Halifax Harbour
Water Quality Monitoring Program
Quarterly Report #14
(September 25 to December 17, 2007**)**

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PREFACE

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

The weekly/bi-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/bi-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. Project reports and data are available on the Halifax Regional Municipality (HRM) website:
http://www.halifax.ca/harboursol/waterqualitydata.html

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

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1 Introduction

This quarterly report is a summary of Halifax Harbour Water Quality Monitoring Project (HHWQMP) data collected from 25 September to 17 December 2007 (surveys 139 to 145). The results of the individual surveys are documented in survey reports. In this report, the data for the period are discussed in terms of compliance/exceedance of applicable water quality guidelines (Halifax Harbour Task Force, 1990), and how they affect recommendations for program modification. An emphasis in this report is a continued assessment of the efficacy of the sampling program and of the potential introduction of systematic sampling bias in the data. This is a necessary step in the more detailed statistical analysis of the data that can occur subsequently. This report discusses just the fourteenth quarter. Every fourth quarterly report includes an annual summary of data and trends over the previous four quarters. In the interest of making each quarterly report useful as a stand alone document, there is a significant amount of repetition of background information among the quarterly reports.

2 Reporting

The basic report format for both survey and quarterly reports is discussed in detail in the introduction of the project report binder and in Quarterly Report 1 (QR1, JWL and COA, 2004). Slight modifications and enhancements to the reports continue to be made as experience dictates. This quarter as of survey 144 (5 Dec 07) 1 and 10 m maps of fecal coliform have been added to the end of the survey reports. As well, Figure 2 in the quarterly reports has been slightly modified. The symbols have been changed to increase legibility and sites without water quality sampling have been eliminated. This includes C5 that was sampled for coliform only in the first survey.

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

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

3 Sampling Program

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

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

3.1 Program Changes

There have been no program changes this quarter. A summary of the sampling and analysis schedules and relevant established criteria in place at the end of fourteenth quarter (17 Dec 2007) are in Table 1. This table indicates that the carbonaceous biochemical oxygen demand ($CBOD_5$) and total oil and grease (TOG) analyses, discontinued from regular sampling due to lack detection, are retained for supplemental samples.

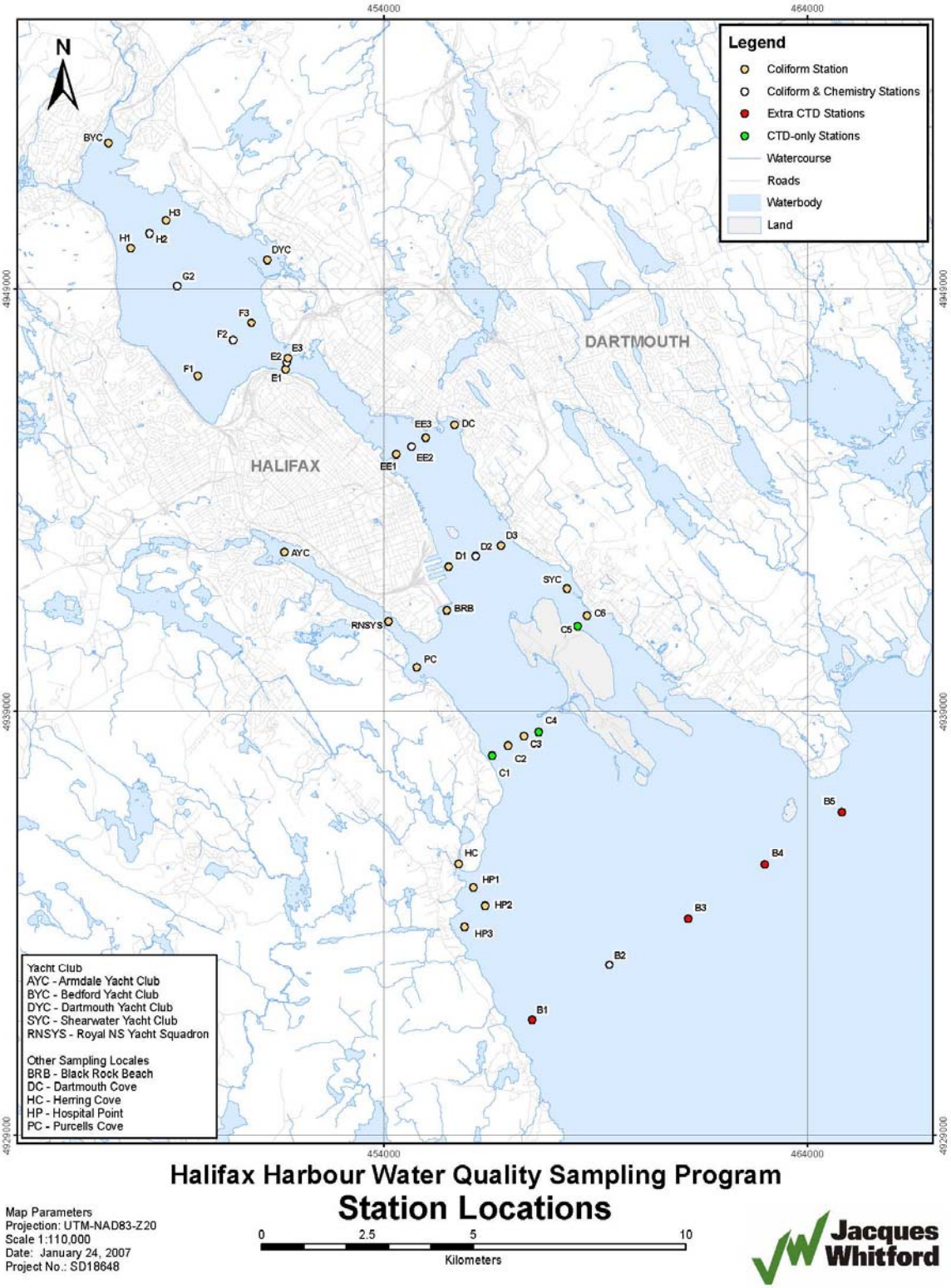

Figure 1. Halifax Inlet sample locations.

Table 1. Summary of measured parameters as of 17 December 2007.

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

3.2 Supplemental Samples

Based on recommendations from Quarterly Report 2, a supplemental sample protocol has been instituted to take opportunistic samples of visible water quality features in the Harbour, or to document unusual discharge conditions (e.g. bypass etc). These samples are acquired on a discretionary and exploratory basis when an interesting feature, such as a visible front, plume, or patch of visibly deteriorated water quality is encountered. It is anticipated that these samples will have lower water quality than most normal samples. As such, the samples are processed for the full range of parameters specified at the beginning of the program, including parameters which have been eliminated from normal sampling due to lack of detection. During this quarter, there were two supplemental samples. The first was in survey 140 (10 Oct 07), in a patch of discoloured water at H3, a site regularly sampled for bacteria, and the second was in survey 144 (5 Dec 07), in a visible plume near the newly functioning Halifax STP outfall.

3.3 Sampling Order

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

Also, Table 2 lists the missed stations and additional samples (described above) for each survey. During this quarter, there were no missed samples.

3.4 Data Return

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

3.5 Sampling Bias

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

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

Date	25-Sep-07	10-Oct-07	24-Oct-07	6-Nov-07	21-Nov-07	5-Dec-07	17-Dec-07
Survey	139	140	141	142	143	144	145
1	AYC	AYC	AYC	C2	AYC	AYC	AYC
2	RNSYS	RNSYS	RNSYS	C1	RNSYS	RNSYS	PC
3	BRB	PC	PC	HC	PC	PC	EE3
4	D1	BRB	BRB	HP1	BRB	C1	EE2
5	EE1	C4	D1	HP2	D1	C2	D3
6	E1	C3	D2	HP3	D2	BRB	D2
7	E3	B2	EE1	B2	EE1	D1	SYC
8	E2	HP3	EE2	C3	EE2	D2	C6
9	F1	HP2	E1	C4	E1	EE2	C5
10	H1	HP1	E3	C5	E3	EE1	C4
11	BYC	HC	E2	C6	E2	E1	C3
12	H3	C1	F1	SYC	F1	E3	B2
13	H2	C2	F2	D3	F2	E2	HP3
14	G2	D1	G2	EE3	G2	F1	HP2
15	DYC	EE1	H1	F3	H1	F2	HP1
16	F3	F1	H2	DYC	H2	G2	HC
17	F2	G2	BYC	H3	BYC	H1	C1
18	EE3	H1	H3	BYC	H3	H2	C2
19	EE2	BYC	DYC	H1	DYC	BYC	BRB
20	D3	H3	F3	H2	F3	H3	D1
21	D2	H2	EE3	G2	EE3	DYC	EE1
22	SYC	DYC	D3	F1	D3	F3	F1
23	C6	F3	SYC	F2	SYC	EE3	G2
24	C5	F2	C6	E1	C6	D3	H1
25	C4	E1	C5	E3	C5	SYC	BYC
26	C3	E2	C4	E2	C4	C6	H3
27	B2	E3	C3	EE1	C3	C5	H2
28	HP3	EE3	B2	EE2	B2	C4	DYC
29	HP2	EE2	HP3	D1	HP3	C3	F3
30	HP1	D3	HP2	D2	HP2	B2	F2
31	HC	D2	HP1	BRB	HP1	HP1	E1
32	C1	SYC	HC	PC	HC	HP2	E3
33	C2	C6	C1	RNSYS	C1	HP3	E2
34	PC	C5	C2	AYC	C2	HC	RNSYS
No data							
Supplemental		H3-1m				Halifax STP Outfall	

Table 3. Quarter fourteen data return.

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

Bacteria	Target	Achieved	
28 sites			
F Coliform	434	432	
Total	**434**	**432**	**100%**

Profiles	Target	Achieved	
31 sites			
C-T	238	234	
Dissolved Oxygen	238	224	
Chlorophyll	238	234	
Total	**714**	**692**	**97%**
All data records	**1540**	**1516**	**98%**

3.5.1 Time of Day

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

Figure 2 shows the sampling time at each site since the start of the program in June 2004. The data from the fourteenth quarter are shown in red. In this figure the sample sites are generally sorted from north to south. There are a few patterns that emerge that have been documented previously. The stations at the north end of Bedford Basin have a smaller range of sampling times. This is because logistics dictates that the surveys never start or

end in the Basin. In general, the range of sampling times increases with distance south, a function of travel time from the Armdale Yacht club in the Northwest Arm. Even if a site is sampled first, it still takes time to travel there. Given that sampling begins at the same time every week, these effects are unavoidable.

The diagram indicates that overall, given the constraints, the entire field was relatively uniformly sampled. The Northwest Arm that has a built in early morning/late afternoon bias had six of seven surveys in the early morning.

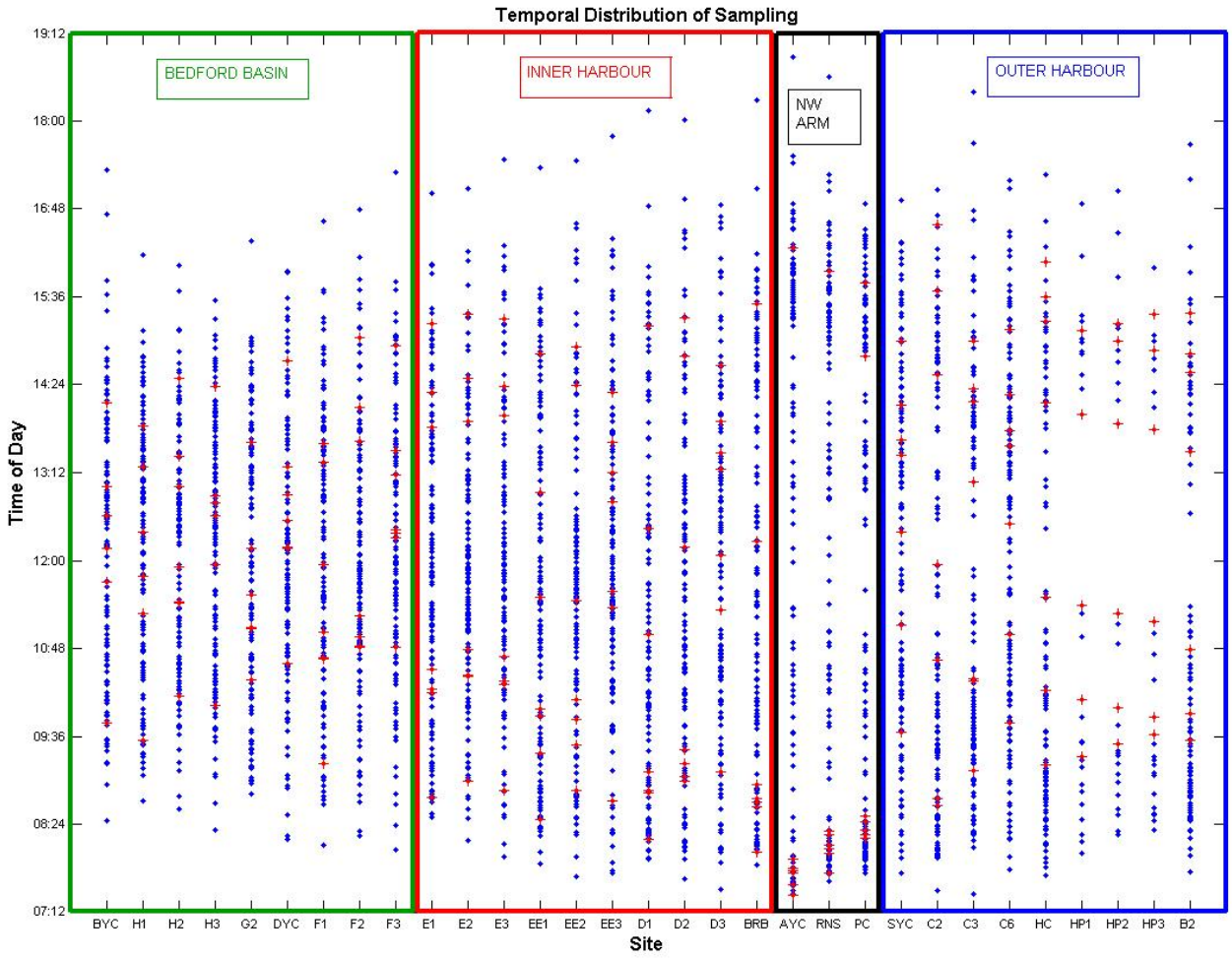

Figure 2. Temporal sampling distribution by site over entire program. Red markers denote points from 25 September to 17 December 2007.

3.5.2 Water Levels

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

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

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

The probability distribution of water level (above chart datum) as derived from the tide gauge at the Naval Dockyard in Halifax (CHS station 490) for the period September to December 2007 is shown in Figure 3. In an ideal situation each site would be sampled in a distribution similar to the overall baseline distribution. Figure 4 shows the distribution of water levels at each site at the time of sampling (blue bars) compared to the overall water level distribution for the quarter, as represented by the red line recreated from Figure 3.

This shows that for this quarter, in the Basin and Inner Harbour lower water levels are over represented in the sampling distribution. South of this, and in the Northwest Arm, the distribution is more representatively sampled, though there is a tendency toward oversampling of high water levels. Since sampling has been switched to bi-weekly, the number of samples in a quarter has been roughly halved. Therefore a somewhat deteriorated representation of the water level range is inevitable. If more detailed analysis is performed, particularly in the Inner Harbour where water level/tidal phase is more important, the analysis may have to include the tidal phase explicitly.

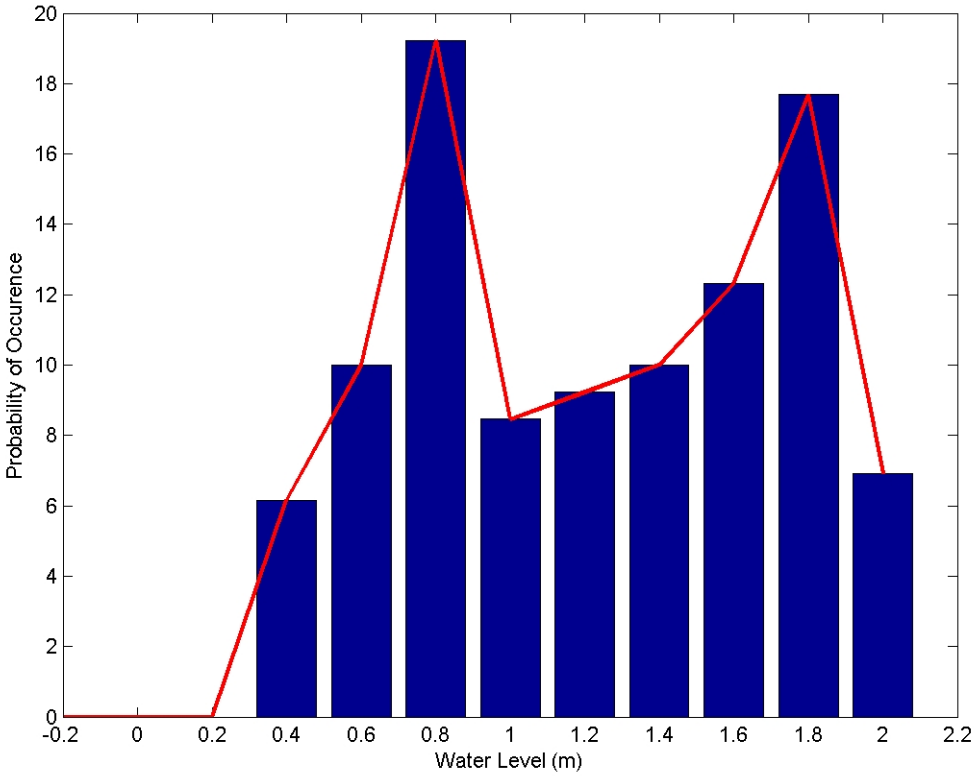

Figure 3. Probability distribution of water levels in Halifax, September to December 2007.

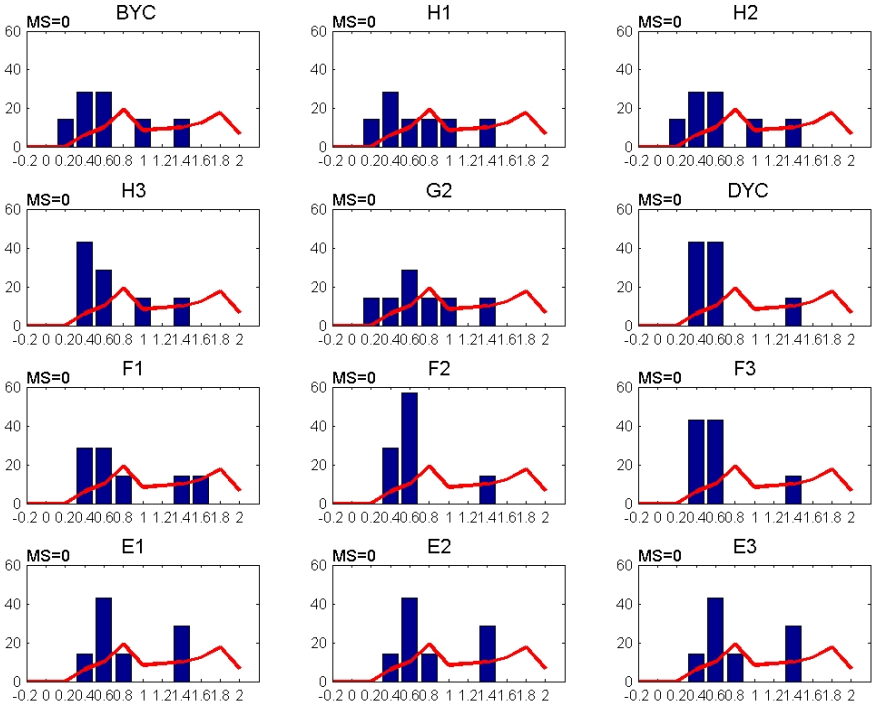

Figure 4a. Water level distribution at each site during sampling 25 September to 17 December 2007. Note: MS = Missed samples.

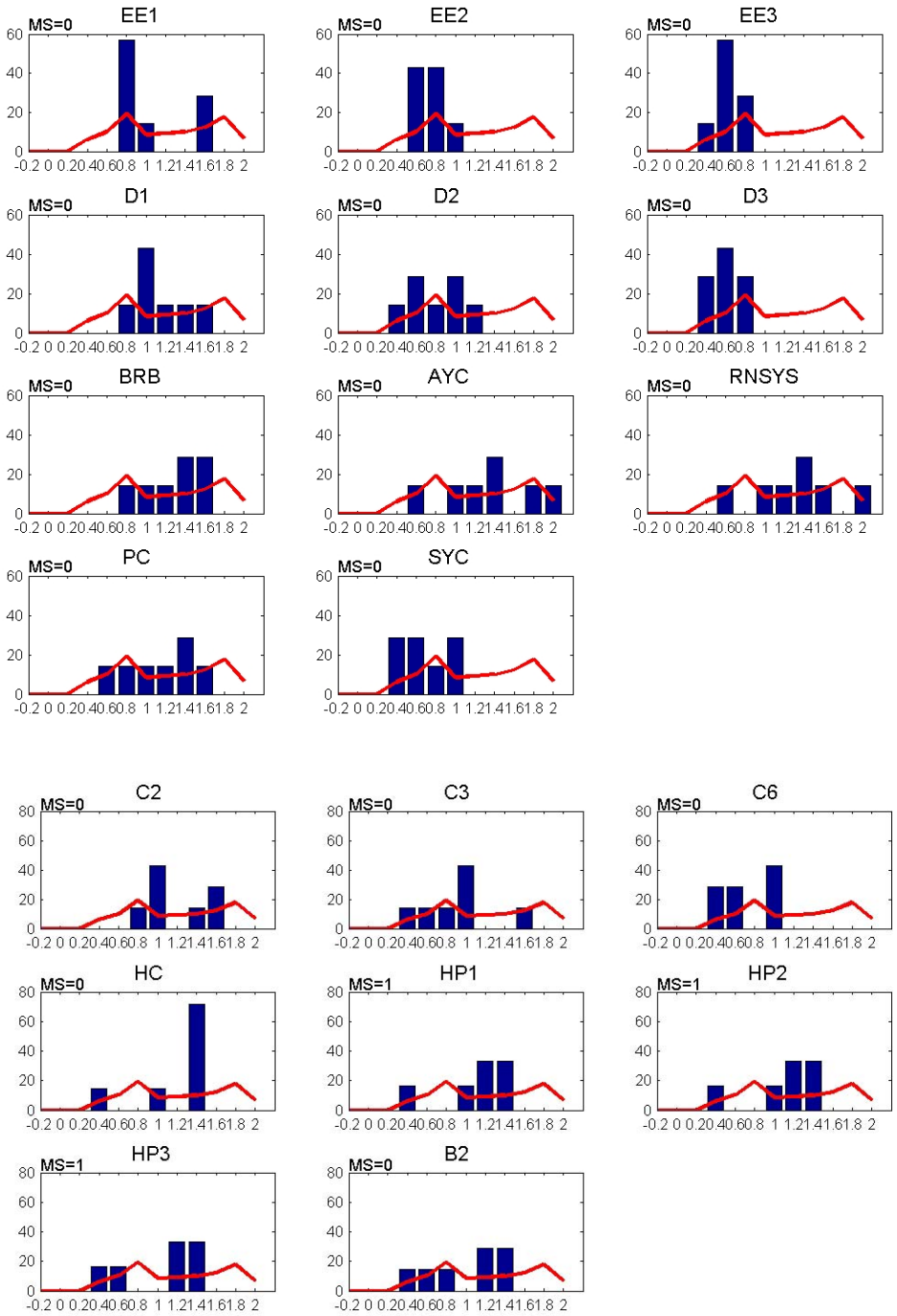

Figure 4b. Water level distribution at each site during sampling 25 September to 17 December 2007. Note: MS = Missed samples.

3.5.3 Precipitation

Rainfall affects both the sewage loads and the dynamics of the Harbour. In a combined sewer system, like in Halifax, increased flow due to a rainfall event can mobilize material that has collected in the sewer pipes in low flow conditions resulting in quite high loads. Additionally, in response to the increased fresh water input, the harbour can become more stratified, enhancing estuarine circulation. The combination of increased flow and stratification can have a significant effect on the near field behaviour of the plumes from the outfalls. These effects lag the rainfall and persist for a period of time after the rain stops. The duration of the impact, of course, depends on the magnitude of the rain event and the condition of the watershed. For purposes of discussion we have, somewhat arbitrarily, selected a three day (72 hour) precipitation window for our analysis. The red line in Figure 5 depicts the probability distribution of precipitation integrated over the current and previous two days for this quarter (25 September to 17 December, 2007). The blue bars on this plot represent a similar analysis performed for sampling days only. The plot indicates that our sampling has been biased toward dry weather. Days with no precipitation for the previous 72 hours occurred 40% of the time but represent 70% of our sampling days. There were no really large rainfall events this quarter, nonetheless, the larger rainfall events during the quarter were sampled.

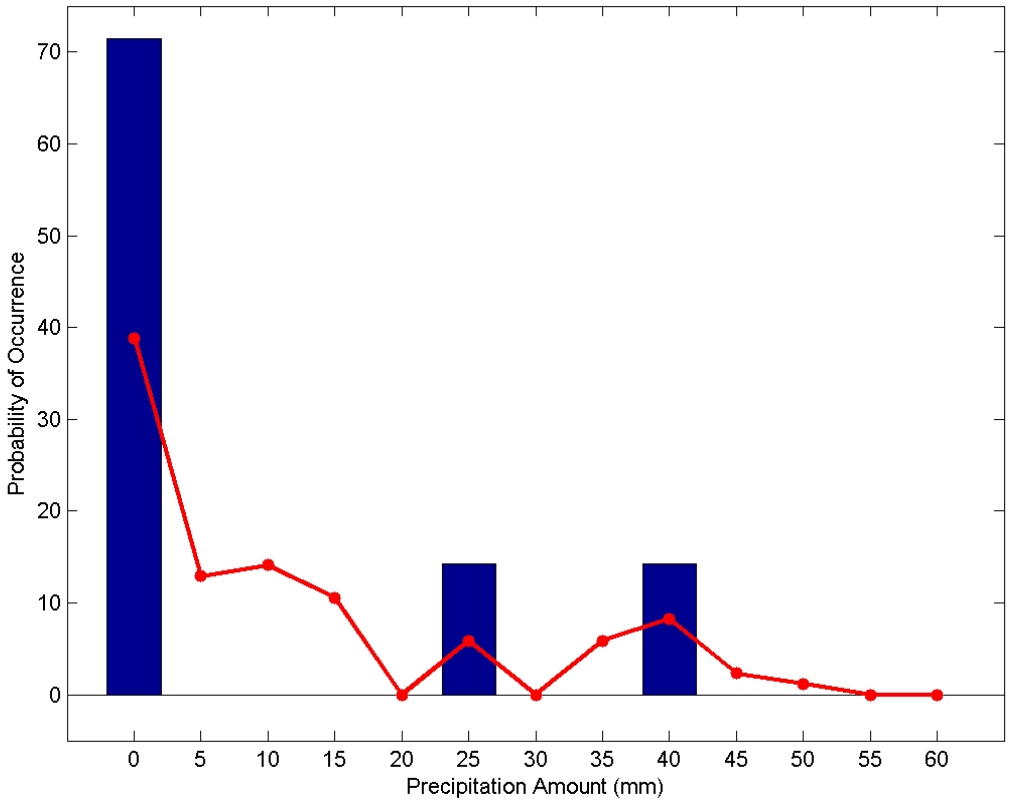

Figure 5. Probability distribution of cumulative 72 hour rainfall, 25 September to 17 December 2007.

4 Water Quality Results and Discussion

Results of the water quality sampling are discussed in the following sections with emphasis on compliance with water quality guidelines, and any need for modifications to the program. This quarter the connections to Halifax STP were being made. This started with the connection of the Duffus St. pumping station on about 1 November 07. This ended the sewage bypass to the Fairview Cove CSO. The connections continued until by the end of the quarter pretty much the entire Halifax waterfront had been connected to the plant. The UV disinfection system was operating only sporadically and partially during this period. The pumping stations in the Northwest Arm are not yet operational so the discharge at Chain Rock outfall continues.

4.1 Fecal Coliform

4.1.1 Out-of-Range Values

The adaptive lab procedure, using different fecal coliform detection ranges for different sites, developed as a result of previous recommendations, has reduced the number of out-of-range values significantly. For this quarter there were two out-of-range values. These were at the SYC site (survey 140) and the RNSYS site (survey 142). These were very unusual at these sites, but may reflect the changing loading during this quarter.

4.1.2 Quarterly Means

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

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

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

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

For the 1 m samples, the mean coliform levels are relatively high throughout the Inner Harbour and extending south to BRB and Eastern Passage. The high values are shifted to the south of the main sources; this may reflect the shifting source location as the Halifax STP comes on-line. In addition to the Inner Harbour high levels, there are mean values above 200 cfu/100mL at RNSYS in the Northwest Arm and at HP1 and HC, these are all sites affected periodically by single large outfalls. The 10m samples are generally lower with any values over 200 cfu/100 mL restricted to the Inner Harbour. The mean distribution in the Basin is a bit unusual in that the values in the 1m samples at F1 and F2 are higher than in the 10m samples. However, everywhere in the Basin the difference between the values in the 1 and 10m samples is not very great. Given the changing loading scenario throughout the quarter it is difficult to comment on this in much detail.

The geometric mean values exceeding the swimming guidelines are mostly limited to the Inner Harbour, where there are no Task Force guideline limits on bacteria. However in this quarter there are also high mean values in the Class SB areas just south of the Inner Harbour. A more rigorous discussion of guideline exceedance follows.

4.1.3 Guideline Exceedance

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

Interpreting this procedure in our context results in a bi-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.

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

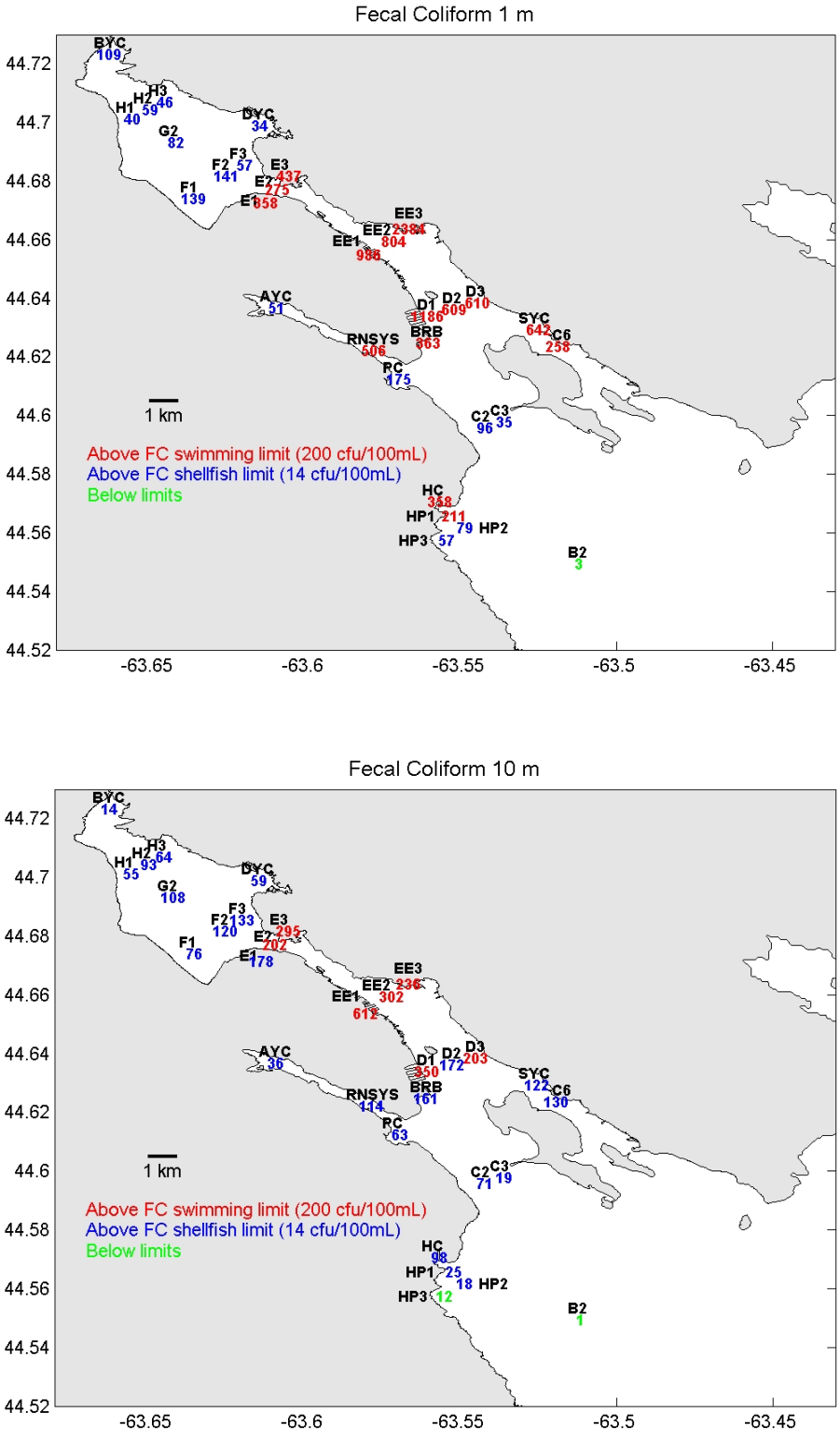

Figure 6. Fecal coliform geometric means (cfu/100mL) at 1m and 10m, 25 September to 17 December 2007.

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

1 m Samples

As seen in the Table 4 below, for this quarter, the near surface water (1 m) at sections EE and D in Inner Harbour would be deemed "unacceptable" for primary body contact essentially all of the time. There is a shift in time. It appears that the area affected by "unacceptable" water quality shifts southward during the quarter. At sites to the south of the Inner Harbour (e.g. BRB, PC, SYC and section C) the water quality seems to degrade with time, while sites in the Narrows and southern Basin seem to have improved water quality. This could be due to the changing source location but seems to start before the sewer connections started, at about 1 November 07, or just before survey 142 (6 Nov 07). It is probably caused by a combination of source location, change in sunlight and oceanographic/meteorological conditions.

Other than this there are consistent "unacceptable" levels at the HP and HC sites likely due to effects of the Tribune Head.

10 m Samples

Referring to Table 5, the 10m floating mean values for this quarter show "unacceptable" water quality constantly only at site EE1. South of this (i.e. section D, BRB, SYC and C6) the water trends to "unacceptable" through the quarter. North of this (i.e. the remainder of section EE, sections E and F) the water trends to "acceptable". This is the same trend seen in the 1m samples.

Task Force Guidelines

Most of the sites that are regularly deemed unacceptable for swimming are in the Inner Harbour that is classified SC by the Halifax Harbour Task Force. There are no Task Force limits on bacteria in this area. The greatest number of Task Force guideline exceedances normally occur in the class SB areas just outside the Inner Harbour; that is, in the southern Basin, Black Rock Beach and the Northwest Arm, particularly the PC and RNSYS sites. This quarter there are limited SB guideline exceedances both north and south of the Inner Harbour. By the end of the quarter there are no "unacceptable" values in the Basin, but quite extensive exceedances in the class SB areas to the South (i.e. the Northwest Arm, Eastern Passage and Section C). The Outer Harbour is the only region classified SA. This has a lower requirement (14 cfu/100 mL) than the swimming criteria. The sites within the Task Force "Outer Harbour" boundaries are B2, HC and the HP section. This quarter HC (Herring Cove) never meets the SA criteria. The HP sites very seldom meet the SA guideline, but these sites are periodically affected by the plume from

the Tribune Head outfall. This quarter, site B2 meets the SA criteria at the beginning of the quarter, but not in the last two surveys.

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

	Outer Harbour							Northwest Arm			Eastern Pass		Inner Harbour		
	B2	HP1	HP2	HP3	HC	C2	C3	PC	RNSYS	AYC	C6	SYC	BRB	D1	D2
Survey139	1 (2)	208 (3)	20 (3)	50 (3)	497 (3)	8 (3)	4 (3)	19 (3)	266 (3)	20 (3)	18 (3)	48 (2)	156 (3)	1076 (3)	373 (3)
Survey140	1 (2)	451 (3)	49 (3)	53 (3)	281 (3)	10 (3)	4 (3)	65 (3)	1635 (3)	56 (3)	137 (3)	326 (3)	311 (3)	3628 (3)	589 (3)
Survey141	4 (2)	139 (3)	361 (3)	74 (3)	373 (2)	72 (3)	28 (3)	419 (3)	1546 (3)	38 (3)	1777 (3)	1678 (3)	651 (3)	2608 (3)	1528 (3)
Survey142	2 (3)	171 (3)	616 (3)	314 (3)	373 (2)	322 (3)	94 (3)	958 (3)	2260 (3)	41 (3)	2363 (3)	5400 (3)	687 (3)	2216 (3)	1560 (3)
Survey143	4 (2)	211 (3)	469 (3)	239 (3)	506 (2)	963 (3)	522 (3)	1110 (3)	773 (3)	82 (3)	1097 (3)	1916 (3)	728 (3)	1110 (3)	2080 (3)
Survey144	19 (2)	551 (3)	34 (3)	121 (3)	511 (3)	701 (3)	246 (3)	656 (3)	1080 (3)	115 (3)	467 (3)	979 (3)	575 (3)	737 (3)	690 (3)
Survey145	19 (2)	266 (3)	40 (3)	12 (3)	251 (3)	332 (3)	120 (3)	287 (3)	216 (3)	155 (3)	396 (3)	429 (3)	447 (3)	699 (3)	389 (3)

	Inner Harbour							Bedford Basin								
	D3	EE1	EE2	EE3	E1	E2	E3	F1	F2	F3	DYC	G2	H1	H2	H3	BYC
Survey139	443 (3)	432 (3)	1297 (3)	254 (3)	2644 (3)	492 (3)	836 (3)	147 (3)	427 (3)	86 (2)	80 (3)	155 (3)	47 (3)	42 (3)	54 (3)	128 (3)
Survey140	264 (3)	948 (3)	1297 (3)	401 (3)	885 (3)	298 (3)	718 (3)	71 (3)	194 (3)	29 (2)	39 (3)	95 (3)	86 (3)	45 (3)	60 (3)	102 (3)
Survey141	1048 (3)	2609 (3)	2715 (3)	15251 (3)	510 (3)	315 (3)	544 (3)	70 (3)	227 (3)	69 (3)	27 (3)	62 (3)	67 (3)	55 (3)	32 (3)	55 (3)
Survey142	752 (3)	5260 (3)	2272 (3)	8953 (3)	251 (3)	305 (3)	362 (3)	225 (3)	151 (3)	95 (3)	31 (3)	155 (3)	130 (3)	130 (3)	61 (3)	152 (3)
Survey143	989 (3)	2737 (3)	933 (3)	3544 (3)	154 (3)	524 (3)	297 (3)	193 (3)	156 (3)	100 (3)	31 (3)	100 (3)	89 (3)	180 (3)	85 (3)	186 (3)
Survey144	537 (3)	497 (3)	195 (3)	2486 (3)	59 (3)	157 (3)	264 (3)	195 (3)	58 (3)	38 (3)	19 (3)	46 (3)	47 (3)	75 (3)	66 (3)	117 (3)
Survey145	680 (3)	422 (3)	176 (3)	5963 (3)	70 (3)	138 (3)	276 (3)	81 (3)	43 (3)	26 (3)	15 (3)	23 (3)	11 (3)	37 (3)	30 (3)	66 (3)

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

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

	Outer Harbour							Northwest Arm			Eastern Pass		Inner Harbour		
	B2	HP1	HP2	HP3	HC	C2	C3	PC	RNSYS	AYC	C6	SYC	BRB	D1	D2
Survey139	1 (2)	3 (3)	2 (3)	2 (3)	50 (3)	34 (3)	13 (3)	17 (3)	72 (3)	17 (3)	53 (3)	16 (3)	50 (3)	124 (3)	21 (3)
Survey140	1 (2)	5 (3)	3 (3)	2 (3)	71 (3)	77 (3)	9 (3)	105 (3)	123 (3)	38 (3)	80 (3)	51 (3)	218 (3)	371 (3)	163 (3)
Survey141	3 (2)	25 (3)	13 (3)	6 (3)	184 (3)	67 (3)	9 (3)	155 (3)	138 (3)	36 (3)	159 (3)	110 (3)	371 (3)	473 (3)	492 (3)
Survey142	2 (3)	53 (3)	51 (3)	17 (3)	176 (3)	77 (3)	9 (3)	231 (3)	189 (3)	50 (3)	147 (3)	176 (3)	415 (3)	682 (3)	675 (3)
Survey143	3 (2)	106 (3)	111 (3)	35 (3)	214 (3)	125 (3)	28 (3)	103 (3)	114 (3)	56 (3)	181 (3)	219 (3)	221 (3)	434 (3)	488 (3)
Survey144	1 (2)	91 (3)	55 (3)	92 (3)	265 (3)	175 (3)	76 (3)	155 (3)	166 (3)	81 (3)	192 (3)	402 (3)	223 (3)	407 (3)	338 (3)
Survey145	1 (2)	97 (3)	60 (3)	44 (3)	106 (3)	138 (3)	65 (3)	65 (3)	108 (3)	53 (3)	279 (3)	661 (3)	204 (3)	504 (3)	354 (3)

	Inner Harbour							Bedford Basin								
	D3	EE1	EE2	EE3	E1	E2	E3	F1	F2	F3	DYC	G2	H1	H2	H3	BYC
Survey139	35 (3)	1169 (3)	361 (3)	276 (3)	238 (3)	166 (3)	243 (3)	87 (3)	92 (3)	117 (3)	75 (3)	189 (3)	45 (3)	88 (3)	79 (3)	3 (3)
Survey140	119 (3)	1059 (3)	792 (3)	733 (3)	616 (3)	446 (3)	385 (3)	221 (3)	208 (3)	216 (3)	80 (3)	366 (3)	61 (3)	391 (3)	118 (3)	4 (3)
Survey141	216 (3)	1277 (3)	1889 (3)	943 (3)	655 (3)	286 (3)	567 (3)	110 (3)	290 (3)	452 (3)	90 (3)	297 (3)	31 (3)	155 (3)	72 (3)	14 (3)
Survey142	281 (3)	609 (3)	800 (3)	690 (3)	244 (3)	261 (3)	447 (3)	155 (3)	327 (3)	586 (3)	132 (3)	136 (3)	62 (3)	157 (3)	88 (3)	33 (3)
Survey143	328 (3)	615 (3)	497 (3)	216 (3)	198 (3)	254 (3)	447 (3)	95 (3)	141 (3)	250 (3)	109 (3)	82 (3)	92 (3)	63 (3)	76 (3)	60 (3)
Survey144	579 (3)	208 (3)	82 (3)	61 (3)	71 (3)	113 (3)	148 (3)	52 (3)	67 (3)	47 (3)	42 (3)	59 (3)	70 (3)	55 (3)	51 (3)	38 (3)
Survey145	865 (3)	322 (3)	54 (2)	69 (3)	97 (3)	189 (3)	237 (3)	33 (3)	57 (3)	34 (3)	21 (3)	48 (3)	60 (3)	58 (3)	37 (3)	28 (3)

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

4.2 Ammonia Nitrogen

Ammonia nitrogen is an important component in the nutrient balance in an estuary, and in high concentrations has potential for toxic effects; however, there is currently no marine water quality guideline for ammonia (CCME, 1999). The values obtained for this period are shown in Table 6. In addition, the quarterly mean and max values are plotted by station in Figure 7. The laboratory "reportable detection limit" (RDL) for ammonia nitrogen is 0.05 mg/L. For the purpose of computing statistics, the RDL/2, or 0.025 mg/L was used for values below detection. Missed samples are excluded from the calculations.

Ammonia nitrogen has consistently been present at levels that are around the detection limit of 0.05 mg/L. In this quarter, at 1 m, 84 % of samples had detectable levels of ammonia and at 10 m, 78 % of samples had detectable levels. This is relatively high detectability. The mean value over the quarter is about 0.11 mg/L. The maximum observed concentration is 2.0 mg/l at B2-1m on survey 140. This is relatively a very high

value and the QAQC sample, also taken at B2-1m, had a value of 0.08 mg/L. So this value is in question. Nonetheless there were several other high values in this survey (e.g. 0.81 and 0.33 mg/L). This corresponds to observations of turbid water in the Northern Basin (supplemental sample at H3) and at other locations around the harbour. Aside from this survey, the ammonia levels were low in the first survey of the quarter (mean 0.4 mg/L), increase to a mean of about 0.10 mg/L through the middle of the quarter and drop back to a mean of about 0.06 mg/L at the end of the quarter. Except for the single high value at B2, the ammonia concentration is lower in the Outer Harbour. Overall, there does not appear to be a simple correlation between ammonia concentrations and meteorological events/oceanographic conditions, as is seen in the coliform data.

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

1m	B2	D2	EE2	E2	F2	G2	H2	mean	max
139 (25 Sep 07)	ND	ND	ND	ND	ND	ND	0.06	0.03	0.06
140 (10 Oct 07)	2.00	0.19	0.07	0.81	0.20	0.05	0.07	0.48	2.00
141 (24 Oct 07)	0.09	0.10	0.10	0.14	0.09	0.10	0.07	0.10	0.14
142 (6 Nov 07)	0.18	0.08	0.08	0.15	0.13	0.07	0.11	0.11	0.18
143 (21 Nov 07)	ND	0.09	0.13	0.09	0.11	0.11	0.09	0.09	0.13
144 (5 Dec 07)	0.12	0.07	0.08	0.08	0.08	0.08	0.11	0.09	0.12
145 (17 Dec 07)	ND	0.07	0.07	0.06	0.06	0.06	0.07	0.06	0.07
mean	0.35	0.09	0.08	0.19	0.10	0.07	0.08	0.14	
max	2.00	0.19	0.13	0.81	0.20	0.11	0.11		2

10m	B2	D2	EE2	E2	F2	G2	H2	mean	max
139 (25 Sep 07)	0.07	0.05	ND	0.06	ND	ND	ND	0.04	0.07
140 (10 Oct 07)	ND	0.16	0.12	0.1	0.08	0.33	0.10	0.13	0.33
141 (24 Oct 07)	0.08	0.11	0.13	0.12	0.12	0.11	0.12	0.11	0.13
142 (6 Nov 07)	ND	0.08	0.08	0.19	0.08	0.07	0.08	0.09	0.19
143 (21 Nov 07)	ND	0.06	0.07	0.06	0.11	0.07	0.07	0.07	0.11
144 (5 Dec 07)	ND	ND	0.05	0.08	0.08	0.08	0.06	0.06	0.08
145 (17 Dec 07)	ND	0.06	0.06	0.12	0.06	0.05	ND	0.06	0.12
mean	0.04	0.08	0.08	0.10	0.08	0.11	0.07	0.08	
max	0.08	0.16	0.13	0.19	0.12	0.33	0.12		0.33

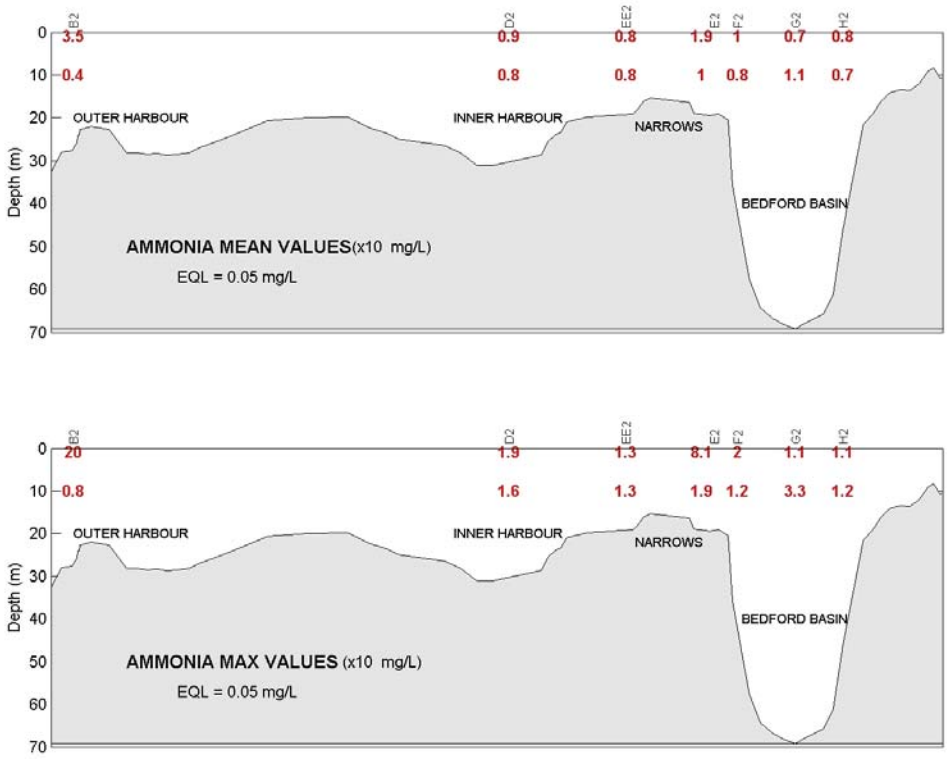

Figure 7. Mean and maximum values of ammonia nitrogen (X10 mg/L) over all fourteenth quarter samples.

4.3 Carbonaceous Biochemical Oxygen Demand

Further to a recommendation in Quarterly Report 2, $CBOD_5$ analysis for regular samples ceased on 25 May 2005, due to lack of detectable values. $CBOD_5$ analysis continues for supplemental samples, where there have been detectable values. The supplemental samples at the Halifax STP outfall were analyzed for $CBOD_5$. The concentrations were not detectable.

4.4 Total Suspended Solids

A summary of the TSS values for this quarter is shown in Table 7. There were 4 samples that were below the RDL of 0.5 mg/L. For purposes of statistics, values below the detection limit are replaced by RDL/2 or 0.25 mg/L. The quarterly mean and max values are plotted by station in Figure 8. This quarter's site average values were in the range of 2.4-6.2 mg/L. The maximum values, by site, ranged from 4-15 mg/L. Overall, as with ammonia, there does not appear to be a simple correlation between TSS concentrations and meteorological events/oceanographic conditions. There are occasional higher values

that seem to be associated with more extreme events (e.g. storms, plankton blooms etc). These events are generally identifiable visually and are usually documented in field notes. In this quarter there were significantly high TSS values in the Basin in the first four surveys. After this the concentrations became more uniform and generally dropped. The survey mean value in the last survey was low at about 1.3 mg/L. In general, except as noted in the Basin, high values seem to occur most anywhere, but the concentrations at B2 in the Outer Harbour tend to be lower.

Table 7. TSS (mg/L) summary.

1m	B2	D2	EE2	E2	F2	G2	H2	mean	max
139 (25 Sep 07)	ND	3.6	6.0	7.4	3.1	4.4	9.0	4.8	9.0
140 (10 Oct 07)	1.4	6.2	4.1	2	7.2	4.9	12.0	5.4	12.0
141 (24 Oct 07)	1.5	3.6	2.9	3.9	1.4	3.3	14.0	4.4	14.0
142 (6 Nov 07)	2.0	4.3	3.0	4.8	4.5	8.8	2.4	4.3	8.8
143 (21 Nov 07)	5.0	4.0	2.0	2.0	1.0	1.0	3.0	2.6	5.0
144 (5 Dec 07)	4.7	2.3	2.9	1.3	1.9	1.8	1.6	2.4	4.7
145 (17 Dec 07)	2.0	2.0	2.0	0.7	0.9	ND	1.6	1.3	2.0
mean	2.4	3.7	3.3	3.2	2.9	3.5	6.2	3.6	
max	5.0	6.2	6.0	7.4	7.2	8.8	14.0		14.0

10m	B2	D2	EE2	E2	F2	G2	H2	mean	max
139 (25 Sep 07)	1.0	1.8	2.4	4.2	8.8	7.6	4.0	4.3	8.8
140 (10 Oct 07)	4.0	3.6	5.0	2.8	4.9	4.0	1.8	3.7	5.0
141 (24 Oct 07)	3.3	3.0	3.7	5.1	5.7	4.1	4.5	4.2	5.7
142 (6 Nov 07)	1.5	5.7	2.7	1.9	3.5	5.9	2.6	3.4	5.9
143 (21 Nov 07)	3.0	15.0	2.0	3.0	3.0	7.0	4.0	5.3	15.0
144 (5 Dec 07)	2.2	1.1	1.4	1.2	1.8	1.5	3.4	1.8	3.4
145 (17 Dec 07)	2.3	2.0	2.0	0.6	ND	ND	1.5	1.2	2.3
mean	2.5	4.6	2.7	2.7	4.0	4.3	3.1	3.4	
max	4.0	15.0	5.0	5.1	8.8	7.6	4.5		15.0

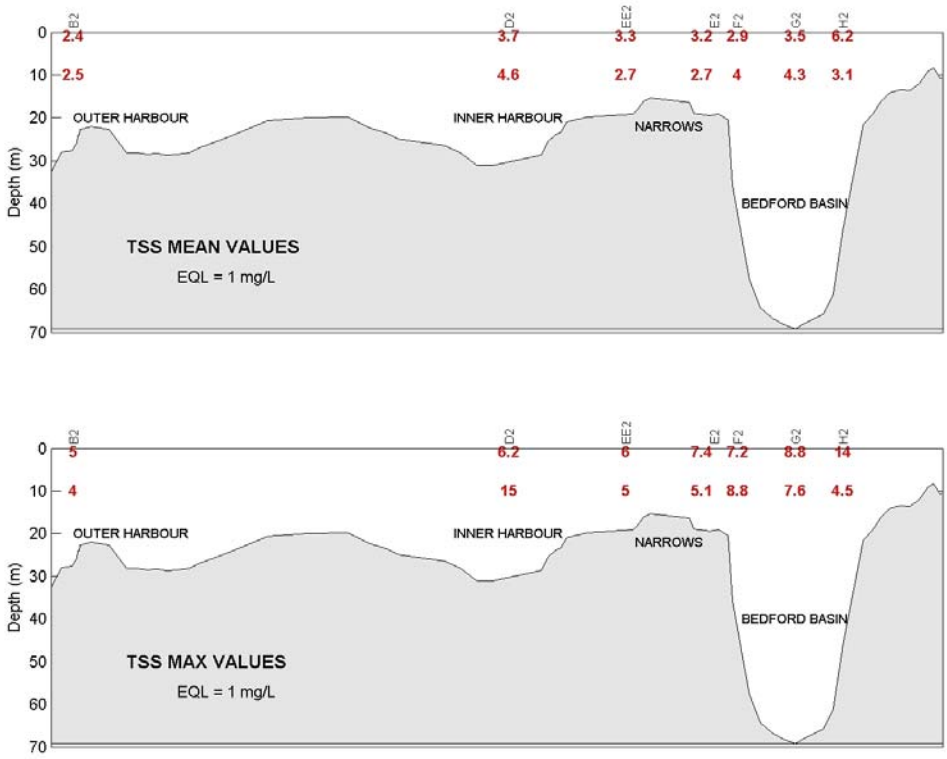

Figure 8. Mean and maximum values of total suspended solids (mg/L) over all fourteenth quarter samples.

4.5 Total Oils and Grease

Based on recommendations in Quarterly Report 5 regular sampling for total oil and grease was discontinued in, survey 73 (23 Nov 06). The analysis is retained for supplemental samples. The supplemental samples taken this quarter were not analyzed for total oil and grease.

4.6 Metals

The results of the metals analysis are summarized in Figure 9. For this plot the non-detectable values are considered zero. Through the whole quarter there were seven guideline exceedances, three of mercury and four of copper. There were two surveys that stand out. Survey 139 (25 Sep 07) had a single mercury concentration of 0.030 µg/L at H2-10m that exceeded the 0.025 µg/L guideline. Notably, also in this survey all samples had detectable levels of mercury and six had levels of 0.02 µg/L, approaching the guideline. There were also six elevated copper values, approaching, but not exceeding the 2.9 µg/L guideline. Mercury is generally marginally detectable at the 0.01 µg/L detection limit. In survey 143 (21 Nov 07) two samples had very high mercury levels (both 0.44 µg/L), more than 17 times the guideline. All other samples in this survey had

detectable mercury values that were below the guideline. In this same survey there were three samples with copper values in excess of the 2.9 µg/L guideline, the highest value (13.7 µg/L) was nearly five times the guideline. Outside of these two surveys there was a single copper exceedance (7.0 µg/L) at D2-1m in survey 144 (5 Dec 07).

Aside from these samples this plot shows that of the metals for which guidelines exist copper, manganese and zinc regularly have detectable levels. Lead and nickel are occasionally detectable, while cadmium was not detected. Iron is regularly detected, but has no guideline. Note that cobalt is also measured but has no guideline and is not regularly detectable, so it is not reported here, but is in the survey data files.

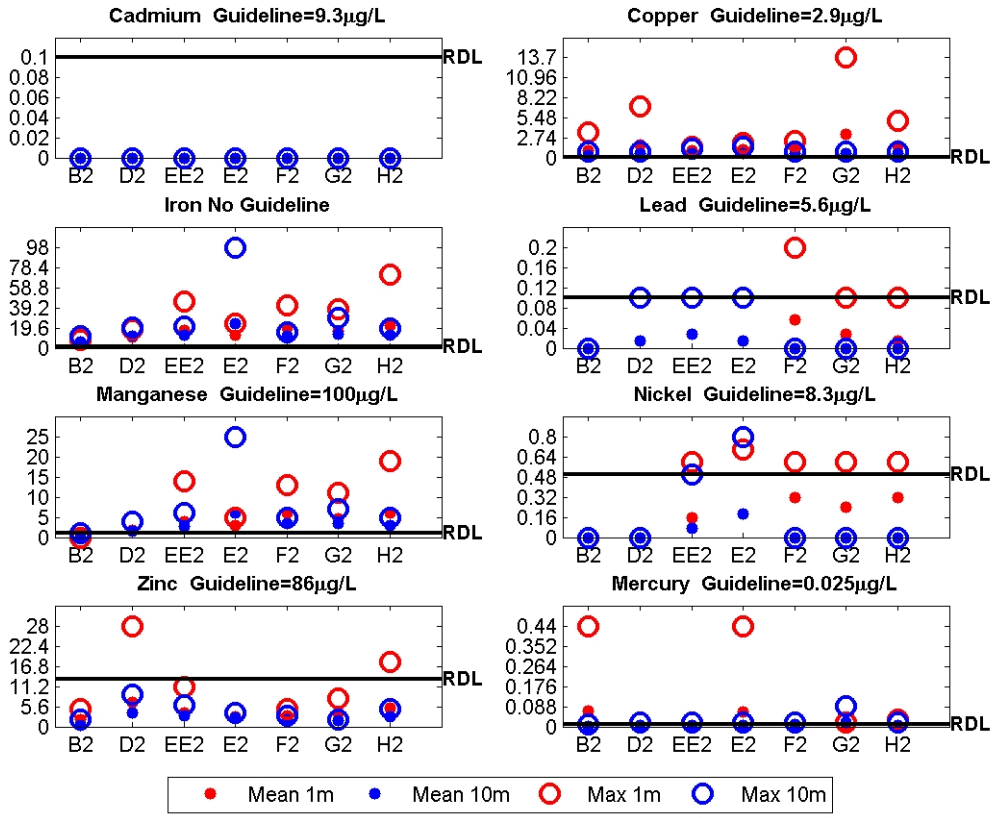

Figure 9. Mean and maximum values of metals (µg/L) over all fourteenth quarter samples.

4.7 Profile Data

The CTD used in this program measures continuous profiles of temperature, salinity, fluorescence and dissolved oxygen with depth. In early quarterly reports (up to Quarterly Report 8) the profile data was compared to the BBPMP data from the centre of Bedford

Basin. This provided a check on the ranges and quality of the data collected for this survey. BBPMP has discontinued the time series contour plots so this comparison is no longer feasible. However, the contour plots of profile time series are useful in visualizing the longer term variation in the state of the harbour. These plots are continued in the annual summary section of every fourth quarterly report (12, 16 and 20).

4.7.1 Salinity and Temperature

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

4.7.2 Fluorescence

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

The phytoplankton in Halifax Harbour generally exhibit more or less typical estuarine behaviour in the winter. That is, low productivity (<5 mg/m^3) during the winter followed by the strongest bloom of the year (40-80 mg/m^3) as sunlight returns in the spring (typically March). After the spring bloom, when light is plentiful, the behaviour seems to be affected by anthropogenic nutrient input. There are sporadic phytoplankton blooms throughout the summer and into the fall. These blooms can be close to the spring bloom in magnitude (30-40 mg/m^3) and occur until the drop in light levels in late fall and winter. There is a less distinct fall bloom that does not appear to be significantly different in intensity, based on fluorescence, than the blooms occurring throughout the summer. Phytoplankton blooms tend to start in the Basin and migrate outward to the rest of the

harbour. The profile maximum values generally decrease in magnitude and occur lower in the water column further out of the harbour. The data in the Basin generally represents the maximum concentrations observed and is representative of the timing of phytoplankton activity in the remainder of the harbour. During this quarter there were three surveys, 126 (28 Mar 07), 130 (23 May 07) and 131 (5 Jun 07), with significant (> 20 mg/m^3) fluorescence levels. Between these surveys the levels were moderate, but generally well above the winter "background' levels (< 3 mg/m^3).

4.7.3 Dissolved Oxygen

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

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

Survey	HHWQMP (mg/L)		BBPMP (mg/L)		Ratio (BBPMP/HHWQMP)	
Number	1m	10m	1m	10m	1m	10m
139 (25 Sep 07)	9.9	7.70	8.9	7.7	0.89	1.00
140 (10 Oct 07)	8.3	6.40	8.6	7.1	1.03	1.12
141 (24 Oct 07)	8.3	6.70	9.1	7.3	1.10	1.09
142 (6 Nov 07)	9.7	8.10	10.0	8.3	1.03	1.02
143 (21 Nov 07)	9.3	7.80	10.9	8.1	1.17	1.04
144 (5 Dec 07)	9.5	9.70	na	na	na	na
145 (17 Dec 07)	6.4	6.40	8.4	9.1	1.32	1.43

The data is quite comparable given the uncertainties, including the differences in time and location. The exception is survey 145 where the HHWQMP data is 30-40% lower than the BBPMP data. There were problems with the CTD during that survey causing rejection of a large part of the data during quality control. The data not rejected had very low values causing a caution to be issued regarding its use. As the reason for the low values is unknown, even scaled as indicated by the BBPMP comparison, the survey 145 data remains questionable.

The Harbour Task Force Class SA, SB and SC water use classifications have guidelines for dissolved oxygen of 8.0, 7.0 and 6.0 mg/L respectively. Class SA pertains to the Outer Harbour and Class SC pertains to the Narrows and Inner Harbour. The remainder of the harbour is classified as SB. To date, oxygen levels as measured in the program are with some exceptions, relatively high in surface waters, and chronically low in the deep water of Bedford Basin. This is consistent with the existing understanding that Bedford Basin is a fjord, in which at least periodic depressed oxygen in bottom water is typical. For this quarter, there is an exceedance of the class SB guideline at the head, and in the bottom water, of the Northwest Arm in survey 140 (10 Oct 07). Throughout most of the quarter the DO in the Basin bottom water is below the class SB guideline. In survey 144 there is what appears to be a small intrusion that raises the DO of the deep water in the Basin but not above the guideline. The BBPMP data indicates that the levels remain below 7.0 mg/L at the end of the quarter.

4.8 Supplemental Samples

H3

A supplemental sample was taken in survey 140 (25 Sep 07) at 12:53 ADT. The sample was taken at the regular H3 site, normally only sampled for fecal coliform. The water there was very turbid and red-brown in colour. The water appeared cloudy, relatively patchy and with no large particulates observed. It was not clear whether the material was plankton or sediment. There was no obvious sediment source. The sample was taken as near the surface as possible. The colour appeared maximum at H3 (secchi 2.0 m) but was evident over quite a large area including H2 (secchi 2.25 m) and F3 (secchi 2.25 m). There were very high fluorescence levels at H3 (75 mg/m^3) and high levels at H2 (>30 mg/m^3) but not at F3 (approx 10 mg/m^3). A photo of the water surface is included (Figure 10). The results of the lab analysis are presented in Table 9. The TSS values at H3 were very high (29 mg/L). This compares with 12 mg/L at H2 and a survey mean value of approximately 4.6 mg/L. The metals in the sample were the highest of any measured in the survey. The copper concentration was 2.9 ug/L, just at the guideline level. There were no other metals close to guideline exceedance. The elevated metals may suggest a sediment source.

Figure 10. Patchiness in water at H3.

Table 9. H3 sample results.

	UNITS	1m	RDL
BACTERIA			
Fecal Coliform	cfu/100mL	15	1
INORGANICS			
Carbonaceous BOD	mg/L	NA	5
Nitrogen (Ammonia Nitrogen)	mg/L	0.05	0.05
Total Suspended Solids	mg/L	29	0.5
OIL & GREASE			
Total Oil & Grease	mg/L	NA	5
METALS WITH GUIDELINES			
Cadmium (Cd)	ug/L	ND	0.1
Copper (Cu)	ug/L	2.9	0.1
Lead (Pb)	ug/L	ND	0.1
Manganese (Mn)	ug/L	3.0	1
Mercury (Hg)	ug/L	ND	0.01
Nickel (Ni)	ug/L	1.4	0.5
Zinc (Zn)	ug/L	10.0	1
METALS WITH NO GUIDELINES			
Cobalt (Co)	ug/L	ND	0.1
Iron (Fe)	ug/L	9.0	1

Halifax Treatment Plant Outfall

A supplementary sample was taken at the Halifax STP outfall on survey 144 (5 Dec 07), 09:43 AST. This sampled a large visible plume over the new STP outfall. Connections to the STP had begun approximately one month previous and were ongoing. The outfall was visible from a distance due to birds (Figure 11). Near the outfall the plume was visible primarily due to reduced capillary waves (Figures 12 and 13). The water inside the plume appeared relatively clear. Samples were taken at 1 and 10m at a site (44° 39.23" N, 63° 34.49" W) inside the visible plume directly in front of the Casino about 70 m from the wharf. The results of the analysis are shown in Table 10. The results are generally unremarkable. The fecal coliform levels are somewhat higher than the closest regular site (EE1), but not high compared to other values in the Inner Harbour. Likewise the TSS is equal to the maximum value observed elsewhere, but not particularly high.

Figure 11. Halifax STP outfall with birds.

Figure 12. Plume along shore by Casino.

Figure 13. Plume edge from sample site.

Table 10. Halifax STP outfall sample, lab results (5 Dec 07).

	UNITS	1m	10m	RDL
BACTERIA				
Fecal Coliform	cfu/100mL	540	370	1
INORGANICS				
Carbonaceous BOD	mg/L	ND	ND	5
Nitrogen (Ammonia Nitrogen)	mg/L	0.12	0.09	0.05
Total Suspended Solids	mg/L	4.7	2.4	0.5
OIL & GREASE				
Total Oil & Grease	mg/L	NA	NA	5
METALS WITH GUIDELINES				
Cadmium (Cd)	ug/L	ND	ND	0.1
Copper (Cu)	ug/L	0.9	0.6	0.1
Lead (Pb)	ug/L	0.1	ND	0.1
Manganese (Mn)	ug/L	3.0	4.0	1
Mercury (Hg)	ug/L	ND	0.01	0.01
Nickel (Ni)	ug/L	0.6	ND	0.5
Zinc (Zn)	ug/L	5.0	2.0	1
METALS WITH NO GUIDELINES				
Cobalt (Co)	ug/L	ND	ND	0.1
Iron (Fe)	ug/L	16.0	30.0	1

5 Summary

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

5.1 Reporting

Survey Reports

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

Changes

- This quarter, in survey 144 (5 /Dec 07), an additional graphic, maps of fecal coliform concentrations at 1 and 10m, has been added to the survey reports.

Quarterly Reports

The Quarterly report discussion is limited to the data of that quarter. Every fourth Quarterly report includes a section reviewing the data over the last year. Each quarterly report contains a discussion of any supplemental samples taken in the quarter.

Changes

- Figure 2 has been modified slightly to improve legibility.

5.2 Sampling Program

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

Changes

- None

5.3 Water Quality Parameters

Fecal Coliform

In general, the geometric mean coliform values are well above primary contact guidelines in the Inner Harbour. Outside of the Inner Harbour high values are more sporadic. The occurrence of high values outside the Inner Harbour are primarily dependant on oceanographic conditions that may transport water from the Inner Harbour either up or down harbour, and secondarily dependant on loading events (e.g. storms) that may increase loads thereby raising levels everywhere. Both of these often act together. This quarter, starting just before survey 142 (6 Nov 07) the connection of sewer-sheds to the new Halifax STP is ongoing. The changing distribution of sources has certainly affected the observed fecal coliform distributions in the Harbour. In general, the fecal coliform concentrations are quite high and widely distributed. The distribution of high values in both the 1 and 10m samples seem shifted to the south.

With respect to compliance with Task Force guidelines the most numerous exceedances are in the SB classified areas adjacent to the Inner Harbour. This quarter, class SB exceedances are fairly widespread and are generally to the south of the Inner Harbour (i.e BRB, SYC, PC, RNSYS and Section C). The class SA guideline in the Outer Harbour is generally not met at HC and the HP sites, likely due to the periodic influence of the Tribune Head outfall. The class SA guideline is met at B2 at the start of the quarter, but not in the last two surveys of the quarter.

Changes

There has been additional bacteria monitoring initiated in the Northwest Arm. The purpose is to establish storm induced transients once the effluent from the Chain Rock outfall is diverted to the STP. When this occurs there will be no regular discharge to the Arm, but there are several CSO's still in place that will discharge during heavy rainfall. This is not strictly part of this project and the data is reported under separate cover. The monitoring includes surface samples for both fecal coliform and enteroccoci. This data will allow a comparison of the two tracers and if desired to evaluate the use of fecal coliform for a proxy for enterococci in the Harbour. This helps to address the "outstanding item" below.

Outstanding item:

The current Canadian Environmental Quality Guidelines (ceqg-rcqe.ccme.ca) recommend enterococci over fecal coliform as a tracer of human waste contamination in salt water. There are several practical reasons for continuing to monitor fecal coliform including historical continuity, and consistency with WWTP monitoring procedures. The trend toward enterococci will likely continue and it would be advantageous to future

endeavours if the monitoring program could bridge to the use of this tracer. Enterococci are considered to be more specific than fecal coliform in identifying contamination by human waste. In Halifax the overwhelming source of bacterial contamination is sewage. The concentration of fecal coliform in the Harbour would likely correlate very strongly with the more human specific enterococci. Limited sampling of both parameters could allow investigation of this correlation.

Ammonia Nitrogen

Ammonia nitrogen has consistently been present at levels that are around the detection limit of 0.05 mg/L. Overall, in this quarter, just over 80% of samples had detectable levels of ammonia. The values are generally relatively uniform throughout the harbour except they tend to be somewhat lower in the Outer Harbour at B2. There is definite temporal variability. The survey with the lowest values was survey 139 (25 Sep 07) and the survey with the highest values was survey 140 (10 Oct 07). The high values correspond to a period of visually deteriorated water quality in several locations around the harbour, including the northern Basin. There was a supplemental sample taken at H3, in very turbid water, however the ammonia level in this sample was just at the detection limit. There does not seem to be a simple correlation between ammonia concentrations and meteorological/oceanographic conditions, as is evident in the coliform data.

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

Changes
- None

$CBOD_5$

Based on recommendations in Quarterly Report 2, $CBOD_5$ was dropped from regular analysis in survey 49 (25 May 05). Until that time there were an insignificant number of regular samples with detectable $CBOD_5$ at the 5 mg/L level. $CBOD_5$ has been retained as a tracer for the supplemental sampling program. The $CBOD_5$ samples taken at the Halifax STP outfall had non-detectable concentrations.

Changes
- None

Total Suspended Solids

The TSS values in the harbour are generally moderate with no obvious strong correlation in space or time with oceanographic or sewage loading conditions. This quarter the survey means ranged from about 1.3 to 5.0 mg/L. There are at times higher values that seem to be associated with more extreme events (e.g. storms, plankton blooms etc). These events are generally identifiable visually and are usually documented in field notes. The supplemental sample taken is visibly turbid water at H3 (survey 140) had a TSS value of 29 mg/L, nearly twice as high as the maximum value in regular samples over the quarter (15 mg/L). The only clear spatial pattern is that the TSS is generally lower in the outer Harbour at B2. However, this quarter the survey maximum values occurred at B2 for the last two surveys.

Changes:
- None

Total Oils and Grease

Based on recommendations in Quarterly Report 5, total oil and grease was dropped from regular analysis in survey 75 (23 Nov 05), due to lack of detection. It is retained in supplemental sample analysis. This quarter there was no TOG analysis.

Changes
- None

Metals

In general the metals with guidelines are present at levels well below the guidelines. The metal that is consistently closest to exceeding the guideline is copper. In this quarter there were two surveys, 139 (25 Sep 07) and 143 (21 Nov 07) that had unusually high metals concentrations. Between these two surveys there were three guideline exceedances for both copper and mercury. In both surveys all samples had detectable mercury values (not usually detectable) and there were several copper concentrations that were near guideline levels. There was no obvious reason for these elevated values. In addition to these surveys there was a single exceedance of the copper guideline in survey 144 (5 Dec 07).

Changes:
- None

Fluorescence

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

the detailed phytoplankton analysis at the BBPMP site. During this quarter the fluorescence levels started out moderate. There was what appeared to be a relatively intense bloom in the middle of the quarter (survey 142, 6 Nov 70) perhaps the fall bloom. After this the levels subsided to very low, near background (< 2.0 mg/m^3) levels by the final survey.

Changes
- None

Dissolved Oxygen

To date, oxygen levels as measured in the program, are with some exceptions relatively high in surface waters, and chronically low in the deep water of Bedford Basin. This is consistent with the existing understanding that Bedford Basin is a fjord, in which depressed oxygen in bottom water is typical. This quarter the ground truthed BBPMP DO data and the newly calibrated HHWQMP DO data are comparable. There was CTD problems in the last survey of the quarter (145, 17 Dec 07) and the DO data is questionable for that survey. Overall the data suggests a persistent SB exceedance in the bottom water of the Basin throughout the quarter. There is a minor intrusion of oxygenated water in noted in survey 144, but not enough to raise all the deep water above 7.0 mg/L. Besides this chronic condition, the bottom and head of the NW Arm drop below 7.0 mg/L briefly (Survey 140). There are continuing issues of DO sensor calibration/ground truth (Section 4.7.3).

Changes
- None

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