occurrences. The values all range from 20-40 µg/L, except the single high value at B2 (10 m), which had a concentration of 70 µg/L. These are all below the guideline of 100 µg/L.

There have been 10 independent determinations of zinc in excess of the EQL of 50 µg/L (Table 14). This represents 3% of all samples. This is a very sparse sampling from which to determine any trends and the significance of the following observations is uncertain. The occurrences are distributed 1, 4, 2, and 3 among quarters. Four of the elevated values occurred at D2, with the remainder distributed from the outer Harbour to the head of the Basin. There were about an equal number in the 1 and 10m samples. Seven of these values were between 50 and the guideline value of 86 µg/L, however, there were three values which exceeded the guideline. Most notable was a value of 1100 µg/L in the 1m sample at B2 on 3 Aug 04.

Lead in excess of the EQL of 5 µg/L, has been detected in five samples, or 1.5 % of samples. Four of the five values were in the Basin. Four were in the second quarter, and one in third. No vertical variations were evident. The guideline for lead is 5.6 µg/L, which was exceeded in 3 of the 5 samples.

As mentioned above, any detectable value of copper (EQL = 20 µg/L) exceeds the guideline of 2.9 µg/L. There have been three independent determinations of copper concentrations greater than the detection limit. These occurred on separate surveys and at different sites. Two of these were just above the limit but one, G2-1m on 25 Mar 05, registered a value of 120 µg/L.

The remaining metals for which no guidelines exist include boron, lithium, strontium, titanium and uranium. These metals are regularly detected, and have quite consistent concentrations across all samples and all surveys. Typical concentrations are: boron (4000 µg/L), lithium (180 µg/L), strontium (6300 µg/L), titanium (70 µg/L), and uranium (3.2 µg/L). Other metals show up sporadically; aluminum, has occurred in eight samples, vanadium in five samples, and iron, molybdenum and thallium each once. These are documented in the weekly reports

The resolution of metals concentrations in the harbour has been recognized as an issue. Options for modifying the program were discussed and recommendations made in previous reports. The implications of these recommendations are currently under consideration.

Table 13. Manganese levels over the first four quarters.

Manganese	EQL= 20 µg/L	Guideline=100 µg/L	
Survey Date	Value (µg/L)	Site	Depth (m)
22-Jul-04	25	E2	10
	42	H2	10
3-Aug-04	28	D2	1
	31	F2	1
18-Aug-04	21	EE2	10
	21	G2	10
31-Aug-04	20	D2	10
	24	F2	10
14-Sep-04	22	D2	10
	24	F2	10
28-Sep-04	70	B2	10
	33	F2	10
26-Oct-04	24	F2	1
2-Mar-05	21	EE2	1
	21	H2 (DUP)	10
15-Mar-05	24	H2	10
	26	F2	1
12-Apr-05	29	E2	1
	23	F2	1
	28	G2	1
10-May-05	36	E2	1
	36	F2	1
	34	F2(QA/QC)	1
	33	G2	1
	38	H2	1
25-May-05	35	H2	1
	35	H2(QA/QC)	1
8-Jun-05	20	EE2	1
	21	H2	1

Table 14. Zinc levels over the first four quarters.

Zinc EQL = 50 µg/L Guideline = 86 µg/L

Survey Date	Value(µg/L)	Site	Depth (m)
3-Aug-04	1100	B2	1
28-Sep-04	56	B2	10
	60	F2	10
13-Oct-04	83	H2	1
26-Oct-04	71	D2	1
15-Feb-05	58	D2	10
	90	D2 (DUP)	10
2-Mar-05	55	D2	1
31-Mar-05	78	D2	10
8-Jun-05	75	F2	1
	140	G2	1

Table 15. Lead levels over the first four quarters.

Lead EQL= 5 µg/L Guideline = 5.6 µg/L

Survey Date	Value (µg/L)	Site	Depth (m)	Notes
28-Sep-04	5.2	D2	10	
13-Oct-04	8.2	H2	1	QAQC <5
	5.5	H2	10	
9-Nov-04	8	F2	1	
	5.1	G2 (QAQC)	1	primary <5
5-Jan-05	14	G2	10	

Table 16. Copper levels over the first four quarters.

Copper EQL = 20 µg/L Guideline = 2.9 µg/L

Survey Date	Value(µg/L)	Site	Depth (m)
3-Aug-04	24	B2	10
21-Dec-04	25	G2 (DUP)	1
9-Jan-05	21	EE2 (DUP)	10
15-Feb-05	21	D2	10
	23	D2 (DUP)	10
15-Mar-05	120	G2	1

5.7 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). 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.

The data shows that from late fall through the spring bloom, the harbour behaves as a typical estuary. This period extends from about week 18, at the end of October, until about week 45, at the end of April. At the start of this period are several weeks of relatively low activity, with maximum values of about 1-6 mg/L. This marks the cooling down of activity in the fall of 2004. By the beginning of December, the values have dropped to around 0.5 to 1.0 mg/m^3 and remain at this level through the winter until the beginning of March 2005. In the first few weeks of March, values begin to increase and spring bloom begins in earnest in the middle of March. During the bloom, maximum concentrations of 20-40 mg/m^3 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, but as high as 9 mg/m^3 . The bloom continues until the second or third week in April 2005.

Outside of this period, the fluorescence levels are much more erratic. At the beginning of the data set, throughout July 2004, there is a bloom that has maximum values of up to 51 mg/m^3 at the head of the Northwest Arm (AYC). This bloom is evident elsewhere in the Harbour with somewhat lower values of up to 30 mg/m^3 in the Inner Harbour and Basin. After this, through August, September and most of October there is a lot of week to week variability with maximum values generally varying from 10 to 20 mg/L. There appears to be no distinct fall bloom, though there is a bit of a maximum in the third week of October.

At the end of the data set, in the late spring, from the end of April through the middle of June, conditions seem similar to the summer conditions, with even more week to week variability. There are two noncontiguous weeks with maximum values less than 3 mg/m^3 and conversely there are two noncontiguous weeks where there are maximum values greater than 40 mg/m^3. The additional weeks have intermediate maximum values of around 10 – 20 mg/m^3.

It appears from this cursory analysis that the spring bloom may be extended, sporadically, throughout the spring, summer and fall, until activity ceases due to lack of light in the late fall and winter.

5.8 Dissolved Oxygen

Perhaps the most oceanographically interesting feature of the harbour is Bedford Basin. The Basin is a fiord. Here, the deep water (70m) is relatively isolated by a shallow sill

(20m) and is only renewed periodically by the upwelling over the sill of dense shelf bottom water. 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. At the same time, vertical diffusion slowly decreases the bottom water density by mixing with less dense overlying water. Every so often, dense bottom water upwells into the harbour, flowing over the sill to displace and mix with the bottom water. Historical information indicates that these events occur on average once or twice a year in Bedford Basin. In the first year of the HHWQMP, one such renewal cycle has been witnessed (Figure 10). At the start of the program, in June 2004, the DO was relatively high (6.6 mg/L) and dropped monotonically until the end of Jan 2005. In the following weeks, a minor intrusion raised the DO slightly. In the middle of March a major intrusion occurs raising the DO to a max of 9.7 mg/L. From then until the end of the year, the DO resumes its monotonic decrease to about 6 mg/L.

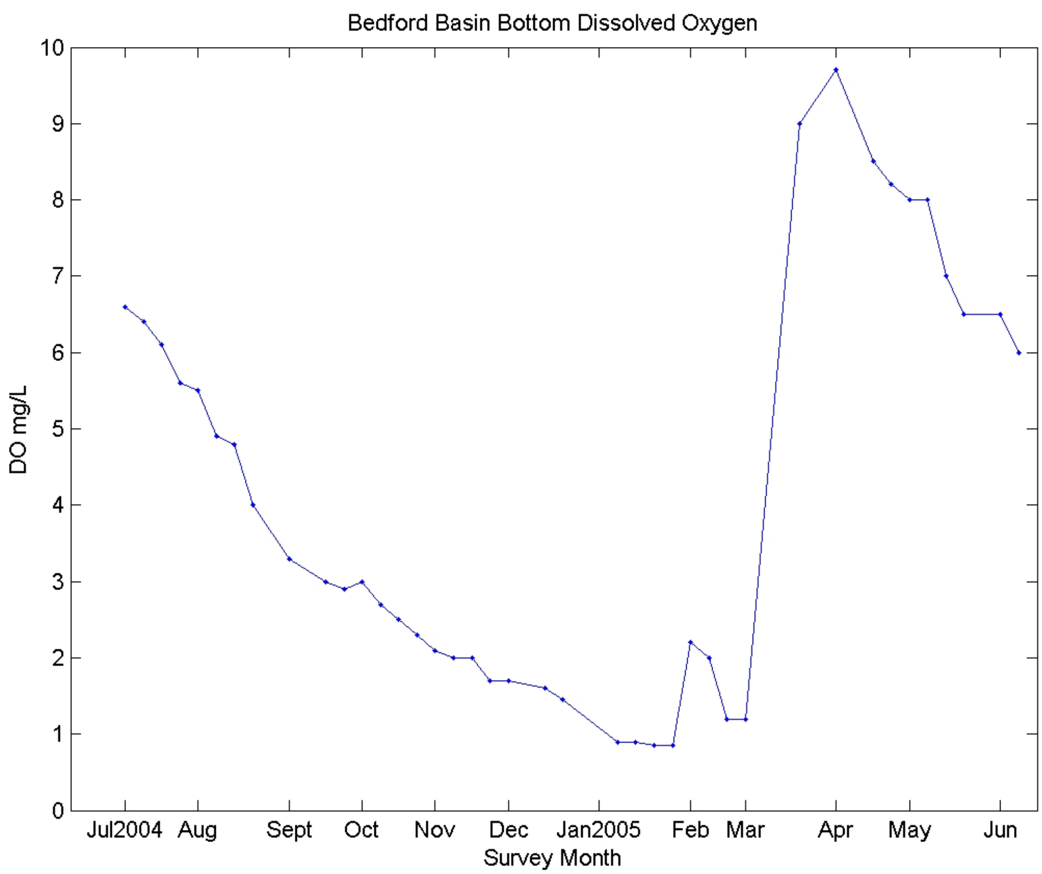


Figure 21. Timeseries of dissolved oxygen at the bottom of Bedford Basin.

The bottom water of Bedford Basin is usually in violation of the class SB guideline of 7.0 mg/L. This is in large part a natural phenomenon, but may be exacerbated by increased organic input.

For the most part, over this period, the surface water of the harbour met the region-specific guidelines. There have been some exceptions. In the first few weeks of the program, the class SB guideline (7.0mg/L) was exceeded in the bottom water of the NW Arm (at AYC). A little later in the first quarter, there was a period when the data indicated that the Class SA guideline (8.0 mg/L) was exceeded at B2. This was a period when there were some problems with the DO sensor, so this observation is not particularly robust. There have been other times when the data indicate oxygen concentrations below the Outer Harbour guideline at B2 (Class SA). The Class SA guideline is relatively high, and there have been questions raised in previous reports about the absolute values of the DO data. These questions are primarily based on values which at times seem intuitively to be too low. Improving confidence in these values is an ongoing concern and focus of discussion (Section 6).

5.9 Supplemental Samples

To date there have been three supplemental samples of visible features taken. These are documented in detail in QR#3 and earlier in this report (section 4.10), and are summarized here. The location of the sample sites is shown in Figure 10.

Sample SS #1 was acquired at 14:45 on 15 Mar 05 at 44º 40.218´ N, 63º 35.862´ W (NAD83). SS #1 sampled a visible surface plume associated with the Duffus Street outfall near the Narrows. This plume is a persistent feature that varies in magnitude.

Sample SS #2 was taken directly in the "boil" of the outfall off the Peace Pavilion Park in Dartmouth. The location was SS#2 44º 39.600´ N, 63º 34.200´ W (NAD 83). This is a persistent feature that is almost always visible. The sample was taken at around 11:40 on 12 Apr 05, a time when it was particularly evident.

Sample SS #3 was obtained at approximately 15:30 on 21 Apr 05, inside a visible surface feature in the vicinity of Pier A. The location was 44º 38.177´ N, 63°38.177´W (NAD83). This is a commonly visible feature, a result of the large outfall between Pier A and Pier 21, and the storm overflow at the end of Pier A.

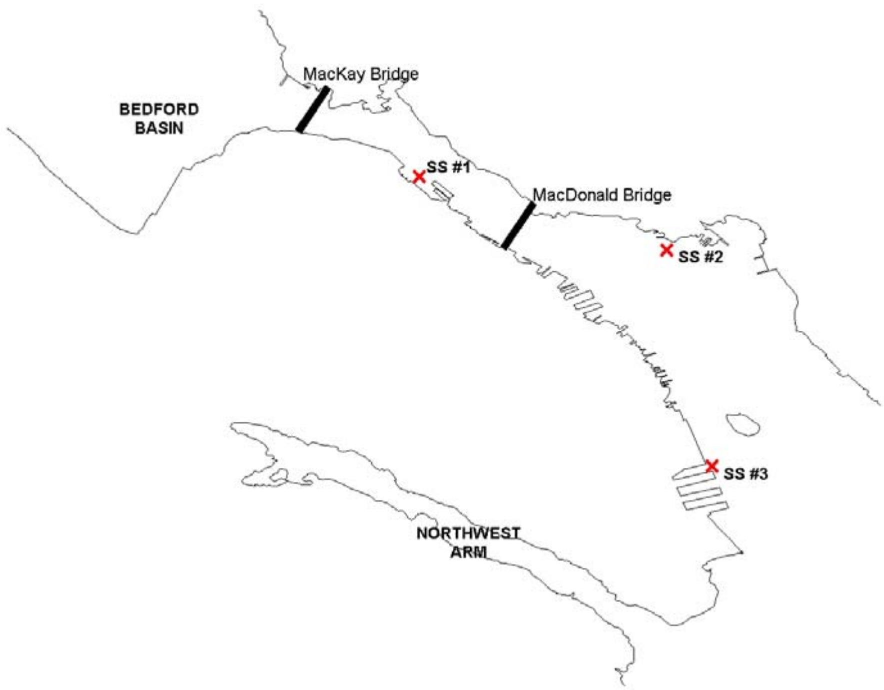


Figure 22. Location of Supplemental Samples SS#1 – SS#3

Table 17. Detectable parameters measured in SS#1, SS#2 and SS#3

Parameter	Units	Value		
		SS01	**SS02**	**SS03**
Fecal Coliform	CFU/100mL	64,000	>10,000	>10,000
Ammonia (N)	mg/L	0.55	0.41	0.32
$CBOD_5$	mg/L	5.7	6.4	6.2
TSS	mg/L	14	17	15

6 Summary and Action Items

For each item, a brief statement of summary is provided along with any changes that occurred during the quarter, and action items resulting from discussions of the issues with the Harbour Solution Project Team. These items reflect issues arising in this quarter as well as issues carried forward from previous quarterly reports. Issues from previous reports are identified as "ongoing", and are listed with the number of the quarterly report in which they first occurred. These issues may include issues deferred until a later date, items in progress but not completed, or longer term items requiring continuing consideration.

6.1 Reporting

<u>Weekly Reports</u>

Summary Statement – The weekly 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 – Corrections of minor errors in analysis routines.

Action

1. Continued review of reports for suitability, considering potential circulation.
2. (Ongoing item QR#3) Inclusion of Errata sheet in weekly report binder

<u>Quarterly Reports</u>

Summary Statement. Based on discussions in QR#3, the quarterly report format has been changed somewhat. These changes are to address the problem of ever increasing report size, to provide more timely progress information for project management, and to provide a mechanism to have vetted action items documented in the quarterly reports. The changes limit the discussions in the quarterly report to the data of that quarter. There remains a future reporting issue of comparison of data between years.

Changes

1. Removal of discussions of variations between quarters in the water quality parameters.
2. Inclusion of sections in final QR of the year (QR #4, 8, 12 etc.) summarizing the annual data.
3. Institution of a procedure where a draft of the summary and action items section (this section) of the QR are delivered in advance of the technical section of the report.

Action

1. Continued development of content and format, with respect to project requirements.
2. Consideration of budget and schedule implications of report changes.
3. Consideration of reporting implication of inter-annual data comparison.
4. Outstanding item (QR#1): Documentation of sampling and analysis methods along with QA/QC procedures for inclusion in the project binder.

6.2 Sampling Program

Summary Statement – Sampling continues as per the end of the third quarter.

Changes –None

Action

1. Continued analysis of sampling scheme with respect to sample bias versus boat travel time with adjustment of scheduling to improve efficiency as dictated.
2. Continued consideration of modification to the analysis suite to include/improve/remove some parameters (see sections below).
3. Outstanding item (QR#3): Consider additional/or substituted sampling sites to address Herring Cove and/or recreational area issues.

6.3 Water Quality Parameters

<u>Fecal Coliform</u>

Summary Statement –

Overall, the fourth quarter levels are similar to those reported in the third quarter, although there is a difference in the spatial distribution. High values are prevalent in the Inner Harbour but can occur at any site during appropriate conditions. A variable analysis resolution scheme, implemented as a result of previous recommendations reduced the out-of-range values to only three this quarter. These values occurred in a 1m sample at station D1, and twice in the 10 m sample at EE1. The resolution at D1-1m has been addressed in previous reports, however these are the first out-of-range values at the 10 m EE1 station. The analysis of high and low values to date supports a recommendation that at EE1-10m reduced resolution would result in negligible data loss at the low end, and better data recovery overall.

The current CCME guidelines recommend enterococci over fecal coliform for a tracer of human waste contamination in salt water. There are several practical reasons for continuing to monitor fecal coliform including historical continuity, and consistency with WWTP monitoring procedures. The trend toward enterococci will likely continue and the monitoring program should recognize that at some level.

Changes – none.

Action

1. Ongoing (QR#3): Include the 1m sample at station D1 (D1-1m) in the reduced resolution (CFU/10 ml) group. (This has been implemented as of the writing of this report).
2. Include the 10m sample at station EE1 (EE1-10m) in the reduced resolution (CFU/10 ml) group.
3. Ongoing (QR#1): Consider inclusion of enterococci as an alternate and/or additional tracer.

Ammonia Nitrogen

Summary Statement – Ammonia nitrogen has detectable values in 58% of samples this quarter. 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 continue to be considered for monitoring.

The BBPMP monitors nutrients at their site in Bedford Basin, including nitrate, silicate and phosphate, it is possible that the analysis of nitrate at an expanded number of sites could be included in a future cooperation agreement.

Changes – None.

Action

1. Ongoing (QR#1): Consider monitoring more nitrogen species.
2. Continued discussions with BBPMP regarding cooperation in nutrient monitoring.

$CBOD_5$

Summary Statement – Based on recommendations in QR#2 $CBOD_5$ was dropped from regular analysis on 25 May 05. Until that time there were no samples with detectable $CBOD_5$ at the 5 mg/L level. $CBOD_5$ has been retained as a tracer for the supplemental sampling program. The two supplementary samples in this period both had $CBOD_5$ levels above 6 mg/L.

Changes – $CBOD_5$ was dropped from regular monitoring on 25 May 05.

Action - None

Total Suspended Solids

Summary Statement –Total suspended solids averaged 10-11 mg/L over the quarter, nearly twice the average of the previous quarter. The lowest values were on the order of 3 mg/L, with all samples above the detection limit. Based on past data, it is expected that there will be future values below the detection limit.

Changes – None.

Action

Ongoing (QR#2,3): Change to larger water samples(1 L) to reduce EQL to 0.5 mg/L (currently 1 mg/L).

Total Oils and Grease

Summary Statement –There have been no detectable levels of Total Oil and Grease using either sampling procedure during this quarter

Changes – Based on discussions of the recommendations from the first quarterly report, the Total Oil and Grease sampling procedure has been modified. Since 10 May, this analysis has been performed only in a surface grab sample at the chemistry sampling sites, rather than at the 1 and 10m sample depths.

Action

Revisit the review of Total Oil and Grease data at the end of next quarter.

Metals

Summary Statement –

There was one measured exceedance (zinc) of metals guideline over the period, with thirteen values above detection limit (ten manganese, and three zinc). Four of the manganese values were in the same week, and all in the surface samples of the Basin. The metals concentrations in the harbour are under-resolved by our present technique. To date the metals analysis has resulted in approximately 98% non-detectable values for metals for which guidelines exist.

Changes – None.

Action – Develop a modified sampling protocol for metals based on previously discussed modifications (QR#2, Section 4.6). This aim is to resolve the existing metals concentrations in the harbour at a resolution in time and space compatible with the scope of the project.

Chlorophyll *a*

Summary Statement - Uncalibrated fluorescence provides a relative measure of chlorophyll and hence phytoplankton activity throughout the harbour, but the absolute quantification of phytoplankton mass requires lab analysis of water samples. The phytoplankton dynamics of the harbour is an important piece of the overall oxygen dynamics in the harbour. The BBPMP collects water samples at their site in Bedford Basin and perform the required lab analyses to extend the utility of the fluorescence data. Discussions are underway to investigate cooperation with the BBPMP to have chlorophyll analysis performed at selected HHWQMP sites throughout the Harbour.

Changes – None.

Action – Ongoing (QR#3) Continue dialogue with BIO (BBPMP) to investigate procedures to enhance the utility of the HHWQMP data.

Dissolved Oxygen

Summary Statement – To date, oxygen levels as measured in the program, are generally 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 surface waters, while generally higher than applicable guidelines, do seem to exhibit some measurable oxygen depression. In situ oxygen measurements are particularly sensitive to a variety of factors. There is some discrepancy with data collected from other sources, other instruments deployed by HHWQMP and the monitoring data of BBPMP. Given this and the fact that dissolved oxygen is perhaps the most important indicator of the health of a water body, it is therefore very important to insure the quality of the collected data. If sewage load is contributing to oxygen depression in the harbour it may be the critical parameter in future waste management decisions.

Changes – .none

Action –

1. Ongoing (QR#3) Continue dialogue with BIO (BBPMP) to coordinate sampling and maximize cross comparison of data for ground truth purposes. .
2. Ongoing (QR#1) Consider collecting samples for Winkler titration either by BBPMP or privately sourced

7 References

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