Halifax Harbour
Water Quality Monitoring Program
Quarterly Report #10
(26 September 2006 to 5 December 2006**)**

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PREFACE

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

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

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

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1 Introduction

This quarterly report is a summary of Halifax Harbour Water Quality Monitoring Project (HHWQMP) data collected from 26 September 2006 to 5 December 2006 (surveys 113 to 118). 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 tenth 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 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. In this quarter, three "coliform" sites (HP1, HP2 and HP3) were added in the Outer Harbour, in the vicinity of the planned STP there. This has resulted in additional "HP section" plots in the survey reports.

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 timeseries plots at selected depths. Selected points from the BBPMP Dissolved Oxygen (DO) profiles are compared with the HHWQMP DO for purposes of ground truthing. The timeseries 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. In addition, the sampling program is modified periodically, necessitating changes in the 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 now conducted on a biweekly basis as of July 2006. Sampling is conducted from one of several vessels, operated by Connors Diving Services Ltd., based at the Armdale Yacht Club. The details of the sampling program are discussed in the introduction section of the project report binder and Quarterly Report 1. The locations of the 34 regular sampling sites (including the 3 new HP 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

In this quarter, starting with survey 114 (10 Oct 2006) three additional "coliform" sites were added to the sampling program. These sites (HP1, HP2 and HP3) are located off Hospital Point in the vicinity of the third of the Harbour Solutions Project sewage treatment plant (Figure 1). In addition, starting with survey 114, the three sites on section E in the Narrows, are sampled consecutively instead of being sampled in the "circuit" pattern used for the rest of the sites. The Narrows experience the largest tidal currents in the harbour and represent a transition between the Basin and the Inner Harbour, areas that can be quite hydrographically distinct. The Narrows, therefore, is often the area with the largest spatial and temporal gradients in hydrographic properties. To date, the section E plots in the survey reports sometimes show cross channel variations in hydrographic properties that are ambiguous in time and space. That is, it is unclear whether they are actually cross channel variations or an artifact of the difference in time of the CTD casts. Sampling all three sites consecutively will eliminate this ambiguity. This ambiguity is somewhat of an issue at all sections, but the potential effect is much smaller in the remainder of the harbour and the circuit sampling has other benefits that are felt to outweigh the potential concerns.

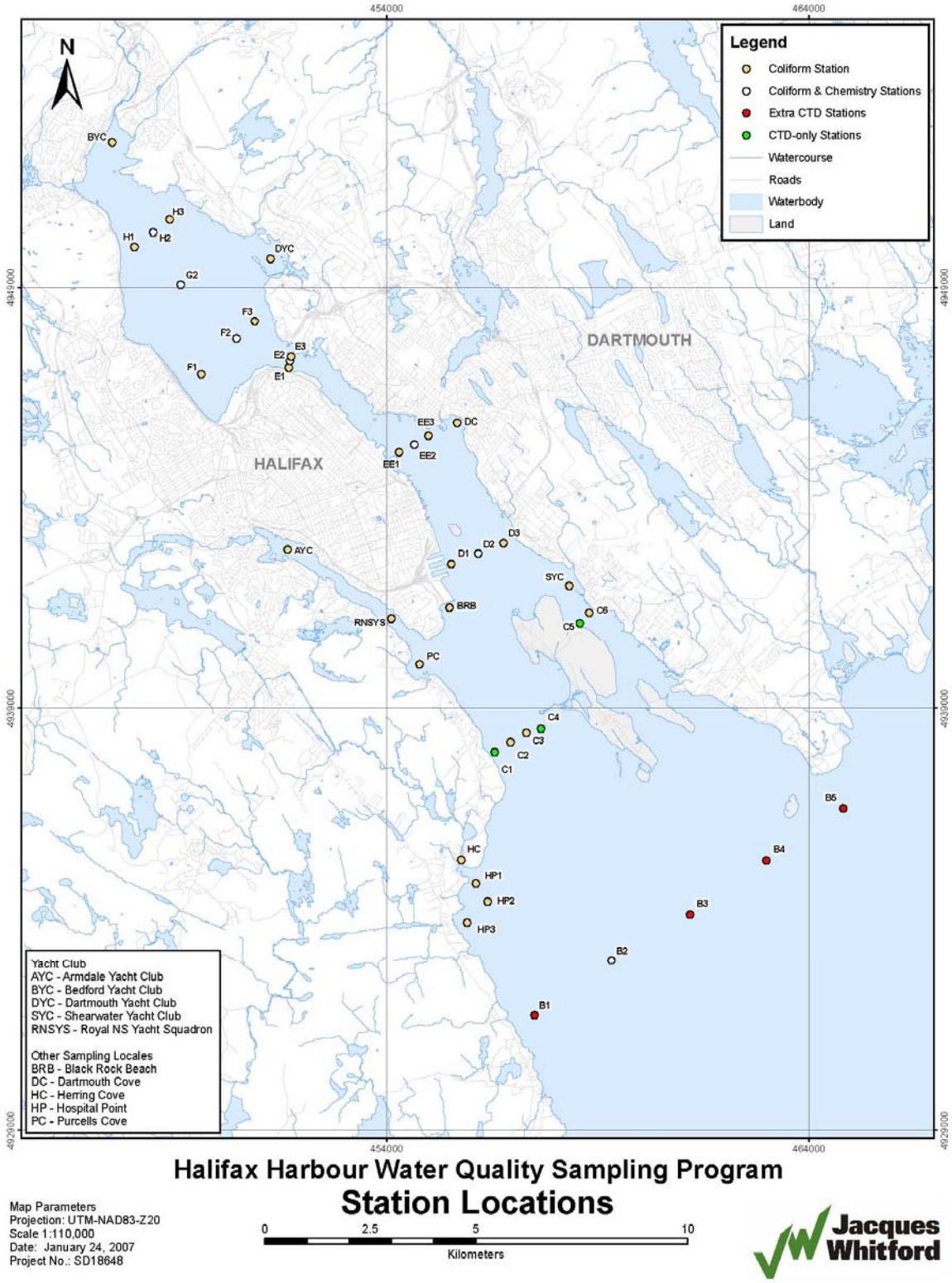

Figure 1. Halifax Inlet sample locations.

A summary of the sampling and analysis schedules and relevant established criteria in place at the end of tenth quarter (5 Dec 06) are in Table 1. This table indicates that the $CBOD_5$ and total oil and grease analyses, discontinued from regular sampling due to lack detection, are now performed only for "supplemental samples".

Table 1. Summary of measured parameters as of 5 December 2006.

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

3.2 Supplemental Samples

Based on recommendations from Quarterly Report 2, a supplemental sample protocol has been instituted to take opportunistic samples of visible water quality features in the Harbour. 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 there was a supplemental sample taken in Fairview Cove for survey 113. There were also some additional individual samples taken for fecal coliform, at a site near the Mill Cove outfall in survey 113, and $CBOD_5$ samples taken at F1 and F2 in surveys 116 and 117.

3.3 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 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 week in the tenth quarter is presented in Table 2. Note that, as discussed in section 3.1, starting with survey 114, the Section E sites are sampled consecutively.

Table 2 also lists the missed stations and any additional samples (described above) for each survey. Note that on survey 114, the number of regular sites increase from 31 to 34, with the addition of the HP sites. Overall, during this quarter, there was only one missed coliform station (D3, survey 117). This converts to a total of 2 missed bacteria samples and 1 missed CTD profile.

Table 2. Sample collection order (green sites are CTD only, blue indicates no CTD data, red indicates sample only)

Date	26 Sep 06	10 Oct 06	24 Oct 06	8 Nov 06	21 Nov 06	5 Dec 06
Survey	113	114	115	116	117	118
1	PC	AYC	AYC	HC	AYC	AYC
2	C2	RNSYS	RNSYS	HP1	RNSYS	RNSYS
3	C1	PC	PC	HP2	PC	BRB
4	HC	B2	C1	HP3	C1	D1
5	B2	HP3	C2	B2	C2	EE1
6	C3	HP2	BRB	C1	BRB	E1
7	C4	HP1	D1	C2	D1	E3
8	C5	HC	D2	C3	D2	E2
9	C6	C1	EE1	C4	EE1	F1
10	SYC	C2	EE2	BRB	EE2	H1
11	D3	BRB	E1	D1	E3	BYC
12	D2	D1	E3	D2	E2	H3
13	EE3	D2	E2	EE1	E1	H2
14	EE2	EE2	F2	EE2	F1	G2
15	E3	EE1	F1	E3	F2	DYC
16	E2	E1	G2	E2	G2	F3
17	F2	E3	H1	E1	BYC	F2
18	F3	E2	H2	F2	H1	EE3
19	DYC	F2	BYC	F1	H2	EE2
20	H3	F1	H3	G2	H3	D2
21	H2	G2	DYC	H1	DYC	D3
22	BYC	H1	F3	H2	F3	SYC
23	H1	H2	EE3	BYC	EE3	C6
24	G2	BYC	D3	H3	SYC	C5
25	F1	H3	SYC	DYC	C6	C4
26	E1	DYC	C6	F3	C5	C3
27	EE1	F3	C5	EE3	C4	B2
28	D1	EE3	C4	D3	C3	HP3
29	BRB	D3	C3	SYC	B2	HP2
30	RNSYS	SYC	B2	C6	HP2	HP1
31	AYC	C6	HP3	C5	HP3	HC
32		C5	HP2	PC	HP1	C1
33		C4	HP1	RNSYS	HC	C2
34		C3	HC	AYC		PC
No data					D3	
Supplemental	Fairview Cove Mill Cove (FC)			F1, F2 ($CBOD_5$)	F1, F2 ($CBOD_5$)	

3.4 Data Return

The only missed data for the quarter was due to the single missed “coliform" site (D3) in survey 117 (21 Nov 06). The overall data return for the quarter is summarized in Table 3.

Table3. Quarter 10 data return.

Chemical	Target	Achieved	Percent Return
7 sites			
NH3	84	84	100%
TSS	84	84	100%
Metal scan	84	84	100%
Mercury	84	84	100%
Total	**336**	**336**	**100%**

Bacteria	Target	Achieved	
28 sites			
F Coliform	366	364	99%
Total	**366**	**364**	**99%**

Profiles	Target	Achieved	
31 sites			
C-T	201	200	100%
Dissolved Oxygen	201	200	100%
Chlorophyll	201	200	100%
	603	**600**	**100%**

All data records	**1305**	**1300**	**100%**

3.5 Sampling Bias

There are two issues regarding potential bias in the dataset. The first is the relative bias between sites, i.e. 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 tenth quarter.

3.5.1 Time of Day

Sewage flows have significant regular diurnal variations, which can affect the water quality in the Harbour on short timescales. In 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 represents the sampling time at each site since the start of the program in June 2004. The data from the tenth 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, which 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. In this quarter the midday bias in the Basin is greater than historically, with all surveys between 10:00 and 14:30. 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 exception is the E section (now sampled consecutively) and the D2 and EE2 sites. The centre "2" stations are sometimes sampled with the "1" stations and sometimes with the "3" stations. This quarter, by chance, the routes combined the centre samples with whichever sample was being sampled early in the day. The result is these samples have a morning bias. The Northwest Arm has a strong early morning/late afternoon bias. Because of travel time constraints, each survey either begins or ends in the Arm. In this quarter the sampling was balanced between morning and afternoon. The Outer Harbour also shows a morning and afternoon bias for similar reasons, discussed in Section 3.3.

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 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 of longer period and, except in extreme 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 over ridden by local/regional meteorological effects (Hurlbut et al., 1990). This means, for example, that the surface current may not always be going out on a falling tide. However, the occurrence of surges is relatively random and the possibility of inducing a systematic sampling bias is small compared with that of the very regular higher frequency tides. The tides in Halifax Harbour are classified as semidiurnal, meaning that there are two high and two low tides in a day.

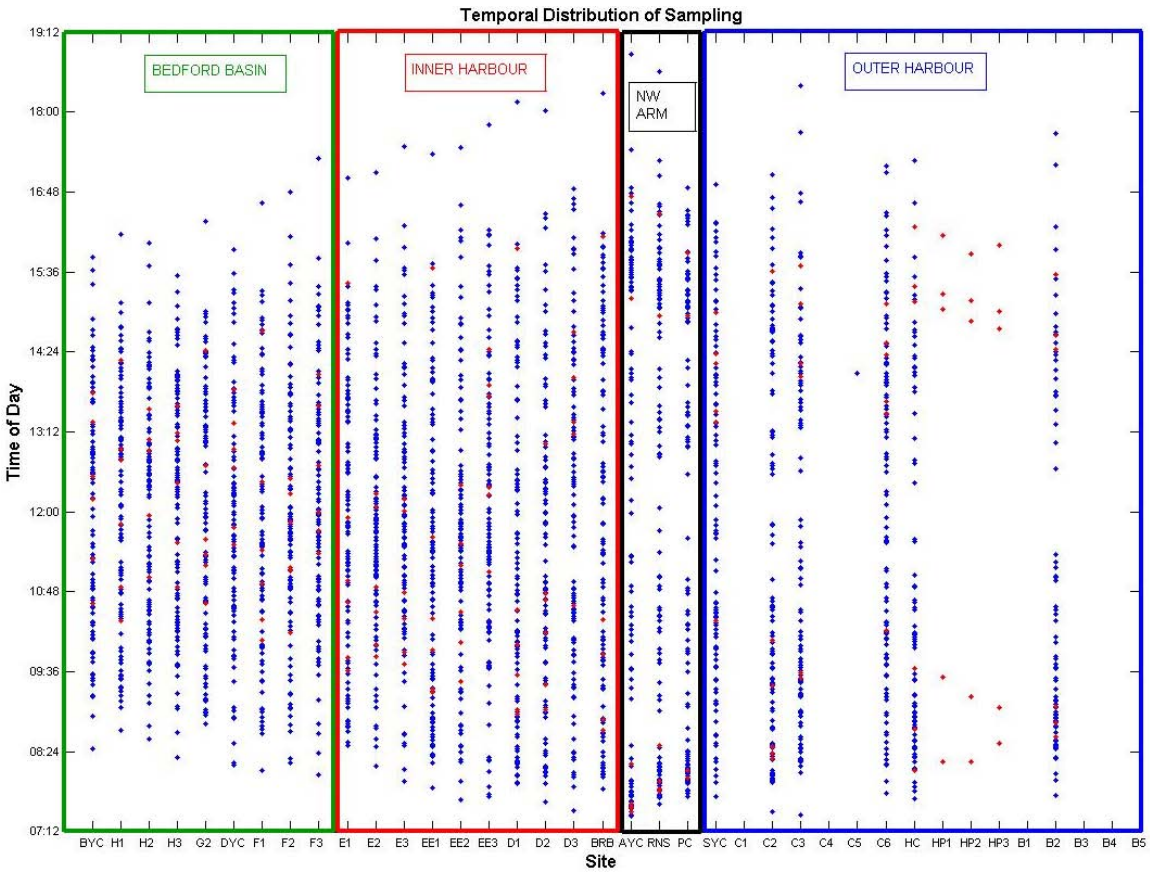

Figure 2. Temporal sampling distribution by site over entire program. Red markers denote points from 26 September 2006 to 5 December 2006.

There is also a potential bias introduced by regular biweekly sampling. Sampling which 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 2006 to December 2006 is shown in Figure 3. The overall water level distribution has a peak

at 0.6 m and a minimum at 1.6 m. In an ideal situation each site would be sampled in a distribution similar to the overall distribution. The red line connecting the bars is the baseline, recreated in each panel of Figure 4, against which water levels during sampling are compared. With biweekly sampling, there are fewer surveys in a quarter and the shape of the sampling distribution will not be as well defined as with the previous weekly sampling.

Figure 4 shows the distribution of water levels at each site at the time of sampling (blue bars) compared to the overall water level distribution for the quarter (red line). The sampling distributions show that in general, north of section C, the lower water levels are under-sampled; in some sites this is quite marked. The exceptions are sites D2 and EE2. The sampled water level for these sites is much closer to the overall water level distribution. The reason that these sites are different is likely the same reason that the time of day distribution is different for these sites as discussed in Section 3.5.1. South of section C, in the Outer Harbour, the higher water levels are slightly under-sampled, though the distribution, with respect to the overall water level distribution, is much more balanced. 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.

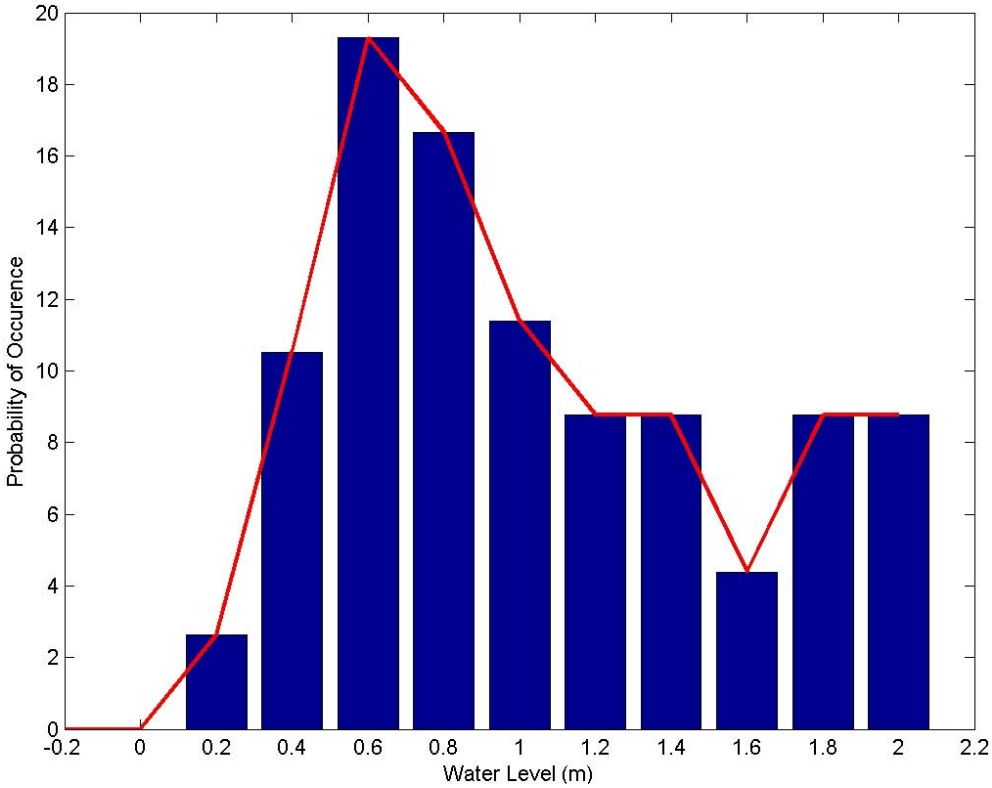

Figure 3. Probability distribution of water levels in Halifax, June to September 2006.

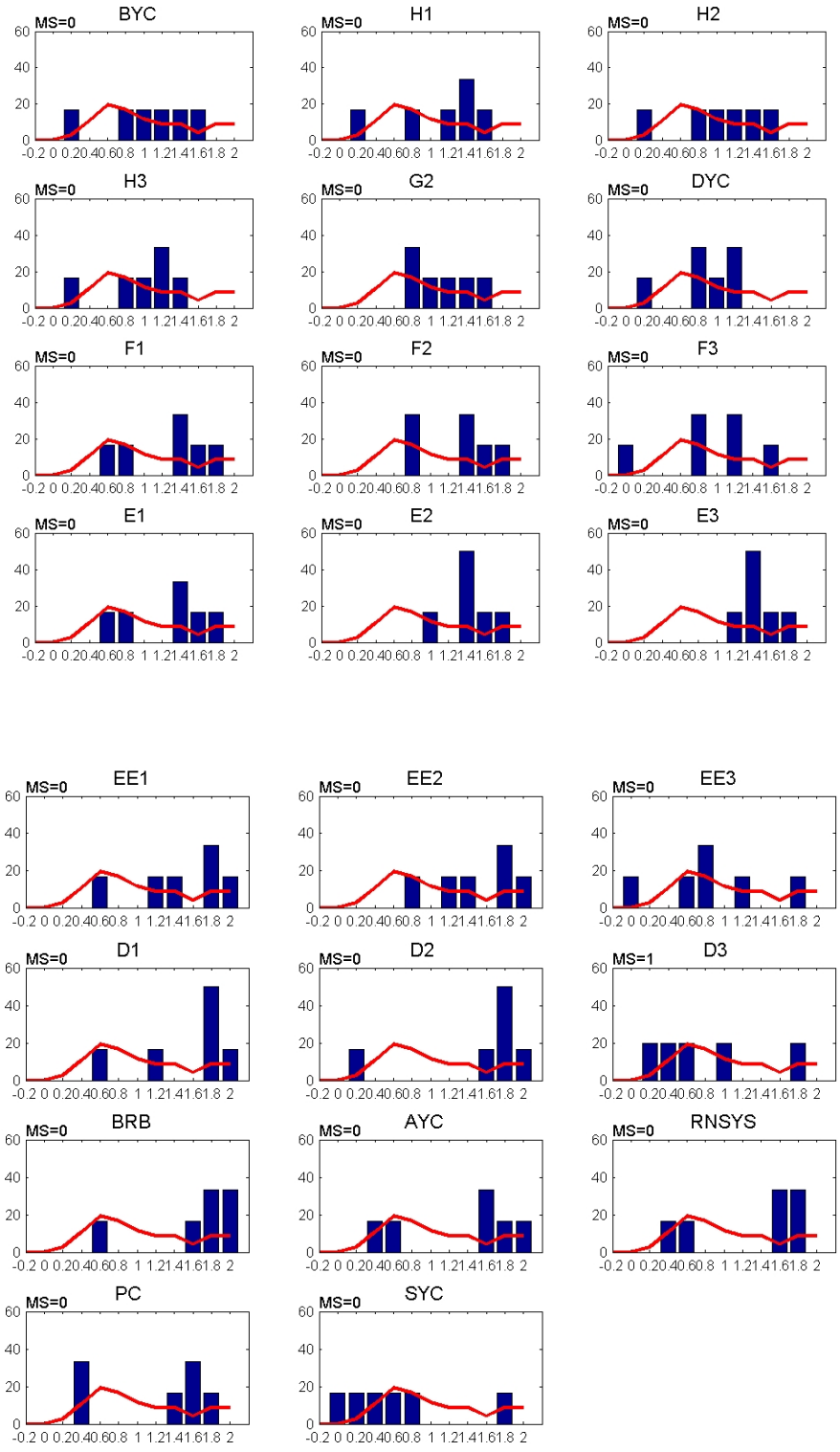

Figure 4a. Water level distribution at each site during sampling 26 September 2006 to 5 December 2006. Note: MS = Missed samples

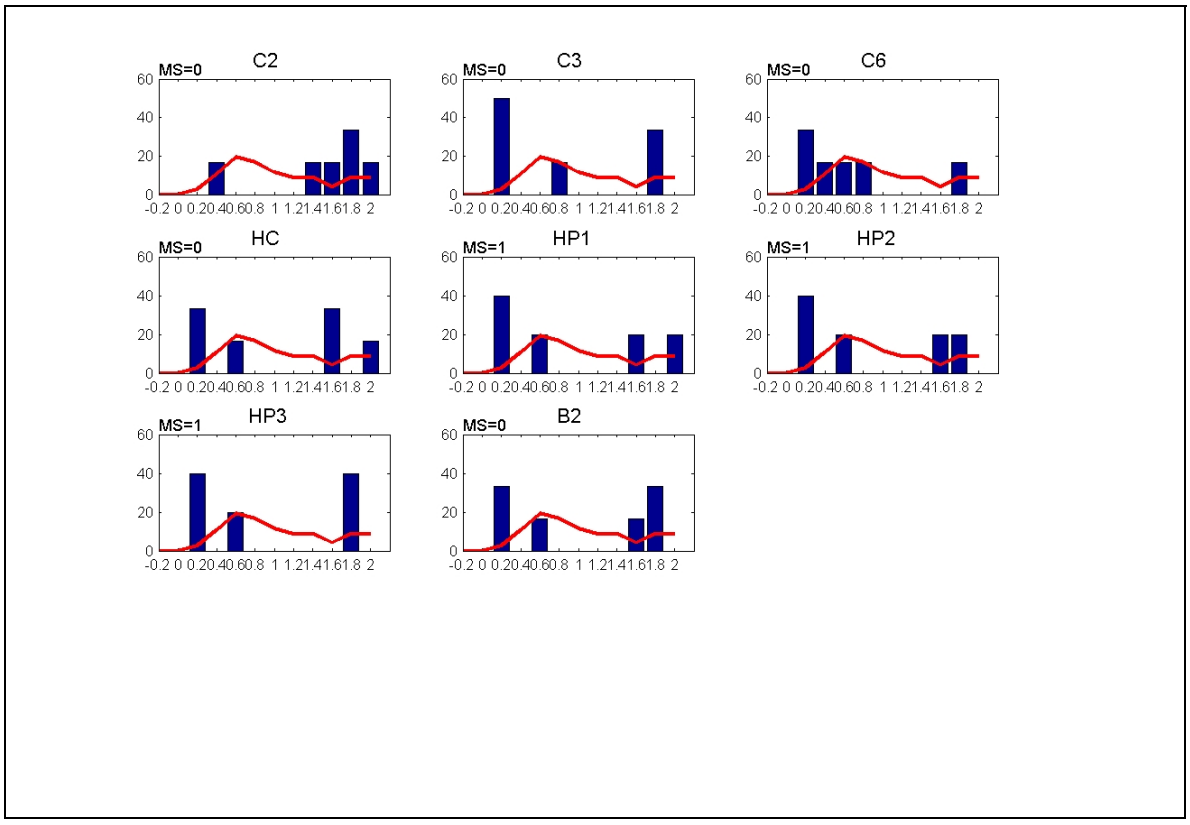

Figure 4b. Water level distribution at each site during sampling 26 September 2006 to 5 December 2006. Note: MS = Missed samples

3.5.3 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 and persist for a 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 (72 hour) precipitation window for our analysis. The red line in Figure 5 depicts the probability distribution of precipitation integrated over the current and previous two days for this quarter (26 Sep to 5 Dec 06). The blue bars on this plot represent a similar analysis performed for sampling days only. The plot indicates that there were relatively large rainfall events (25-40 mm) that were missed by the sampling. The largest integrated rainfall sampled was 20 mm that is relatively moderate. The sampling distribution has a dry weather bias compared with the overall distribution.

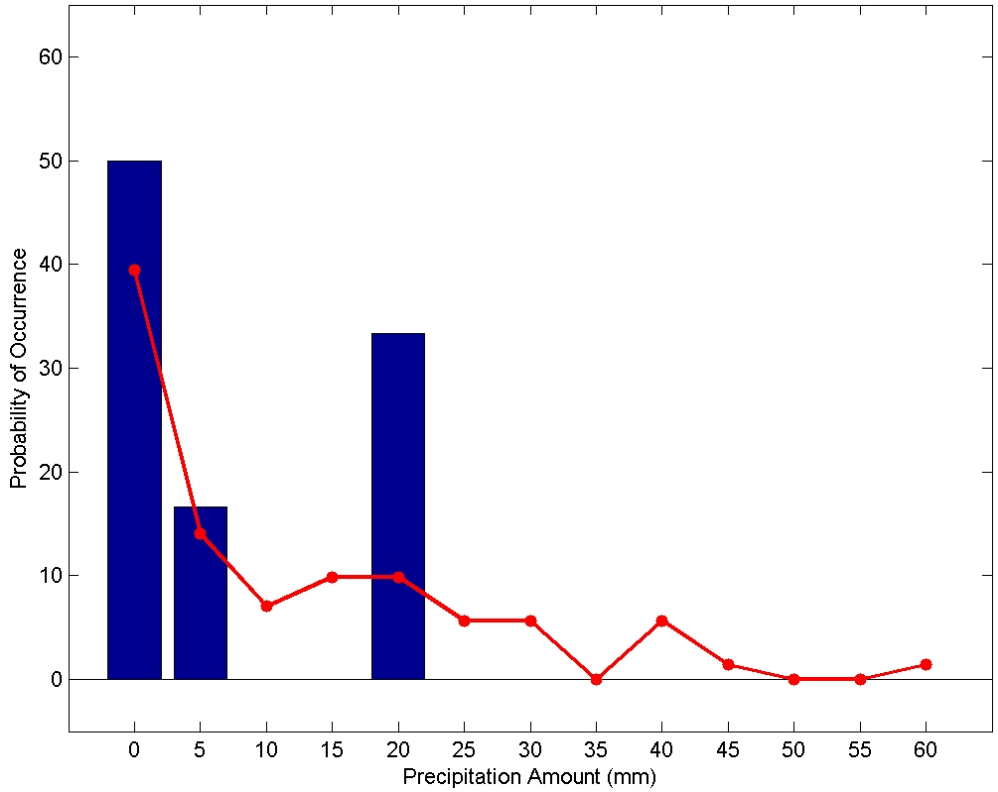

Figure 5. Probability distribution of cumulative 72 hour rainfall, 26 September 2006 to 5 December 2006.

4 Water Quality Results and Discussion

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

4.1 Fecal Coliform

4.1.1 Out-of-Range Values

The adaptive lab procedure, using different fecal coliform detection ranges for different sites, developed as a result of previous recommendations, has reduced the number of out-of-range values significantly. For this quarter there are three out-of-range values, all in survey 115 (24 Oct 2006). These were in the 1 m samples at D3 and RNSYS and the 10 m sample at E1. These were likely the result of unusual conditions that caused high values throughout the Inner Harbour and NW Arm (see Survey Report 115). Based on previous data these levels were anomalous. There would likely be more data lost at the low end if the detection range was increased (higher values, lower resolution) for these sites, so it will not be changed.

4.1.2 Quarterly Mean Values

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

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

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

Maps representing the geometric mean values over all samples for the tenth 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.

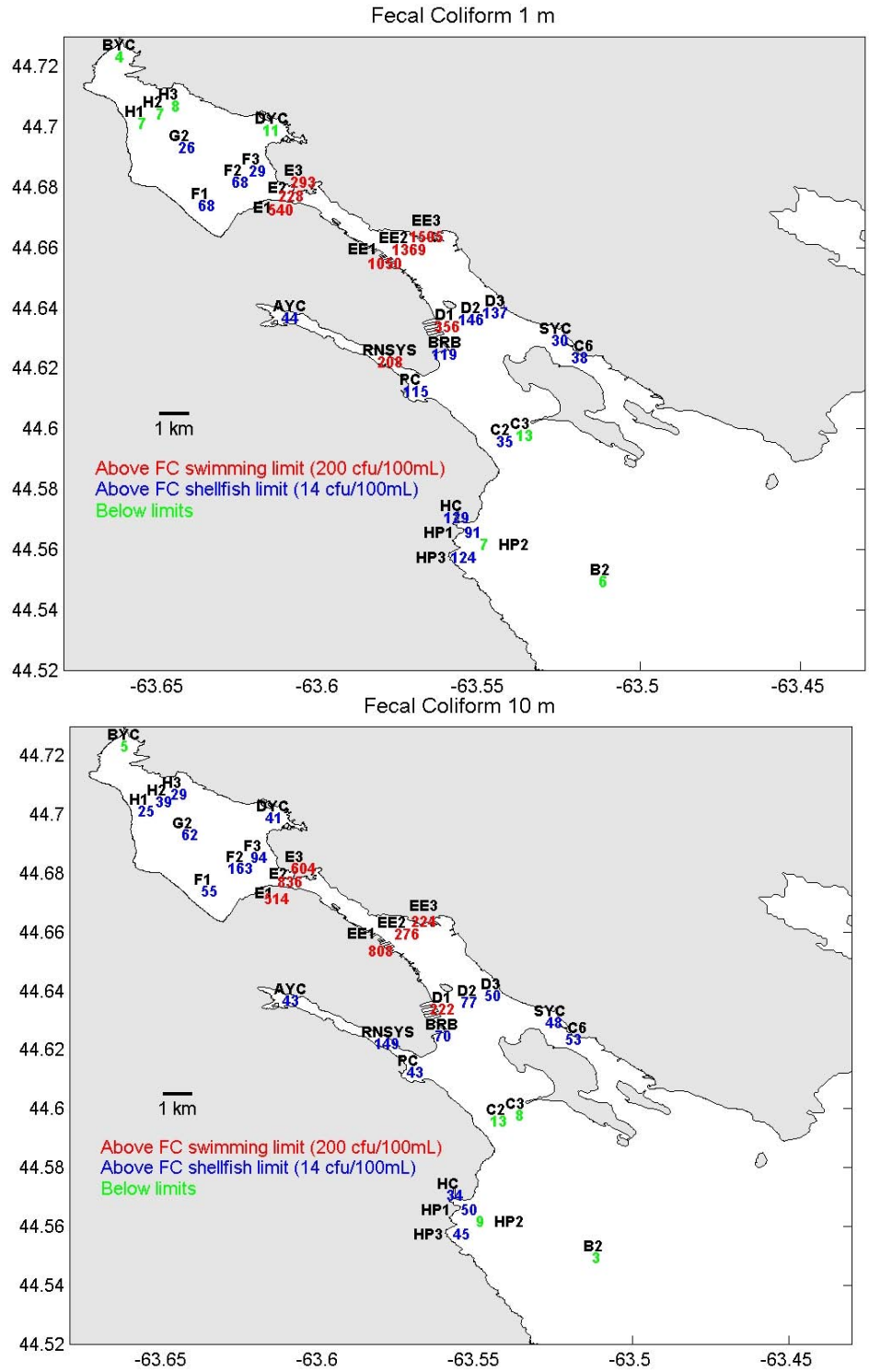

Figure 6. Fecal coliform geometric means (cfu/100mL), 26 September 2006 to 5 December 2006.

For both the 1 m and the 10 m samples, the geometric mean coliform values are high in the Inner Harbour, particularly in the northern Inner Harbour. The highest values in the 1m samples are at section EE, while at 10 m it is at section E. South of the Narrows, with a few exceptions, the 1m values are higher than the 10m values, in the Narrows and north the 10m samples generally have higher values. This relatively familiar distribution suggests a net "estuarine" flow with contaminated Inner Harbour water flowing in a lower layer into the Basin. A confusing factor this quarter is the ongoing diversion of sewage to the Fairview Cove CSO from the Duffus St. outfall. This moves sewage from the relatively high energy Narrows to the sheltered Fairview Cove. This seems to have moved the "centre" of the bacteria distribution to the north compared to previous observations. Interestingly there remain low but measureable values in the Outer Harbour. A more rigorous discussion of guideline exceedance follows.

The additional samples at Mill Cove on survey (113, 26 Sep 06) Bedford Outfall 1 and 10 m had no detectible levels. Fairview Cove (survey 113) the levels were relatively high 50 cfu/ml at 10 m and 13,000 cfu/ml at 1 m.

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 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. This strictly applies only to areas classified SB (recreational) by the Task Force (Table 1). The original weekly sampling regimen resulted in five samples within 30 days and allowed a fairly rigorous application of this analysis. The change to biweekly sampling 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 weekly/biweekly assessment, at three levels:

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

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

Tables 4 and 5 show the results of the analysis for the 1 m and 10 m samples respectively. The tables represent the floating 30 day geometric mean and, in parentheses,

the number of samples (max 3) used in the average. The values are colour coded to represent acceptable (green), questionable (yellow) and unacceptable (red) levels.

1 m Samples

For this quarter, the near surface water (1 m) all the Inner Harbour sites (E, EE and D) is "unacceptable" most of the time. Only site D3, on the Dartmouth side, is below the guideline more than half the time. Outside of the Inner Harbour there are sporadic "unacceptable" or "questionable" values in many places. This is largely due to episodic advection of poorly diluted sewage either from the Inner Harbour or local outfalls, e.g.: the Chain Rock outfall and storm overflows in the NW Arm, the Fairview Cove CSO in the Basin, and the Tribune Head outfall near the Herring Cove (HC) and Hospital Point (HP) sites. There is a general increase in the number of "unacceptable" values through the quarter.

10 m Samples

Referring to Table 5, as with the 1m samples, the floating mean values in the Inner Harbour are "unacceptable" most of the time. The levels are generally somewhat lower than the 1m samples, particularly at section D. Site D2 has no "unacceptable" values. Elsewhere, as with the 1m samples, the concentrations are typified by sporadic high values causing "questionable "values. The trend toward higher values at the end of the quarter in the 1m samples is not apparent in the 10m data, except that survey 118 was anomalously high.

Task Force Guidelines

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

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
Survey113	5 (1)				339 (2)	12 (3)	10 (3)	43 (3)	47 (3)	11 (3)	28 (3)	23 (3)	25 (3)	106 (3)	36 (3)
Survey114	11 (2)	51 (1)	1 (1)	130 (1)	116 (2)	15 (3)	10 (3)	280 (3)	9 (3)	7 (3)	9 (3)	10 (3)	120 (3)	1189 (3)	207 (3)
Survey115	5 (3)	10 (2)	3 (2)	411 (2)	129 (3)	22 (3)	32 (3)	1030 (3)	99 (3)	12 (3)	15 (3)	13 (3)	243 (3)	478 (3)	928 (3)
Survey116	5 (3)	48 (3)	2 (3)	55 (3)	131 (3)	17 (3)	3 (3)	249 (3)	711 (3)	104 (3)	10 (3)	7 (3)	331 (3)	478 (3)	149 (3)
Survey117	3 (3)	123 (3)	7 (3)	65 (3)	106 (3)	113 (3)	15 (3)	172 (3)	1216 (3)	86 (3)	61 (3)	54 (3)	234 (3)	520 (3)	224 (3)
Survey118	8 (3)	396 (3)	12 (3)	56 (3)	83 (3)	257 (3)	31 (3)	64 (3)	524 (3)	228 (3)	115 (3)	102 (3)	172 (3)	492 (3)	189 (3)

	Inner Harbour							Bedford Basin								
	D3	EE1	EE2	EE3	E1	E2	E3	F1	F2	F3	DYC	G2	H1	H2	H3	BYC
Survey113	68 (3)	521 (3)	827 (3)	2042 (3)	686 (3)	158 (3)	364 (3)	94 (3)	108 (3)	68 (3)	34 (3)	7 (3)	2 (3)	3 (3)	4 (3)	2 (3)
Survey114	195 (3)	805 (3)	1991 (3)	1635 (3)	175 (3)	47 (3)	141 (3)	30 (3)	34 (3)	20 (3)	7 (3)	5 (3)	2 (3)	4 (3)	5 (3)	1 (3)
Survey115	925 (3)	1028 (3)	1911 (3)	1989 (3)	222 (3)	70 (3)	159 (3)	23 (3)	13 (3)	5 (3)	3 (3)	6 (3)	4 (3)	3 (3)	1 (3)	3 (3)
Survey116	122 (3)	1657 (3)	5026 (3)	2072 (3)	461 (3)	524 (3)	476 (3)	29 (3)	31 (3)	9 (3)	2 (3)	36 (3)	7 (3)	10 (3)	4 (3)	4 (3)
Survey117	274 (2)	1955 (3)	2299 (3)	2841 (3)	552 (3)	367 (3)	361 (3)	85 (3)	44 (3)	8 (3)	4 (3)	69 (3)	15 (3)	9 (3)	9 (3)	7 (3)
Survey118	89 (2)	1441 (3)	1272 (3)	2084 (3)	465 (3)	221 (3)	226 (3)	225 (3)	96 (3)	35 (3)	15 (3)	203 (3)	21 (3)	25 (3)	42 (3)	7 (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
Survey113	17 (1)				63 (2)	4 (3)	4 (3)	18 (3)	180 (3)	33 (3)	32 (3)	17 (3)	31 (3)	285 (3)	44 (3)
Survey114	4 (2)	56 (1)	4 (1)	180 (1)	24 (2)	4 (3)	6 (3)	25 (3)	105 (3)	21 (3)	14 (3)	9 (3)	89 (3)	591 (3)	80 (3)
Survey115	3 (3)	20 (2)	3 (2)	38 (2)	31 (3)	7 (3)	6 (3)	32 (3)	118 (3)	14 (3)	16 (3)	24 (3)	71 (3)	485 (3)	63 (3)
Survey116	1 (3)	30 (3)	3 (3)	32 (3)	48 (3)	15 (3)	7 (3)	64 (3)	185 (3)	15 (3)	24 (3)	27 (3)	109 (3)	304 (3)	56 (3)
Survey117	2 (3)	46 (3)	6 (3)	20 (3)	31 (3)	16 (3)	9 (3)	55 (3)	113 (3)	32 (3)	80 (3)	75 (3)	46 (3)	86 (3)	52 (3)
Survey118	4 (3)	92 (3)	19 (3)	50 (3)	25 (3)	47 (3)	27 (3)	105 (3)	99 (3)	133 (3)	148 (3)	178 (3)	90 (3)	111 (3)	141 (3)

	Inner Harbour							Bedford Basin								
	D3	EE1	EE2	EE3	E1	E2	E3	F1	F2	F3	DYC	G2	H1	H2	H3	BYC
Survey113	10 (3)	896 (3)	172 (3)	257 (3)	243 (3)	1003 (3)	868 (3)	80 (3)	159 (3)	261 (3)	49 (3)	39 (3)	43 (3)	28 (3)	85 (3)	4 (3)
Survey114	31 (3)	1008 (3)	190 (3)	320 (3)	235 (3)	901 (3)	463 (3)	47 (3)	146 (3)	82 (3)	30 (3)	35 (3)	22 (3)	18 (3)	14 (3)	4 (3)
Survey115	46 (3)	941 (3)	91 (3)	104 (3)	684 (3)	1160 (3)	602 (3)	19 (3)	41 (3)	55 (3)	24 (3)	27 (3)	10 (3)	9 (3)	3 (3)	3 (3)
Survey116	80 (3)	1165 (3)	313 (3)	224 (3)	2200 (3)	1719 (3)	1143 (3)	39 (3)	125 (3)	54 (3)	31 (3)	46 (3)	6 (3)	21 (3)	4 (3)	4 (3)
Survey117	135 (2)	592 (3)	294 (3)	97 (3)	1045 (3)	918 (3)	779 (3)	40 (3)	102 (3)	41 (3)	29 (3)	35 (3)	8 (3)	35 (3)	14 (3)	5 (3)
Survey118	297 (2)	672 (3)	576 (3)	350 (3)	317 (3)	494 (3)	371 (3)	80 (3)	442 (3)	61 (3)	52 (3)	134 (3)	30 (3)	135 (3)	94 (3)	7 (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 has potential for toxic affects; 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 sample are excluded from the calculations.

Ammonia Nitrogen has consistently been present at levels that, on average, are around the detection limit of 0.05 mg/L. Overall, in this quarter, at 1 m 73.8 % of samples had detectable levels of ammonium and at 10 m 64.3 % of samples had detectable levels. This is relatively high. The mean values in the 1m sample, seem to show a trend of relatively uniform values in the Basin, a maximum value at E2 of E2, then a decrease to minimum values at B2 in the Outer Harbour. For all but one measurement the samples at B2 were below the 0.05 mg/L detection limit. The distribution of maximum values in the 10m samples is similar but the highest values tend to occur further up harbour. In general the week to week means do not vary greatly over the quarter. The exception is survey 114 (10 Oct 06) that had the quarterly minimum values with all but four samples below the detection limit. There was a relatively strong phytoplankton bloom during this survey (see the survey report). Overall, there does not appear to be a strong correlation between ammonia concentrations and meteorological events/oceanographic conditions, as is seen in the coliform data.

For the supplemental sample at Fairview Cove (survey 113, 26 Sep 06) the levels of ammonium were relatively high, 0.12 mg/L at 10 m and 0.33 mg/L at 1 m. This highest value is nearly 2 times greater than the maximum level measured in regular sampling during this quarter.

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

1m	B2	D2	EE2	E2	F2	G2	H2	mean	max
113 (26 Sep 06)	0.05	0.06	0.06	0.08	0.06	0.07	0.07	0.06	0.08
114 (10 Oct 06)	ND	ND	0.09	ND	ND	ND	ND	0.03	0.09
115 (24 Oct 06)	ND	0.12	0.11	0.12	0.1	0.11	0.11	0.10	0.12
116 (8 Nov 06)	ND	ND	0.18	0.08	0.08	0.07	0.07	0.08	0.18
117 (21 Nov 06)	ND	0.07	0.1	0.11	0.1	0.09	0.08	0.08	0.11
118 (5 Dec 06)	ND	0.08	0.09	0.12	0.12	0.12	0.11	0.10	0.12
mean	0.03	0.06	0.11	0.09	0.08	0.08	0.08	0.08	
max	0.05	0.12	0.18	0.12	0.12	0.12	0.11		0.18

10m	B2	D2	EE2	E2	F2	G2	H2	mean	max
113 (26 Sep 06)	ND	ND	ND	0.07	0.08	0.06	0.12	0.06	0.12
114 (10 Oct 06)	ND	ND	ND	ND	0.06	0.07	0.09	0.05	0.09
115 (24 Oct 06)	ND	ND	ND	0.09	0.12	0.12	0.12	0.08	0.12
116 (8 Nov 06)	ND	ND	0.08	0.06	0.07	0.05	0.06	0.05	0.08
117 (21 Nov 06)	ND	ND	0.06	0.09	0.09	0.07	0.07	0.06	0.09
118 (5 Dec 06)	ND	0.08	0.08	0.1	0.1	0.09	0.09	0.08	0.10
mean	0.03	0.03	0.05	0.07	0.09	0.08	0.09	0.06	
max	0.03	0.08	0.08	0.10	0.12	0.12	0.12		0.12

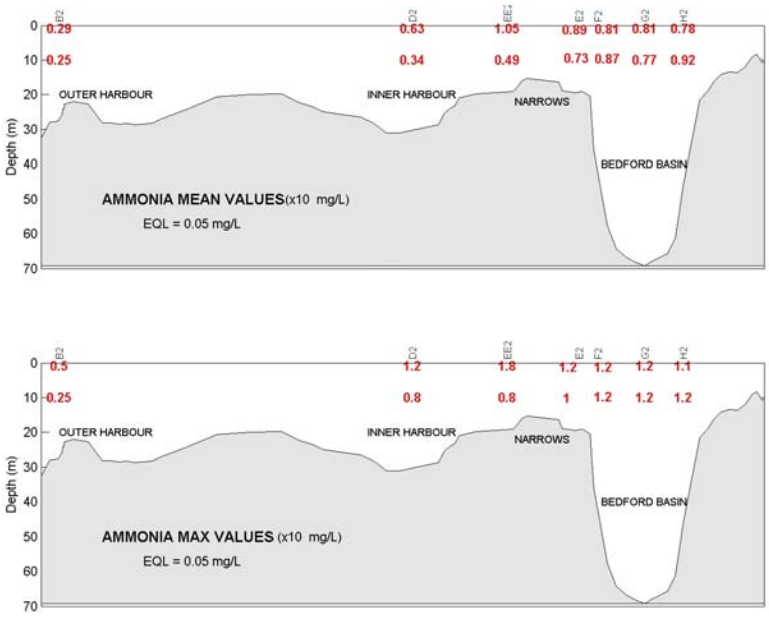

Figure 7. Mean and maximum value of ammonia nitrogen (X10 mg/L) over all tenth quarter samples

4.3 Carbonaceous Biochemical Oxygen Demand

Further to a recommendation in Quarterly Report 2, $CBOD_5$ analysis ceased on 25 May 2005, due to lack of detectable values. $CBOD_5$ analysis continues for supplemental samples, where there have been detectable values. This quarter there have been $CBOD_5$ measurements made for the supplemental sample in Fairview Cove (survey 113, 26 Sep 06) and at the regular sites F1 and F2 in surveys 116 (8 Nov 06) and 117 (21 Nov 06). There were no values above the detection limit.

4.4 Total Suspended Solids

A summary of the TSS values for this quarter is shown in Table 7. There were four samples that were below the RDL of 0.5 mg/L that occurred in survey 115 (24 Oct 2006). As with total nitrogen, for samples below the detection limit, a value of one half the RDL (0.25 mg/L) is used for statistical purposes. The quarterly mean and max values are plotted by station in Figure 8. This quarter's values ranged from 0.5-8 mg/L at 1 m and 0.5-5 mg/L at 10 m. Overall there does not appear to be a clear spatial pattern, except that the Outer Harbour tends to have somewhat lower values. For the most part the values are relatively low this quarter. The exception is survey 114 (10 Oct 06) that has significantly higher values. As discussed, this survey occurred during a relatively strong phytoplankton bloom. This is shown in the fluorescence data and seems to show up in the NH_3 as well (see survey report 114).

Table 7. TSS Summary (mg/L)
Note: green highlights indicate values below detection limits (1 mg/L); 0.5 mg/L was used for values below detection.

1m	B2	D2	EE2	E2	F2	G2	H2	mean	max
113 (26 Sep 06)	1.0	1.0	1.0	1.2	1.8	1.0	2.5	1.4	2.5
114 (10 Oct 06)	0.8	2.2	7	5	6.2	4.6	8	4.8	8.0
115 (24 Oct 06)	0.6	1.0	ND	1.0	1.0	1.8	1.6	1.1	1.8
116 (8 Nov 06)	0.9	1.0	1.0	1.0	2.5	2	4	1.8	4.0
117 (21 Nov 06)	1.8	1.2	2.2	1.9	2.2	1.1	1.8	1.7	2.2
118 (5 Dec 06)	1	2	3	2	1	2	1	1.7	3.0
mean	1.0	1.4	2.4	2.0	2.5	2.1	3.2	2.1	
max	1.8	2.2	7.0	5.0	6.2	4.6	8.0		8.0

10m	B2	D2	EE2	E2	F2	G2	H2	mean	max
113(26 Sep 06)	0.8	1.9	1	3.1	0.8	3.8	1.3	1.8	3.8
114 (10 Oct 06)	1	4	4	2.9	5	4	2	3.3	5.0
115 (24 Oct 06)	ND	ND	1	3	0.7	ND	2	1.2	3.0
116 (8 Nov 06)	0.8	1	1.2	1.4	1	2.1	4	1.6	4.0
117 (21 Nov 06)	1.8	1.2	2.6	3.1	1.1	1.5	1.2	1.8	3.1
118 (5 Dec 06)	1.2	1.4	1	1	2.1	1.1	2	1.4	2.1
mean	1.02	1.67	1.80	2.42	1.78	2.17	2.1	1.8	
max	1.8	4.0	4.0	3.1	5.0	4.0	4.0		5.0

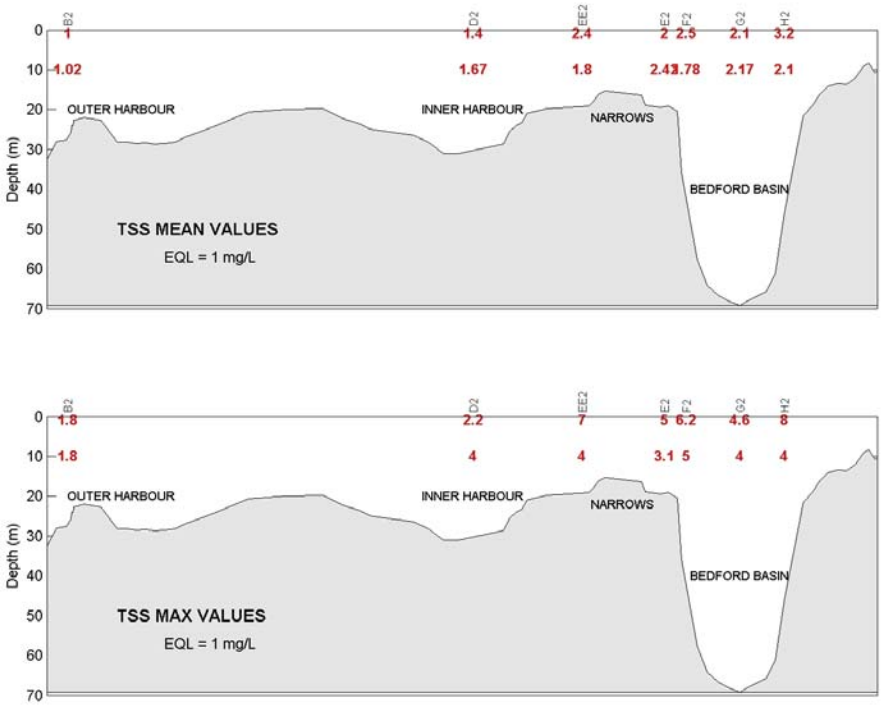

Figure 8. Mean and maximum values of total suspended solids (mg/L) over all tenth quarter samples.

4.5 Total Oils and Grease

Based on recommendations in Quarterly Report 5 regular sampling for total oil and grease was discontinued on 23 November 2005 (survey 75). The analysis is retained for supplemental samples. The supplemental sample in this quarter had non detectable levels (<5.0 mg/L) of total oil and grease.

4.6 Metals

As discussed in Section 3.1, a high resolution metals analysis began on survey 111. Therefore, this is the first quarter with high resolution metals data for the whole quarter.

The results of this are summarized in Figure 9. For this plot the non-detectable values are considered zero. This 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 and mercury were 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. There were no guideline exceedances observed. The metal regularly closest to the exceedance level is copper with a mean value just under 25% of the guideline.

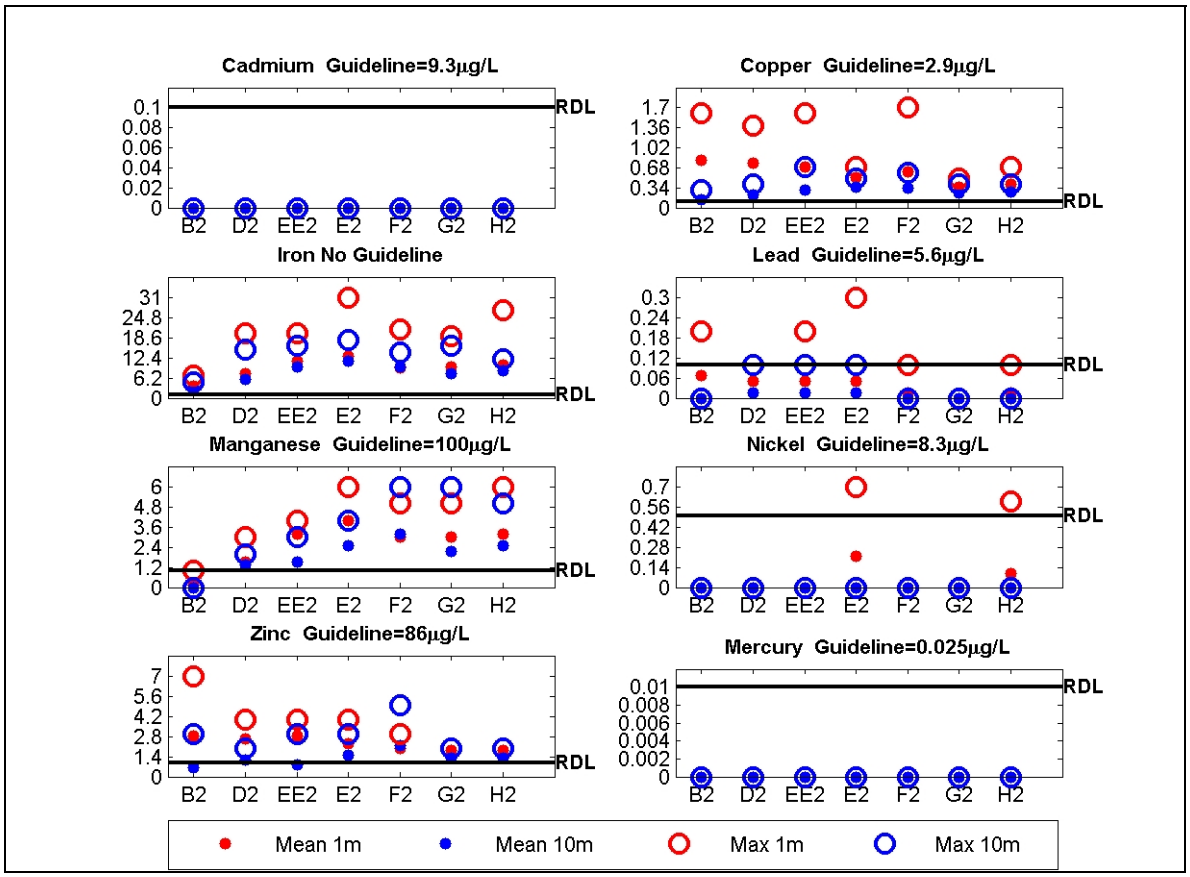

Figure 9. Summary of metals observations.

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 timeseries contour plots so this comparison is no longer feasible. However, the contour plots of profile timeseries are useful in visualizing the longer term variation in the state of the harbour. These plots will be continued in the annual summary section of every fourth quarterly report (i.e., 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 timeseries, 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 the fluorescence levels were generally low decreasing by the end of the quarter to annual minimum values (1-2 mg/m^3). The major exception is a relatively intense bloom (fall bloom?) documented in survey 114 (10 Oct 06). The maximum observed fluorescence level was 54 mg/m^3. This event seems to be reflected in other data sets (e.g. NH_3, TSS and DO).

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 is used to adjust their profile data. As discussed previously (Section 2.0) the data presentation that has been used for instrument comparison has been discontinued by BBPMP. However plots of the weekly profile data are still available. 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, often at a different time of day, so direct correspondence is not to be expected.

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

Survey	HHWQMP, site G2 (mg/L)		BBPMP (mg/L)		Ratio (BBPMP/HHWQMP)	
Number	1m	10m	1m	10m	1m	10m
113(26 Sep 06)	5.9	4.70	6.0	4.7	1.02	1.00
114(10 Oct 06)	8.7	6.60	9.1	7.0	1.05	1.06
115(24 Oct 06)	6.3	5.30	6.7	5.4	1.07	1.02
116(8 Nov 06)	6.3	5.20	6.9	5.6	1.09	1.07
117(21 Nov 06)	6.6	6.20	7.4	6.4	1.13	1.04
118 (5 Dec 06)	7	6.20	7.9	6.7	1.12	1.08

The data is generally comparable, given the uncertainties including the differences in time and location. The HHWQMP data on average is slightly lower than the BBPMP data, a trend that may be increasing toward the end of the quarter.

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. Throughout most of this quarter the dissolved oxygen measurements indicate levels below applicable guidelines in much or all of the Harbour. In the Inner Harbour (class SC) the 6.0 mg/L guideline is never exceeded over the entire water column. By the end of the quarter the DO is relatively uniform throughout the harbour at 6-7 mg/L. This is below guidelines in all SA and SB areas, but nowhere in the class SC area. An exception to the low values occurs in the near surface waters of the Basin on survey 114. Here the DO is relatively high (about 9 mg/L). This feature corresponds to high fluorescence values.

4.8 Supplemental Samples

Fairview Cove

During this quarter there was one supplemental sample (survey 113, 26 Sep 06) taken in the visible plume from the Fairview Cove combined sewer overflow (Figure 10). Fairview Cove is quite sheltered and has very low tidal currents. The sample was taken at 15:10, the tide was close to low and the wind was approximately 20 km/hr out of the west (approximately along shore). The plume was very visible, with turbid water and visible detritus and flocculated particulates (Figure 11). The plume followed the wharf front and was sampled at a site (44° 39.970' N, 63°' 37.753' W) about 200m along the wharf front (NNE) from the outfall (Figure 12). Field notes indicate that there was visible detritus in the water at this site. Both 1 and 10m samples were taken and were analyzed for a full suite of parameters.

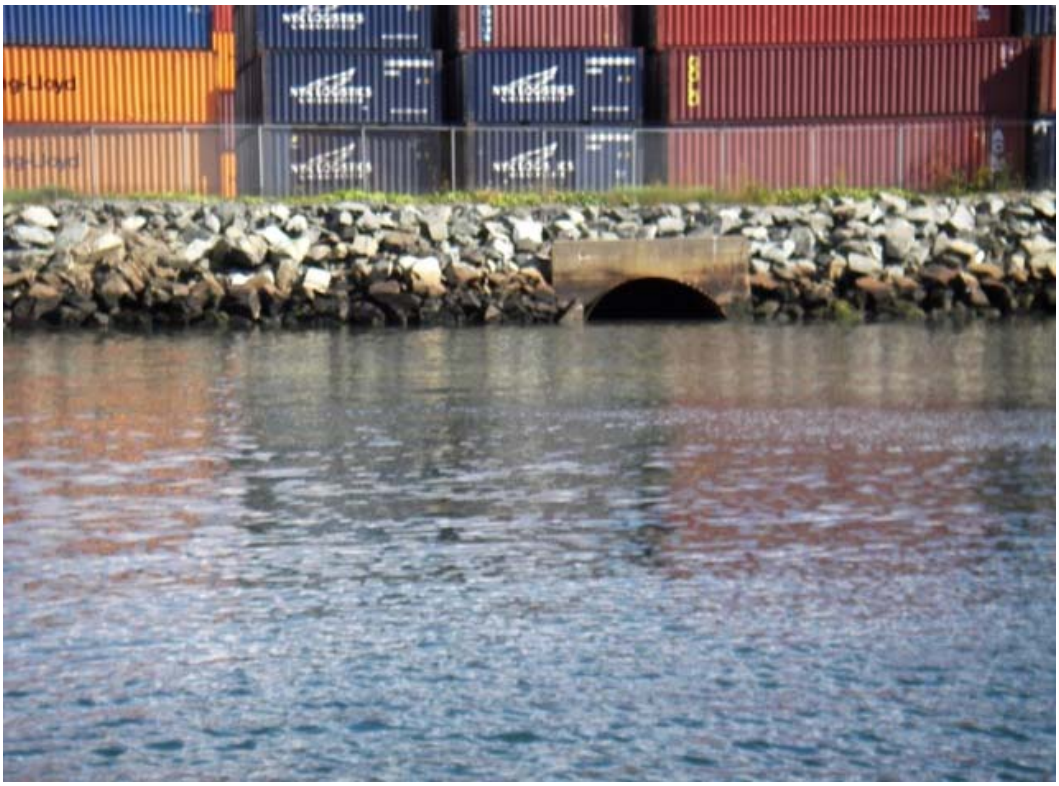

Figure 10. Fairview Cove combined sewer overflow (CSO)

Figure 11. Turbid water off Fairview Cove CSO.

Figure 12. View from sample site toward Fairview Cove CSO.

The results of the lab analysis are presented in Table 9. The most striking values are FC (13,000 cfu/100 mL) and NH_3 (0.33 mg/L) in the 1m sample. These are significantly higher than values normally measured in the regular surveys but not as high as some supplemental values. The NH_3 value is almost twice as high as any regular value measured in this quarter. The 10m samples have values that are elevated but not particularly notable. Somewhat surprising given the visual observations is that the TSS levels are relatively low (2.3 mg/L at 1 m and 2.0 mg/L at 10 m). The suggestion is that relatively large sized sewage related detritus (much appears to be tissue paper) is concentrated in the very surface water. There are three metals with detectable concentrations (copper, manganese and zinc). The copper concentration is in the range of the maximums measured at the regular sample sites, while the manganese and zinc levels are typical. For all detectable parameters the water quality in the 1m sample is reduced over the 10m sample. There are no guideline exceedances.

Table 9. Supplemental sample lab results.

	UNITS	1m	10m	RDL
BACTERIA				
Fecal Coliform	CFU/100mL	13000	15	10
INORGANICS				
Carbonaceous BOD	mg/L	ND	ND	5
Nitrogen (Ammonia Nitrogen)	mg/L	0.33	0.12	0.05
Total Suspended Solids	mg/L	2.3	2	0.5
OIL & GREASE				
Total Oil & Grease	mg/L	ND	NA	5
METALS WITH GUIDELINES				
Cadmium (Cd)	ug/L	ND	ND	0.1
Copper (Cu)	ug/L	1.3	0.4	0.1
Lead (Pb)	ug/L	ND	ND	0.1
Manganese (Mn)	ug/L	3	1	1
Mercury (Hg)	ug/L	ND	ND	0.01
Nickel (Ni)	ug/L	ND	ND	0.5
Zinc (Zn)	ug/L	2	1	1
METALS WITH NO GUIDELINES				
Cobalt (Co)	ug/L	ND	ND	0.1
Iron (Fe)	ug/L	13	9	1

Additional Individual Samples

There were several additional individual samples taken during the quarter. Additional fecal coliform samples were taken near the Mill Cove Sewage Treatment Plant in Bedford, during survey 113 (26 Sep 06). These were at the site of a sediment sample taken by a research team from Dalhousie University that was on board that day. Also station F1 and F2 were sampled for $CBOD_5$ in surveys 116 (8 Nov 06) and 117 (21 Nov 06). These were investigating the effect of the temporary sewage diversion from Duffus St, to Fairview Cove.

The Mill Cove site was located very approximately 200m NE from the Mill Cove outfall at 44° 43.009' N, 63° 40.125’ W. The FC levels were not detectable at the 10 cfu/100 mL detection limit for the analysis sensitivity used.

The $CBOD_5$ analysis for the F1 and F2 sites had no detectable values at the 5 mg/L detection limit.

5 Summary

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

5.1 Reporting

Survey Reports

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

Changes

– The "section" plots in the survey reports now include an HP section to reflect the addition of the HP sites.

Quarterly Reports

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

Changes

– None

5.2 Sampling Program

Sampling continues as per the end of the ninth quarter. There is a potential bias being introduced in the NW Arm based on selection of sampling routes (see Quarterly Report 9).

Changes

– Three additional "coliform" sites (HP1, HP2 and HP3) were added to the sampling program as of Survey 114 (10 Oct 06). These sites are in the vicinity of the planned Sewage Treatment Plant at Hospital Point (Figure 1).

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 and raise levels everywhere. Both of these mechanisms often act together. The ongoing diversion of sewage from the Duffus St. Outfall to the Fairview Cove Combined Sewer Overflow seems to be shifting the area normally affected by high bacteria concentrations northward. The relatively familiar pattern of higher bacteria levels in the 10m samples in the Basin and in the 1m samples south of the Narrows appears mostly unaffected, except at F1, the nearest site to Fairview Cove, where this pattern is reversed. With respect to compliance with Task Force guidelines the most numerous exceedances are in the class SB rated areas adjacent to the Inner Harbour. That is, to the north, the southern Basin (section F) and to the south, Black Rock Beach and section C. There are also periodic guideline exceedances in the Northwest Arm, dependent on the trajectory of the plume from the Chain Rock outfall in Point Pleasant Park and local affects of various storm overflows along the Arm.

The existing variable sample resolution scheme resulted several out-of-range values in this quarter. These all occurred in one survey and were likely the result of unusual conditions that caused high values throughout the Inner Harbour and NW Arm. The lab resolution has been left unchanged.

Changes
- None

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

Ammonia Nitrogen

Ammonia nitrogen has consistently been present at levels that are at or slightly above the detection limit of 0.05 mg/L. Overall, in this quarter, at 1 m 73.8 % of samples had detectable levels of ammonia and at 10 m 64.3 % of samples had detectable levels. The mean values tend to be slightly higher in the Inner Harbour, relatively uniform in the Basin and lowest in the Outer Harbour. The mean value throughout the harbour through the quarter is about 0.07 mg/L, with a single maximum value of 0.18 mg/L. The supplemental sample (section 4.8) taken in a visible sewage plume had an ammonia level (0.33 mg/L) almost twice as high as the maximum value measured at regular sample sites.

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 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.

For the $CBOD_5$ analysis performed in this quarter, i.e. the supplemental sample in survey 113 (26 Sep 06), F1 and F2 in surveys 116 (8 Nov 06) and 117 (21 Nov 06), the levels were below the 5 mg/L detection limit.

Changes
– None

Total Suspended Solids

The TSS values in the harbour are generally moderate with no obvious strong correlation in space or time with oceanographic or sewage loading conditions. There are occasional higher values that seem to be associated with more extreme events (e.g. storms, plankton blooms etc). These events are generally identifiable visibly and are usually documented in field notes. This quarter the levels were quite low and uniform with mean values of about 2.0 mg/L. The exception was survey 114. This survey was associated with increased fluorescence and had mean TSS values about twice as high as the overall survey means.

Changes
– None

Total Oils and Grease

Based on recommendations in Quarterly Report 5, total oils and grease was dropped from regular analysis on 23 November 2005 (survey 75) due to lack of detection. It is retained in supplemental sample analysis. The supplemental sample at Fairview Cove (survey 113) was analyzed for Total Oil and Grease and had non-detectable levels.

Changes

– None

Metals

Starting in survey 111 (29 Aug 06) a higher resolution metals analysis was instituted. This is the first quarter that this has been in place for the whole quarter. The results indicate that the analysis will give allow good quantification of several metals for which guidelines exist (copper, manganese, zinc and lead). The analysis will also allow evaluation of guideline compliance for cadmium, nickel and mercury, though these metals are seldom present in detectable concentrations. There have been no guideline exceedances documented. The metal that is regularly closest to exceedance is copper with mean values that approach 25% of the guideline.

Changes
– None

Fluorescence

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

During this quarter the fluorescence generally dropped to near background levels (1-2 mg/L). The exception was survey 114 (10 Oct 06) where an apparent phytoplankton bloom (fall bloom) had values as high as 54 mg/m^3 in the Basin.

Changes
- None

Dissolved Oxygen

To date, oxygen levels as measured in the program, are generally relatively high in surface waters, and chronically low in the deep water of Bedford Basin. This is consistent with the existing understanding that Bedford Basin is a fjord, in which depressed oxygen in bottom water is typical. This quarter, the data indicated widespread guideline exceedance throughout much of the Harbour. The class SC guideline (6.0 mg/L) in the Inner Harbour was never exceeded throughout the water column. There are continuing issues of DO sensor calibration/ground truth (Section 4.7.3). This quarter comparison with the ground truthed BBPMP DO data indicates very good correspondence.

Changes
– None

6 References

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