Halifax Harbour
Water Quality Monitoring Program
Quarterly Report #6

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PREFACE

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

The weekly data sets are reviewed on a quarterly basis (13 weeks). The main objective of the quarterly reports is to summarize and evaluate the weekly data sets in terms of water quality objectives and concerns. The quarterly report also provides an opportunity to review the effectiveness of various aspects of the program and recommend changes that will improve the program. Project reports 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 20 Sep 05 to 13 Dec 05 (weekly reports 66 to 78). 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. In this report, the data from the center of Bedford Basin (Station G2) is also compared with data collected at a nearby site by the Bedford Basin Phytoplankton Monitoring Program (BBPMP), a project of scientists with the Department of Fisheries and Oceans at Bedford Institute of Oceanography. This report discusses just the sixth quarter. Every fourth quarterly report includes an annual summary of data and trends over the previous four quarters. In the interest of making the quarterly reports useful as a stand alone document there is a significant amount of repetition of background information among the quarterly reports.

2 Weekly Reporting

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

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

3 Sampling Program

Survey sampling is conducted on a weekly basis from one of several vessels based at the Armdale Yacht Club (AYC). The details of the sampling program are discussed in the introduction section of the project report binder and QR#1. The locations of the 34 regular sampling sites are included for reference in Figure 1. Sampling involves the collection of continuous profile data and discrete water samples at 1 and 10m water depth. The level of analysis varies from site to site: CTD only (CTD only sites); CTD and coliform bacteria (Coliform stations); or CTD, Bacteria, and additional contaminant analysis (Coliform & Chemistry stations). The additional sampling at the Chem sites occurs on a bi-weekly basis. In addition to the regular sites, Figure 1 includes a sample site in Dartmouth Cove, established in response to public concern. At this site, a 1m

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. A summary of the sampling and analysis schedules and relevant established criteria in place at the end of quarter six (13 Dec 05) are in Table 1. There have been changes to the sampling for total oil and grease (TOG), total suspended solids (TSS) and the metal scan this quarter. These changes are discussed in the appropriate sections below. This table indicates that there are several analyses, including TOG and metals, which are now performed only for "supplemental samples". 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. During this quarter, there were no supplemental samples taken. The laboratory analysis on supplementary samples is made possible using funds saved from missed samples during the regular program. During this quarter, there were two missed Chem stations (at both 1 and 10m depths), for a total of four samples, and eight missed bacteria stations (1 and 10m depths), for a total of sixteen missed bacterial samples. These stations were missed due to environmental conditions or conflicting harbour activities (e.g. diving operations). The specifics of the missed stations are described in the weekly reports.

3.1 Sampling Order

Sampling generally occurs on Tuesday, with Wednesday and Thursday as contingency days. Every week the sampling order is varied to minimize biasing the collected data with respect to known diurnal variations in sewage load and sunlight. A variable circuit is used that results in 'quasi' random sampling, subject to certain operational constraints. This procedure is discussed in QR#1. The sampling order for each week in the sixth quarter is presented in Table 2.

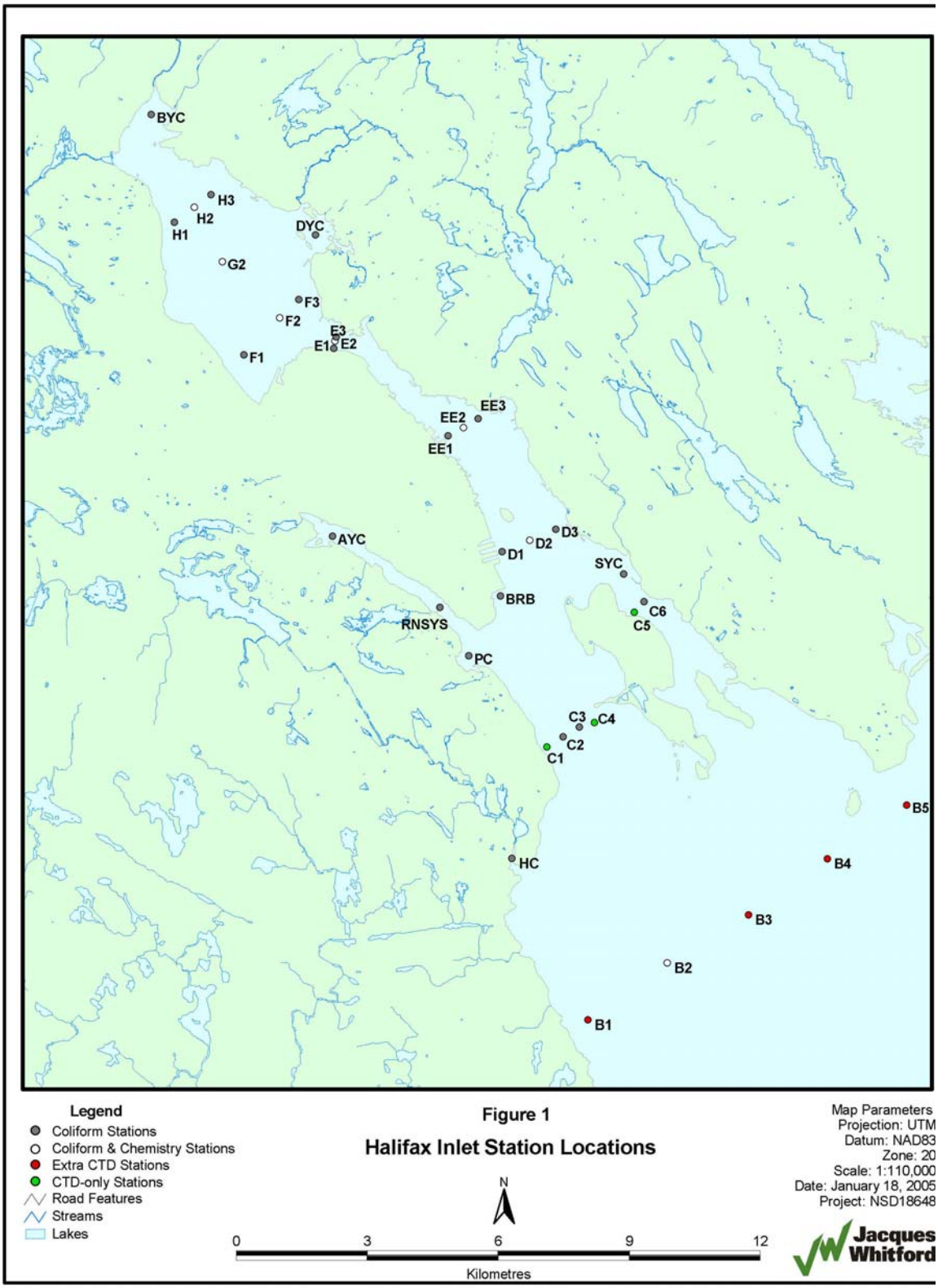

Figure 1. Halifax Inlet Sample Locations

Table 1. Summary of measured parameters as of 13 Dec 05.

	EQL		Harbour Task Force Guideline	Water Use Category	Sampling Stations (refer to Fig. 1)	Sampling frequency
	value	units				
Profile Data					All	weekly
Salinity	n/a	PSU	n/a	n/a		
Temperature	n/a	C°	n/a	n/a		
Chlorophyll *a*	n/a	ug/L	n/a	n/a		
			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	weekly
Fecal Coliform	0	cfu/ 100mL	14 200	SA SB		
Chemical Samples						
CBOD	5	mg/L	none		Supplemental sites	unscheduled
Ammonia Nitrogen	0.05	mg/L	none		Chemical sites	bi-weekly
TSS	2.0	mg/L	<10% background	all	Chemical sites	bi-weekly
Total Oil and Grease	5	mg/L	10	all	Supplemental sites	unscheduled
Metal scan					Supplemental sites	unscheduled
Cadmium	3	ug/L	9.3	all		
Chromium	20	ug/L	50.0	all		
Copper	20	ug/L	2.9	all		
Lead	5	ug/L	5.6	all		
Manganese	20	ug/L	100.0	all		
Nickel	20	ug/L	8.3	all		
Zinc	50	ug/L	86.0	all		
Aluminum	100	ug/L	none			
Antimony	20	ug/L	none			
Arsenic	20	ug/L	none			
Barium	50	ug/L	none			
Beryllium	20	ug/L	none			
Bismuth	20	ug/L	none			
Boron	500	ug/L	none			
Cobalt	10	ug/L	none			
Lithium	20	ug/L	none			
Iron	500	ug/L	none			
Molybdenum	20	ug/L	none			
Selenium	50	ug/L	none			
Strontium	50	ug/L	none			
Thallium	1	ug/L	none			
Tin	20	ug/L	none			
Titanium	20	ug/L	none			
Uranium	1	ug/L	none			
Vanadium	20	ug/L	none			

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

Date	20-Sep-05	28-Sep-05	5-Oct-05	11-Oct-05	18-Oct-05	27-Oct-05	2-Nov-05	9-Nov-05	15-Nov-	23-Nov-	29-Nov-	6-Dec-05	13-Dec-05
Survey	66	67	68	69	70	71	72	73	74	75	76	77	78
1	AYC	SYC	AYC	HC	C4	AYC	BRB	HC	AYC	RNSYS	AYC	C2	BRB
2	RNSYS	C6	RNSYS	B2	B2	RNSYS	C2	B2	RNSYS	PC	RNSYS	C1	D1
3	PC	C5	PC	C1	C5	PC	C1	C3	PC	C1	PC	HC	D2
4	HC	C4	C1	C2	C6	C1	HC	C4	BRB	C2	BRB	B2	EE2
5	B2	C3	C2	C3	SYC	C2	C3	C5	D1	BRB	D1	C3	EE1
6	C3	B2	BRB	C4	D3	BRB	C4	C6	D2	D1	D2	C4	E2
7	C4	HC	D1	PC	EE3	D1	SYC	SYC	EE2	EE1	EE2	C5	E1
8	EE3	C1	D2	RNSYS	E3	EE1	C5	D3	EE1	E1	EE1	C6	F2
9	E3	C2	EE2	AYC	F3	E1	C6	D2	E2	F1	E2	SYC	F1
10	E2	PC	EE1	BRB	DYC	F1	D2	EE3	E1	G2	E1	D3	G2
11	F2	RNSYS	E2	D1	H3	G2	D3	EE2	F2	H1	F2	EE3	H1
12	F3	AYC	E1	D2	BYC	H1	EE2	E3	F1	BYC	F1	E3	H2
13	DYC	BRB	F2	EE2	H2	BYC	EE3	E2	G2	H2	G2	F3	BYC
14	G2	D1	F1	EE1	H1	H2	E3	F2	H1	H3	H1	DYC	H3
15	H3	D2	G2	E1	G2	H3	E2	F3	H2	DYC	H2	H3	DYC
16	H2	EE2	H1	E2	F1	DYC	F2	DYC	BYC	F3	BYC	BYC	F3
17	BYC	EE1	H2	F2	F2	F3	F1	H3	H3	F2	H3	H2	E3
18	H1	E2	BYC	F1	E1	F2	G2	H2	DYC	E2	DYC	H1	D3
19	F1	E1	H3	G2	E2	E3	H1	BYC	F3	E3	F3	G2	SYC
20	E1	F2	DYC	H1	EE1	E2	BYC	H1	E3	EE2	E3	F1	C6
21	EE2	F1	F3	H2	EE2	EE2	H2	G2	EE3	EE3	EE3	F2	C5
22	EE1	G2	E3	BYC	D2	EE3	DYC	F1	D3	D2	D3	E1	C4
23	D1	BYC	EE3	H3	D1	D2	H3	E1	SYC	D3	SYC	E2	C3
24	BRB	H1	D3	DYC	BRB	D3	F3	EE1	C6	SYC	C6	EE1	C1
25	D2	H2	SYC	F3	C2	SYC	E1	D1	C5	C6	C5	EE2	C2
26	D3	H3	C6	E3	C3	C6	EE1	BRB	C4	C5	C4	D2	PC
27	SYC	DYC	C5	EE3	C1	C5	D1	C2	C3	AYC	C3	D1	RNSYS
28	C6	F3	C4	D3	PC	C4	PC	C1	B2		B2	BRB	AYC
29	C5	E3	C3	SYC	RNSYS	C3	RNSYS	PC	HC		HC	PC	
30	C2	EE3	B2	C6	AYC			RNSYS	C1		C1	RNSYS	
31		DC	B1	C5				AYC	C2		C2	AYC	
32		D3	HC										

3.2 Sampling Bias

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

3.2.1 Time of Day

Sewage flows have significant regular diurnal variations, which can affect the water quality in the harbour on short timescales. In addition to variations in sewage load, the most obvious diurnal variation is in sunlight. Sunlight is perhaps the major contributor to the die off of bacteria, and can have effects on other parameters, particularly chlorophyll (fluorescence) and dissolved oxygen. The short term variation in sewage load is primarily an issue in the Inner Harbour, relatively close to the outfalls, while sunlight affects the entire Harbour. 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 sixth quarter are shown in red. In this figure the sample sites are generally sorted from north to south. There are a few patterns which emerge. The stations at the north end of Bedford Basin have a smaller range of sampling times. This is because logistics dictates that the surveys never start or end in the Basin. In general, the range of sampling times increases with distance south. This is a function of travel time from the Armdale Yacht club in the Northwest Arm. Even if a site is sampled first, it still takes time to travel there. Given that sampling begins at the same time every week, these effects are unavoidable. Given the necessary operational constraints, the sampling scheme has resulted in a reasonably uniform distribution in the Inner Harbour (Section D through Section E), where diurnal fluctuations would likely be greatest

The diagram also indicates that there is an early morning bias in the Outer Harbour Stations, a result of weather considerations. Each week, a primary and an alternate sampling route are provided to the field team. If the primary route has the Outer Harbour sampled early in the day, the alternate route will have it sampled late in the program. The decision on which route to take is made between the field team and the boat operator considering the weather forecast for the day. Wind, waves and visibility can limit operations in the Outer Harbour and since the wind and wave conditions tend to be worse in the afternoon, a morning bias is introduced. The diurnal variations in conditions in the Outer Harbour are expected to be the least of any harbour region, so this bias is less significant. In this quarter (red dots) the only apparent addition to the bias is this early

morning bias in the Outer Harbour, There is only one instance where sites B2 and HC were sampled after noon. This is likely a result of increasing wind conditions in late Fall restricting operations in the Outer Harbour.

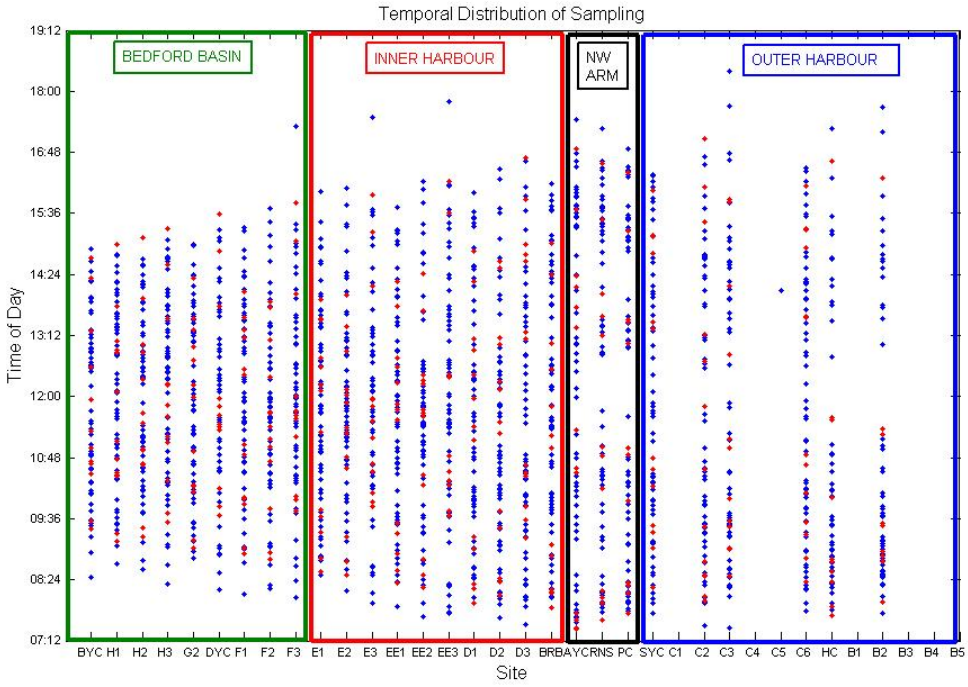

Figure 2. Temporal sampling distribution by site over entire program. Red markers denote points from this quarter.

3.2.2 Water Levels

The water level at the time of sampling can affect the results. The two most obvious effects are expected to be whether a particular sample was taken upstream or downstream (based on 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.

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

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

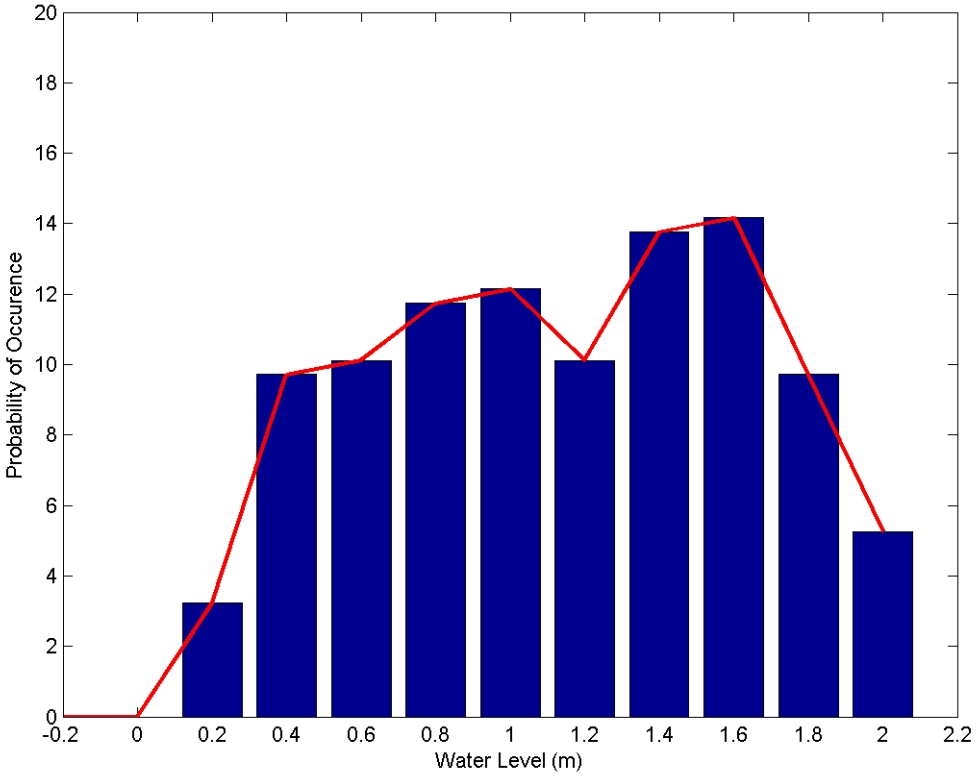

Figure 3. Probability distribution of water levels in Halifax, September 2005 to December 2005.

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, derived above (red line). The sampling distributions show that a relatively full range of water levels has been sampled at each site. The higher water levels appear to be over-sampled in Bedford Basin. This bias disappears south of the Narrows (E section). Here some stations exhibit minor high or low bias but most are relatively well sampled. The water level bias in the the Basin, which is opposite from last quarter, is unlikely an issue as tidal currents in the Basin are very low (i.e. tidal excursions are small) and there are no large shallow water outfalls. The exception to this is the Fairview Cove Combined Sewer Overflow (CSO) which flows during large storms.

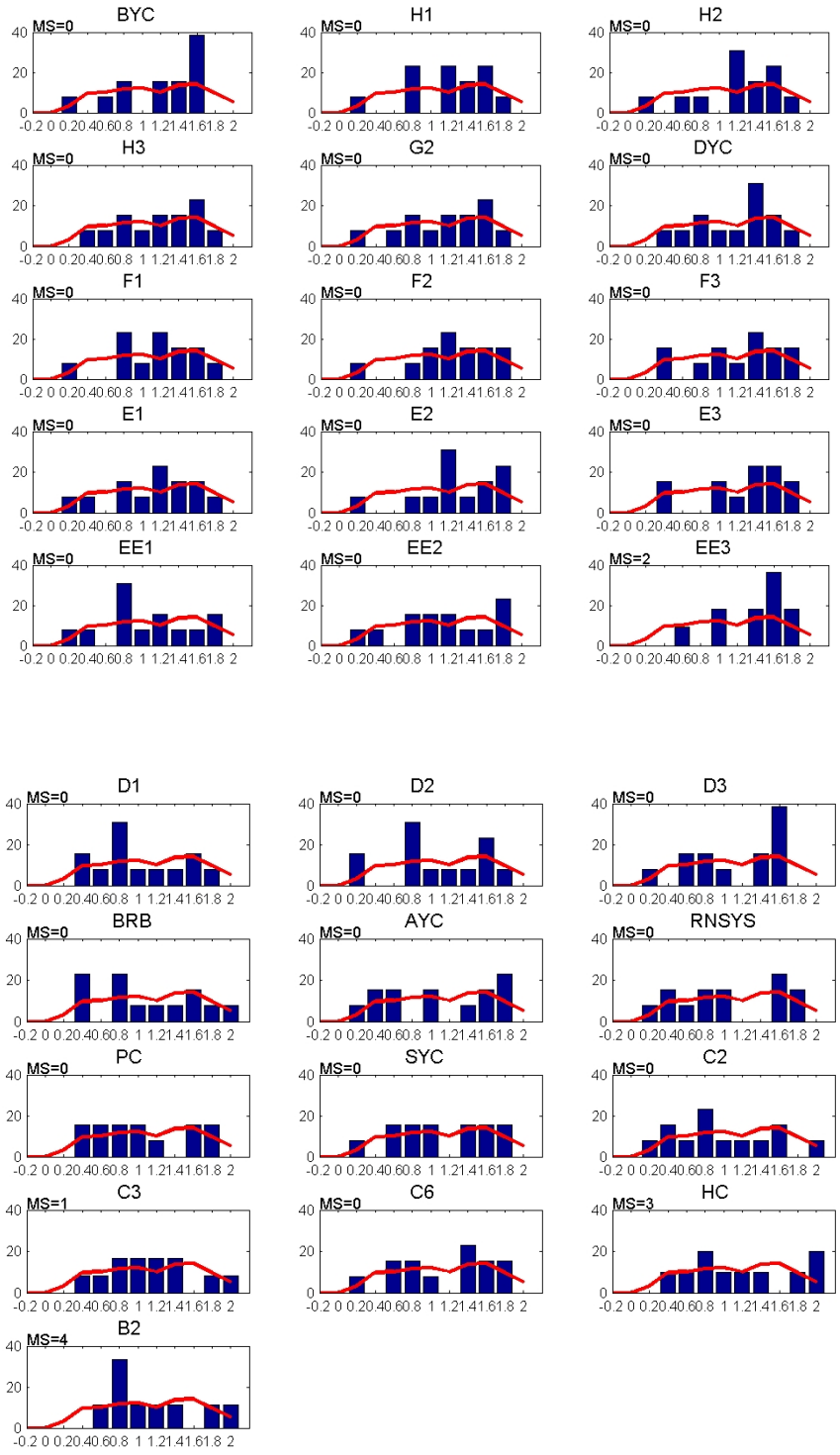

Figure 4. Water level distribution at each site during sampling 20 September 2005 to 13 December 2005. Note: MS = Missed samples

3.2.3 Precipitation

Rainfall affects both the sewage loads and the dynamics of the Harbour. Following a rain event, effluent flow increases in a combined sewage system; collected material in the sewage pipes can be flushed; and the Harbour, in response to the increased fresh water input, can become more stratified, enhancing estuarine circulation. The combination of increased flow and stratification can have a great effect on the near field behaviour of the plumes from the outfalls. These effects lag the rainfall by some time and persist for some period after the rain stops. The duration of the impact, of course, depends on the magnitude of the rain event and the condition of the watershed. For purposes of discussion we have, somewhat arbitrarily, selected a three day (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 the entire program period (23 June 04 to 13 December 05). The blue bars on this plot represent a similar analysis performed for sampling days only. The plot indicates that our sampling has been very representative with respect to precipitation. Over entire period about 47% of days had precipitation less than 5 mm in the 72 hour window. The sampling day distribution also includes 47% of these "dry days". On the other end, we also have a very good match as both distributions have about 3% of days with greater than 60 mm of precipitation in the 72 hour window.

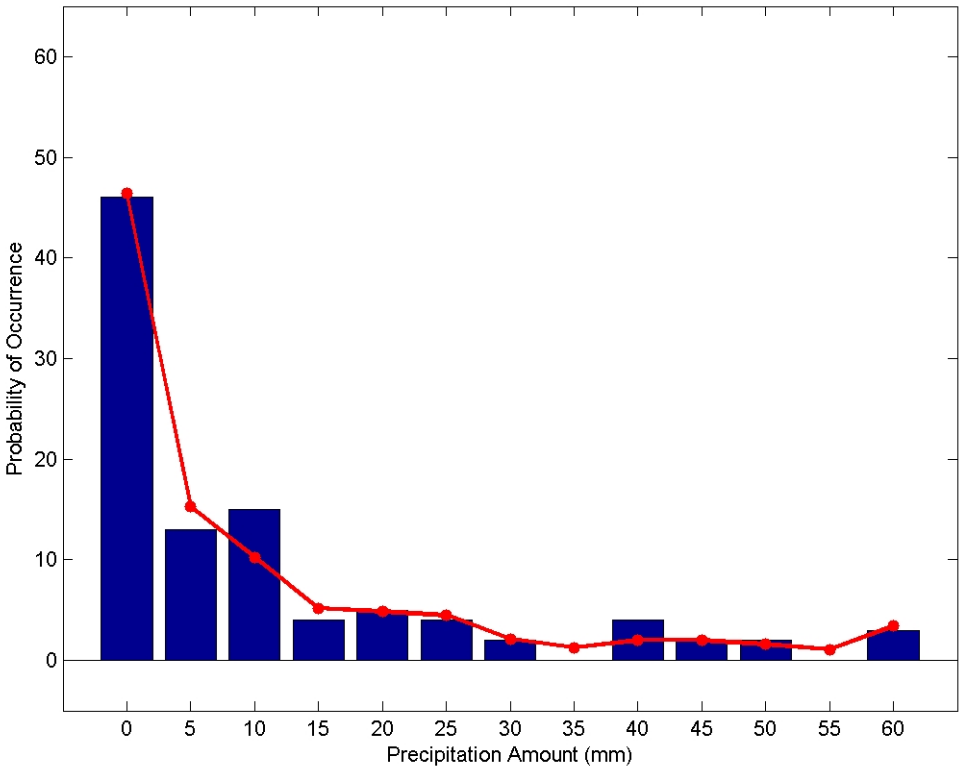

Figure 5. Probability distribution of cumulative 72 hour rainfall, June 2004 through December 2005

3.3 Program Changes

There have been three changes to the sample analysis suite this quarter: both the analysis for Total Oil and Grease and the metal scan were discontinued and the sample size for the TSS analysis was doubled to reduce the EQL to 1 mg/L. All three changes were instituted on the 23 Nov Survey (Survey #75). The original sampling procedure for Total Oil and Grease was modified previously (week 47, 10 May 05) to a surface sample, due to lack of detection. Since that time there had still been no detectable values, so based on the QR#4 recommendation, regular sampling of TOG was stopped. It is still measured in supplemental samples where unusual features are being sampled. Similarly, the detection of metals of interest using the specified metals scan has been quite low and inconclusive. Based on recommendations in QR#5 metals sampling has been suspended and approaches to acquire more appropriate metals data are being considered. There have consistently been TSS levels below the 2 mg/L detection limit. This will be remedied in large part by the 1 mg/L detection limit.

3.4 Supplemental Samples

Based on recommendations from QR#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 were no supplemental samples.

3.5 Sampling Protocol

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.

4 Water Quality Results and Discussion

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

4.1 Fecal Coliform

The Guidelines for Canadian Recreational Water Quality (GCRWQ) (Health and Welfare Canada 1992) evaluate the compliance with 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 (see Lab Resolution section below and in QR#1). For statistical purposes, these values are, relatively arbitrarily, replaced by 14,999. This is simply a number >10,000 which is easily identified.

Maps representing the geometric mean values over all samples for the sixth quarter are presented in Figure 6. In this figure, values in red exceed swimming guidelines (200 cfu/100 mL); values in blue exceed shellfishing guidelines (14 CFU/100 mL); and values in black indicate suitability for either activity. Separate maps are presented for the 1 and 10m samples. In the following discussion it is helpful to refer to the station map (Figure 1).

For both the 1m and 10m samples, the coliform values are high in the Inner Harbour. The maximum values in the 1m samples are in the EE section. The highest values in the 10m samples are in the E section but are relatively uniform between the EE and E sections. At any rate, this represents a displacement of the 10m distribution up harbour relative to the 1m distribution. South of the Narrows the maximum values at any site are in the 1m sample , while in the Narrows and North the highest values tend to be in the 10m sample. This relatively familiar distribution suggests a net "estuarine" flow with contaminated Inner Harbour water flowing in a lower layer into the Basin. In this quarter, mean values exceeding the swimming guidelines occur throughout the Inner Harbour , which is classified SC, with no bacteria guidelines, and extend into adjacent "class SB" areas of the southern Basin, the Outer Harbour and the Northwest Arm, where swimming levels are desired. Swimming levels are also exceeded in Herring Cove. Significantly, there were consistently detectable levels all the way out to site B2.

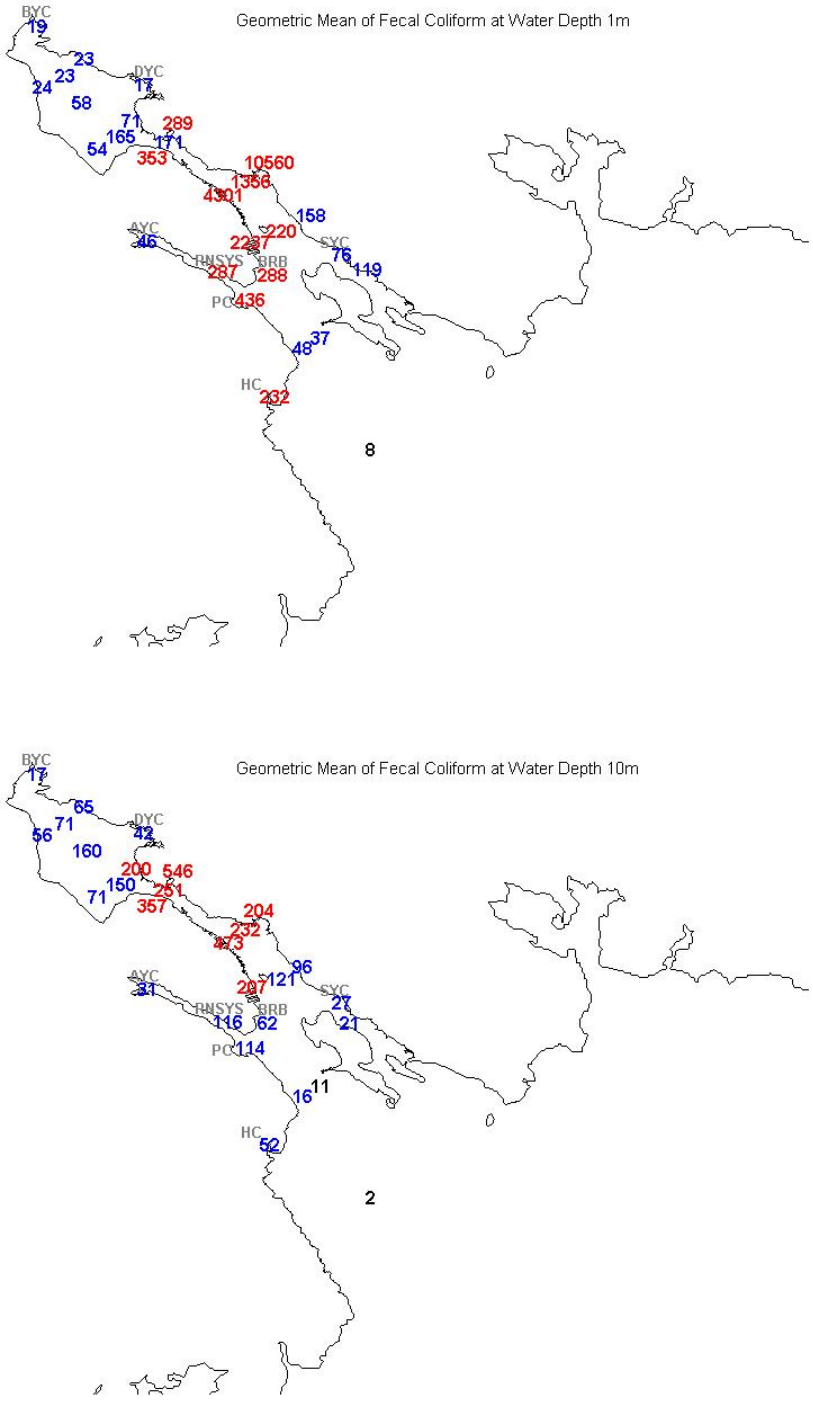

Figure 6. Fecal coliform geometric means (cfu/100mL), 20 September 05 to 13 December 05.

4.1.1 Guideline Exceedance

As presented in QR#1, the Harbour Task Force fecal coliform guidelines (Harbour Task Force, 1990) are interpreted using the methodology presented in the Guidelines for Canadian Recreational Water Quality (Health and Welfare Canada, 1992). The guidelines specify that in swimming areas, the geometric mean of at least five fecal coliform values taken within 30 days should not exceed 200 cfu/100mL, and any sample with values >400 cfu/100mL should trigger re-sampling. Our weekly sampling regime generally meets the criteria of five samples within 30 days.

Interpreting this procedure in our context results in a weekly assessment, at three levels:

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

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

As seen in the tables below, for this quarter, most of the surface water (1m) in the Inner Harbour would be deemed unacceptable for primary body contact most of the time. The distribution of sites with the highest fecal coliform counts reflects their proximity to major sewage outfalls: the EE section to the Peace Pavillion outfall, Historic Properties outfall, and many other smaller outfalls along the waterfront; site D1 to the Pier A outfall; and sites E1 and E3 to the Duffus St. and Tufts Cove outfalls, respectively. The mean values at 10m are often unacceptable, with a similar distribution to the shallower levels, but are somewhat lower values. As discussed above, in the Basin the situation is reversed. The distribution of higher values is similar at both depths, but the 10m values tend to be higher. For this quarter, there are quite a few sites outside the Inner Harbour with occurrences of unacceptable water quality. In fact, most sites experienced unacceptable levels at some time during the quarter. The only sites which did not were B2 in the Outer Harbour and the Northern Basin (H section and BYC) and DYC. Interestingly, consistent with the discussion of the quarterly means above, the bacterial quality at B2 was always acceptable using the swimming criteria. However, the levels at this site were non-negligible and if similar analysis were applied using the shellfishing limit (14 CFU/100 mL) the bacterial water quality would have been unacceptable almost half the time.

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

	Outer Harbour				Eastern Pass		Inner Harbour									
	B2	HC	C2	C3	C6	SYC	BRB	D1	D2	D3	EE1	EE2	EE3	E1	E2	E3
Survey66	2 (5)	97 (5)	2 (5)	1 (4)	62 (5)	19 (5)	56 (5)	264 (5)	21 (5)	8 (5)	2049 (5)	310 (5)	7185 (5)	768 (5)	133 (4)	485 (5)
Survey67	5 (5)	93 (5)	5 (5)	5 (5)	27 (5)	26 (5)	81 (5)	536 (5)	37 (5)	20 (5)	3377 (5)	235 (5)	7792 (5)	186 (5)	53 (4)	178 (5)
Survey68	5 (5)	123 (5)	8 (5)	10 (5)	13 (5)	8 (5)	102 (5)	723 (5)	123 (5)	25 (5)	1684 (5)	239 (5)	9953 (5)	212 (5)	124 (5)	124 (5)
Survey69	7 (5)	474 (5)	34 (5)	26 (5)	27 (5)	20 (5)	213 (5)	1427 (5)	145 (4)	50 (5)	1918 (5)	547 (5)	9234 (5)	94 (4)	200 (4)	118 (4)
Survey70	19 (5)	645 (5)	84 (5)	97 (5)	55 (5)	76 (5)	133 (5)	2217 (5)	156 (4)	86 (5)	1968 (5)	623 (5)	9907 (5)	130 (4)	137 (4)	69 (4)
Survey71	25 (4)	865 (4)	202 (5)	147 (5)	137 (5)	155 (5)	277 (5)	5240 (4)	362 (4)	273 (5)	5152 (5)	1155 (5)	6286 (5)	137 (4)	93 (4)	56 (4)
Survey72	12 (3)	608 (4)	112 (5)	46 (5)	119 (5)	110 (5)	311 (5)	5513 (3)	387 (4)	423 (5)	7629 (5)	3334 (5)	8593 (4)	791 (4)	582 (4)	310 (4)
Survey73	41 (2)	371 (4)	111 (5)	29 (5)	215 (5)	162 (5)	266 (5)	8933 (2)	296 (4)	838 (5)	8167 (5)	3792 (5)	6845 (3)	621 (4)	557 (4)	337 (4)
Survey74	35 (2)	136 (4)	109 (5)	33 (5)	178 (5)	149 (5)	258 (5)	29240 (2)	471 (5)	857 (5)	11488 (5)	4724 (5)	19390 (3)	544 (5)	439 (5)	294 (5)
Survey75	11 (1)	95 (3)	78 (5)	16 (4)	92 (5)	85 (5)	496 (5)	9721 (2)	549 (5)	777 (5)	13881 (5)	6024 (5)	51962 (2)	751 (5)	756 (4)	676 (5)
Survey76	10 (2)	141 (4)	87 (5)	32 (4)	110 (5)	87 (5)	621 (5)	11478 (3)	614 (4)	962 (4)	9010 (5)	6741 (5)	77460 (2)	545 (5)	557 (4)	732 (4)
Survey77	26 (3)	243 (4)	201 (5)	136 (4)	208 (5)	207 (5)	967 (5)	11356 (4)	1245 (4)	1190 (4)	8227 (5)	4968 (5)	47622 (3)	297 (5)	160 (4)	613 (4)
Survey78	26 (2)	354 (3)	477 (5)	578 (4)	263 (5)	245 (5)	1667 (5)	9599 (5)	3336 (4)	1541 (4)	6989 (5)	4523 (5)	47622 (3)	219 (5)	95 (4)	438 (4)

	Bedford Basin									Northwest Arm		
	F1	F2	F3	DYC	G2	H1	H2	H3	BYC	PC	RNSYS	AYC
Survey66	11 (5)	126 (5)	81 (5)	8 (5)	22 (5)	4 (5)	7 (5)	4 (5)	3 (5)	434 (5)	610 (4)	8 (5)
Survey67	9 (5)	58 (5)	48 (5)	8 (5)	13 (5)	4 (5)	7 (5)	4 (5)	3 (5)	264 (5)	373 (4)	12 (5)
Survey68	7 (5)	46 (5)	39 (5)	6 (5)	7 (5)	2 (5)	3 (5)	2 (5)	3 (5)	430 (5)	386 (5)	6 (5)
Survey69	9 (4)	169 (5)	18 (4)	8 (4)	33 (5)	11 (5)	9 (5)	8 (5)	8 (5)	759 (5)	505 (5)	26 (5)
Survey70	26 (4)	130 (5)	20 (4)	11 (4)	83 (5)	26 (5)	19 (5)	22 (5)	18 (5)	563 (5)	287 (5)	38 (5)
Survey71	43 (4)	125 (5)	31 (4)	11 (4)	74 (5)	32 (5)	27 (5)	37 (5)	23 (5)	313 (5)	189 (5)	65 (5)
Survey72	194 (4)	566 (5)	110 (4)	20 (4)	177 (5)	61 (5)	48 (5)	72 (5)	34 (5)	324 (5)	187 (5)	63 (5)
Survey73	336 (4)	643 (5)	137 (4)	29 (4)	297 (5)	114 (5)	84 (5)	141 (5)	56 (5)	260 (5)	92 (5)	93 (5)
Survey74	282 (5)	438 (5)	147 (5)	44 (5)	112 (5)	56 (5)	47 (5)	66 (5)	20 (5)	208 (5)	46 (5)	45 (5)
Survey75	385 (5)	622 (5)	199 (5)	60 (5)	156 (5)	101 (5)	79 (5)	103 (5)	44 (5)	243 (5)	114 (5)	106 (5)
Survey76	242 (5)	402 (5)	141 (5)	46 (5)	112 (5)	63 (5)	50 (5)	67 (5)	44 (5)	498 (5)	142 (5)	126 (5)
Survey77	152 (5)	185 (5)	115 (5)	51 (5)	102 (5)	64 (5)	61 (5)	72 (5)	51 (5)	804 (5)	237 (5)	145 (5)
Survey78	144 (5)	108 (5)	87 (5)	66 (5)	107 (5)	99 (5)	81 (5)	68 (5)	115 (5)	1321 (4)	818 (5)	287 (5)

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

Table 4. 30 day geometric mean (number of samples) of 10m fecal coliform concentrations (CFU/100 mL).

	Outer Harbour				Eastern Pass		Inner Harbour									
	B2	HC	C2	C3	C6	SYC	BRB	D1	D2	D3	EE1	EE2	EE3	E1	E2	E3
Survey66	1 (5)	21 (5)	2 (5)	2 (4)	15 (5)	26 (5)	48 (5)	131 (5)	57 (5)	18 (5)	395 (5)	456 (5)	84 (5)	395 (5)	443 (5)	673 (5)
Survey67	1 (5)	21 (5)	3 (5)	4 (5)	10 (5)	19 (5)	51 (5)	149 (5)	47 (5)	19 (5)	276 (5)	226 (5)	46 (5)	176 (5)	213 (5)	531 (5)
Survey68	1 (5)	39 (5)	5 (5)	4 (5)	6 (5)	15 (5)	64 (5)	111 (5)	40 (5)	22 (5)	191 (5)	112 (5)	33 (5)	315 (5)	225 (5)	455 (5)
Survey69	1 (5)	97 (5)	8 (5)	6 (5)	9 (5)	13 (5)	99 (5)	185 (5)	50 (5)	23 (5)	368 (5)	155 (5)	68 (5)	215 (5)	195 (5)	543 (5)
Survey70	2 (5)	154 (5)	11 (5)	12 (5)	10 (5)	13 (5)	60 (5)	166 (5)	36 (5)	45 (5)	294 (5)	96 (5)	60 (5)	230 (5)	156 (5)	419 (5)
Survey71	3 (4)	276 (4)	18 (5)	16 (5)	19 (5)	21 (5)	71 (5)	183 (5)	49 (5)	95 (5)	335 (5)	107 (5)	198 (5)	235 (5)	148 (5)	362 (5)
Survey72	2 (3)	127 (4)	12 (5)	10 (5)	21 (5)	29 (5)	43 (5)	214 (5)	60 (5)	145 (5)	583 (5)	158 (5)	343 (5)	357 (5)	255 (5)	573 (5)
Survey73	3 (2)	55 (4)	12 (5)	8 (5)	30 (5)	43 (5)	26 (5)	320 (5)	83 (5)	246 (5)	937 (5)	216 (5)	529 (5)	307 (5)	238 (5)	683 (5)
Survey74	7 (2)	38 (4)	27 (5)	12 (5)	31 (5)	50 (5)	44 (5)	478 (5)	125 (5)	451 (5)	868 (5)	261 (5)	707 (5)	368 (5)	238 (5)	566 (5)
Survey75	5 (1)	26 (3)	49 (5)	10 (4)	22 (5)	43 (5)	88 (5)	487 (5)	299 (5)	546 (5)	1259 (5)	355 (5)	1276 (5)	671 (5)	328 (4)	765 (4)
Survey76	5 (2)	40 (4)	63 (5)	16 (4)	16 (5)	26 (5)	68 (5)	343 (5)	382 (5)	528 (5)	1019 (5)	304 (5)	658 (5)	436 (5)	205 (4)	607 (4)
Survey77	6 (3)	42 (4)	74 (5)	33 (4)	27 (5)	27 (5)	80 (5)	320 (5)	530 (5)	310 (5)	537 (5)	254 (5)	401 (5)	473 (5)	198 (4)	656 (4)
Survey78	6 (3)	62 (3)	123 (5)	69 (4)	54 (5)	38 (5)	178 (5)	347 (5)	768 (5)	293 (5)	505 (5)	278 (5)	355 (4)	526 (5)	243 (4)	496 (4)

	Bedford Basin									Northwest Arm		
	F1	F2	F3	DYC	G2	H1	H2	H3	BYC	PC	RNSYS	AYC
Survey66	52 (5)	79 (5)	336 (5)	34 (5)	182 (5)	28 (5)	70 (5)	52 (5)	4 (5)	98 (5)	159 (5)	24 (5)
Survey67	32 (5)	39 (5)	248 (5)	17 (5)	75 (5)	18 (5)	32 (5)	17 (5)	3 (5)	112 (5)	126 (5)	22 (5)
Survey68	29 (5)	47 (5)	146 (5)	22 (5)	75 (5)	32 (5)	33 (5)	19 (5)	4 (5)	133 (5)	105 (5)	16 (5)
Survey69	39 (5)	149 (5)	142 (5)	32 (5)	118 (5)	51 (5)	46 (5)	27 (5)	11 (5)	130 (5)	97 (5)	23 (5)
Survey70	55 (5)	117 (5)	183 (5)	39 (5)	111 (5)	95 (5)	74 (5)	47 (5)	14 (5)	110 (5)	62 (5)	21 (5)
Survey71	60 (5)	115 (5)	214 (5)	61 (5)	121 (5)	96 (5)	79 (5)	53 (5)	21 (5)	110 (5)	63 (5)	28 (5)
Survey72	95 (5)	286 (5)	295 (5)	51 (5)	284 (5)	127 (5)	144 (5)	115 (5)	41 (5)	82 (5)	62 (5)	19 (5)
Survey73	129 (5)	367 (5)	275 (5)	29 (5)	314 (5)	114 (5)	140 (5)	100 (5)	71 (5)	46 (5)	44 (5)	21 (5)
Survey74	136 (5)	340 (5)	193 (5)	30 (5)	308 (5)	100 (5)	128 (5)	102 (5)	47 (5)	91 (5)	45 (5)	23 (5)
Survey75	170 (5)	427 (5)	297 (5)	51 (5)	402 (5)	150 (5)	183 (5)	195 (5)	85 (5)	96 (5)	118 (5)	55 (5)
Survey76	87 (5)	359 (5)	157 (5)	28 (5)	233 (5)	82 (5)	88 (5)	109 (5)	46 (5)	84 (5)	106 (5)	40 (5)
Survey77	90 (5)	221 (5)	123 (5)	41 (5)	152 (5)	77 (5)	77 (5)	97 (5)	41 (5)	141 (5)	124 (5)	55 (5)
Survey78	112 (5)	205 (5)	137 (5)	101 (5)	135 (5)	72 (5)	62 (5)	114 (5)	45 (5)	276 (5)	255 (5)	107 (5)

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

There appears to be a distinct temporal trend in fecal coliform through the quarter in both the 1m and 10 m samples. In both there is a general decrease in bacterial water quality at most sites as the quarter progresses. Combining observations at both depths, the mean values go from a count of 30/12/14 sites (number of sites that are acceptable/questionable/unacceptable), at the start of the quarter, to 12/15/29 at the end. This is likely at least in part due to the decrease in water temperature and reduced sunlight, both of which contribute to the survivability of FC bacteria (USEPA, 1985).

4.1.2 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 three weeks (71-73) there were out of range values reported at site D1-1 m. This is a site where reduced resolution limits (increased range) were in place, but due to a lab oversight the analysis was performed at the normal resolution. These observations are discounted in the following discussion. Nonetheless, during this quarter, there were a total of 17 out of range values. The most notable were during an extreme event sampled on 11 October 05 (week 69). In this case there had been 153 mm of rain in the three days before the survey, resulting in a large freshwater influx (river and CSO) into the Harbour. This event resulted in out of range values in the 1m samples at seven sites, in the Inner Harbour and southern Basin. There were other instances of very high bacteria levels during the quarter. In survey 75 out of range values were reported at four sites, including EE3-1. There were also out of range values at EE3-1 on surveys 72-73. Site EE3-1 is a site where reduced resolution limits (increased range) were already in place. so the out of range values were >100,000 cfu/100mL. This site shows great variability depending on the trajectory of the plume from the relatively close by outfall off the Peace Pavilion Park in Dartmouth, however these are the highest values measured there. Survey 76 had three out of range values and on week 78 there was an out of range value at the PC-1 site. This is also a site that experiences quite high variability depending on the trajectory of the plume from the Chain Rock outfall off Point Pleasant Park.

The event of week 69 was extraordinary and of itself does not warrant a change in analysis resolution. The remainder may have implications that will be assessed in the context of the entire data record since the start of the program and adjusted as required.

4.2 Ammonia Nitrogen

The values obtained for this period are shown in Table 5. The laboratory "estimated quantification level" (EQL) for ammonia nitrogen is 0.05 mg/L. For the purpose of computing statistics, the EQL/2, or 0.025 mg/L was used for values below detection. Missed sample are excluded from the calculations.

Overall, in this quarter, 77% of samples had detectable levels of ammonium. About half the non-detectable values occurred at B2, the furthest site out of the harbour, where there

were only three detectible values all quarter. Interestingly, the highest value observed (0.96 mg/L) was at B2-10m on 6 Dec 05. This value is many times higher than the next highest observation (0.20 mg/L). The remainder, but for one, of the non-detectable values occurred on the first survey of the quarter (week 66, 28 Sep 05), in which there were only three of fourteen possible values above the detection limit.

In this quarter, while there is week-to-week variability, it seems random and there appears to be no definite temporal trend. The 10 m samples seem to have an increasing trend during the quarter but it is slight and influenced by the very high value observed at B2. This trend is probably not significant. There also does not appear to be a strong correlation with meteorological events, as is seen in the coliform data. The longitudinal section plots (Figure 7) of mean and max values indicate that the higher values tend to be in the 1m samples and in the Basin, with values decreasing going out of the harbour. The exception is the single outlier value at B2-10m, which also skews the mean value at this site.

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

1 m	B2	D2	EE2	E2	F2	G2	H2	mean	max
28-Sep-05	0.025	0.08	0.025	0.025	0.025	0.025	0.025	0.03	0.08
11-Oct-05	0.025	0.09	0.12	0.07	0.14	0.13	0.12	0.10	0.14
27-Oct-05	0.025	0.06	0.08	0.12	0.11	0.13	0.13	0.09	0.13
9-Nov-05	0.025	0.09	0.09	0.11	0.10	0.09	0.10	0.09	0.11
23-Nov-05	missed	0.08	0.08	0.17	0.08	0.20	0.18	0.13	0.20
6-Dec-05	0.06	0.1	0.08	0.12	0.12	0.12	0.12	0.10	0.12
mean	0.03	0.08	0.08	0.10	0.10	0.12	0.11	0.09	
max	0.06	0.10	0.12	0.17	0.14	0.20	0.18		0.20

10 m	B2	D2	EE2	E2	F2	G2	H2	mean	max
28-Sep-05	0.06	0.025	0.025	0.025	0.07	0.025	0.05	0.04	0.07
11-Oct-05	0.025	0.06	0.08	0.1	0.09	0.12	0.1	0.08	0.12
27-Oct-05	0.025	0.025	0.06	0.11	0.11	0.13	0.13	0.08	0.13
9-Nov-05	0.025	0.1	0.08	0.09	0.13	0.1	0.1	0.09	0.13
23-Nov-05	missed	0.07	0.07	0.13	0.09	0.14	0.12	0.10	0.14
6-Dec-05	0.94	0.06	0.06	0.11	0.14	0.13	0.12	0.22	0.94
mean	0.22	0.06	0.06	0.09	0.11	0.11	0.10	0.10	
max	0.94	0.10	0.08	0.13	0.14	0.14	0.13		0.94

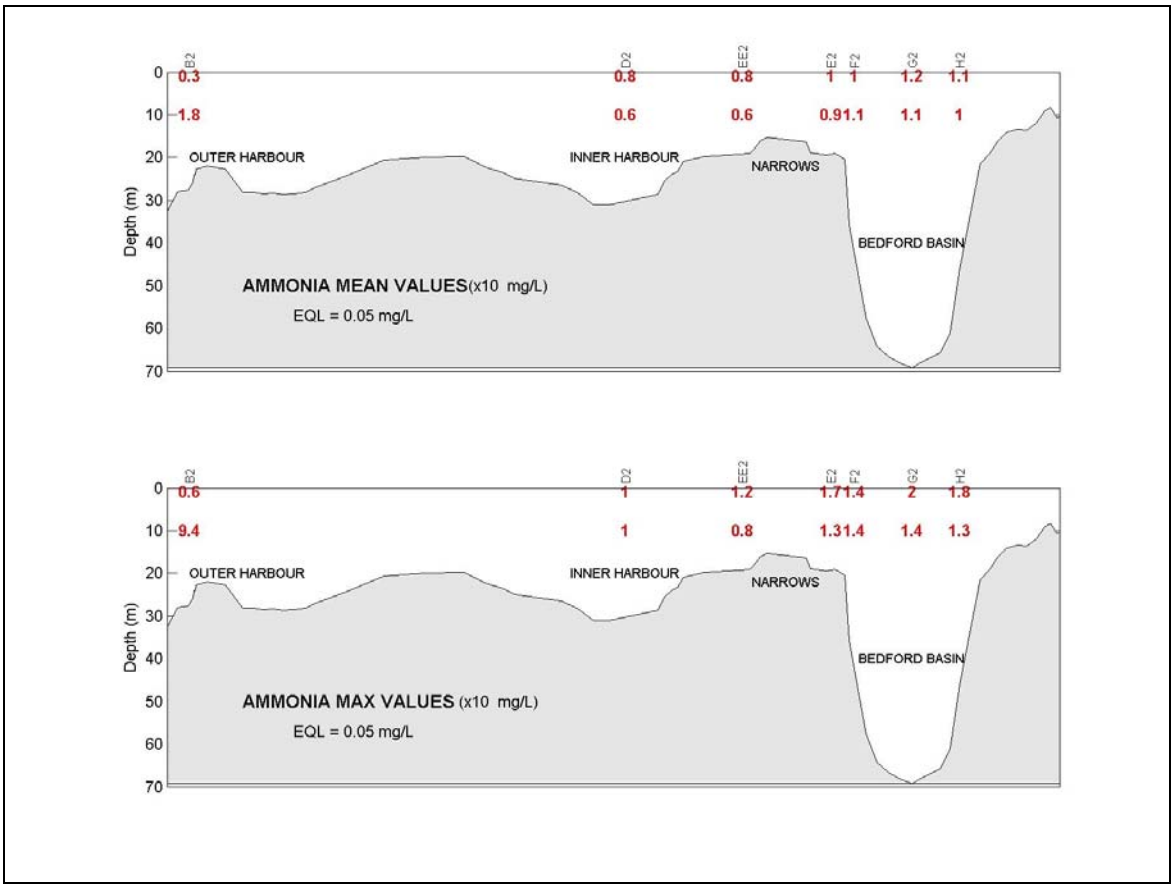

Figure 7. Mean and maximum value of ammonia nitrogen (X10 mg/L) over all sixth quarter samples

4.3 Carbonaceous Biochemical Oxygen Demand

There was no $CBOD_5$ analyses performed this quarter. Further to a recommendation in QR#2, $CBOD_5$ analysis ceased on 25 May 05, due to lack of detectable values. $CBOD_5$ analysis will continue for supplemental samples, where there have been detectable values.

4.4 Total Suspended Solids

A summary of the TSS values for this quarter is shown in Table 6. There were four samples taken during the quarter that were below the EQL of 2 mg/L (note: the EQL was reduced to 1 mg/L on the 23 Nov survey). As with TN, for these samples a value of one half the EQL (1mg/L) is used for statistical purposes. Missed sample are excluded from the calculations. In addition to the table, the quarterly mean and max values are plotted on an along harbour bathymetric section in Figure 8. Similar to last quarter the average values were mostly around 10 mg/L.

Figure 8 shows that the highest quarterly average values of TSS occur in the southern Basin, site F2, and decrease in both directions from there. However, the survey to survey variation (Table 6) is large and survey high values occur at most any station. The highest values in the quarter, in excess of 30 mg/L, occurred in three samples from the southern Basin and Narrows in the 9 Nov survey. These values are nearly twice the next highest observations at these sites. The remainder of the values on that date, south of the Basin are relatively high, but except for B2, not the highest in the quarter. At B2, the observations were the highest of the quarter, though not much higher than on 28 September. While there is significant variability in individual measurements, Table 6 shows that on average the concentrations increase monotonically from the start of the quarter to a maximum in the middle of the quarter (9 Nov, survey 73) and then decrease to the end of the quarter. Generally, there is no obvious temporal variability in the other data sets to explain the observed trend in the TSS data. In particular, there is nothing immediately obvious in the other data sets (particularly meteorology and fluorescence) for 9 Nov to explain the elevated values, except perhaps that it is a time of potentially low flushing.

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

1 m	B2	D2	EE2	E2	F2	G2	H2	mean	max
28-Sep-05	13.0	12.0	11.0	13.0	6.0	5.0	7.0	9.6	13.0
11-Oct-05	10.0	10.0	6.0	7.0	10.0	13.0	11.0	9.6	13.0
27-Oct-05	1.0	6.0	18.0	9.0	16.0	10.0	8.0	9.7	18.0
9-Nov-05	14.0	9.0	11.0	14.0	35.0	1.0	7.0	13.0	35.0
23-Nov-05	missed	9.0	10.0	5.0	6.0	6.0	12.0	8.0	12.0
6-Dec-05	2.0	8.0	4.0	8.0	5.0	4.0	5.0	5.1	8.0
mean	8.0	9.0	10.0	9.3	13.0	6.5	8.3	9.2	
max	14.0	12.0	18.0	14.0	35.0	13.0	12.0		35.0

10 m	B2	D2	EE2	E2	F2	G2	H2	mean	max
28-Sep-05	14.0	14.0	4.0	1.0	5.0	9.0	8.0	7.9	14.0
11-Oct-05	7.0	4.0	14.0	10.0	11.0	9.0	10.0	9.3	14.0
27-Oct-05	1.0	10.0	19.0	5.0	17.0	8.0	8.0	9.7	19.0
9-Nov-05	18.0	10.0	9.0	33.0	37.0	11.0	10.0	18.3	37.0
23-Nov-05	missed	9.0	10.0	8.0	5.0	8.0	6.0	7.7	10.0
6-Dec-05	5.0	7.0	5.0	4.0	8.0	6.0	8.0	6.1	8.0
mean	9.0	9.0	10.2	10.2	13.8	8.5	8.3	9.8	
max	18.0	14.0	19.0	33.0	37.0	11.0	10.0		37.0

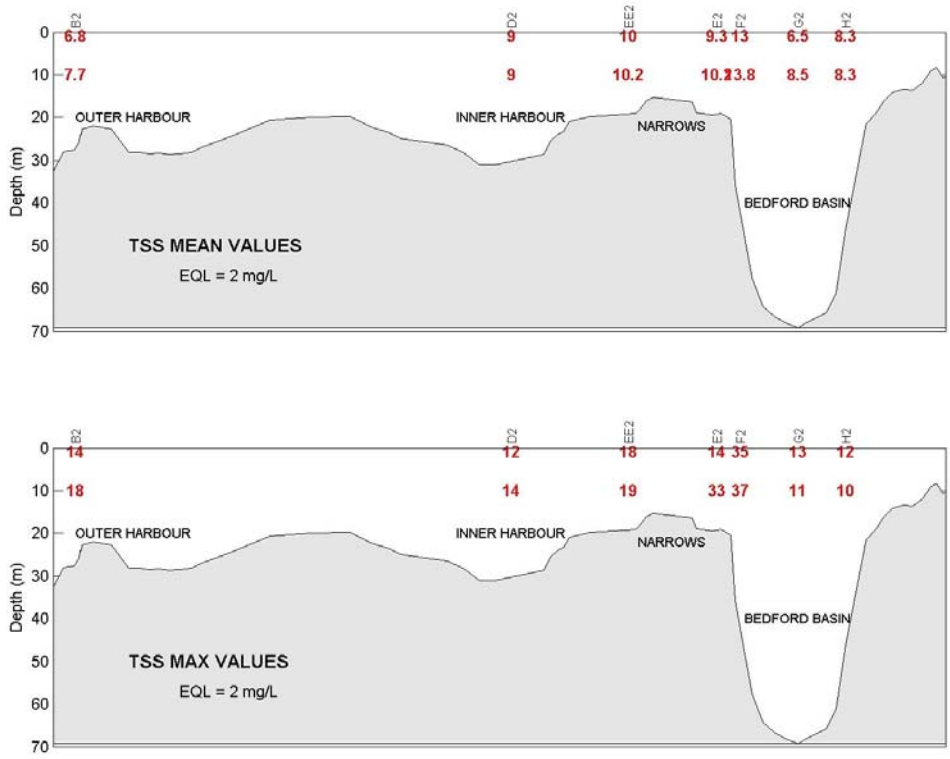

Figure 8. Mean and maximum values of total suspended solids (mg/L) over all sixth quarter samples.

4.5 Total Oils and Grease

During this quarter, total oil and grease analysis was performed only on a surface grab sample at each of the Chem sites. There have been no detectable levels of total oil and grease in any of the samples in this quarter. Based on recommendations in Quarterly report 05 regular sampling for Total Oil and Grease was discontinued on 23 Nov, survey 73. The analysis is retained for supplemental samples.

4.6 Metals

In this quarter the current low level metals scan was discontinued on 23 November (survey number 73). This was in response to recommendations made in Quarterly Report 4. The analysis was inadequately resolving metals concentrations in the harbour and an alternative procedure with higher resolution is being developed. Therefore, in this quarter metals data exist for only the first four of the six detailed ("chem") surveys. There are eight metals for which water quality guidelines exist in the harbour, these are: cadmium, chromium, copper, lead, manganese, mercury, nickel and zinc. The metal scan does not measure mercury so there are seven metals of interest in this study.

In the four surveys there have been fifty three independent measurements of these metals in excess of laboratory EQL's. There were a total of 385 measurements (seven sites x two depths x four surveys x seven metals, discounting one missed stations or two missed samples and accounting for a single sample at Dartmouth Cove). This equates overall to approximately 13.8% detectable values, or, conversely, greater than 86% non-detectable values. This is the highest rate of metals data return for any quarter to date. In addition to the regular samples, there were four QA/QC samples and two lab duplicate samples with detectable metals. These are duplicate samples used to verify the reference values and are therefore not independent. The relevant sixth quarter metals values are summarized in Table 7, and are discussed briefly below.

Zinc

Almost all samples taken during the first three surveys of this quarter had detectable levels of zinc. The first survey had all 15 samples with detectible values, the second survey 12 of 14 samples, and the third, 11 of 12 samples had detectable levels. This represents 93% detectable levels over these three surveys, a percentage much higher than anything seen to date. These high levels continued a trend from the last survey of the previous quarter that had 11 of 14 samples with detectable levels. The fourth survey, the last for which the metals scan was done, had three detectable levels of zinc, a much more typical number. Over the four surveys 75% of samples had detectable levels of zinc. The levels during this period are all quite uniform at just above the EQL of 50 μg/L, with only two (denoted in red in Table 7) of the total of 41 values reaching or exceeding the applicable guideline of 86 μg/L.

Manganese

Manganese was the second most prevalent metal and was present at detectable levels (>20 μg/L) on three out of the four surveys, in a total of eight samples. This amounts to about 14% of samples taken in the four surveys. Five of these eight values were in the 11 Oct (#69) survey. The concentrations ranged from 22 (EQL) to 60 μg/L. In no case was the guideline value of 100 μg/L exceeded.

Chromium

There were two reportable levels (>20 μg/L) of chromium measured in the 11 Oct survey(# 69). These were measured at E2-1 and E2-10 and were both just above 20 μg/L well below the guideline level of 50 μg/L.

Cadmium

A single reportable value (>3 μg/L) of cadmium occurred at E2-1m on 11 Oct. This was below the guideline level of 9.3μg/L.

Table 7. Summary of metal values >EQL from 20 September through 9 November 2005. Metals sampling suspended after 9 Nov 05.

Zinc EQL = 50 µg/L: Guideline=86 µg/L

Survey Date	Concentration mg/L	Site	Depth(m)
28-Sep-05	56	B2	1
	53	B2	10
	50	D2	1
	60	D2	10
	51	E2	1
	54	E2	10
	54	EE2	1
	57	EE2	10
	58	F2	1
	63	F2	10
	57	G2	1
	56	G2	10
	70	H2	1
	53	H2	10
	53	DC	1
	53	DC (DUP)	1
	57	F2(QA/QC)	1
11-Oct-05	57	B2	1
	53	B2	10
	57	D2	1
	50	D2	10
	68	E2	1
	55	E2	10
	62	EE2	1
	52	F2	1
	54	F2	10
	51	G2	1
	53	H2	1
	51	H2	10
	51	H2 (QA/QC)	1
27-Oct-05	72	D2	10
	99	D2	1
	86	E2	10
	58	E2	1
	68	EE2	10
	57	EE2	1
	71	F2	10
	62	F2	1
	60	G2	10
	72	G2	1
	68	H2	1
	64	H2 (dup)	1
	51	E2 (QA/QC)	1
9-Nov-05	67	D2	1
	51	EE2	10
	56	H2	56

Table 7 (continued)

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

Survey Date	Concentration μg/L	Site	Depth(m)
11-Oct-05	60	E2	1
	34	EE2	1
	43	F2	1
	22	G2	1
	29	H2	1
27-Oct-05	32	EE2	10
	32	E2 (QA/QC)	1
9-Nov-05	25	D2	1
	24	EE2	10

Chromium EQL = 20 μg/L: Guideline=50 μg/L

Survey Date	Concentration μg/L	Site	Depth(m)
11-Oct-05	23	E2	1
	22	E2	10

Cadmium EQL 3 μg/L: Guideline=9.3 μg/L

Survey Date	Concentration μg/L	Site	Depth(m)
11-Oct-05	4	E2	1

Lead EQL =5 μg/L: Guideline=5.6 μg/L

Survey Date	Concentration μg/L	Site	Depth(m)
11-Oct-05	6	E2	1

Lead

A single reportable value (6 μg/L) of lead occurred at E2-1m on 11 Oct. This was in excess of the guideline level of 5.6 μg/L.

Metals Summary

Overall, there were three values (denoted in red in Table 7) that exceeded applicable guidelines, two for zinc and one for manganese. The relatively high percentage of detectable metal values is due mostly to high levels of zinc. The prevalence of detectable levels of zinc that was observed in the last survey of the previous quarter has continued into the start of this quarter. There is nothing obvious in the spatial distribution of zinc to indicate a hotspot. This would be expected if there were a point source. There is also nothing in the other data sets, including the analysis for other metal constituents, to

indicate anything particularly unusual oceanographically or with overall sewage loads. There is no known reason for this large scale extended increase in zinc levels but it seems that there must have been some, heretofore undefined, extraordinary source of zinc.

Aside from the large scale elevated zinc levels, the survey on 11 October (#69) was notable. In this survey, while there were many detectable levels of zinc, there were also detectable levels of manganese (5), chromium (2), cadmium (1) and lead (1). These concentrations were centered on site E2 in the Narrows. The maximum value of manganese (60 μg/L) occurred at E2-1m and all of the remaining metals occurred at site E2-1m or E2-10m. These values are likely due to storm runoff. This was a survey following an extremely wet week, which had significant effects on other water quality parameters. From the weekly survey report:

> There has been 153 mm of rain in the three days before this survey, resulting in a huge freshwater influx (river and CSO) to the Harbour. There is surface lens of very fresh water, from CSOs, centered on the Narrows (E section) extending into the southern Basin. This water is up to 50% fresh, and visually and measurably contaminated. Here, Secchi disk depths are on the order of 1m, with metals content and bacteria levels that are the highest observed to date.

4.7 Profile Data

The Bedford Basin Plankton Monitoring Program (BBPMP) is a long standing program of the the Department of Fisheries and Oceans at the Bedford Institute of Oceanography. Starting in 1991,the program has collected a time series to record the weekly state of the plankton ecosystem in Bedford Basin. The purpose is to provide data to assess the environmental variability on weekly to decadal time scales. As part of the program, oceanographic profiles from the centre of Bedford Basin are collected on a weekly basis. The BBPMP data are available on their website: www.mar.dfo-mpo.gc.ca/science/ocean/BedfordBasin. The data consist of (among many other parameters) continuous profiles of temperature, salinity, fluorescence, and dissolved oxygen.
The HHWQMP collects profiles of these variables at all sample stations to give a synoptic view of the oceanographic state of the harbour during the monitoring program. The spatial distribution of these parameters is discussed in the individual weekly survey reports.

The BBPMP sample site (coordinates) and the HHWQMP site G2 are very close to each other and are located near the deepest part of Bedford Basin. Both sites are sampled weekly. The HHWQMP samples on Tuesday, with contingency on Wednesday or sometimes Thursday, while the BBPMP usually samples on Wednesday. The slight shifts in time and location are expected to create only very minor variations in measured parameters. The overlap of these two programs provides a good opportunity to inter-compare and further validate the collected data.

4.7.1 Temperature and Salinity

The HHWQMP and BBPMP temperature and salinity data from 1 Jan 05 until the end of the sixth quarter (mid December 05) are presented in Figures 9 and 10. This quarter corresponds to days 263 to 347. As would be expected the temperature data for each of the two programs show a nearly perfect correspondence. The salinity data for this period also shows high degree of correspondence. Some of the fine detail varies, but this variation can be reconciled by differences in contouring routines and perhaps, in some cases where change is relatively rapid, the difference in sampling day.

There are three main features of these datasets during this quarter. There are two "freshwater" events resulting in low salinities at the surface and a significant intrusion of shelfwater between them. The first event was caused by the very wet weather at the start of the quarter, discussed previously with respect to bacteria and metals concentrations. This started during the week before the 11 Oct survey (day 284) and continued through two relatively wet subsequent weeks. The result was strongly stratified conditions in the top 20m of the Basin. The response to the high rainfall was cut short by a major intrusion of shelf water that displaced much of the water in the harbour, including the Basin surface water. This intrusion is evident in the data from 27 Oct (day 300). This intrusion of warmer saltier shelf bottom water was a response to the passage of hurricane Wilma over the Scotian shelf. In addition to the intrusion there was a storm surge of approximately 20 cm associated with this event. The result of this intrusion was dramatic. All the basin water below 30m was replace by water of >31.5 psu with a temperature of 4-5 C. This is the warmest saltiest bottom water of the year and persists till the end of the quarter. The surface water was replaced by displaced deeper water resulting in a precipitous drop in temperature and increase in salinity of the surface water. The strong stratification evident in the top 20m before the intrusion, was mostly destroyed, though a smaller freshwater signature reestablished itself, due to persistant runoff, shortly after the intrusion. The salinity data suggests that the replacement of the bottom water occurred over a longer period of time perhaps starting at around day 260. In fact, the initial increase in bottom salinity was due to a smaller intrusion that occurred in the week between the 20 Sep (day 263) and the 28 Sept survey (day 271). Subsequent to the major intrusion, three weeks with significant rainfall weeks 74, 75 and 76 contributed to the reestablishment of highly stratified surface conditions. This condition peaked at about week 76 then dissipated somewhat until the stratification was destroyed by another intrusion documented in the 13 Dec survey, the last of the quarter. This intrusion can be seen in the salinity data but is more obvious in the temperature data and the dissolved oxygen data (Fig. 12) where it can be seen as a vertical line at the very end of the record.

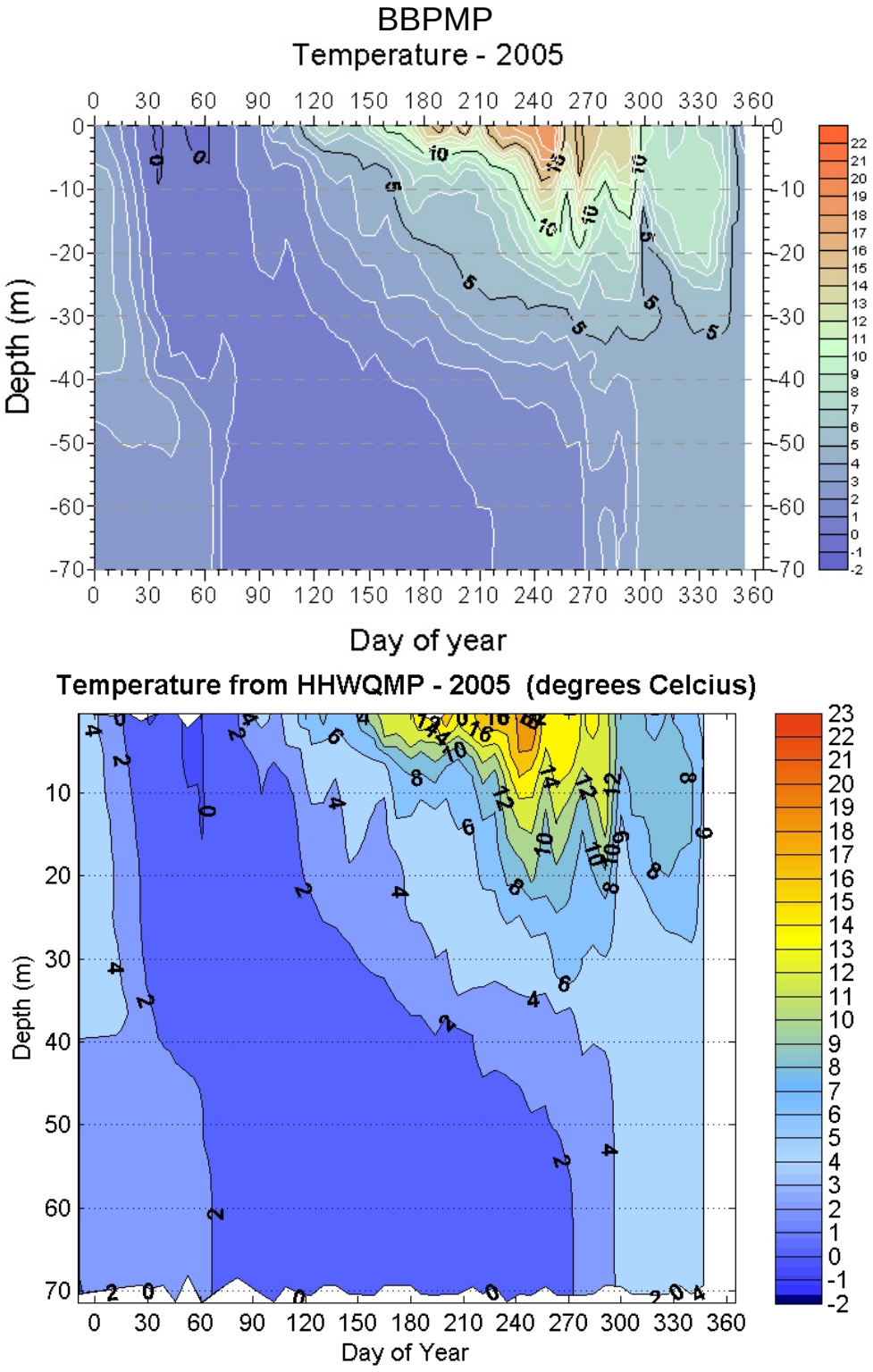

Figure 9. Comparison of BBPMP and HHWQMP temperature data from Station G2 (1 Jan to 13 Dec 2005).

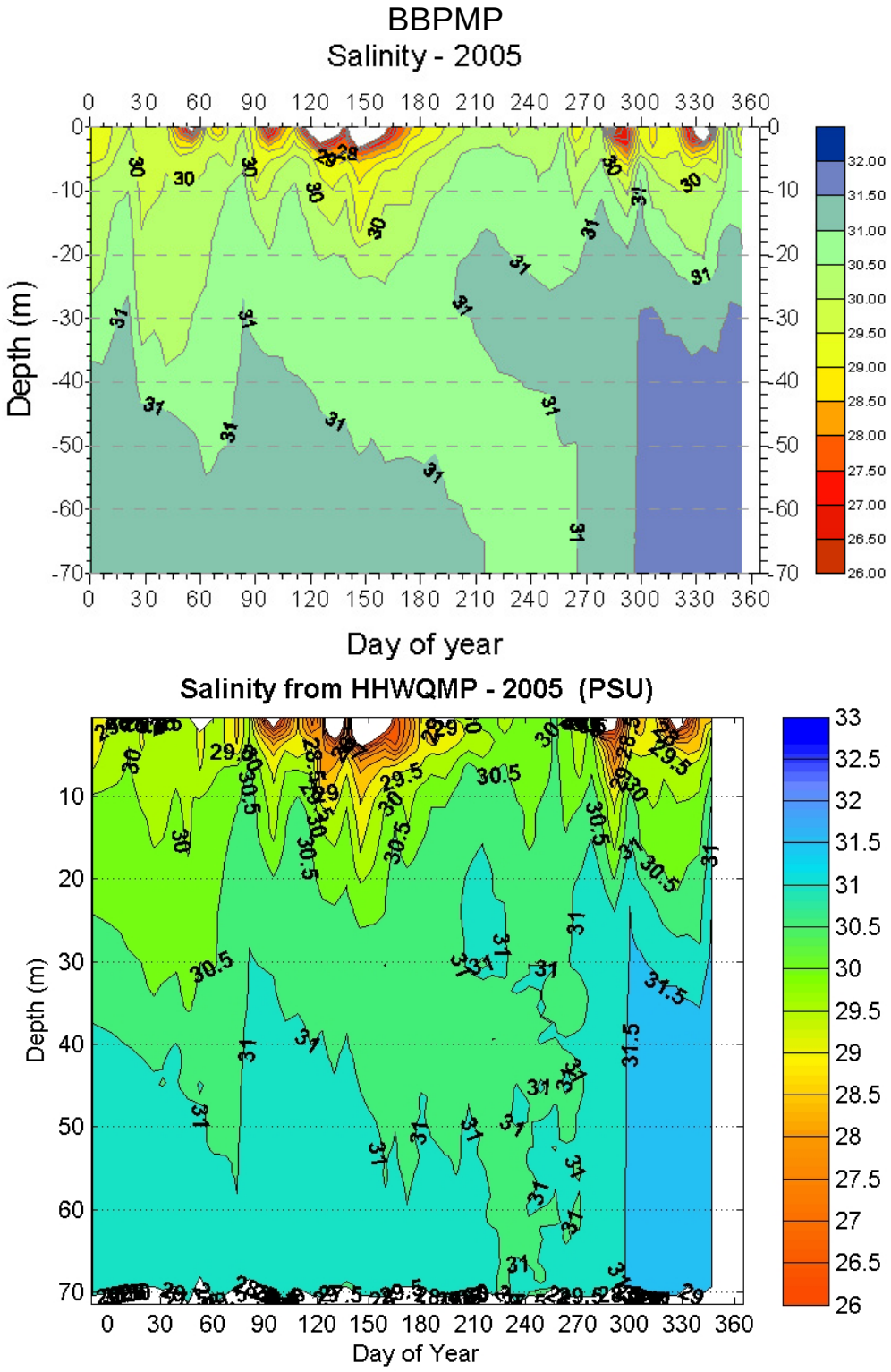

Figure 10. Comparison of BBPMP and HHWQMP salinity data from Station G2 (1 Jan to 13 Dec 2005).

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. The fluorescence values can be useful when considered on a relative basis. This comparison is probably more valid within a survey, where conditions are more likely to be consistent over the harbour, than between surveys which occur under different conditions. The more separated in time, the more uncertain the comparison. Nonetheless, due to the large variability in natural plankton concentrations, the data provides useful information on the relative spatial and temporal variability of phytoplankton activity.

A comparison of HHWQMP fluorescence data with that of the BBPMP is presented in Figure 11. Note that BBPMP data is relative fluorescence presented without dimensions. Also, the BBPMP is presented on a variable scale, while the HHWQMP data is presented on a linear scale. These two factors dictate that the units and figure colours are not directly comparable. The general trends in the two data sets, however, are very similar.

There is a strong phytoplankton bloom at the beginning of the quarter indicated by a period of quite high fluorescence values at a depth of 5-8 metres around day 270. This bloom resulted in the highest fluorescence values of the year. This bloom may have been interrupted by the flushing associated with the shelf water intrusion, discussed above, that was documented in the 28 Sep (day 271) and 5 Oct (day 278) surveys. During this event quite high fluorescence levels > 20 mg/L were documented at B2 (as well has high bacteria levels). Subsequently there was a period of relatively low activity. The effect of the “Wilma intrusion” is quite evident as the values become quite vertically uniform around day 300. After this there is a period of very minor activity which tapers off to near “background” winter values by the end of the quarter.

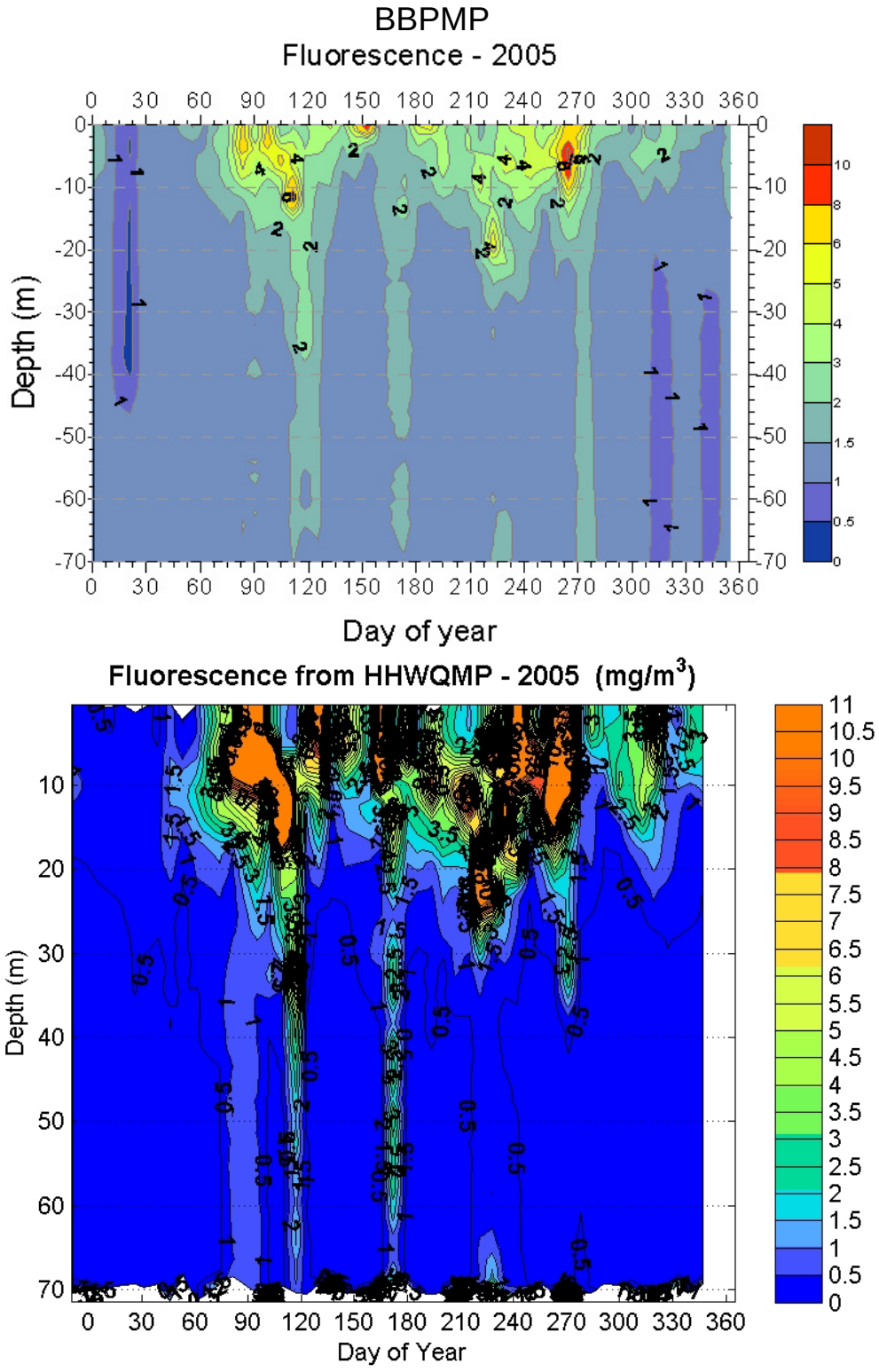

Figure 11. Comparison of BBPMP and HHWQMP fluorescence data from Station G2 (1 Jan to 13 Dec 2005).

4.7.3 Dissolved Oxygen

The 2005 DO data from the BBPMP is being re-evaluated and is not currently available for this quarter. The DO contour plot for the HHWQMP, converted to mL/L is presented in Fig. 12. This can be used for comparison with the on-line data when it becomes available. The conversion factor from mg/L to mL/L is approximately 0.7.

Compared to earlier in the year, the data indicate relatively low near surface DO values throughout the quarter (day 263 through day 347), a trend noted at the end of the previous quarter. The weekly reports document values throughout the harbour in the 6-8 mg/L range, resulting in frequent values below the applicable guidelines in the class SA and SB regions of the harbour. The lowest values occur between days 284 and 300 a period of time of very wet weather and of elevated concentrations of other water quality parameters, particularly coliform and metals. The data during this period indicate DO levels from just below 6 to 7 mg/L. These are below the use specific criteria for all class SA (> 8 mg/L) and SB (>7 mg/L) areas and are borderline for the Inner Harbour, which is classified SC (>6 mg/L). The end of this period corresponds to the "Wilma" intrusion. Referring to Fig. 12, the effect of the intrusion is evident in the bottom water DO levels, but somewhat surprisingly, given the large effect on hydrographic parameters, is not as distinct as the intrusion earlier in the year (about days 70 – 80). This seems to be because the bottom DO levels were not as low at the start and the intruding water was of lower oxygen content. Subsequent to this event the near surface DO levels recover somewhat. Another intrusion is documented in the 13 Dec survey. This results in Bottom DO levels > 4 mL/L and shows up as a thin vertical line at the end of the plot. (note that the extreme looking intrusion at about day 100 and the surface minimum around day 333 are due to erroneous data and will be removed from the plot)

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

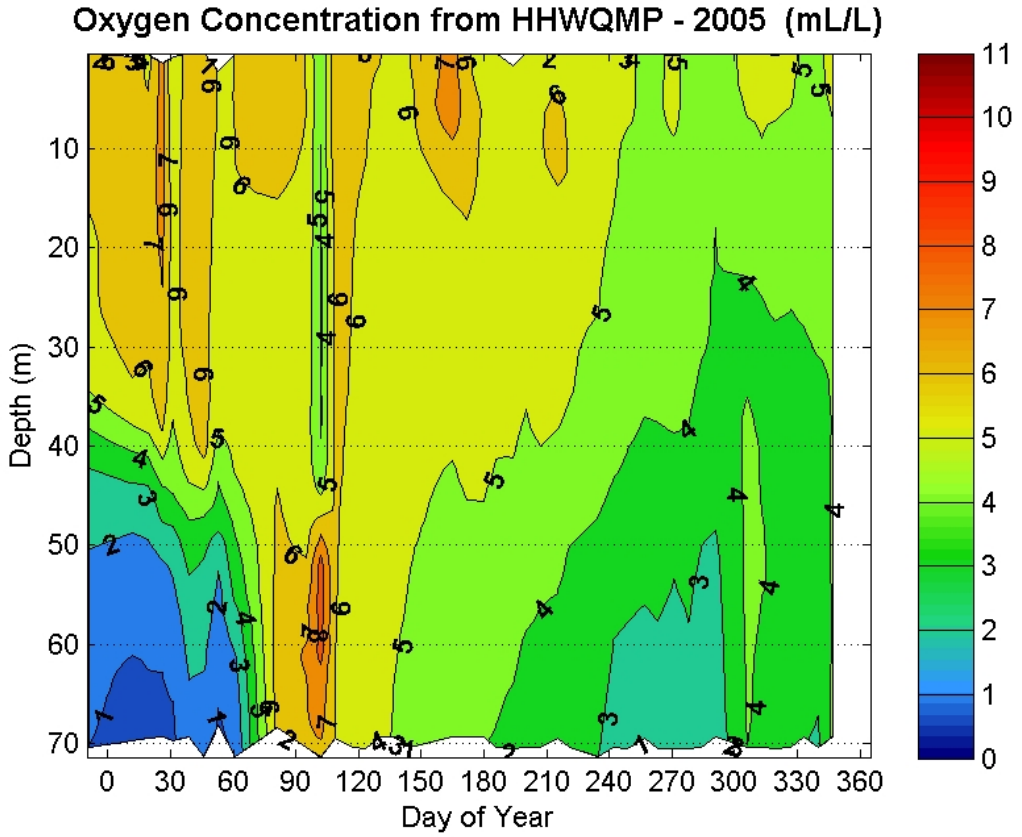

Figure 12. HHWQMP dissolved oxygen data from Station G2 (1 Jan to 13 Dec 2005).

4.8 Supplemental Samples

There were no supplemental samples taken this quarter.

5 Summary and Action Items

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

5.1 Reporting

Weekly Reports

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

Changes – none

Action
Continued review/adjustment of reports to reflect program changes.

Quarterly Reports

Summary Statement – 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. There remains a future reporting issue of comparison of data between years. The documentation of sampling/sample handling/lab procedures/ data analysis remains incomplete.

Changes – None

Action

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

5.2 Sampling Program

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

Changes –none

Action

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

5.3 Water Quality Parameters

Fecal Coliform

Summary Statement – This quarter was characterized by large FC contamination events and generally high fc values. While, based on experience to date, this seems characteristic of the Fall, this is the first time since variable by site analysis resolution was instituted that there were a significant number of out of range values. A seasonal shift might be justified.

The current CCME guidelines 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 the monitoring program should recognize that at some level.

Changes - None.

Action

1. Evaluate the statistics of FC data from the start of the program in light of the data from this quarter and modify the specified analysis as appropriate.
2. Ongoing (QR#1): Consider inclusion of enterococci as an alternate and/or additional tracer.

Ammonia Nitrogen

Summary Statement – The data return for this quarter was 77% which is relatively high , but consistant with previous quarters. Ammonia Nitrogen has consistently been present at levels that are is at or slightly above the detection limit of 0.05 mg/L. Ammonia Nitrogen is an attractive tracer as it is routinely monitored in sewage treatment facilities and therefore has a 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.

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

Changes – None.

Action

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

$CBOD_5$

Summary Statement – Based on recommendations in QR#2, $CBOD_5$ was dropped from regular analysis on 25 May 05. Until that time there was 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

Changes – None

Action - None

Total Suspended Solids

Summary Statement – The TSS concentrations averaged 9-10 mg/L over the quarter, with only 4 values below the detection limit of 2 mg/L, before the TSS water sample size was doubled, which halved the detection limit to 1 mg/L.

Changes – Reduced detection levels were instituted on 23 Nov 05, survey #75.

Action – None

Total Oils and Grease

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

Changes – Based on recommendations in QR # 5, Total Oils and Grease was dropped from regular analysis on 23 Nov 05, survey #75. It is retained in supplemental sample analysis.

Action – None

Metals

Summary Statement – There were relatively many positive metals tests in the beginning of this quarter. See the discussion in section 4.6 above. Because of this, the number of detectable metals in the samples was uncharacteristically high (>13% considering all metals for which guidelines exist). There were three values which exceeded the applicable water quality guidelines, two for zinc and one for lead. This is the highest data return for this analysis to date but still does not resolve expected concentrations (Dalziel et al. 1989) of important metal constituents in the harbour water.

Changes – Based on recommendations in QR # 2, the low resolution metals scan was dropped from regular analysis on 23 Nov 05, survey #75.

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

Fluorescence

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

Changes – None.

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

Dissolved Oxygen

Summary Statement – To date, oxygen levels as measured in the program, are generally high in surface waters, and chronically low in the deep water of Bedford Basin. This is consistent with the existing understanding that Bedford Basin is a fjord, in which depressed oxygen in bottom water is typical. This quarter there was an extended period where the HHWQMP data have indicated that guidelines were exceeded in all area classified SA or SB by the Harbour Task Force (Halifax Harbour Task Force. 1990). There was a shorter period where the data indicated that the class SC guideline of 6 mg/L, which applies to the Inner Harbour, was exceeded at some levels in the water column.

In situ oxygen measurements are particularly sensitive to a variety of factors and there is some discrepancy between the HHWQMP profile data and data collected from other sources, e.g other instruments deployed by HHWQMP, periodic water samples analyzed by winkler titration and the monitoring data of BBPMP in Bedford Basin. In general the measured DO profiles have been somewhat lower than data obtained with other instruments and by winkler titration, however there are significant uncertainties associated with those values as well. On the other hand, the HHWQMP data has corresponded reasonably well, though was generally a bit higher, than the BBPMP data. However the BBPMP has recently removed it's DO data from it's website. The reason for this is as yet uncertain. Given this uncertainty and the fact that dissolved oxygen is perhaps the most important indicator of the health of a water body, it is very important to insure the quality of the collected data. If sewage load is contributing to oxygen depression in the harbour it will be a critical parameter in future waste management decisions.

Changes – none

Action

1. Ongoing (QR#3) Continue dialogue with BIO (BBPMP) to coordinate sampling and maximize cross comparison of data for ground truth purposes.
2. Ongoing (QR#1) Consider alternate ground-truthing procedures, including Winkler titration or laboratory instruments.
3. Institute discussions with other parties (e.g. Dalhousie Oceanography) regarding potential calibration/verification procedures.

6 References

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