Halifax Harbour
Water Quality Monitoring Program
Quarterly Report #9
(June 21, 2006 to September 13, 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). The detailed datasets are also transmitted to the client electronically. 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 21 June 2006 to 13 September 2006 (surveys 105 to 112). 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 ninth 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 the weekly reporting was changed to biweekly as of July 2006, to reflect changes in the sampling schedule discussed in Section 3. Also starting with survey 111, 29 August 2006, a section reporting the results of the reconfigured metals analysis (Section 3.1) has been added.

In previous quarterly reports, 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. During the last quarter (Quarter 8) 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. An Errata/Changes section is included in the Introduction section of the report binder and is updated on a quarterly basis. In addition to errors, the Errata/Changes section documents the changes in the sampling program and reporting.

3 Sampling Program

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 31 regular sampling sites are included for reference 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: CTD only (CTD only stations); CTD and coliform bacteria (Coliform stations); or CTD, Bacteria, and additional contaminant analysis (Chemistry stations). 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

During this quarter the sampling schedule has changed. Until this quarter, surveys were conducted weekly with the additional contaminant analysis at the "chemistry" stations conducted on alternate weeks (odd numbered surveys). After survey 107 (4 July 2006), all sampling is done on a biweekly basis, with the additional sampling at the Chemistry sites being done every survey. Also starting with survey 111 (29 August 2006) a high-resolution atomic spectroscopy metals analysis is included for the chemistry sites. This analysis replaces the previously discontinued metals scan that was not resolving the metals concentrations in the Harbour. The new analysis includes separate scans for a suite of 8 metals (cadmium, copper, lead, manganese, nickel, zinc, cobalt and iron) and mercury. This list includes seven of the eight metals for which guidelines for the harbour (Table 1) have been established. Chromium, for which a guideline exists, is not monitored. Chromium was included in the previous low resolution analyses, with a detection limit of 20 ug/L that compares to the guideline of 50 ug/L. The chromium levels in the harbour, except in rare samples (<10 samples in total), was undetectable at that level over the approximately year and a half of measurement. The detectable levels that were found were only slightly above the detection limit and therefore all well below the guideline value. Cobalt and Iron, that are included in the new scan, have no established guidelines. Mercury was not monitored in the previous analysis but is now included with an EQL of 0.01 ug/L, that compares favourably to the 0.025 ug/L guideline. Also from survey 111 forward the detection limit (EQL) for TSS was reduced from 1.0 mg/L to 0.5 mg/L.

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. A summary of the sampling and analysis schedules and relevant established criteria in place at the end of ninth quarter (13 September 2006) are in Table 1. This table indicates that the BOD_5 and Total Oil and Grease analyses, discontinued from regular sampling due to lack detection, are now performed only for "supplemental samples".

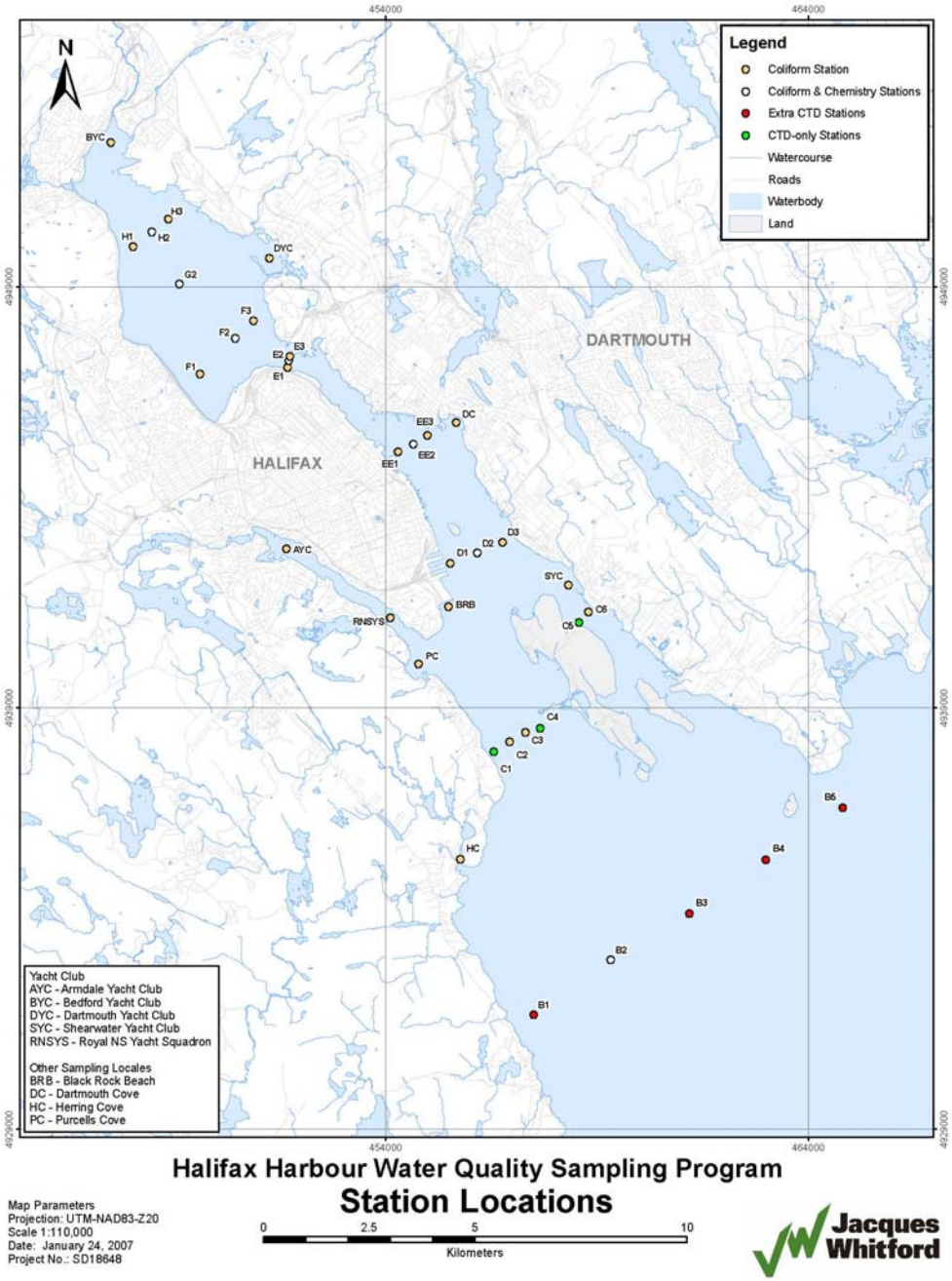

Figure 1. Halifax Inlet sample locations

Table 1. Summary of measured parameters as of 13 September 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
			<10%			
TSS	0.5	mg/L	background	all	Chemical sites	bi-weekly
Total Oil and Grease	5	mg/L	10	all	Supplemental sites	unscheduled
Metal scan						bi-weekly
Cadmium	0.1	ug/L	9.3	all	Chemical sites	
Copper	0.1	ug/L	2.9	all	Chemical sites	
Lead	0.1	ug/L	5.6	all	Chemical sites	
Manganese	1	ug/L	100.0	all	Chemical sites	
Nickel	0.5	ug/L	8.3	all	Chemical sites	
Zinc	1	ug/L	86.0	all	Chemical sites	
Mercury	0.01	ug/L	0.025	all	Chemical sites	
Cobalt	0.1	ug/L	none		Chemical sites	
Iron	1	ug/L	none		Chemical sites	

3.2 Supplemental Samples

Based on recommendations from Quarterly Report #2, a supplemental sample protocol has been instituted to take opportunistic samples of visible water quality features in the Harbour, or to document unusual discharge conditions (e.g. bypass etc). These samples are acquired on a discretionary and exploratory basis when an interesting feature, such as a visible front, plume, or patch of visibly deteriorated water quality is encountered. It is anticipated that these samples will have lower water quality than most normal samples. As such, the samples are processed for the full range of parameters specified at the beginning of the program, including parameters which have been eliminated from normal sampling due to lack of detection. During this quarter in addition to the previously mentioned quasi-regular samples at DC (surveys 108 and 112) there was a supplemental sample of a visible feature at Chain Rock Outfall in the Northwest Arm for survey 110. Also, in response to a temporary bypass from Duffus St. to the Fairview Cove outfall, stations F1 and F2 were sampled for $CBOD_5$ in survey 112.

3.3 Sampling Order

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

Also, Table 2 lists the missed stations and additional samples (described above) for each survey. Overall, during this quarter, there were thirteen missed bacteria stations, three missed chemical stations and two missed CTD only stations. Samples in the Outer Harbour, B2 and sometimes HC, were missed in surveys 108, 111 and 112 due to weather. In survey 109 thirteen stations were missed due to mechanical problems with the boat. This converts to a total of 33 missed bacteria samples, 6 missed chemical samples and 21 missed CTD profiles.

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

	Weekly Sampling			Bi-weekly Sampling				
Date	21 Jun 06	27 Jun 06	04 Jul 06	18 Jul 06	01 Aug 06	15 Aug 06	29 Aug 06	13 Sep 06
Survey	105	106	107	108	109	110	111	112
1	C4	AYC	AYC	D3	HC	HC	C2	BRB
2	C3	RNSYS	RNSYS	EE3	B2	B2	C1	D1
3	C5	PC	PC	E3	C1	C3	HC	EE1
4	C6	C1	C4	F3	C2	C4	C3	E1
5	SYC	C2	C3	DYC	BRB	C5	C4	F1
6	D3	C3	B2	H3	D1	C6	BRB	G2
7	EE3	C4	HC	BYC	D2	SYC	D1	H1
8	E3	BRB	C1	H2	EE2	D3	EE2	BYC
9	F3	D1	C2	H1	EE1	D2	EE3	H2
10	DYC	EE1	BRB	G2	E2	EE3	E3	H3
11	H3	E1	D1	F1	E1	EE2	E2	DYC
12	BYC	F1	EE1	F2	F2	E3	F2	F3
13	H2	G2	E1	E1	F1	E2	F3	F2
14	H1	H1	F1	E2	G2	F2	DYC	E3
15	G2	BYC	G2	EE2	H1	F3	H3	E2
16	F1	H2	H1	EE1	H2	DYC	H2	EE3
17	F2	H3	BYC	D2	BYC	H3	BYC	EE2
18	E1	DYC	H2	D1	H3	H2	H1	D2
19	E2	F3	H3	BRB		BYC	G2	D3
20	EE1	F2	DYC	AYC		H1	F1	SYC
21	EE2	E2	F3	RNSYS		G2	E1	C6
22	D2	E3	F2	PC		F1	EE1	C5
23	D1	EE2	E2	C2		E1	D2	C4
24	BRB	EE3	E3	C1		EE1	D3	C3
25	C2	D2	EE2	C3		D1	SYC	C2
26	C1	D3	EE3	C4		BRB	C6	C1
27	HC	SYC	D2	C5		C2	C5	PC
28	B2	C5	D3	C6		C1	PC	RNSYS
29	PC	C6	SYC	SYC		PC	RNSYS	AYC
30	RNSYS	HC	C6			RNSYS	AYC	
31	AYC	B2	C5			AYC		
Missed sites				B2, HC	DYC, F3, E3, EE3, D3, SYC, C6, C5, C3, C4, PC, RNSYS, AYC		B2	B2, HC
Additional Samples				DC-1m		Chain Rock Outfall		DC-1m, CBOD5-F1, F2

3.4 Data Return

In addition to the missed sites detailed above, there was other data loss. In survey 106 much of the CTD data was corrupt due to a sampling error. There was also one missing coliform sample in survey 109 due to lab error. All considered, the overall data return for the quarter is summarized in Table 3.

Table 3. Quarter nine data return.

Chemical	Target	Achieved	Percent Return
7 sites			
NH3	**100**	**94**	
TSS	**100**	**94**	
Metal Suite	**29**	**25**	
Mercury	**29**	**25**	
Total	**258**	**238**	**92%**

Bacteria	Target	Achieved	
28 sites			
F Coliform	**450**	**419**	
Total	**450**	**419**	**93%**

Profiles	Target	Achieved	
31 sites			
C-T	**250**	**218**	
Dissolved Oxygen	**250**	**199**	
Chlorophyll	**250**	**201**	
Total	**750**	**618**	**80%**
All data records	**1458**	**1275**	**87%**

3.5 Sampling Bias

There are two issues regarding potential bias in the dataset. The first is the relative bias between sites, that is, whether the statistics from one site can be compared with those from another site. The second is the absolute bias with respect to the environmental forcing, or how well the dataset represents typical conditions in the Harbour. Our sampling has operational constraints 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 ninth 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 shows the sampling time at each site since the start of the program in June 2004. The data from the ninth quarter are shown in red. In this figure the sample sites are generally sorted from north to south. There are a few patterns that emerge that have been documented previously. The stations at the north end of Bedford Basin have a smaller range of sampling times. This is because logistics dictates that the surveys never start or end in the Basin. In general, the range of sampling times increases with distance south, a function of travel time from the Armdale Yacht club in the Northwest Arm. Even if a site is sampled first, it still takes time to travel there. Given that sampling begins at the same time every week, these effects are unavoidable. 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 overall there has been an early morning bias in the Outer Harbour stations, a result of weather conditions. 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 often introduced.

In this quarter, there were some additional trends. Due to transit time considerations, the Arm is now sampled either at the beginning or end of the survey. Of the eight surveys this quarter there were two surveys that started in the Northwest Arm, in the remainder, the Northwest Arm was sampled at the end of the day. Also, there was a bias toward earlier sampling in the Basin and Inner Harbour with several sites never being sampled after 13:30.

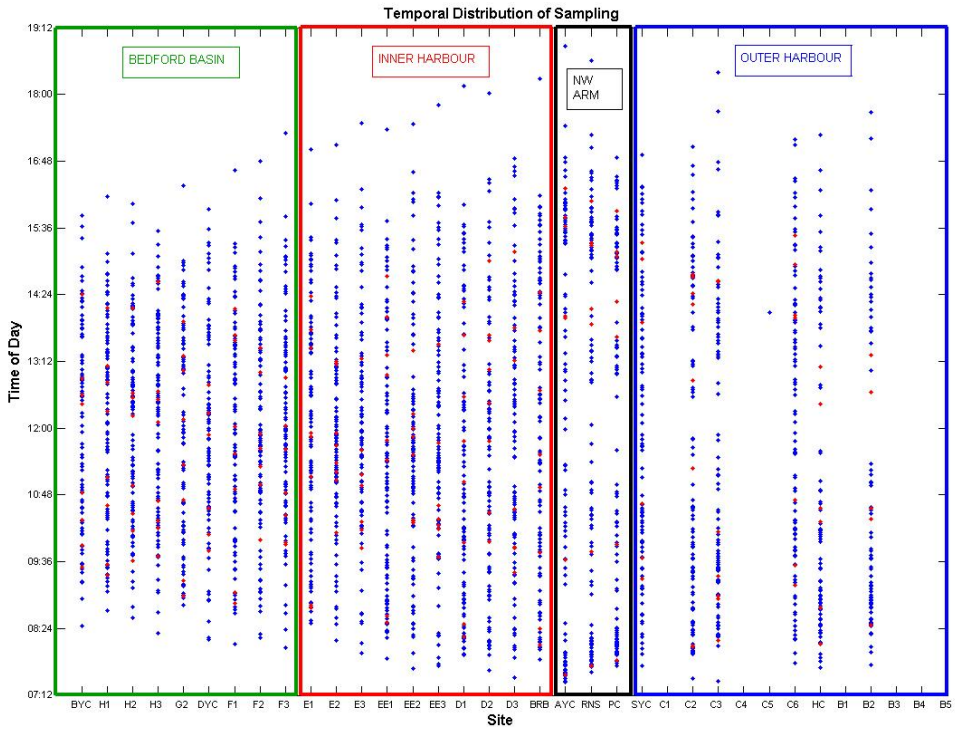

Figure 2. Temporal sampling distribution by site over entire program. Red markers denote points from 21 June 2006 to 13 September 2006.

3.5.2 Water Levels

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

Water level variations in the Harbour are caused by the tides and meteorological forcing. The meteorologically-induced changes are mostly of longer period and, except in large storms, are much smaller in magnitude than the tides. Because of their longer duration their effect on Harbour flushing can be significant and their impact on water quality may warrant investigation in the future. Note that the tidal currents in the Harbour are, for the most part, not that strong and may be 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/biweekly sampling. Sampling that occurs on the same day every second week could occur at the same point in the fortnightly tidal cycle (i.e. the same tidal range). An initial assessment of the tidal signal in Halifax Harbour indicates that the fortnightly cycle is sufficiently irregular (i.e. the tides are sufficiently "mixed"), that this problem is unlikely, particularly given the variation in sampling day (Tuesday or Wednesday, sometimes Thursday). This issue will be monitored and may be revisited more rigorously at a later time.

The probability distribution of water level (above chart datum) as derived from the tide gauge at the Naval Dockyard in Halifax (CHS station 490) for the period June 2006 to September 2006 is shown in Figure 3. The overall water level distribution is slightly bi-modal. The central minimum probability roughly corresponds to the mean tide level. However the distribution is actually relatively flat, between 0.6 m and 1.6 m. In an ideal situation each site would be sampled in a distribution similar to the overall baseline distribution.

Figure 4 shows the distribution of water levels at each site at the time of sampling (blue bars) compared to the overall water level distribution for the quarter, as represented by the red line recreated from Figure 3. This shows that for this quarter, for section EE and north, there was a bias towards sampling higher water levels. South of this, and in the Northwest Arm, the distribution is more uniform. At B2, the farthest out of the harbour, the trend is reversed and the higher water levels are under-sampled. Because sampling has been switched to bi-weekly, the number of samples in a quarter has been roughly halved. Therefore a somewhat deteriorated representation of the water level range is inevitable. If more detailed analysis is performed, particularly in the Inner Harbour where water level/tidal phase is more important, the analysis may have to include the tidal phase explicitly.

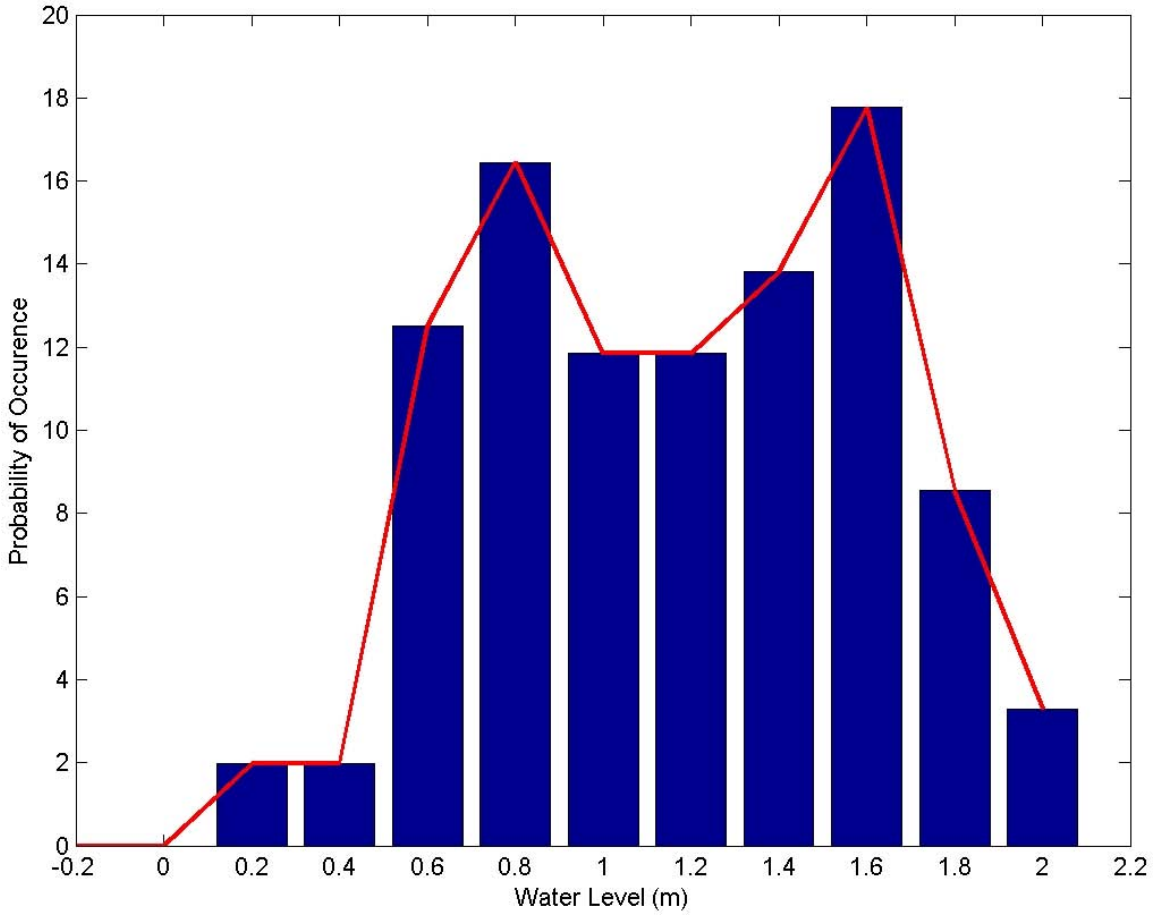

Figure 3. Probability distribution of water levels in Halifax, June to September 2006.

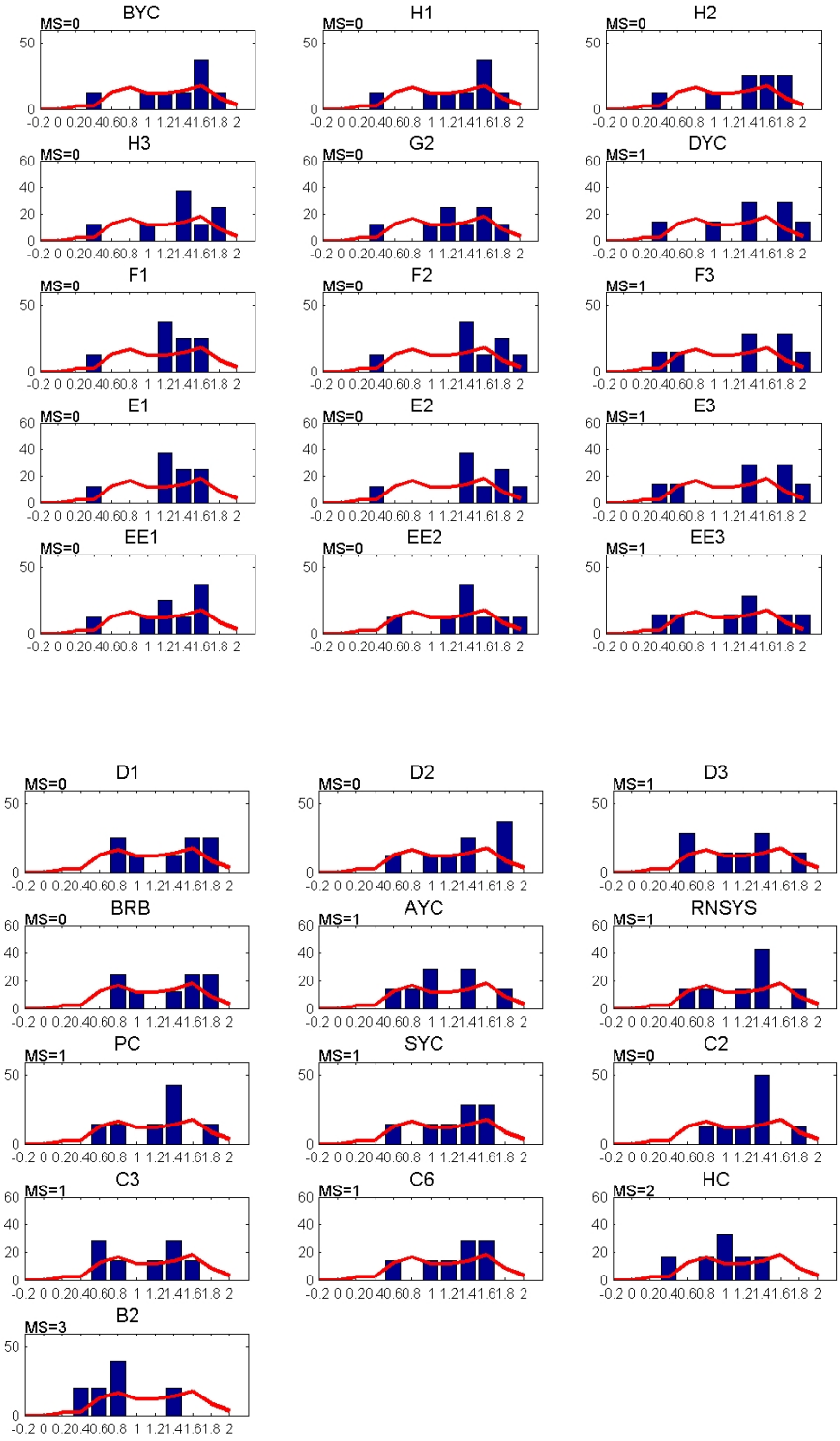

Figure 4. Water level distribution at each site during sampling 21 June 2006 to 13 September 2006. Note: MS = Missed samples.

3.5.3 Precipitation

Rainfall affects both the sewage loads and the dynamics of the Harbour. In a combined sewer system, like in Halifax, increased flow due to a rainfall event can mobilize material that has collected in the sewer pipes in low flow conditions resulting in quite high loads. Additionally, in response to the increased fresh water input, the harbour can become more stratified, enhancing estuarine circulation. The combination of increased flow and stratification can have a significant effect on the near field behaviour of the plumes from the outfalls. These effects lag the rainfall and persist for a period of time after the rain stops. The duration of the impact, of course, depends on the magnitude of the rain event and the condition of the watershed. For purposes of discussion we have, somewhat arbitrarily, selected a three day (72 hour) precipitation window for our analysis. The red line in Figure 5 depicts the probability distribution of precipitation integrated over the current and previous two days for this quarter (21 June to 13 September 2006). The blue bars on this plot represent a similar analysis performed for sampling days only. The plot indicates that our sampling has been reasonably representative with respect to precipitation, though there have been some large (40 to 60 mm) rainfall events missed. Over the entire period, about 45% of days had precipitation less than 5 mm in the 72 hour window while about 57% of sampling days met this criterion. The data therefore has somewhat of a dry weather bias.

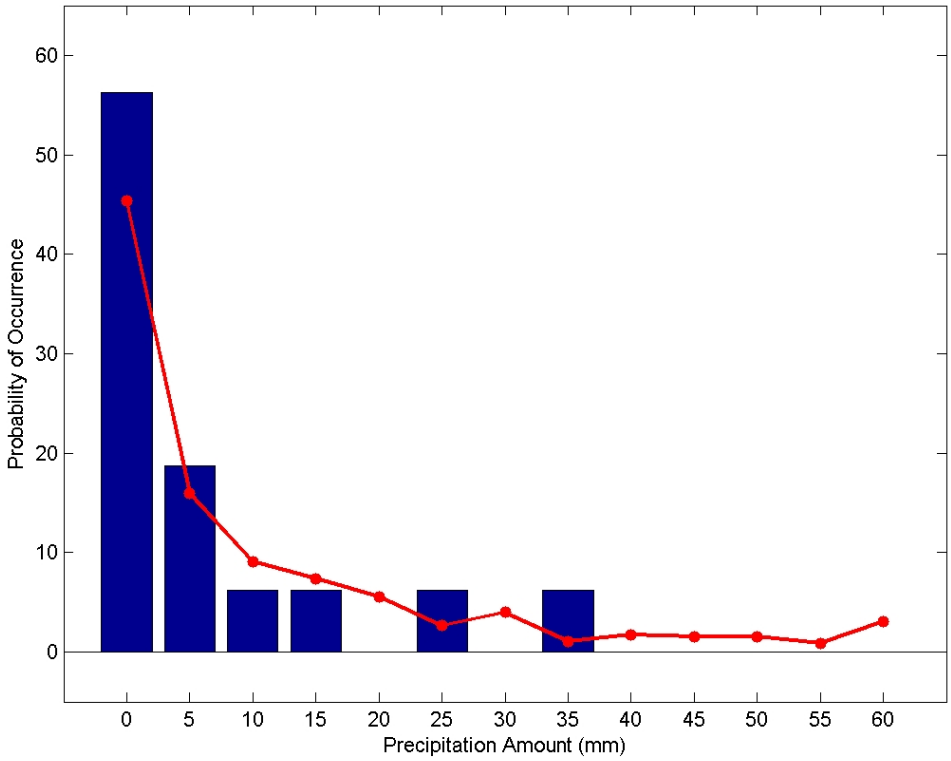

Figure 5. Probability distribution of cumulative 72 hour rainfall, 21 June 2006 to 13 September 2006.

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

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 section 4.1.1 below and Quarterly Report 1). For this analysis out of range values are replaced by 10,000.

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

For the 1 m samples, and to a lesser extent, the 10 m samples, the geometric mean coliform values are high in the Inner Harbour. The center of the spatial distribution at 10m appears to be shifted slightly northward with respect to the center of the distribution at 1m suggesting a net bottom flow into the harbour during the quarter. South of the Narrows, the maximum values at any site are in the 1 m sample. North of the Narrows, in the Bedford Basin, the highest values are as usual, generally in the 10 m sample. This relatively familiar distribution suggests a net "estuarine" flow with contaminated Inner Harbour water flowing in a lower layer into the Basin. The pattern is not as robust as normal, likely due to the temporary diversion of sewage from the Duffus St. outfall in the Narrows to the outfall (CSO) in Fairview Cove in the latter part of the quarter. This has resulted in the introduction of bacteria into the surface water of the Basin, disrupting the normal pattern somewhat.

The geometric mean values exceeding the swimming guidelines occur in much of the Inner Harbour at 1 m and 10 m. Significantly, there were low, but quite consistently detectable levels all the way out to site B2. A more rigorous discussion of guideline exceedance follows.

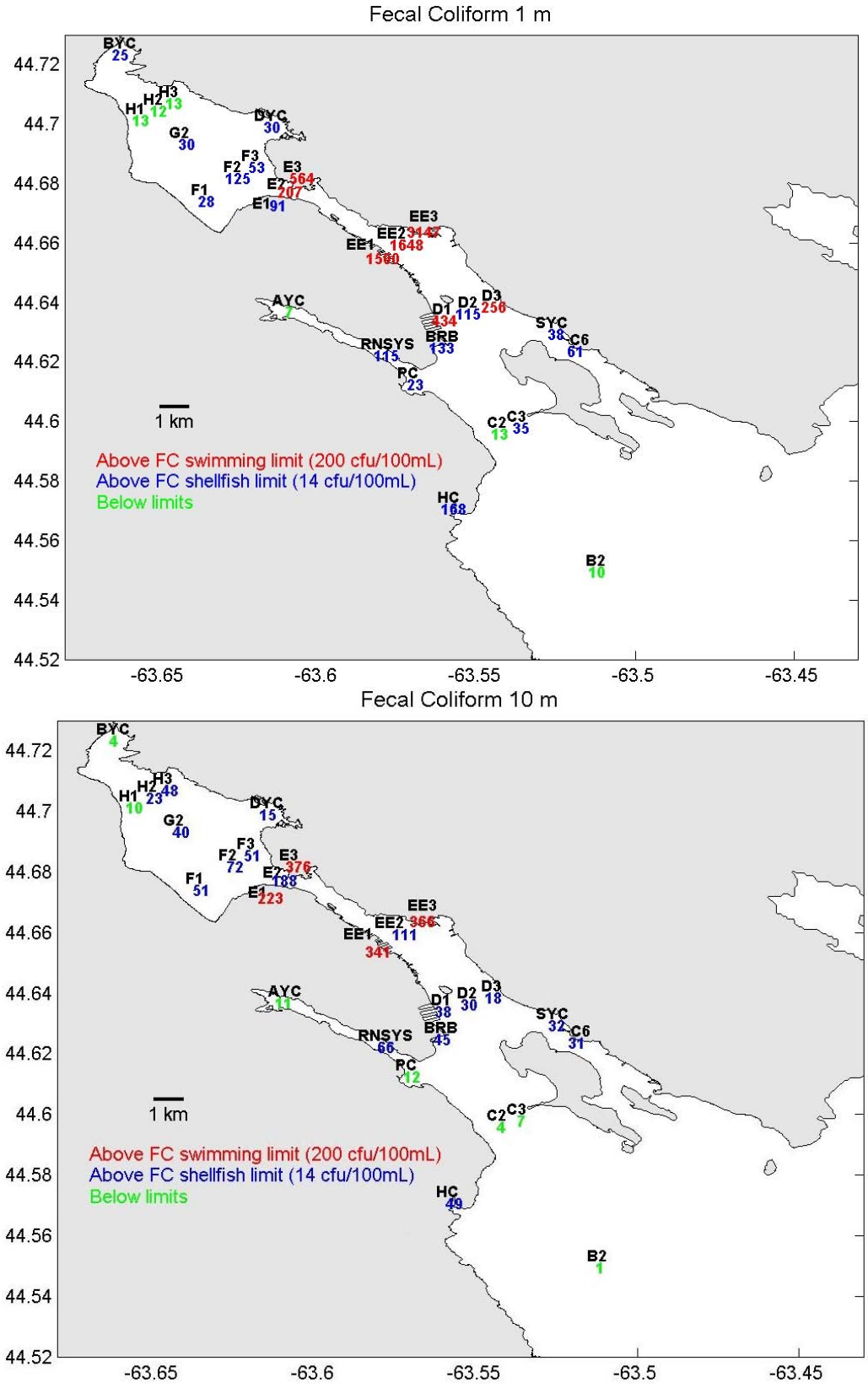

Figure 6. Fecal coliform geometric means (cfu/100mL) at 1m and 10m, 21 June 2006 to 13 September 2006.

4.1.1 Out-of-Range Values

The adaptive lab procedure, using different fecal coliform detection ranges for different sites, developed as a result of previous recommendations, has reduced the number of out-of-range values significantly. For this quarter there were several out-of-range values for 1 m samples: week 106 (27 June) at E1, E2 and E3; week 108 (18 July) at E1, E2, F1 and F2; and week 111 (15 August) E1. These values are no doubt due to temporary diversion of sewage from Duffus St pumping station to the Fairview Cove outfall.

4.1.2 Guideline Exceedance

As presented in Quarterly Report 1, the Harbour Task Force fecal coliform guidelines (Harbour Task Force, 1990) are interpreted using the methodology for swimming areas, presented in the Guidelines for Canadian Recreational Water Quality (Health and Welfare Canada, 1992). The recreational guidelines specify that in swimming areas, the geometric mean of at least five fecal coliform values taken within 30 days should not exceed 200 cfu/100mL, and any sample with values >400 cfu/100mL should trigger re-sampling. This strictly applies only to areas classified SB (recreational) by the Task Force (Table 1). The implications for areas classified SA and SC are discussed subsequently. The original weekly sampling regimen resulted in five samples within 30 days and allowed a fairly rigorous application of this analysis. The change to biweekly sampling, during this quarter, 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.

For this quarter there was weekly sampling for the first two surveys then biweekly thereafter. For consistency, the floating geometric mean presented here is based on three samples spaced every two weeks for all calculations. Therefore, for the first survey of this quarter, 105, surveys 101 and 103 were used, survey 106 was skipped and survey 107 used surveys 105 and 103.

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

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

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

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

1 m Samples

As seen in the Tables 4 below, for this quarter, the near surface water (1 m) at E3 and all of section EE in Inner Harbour would be deemed "unacceptable" for primary body contact essentially all of the time and D1, D3 and BRB are "unacceptable" for over half the time. In the Southern Basin (Section F) and Narrows (Section E) the mean value tends to be unacceptable at the end of the quarter. The increase with time at these sites is most likely related to the temporary diversion of sewage from Duffus St. to Fairview Cove discussed above. In the remainder of Bedford Basin, the means are generally "acceptable" but are characterized by sporadic high values. Aside from the increase with time at sections E and F, the 1m values seem to generally decrease through the quarter. This trend could also in part be due to the sewage diversion.

In the Northwest Arm the RNSYS site has the most variable and most "unacceptable" mean values. This is likely due to periodic impact of the plume from the relatively nearby Chain Rock outfall.

In this quarter, in the Outer Harbour, there are "questionable" and "unacceptable" mean values at the start of the quarter associated with an oceanographic flushing event documented in survey 101 (see the survey report). As discussed above, the survey 101 values are used in the floating average for survey 105. This behaviour is characteristic of the region that has generally acceptable water quality punctuated by brief events that push Inner Harbour water rapidly into the Outer Harbour. Herring Cove is generally different than the Outer Harbour as a whole, being affected by inflow from MacIntosh Run and sometimes the sewage plume from the Tribune Head outfall near the mouth of the cove.

Eastern Passage has generally "acceptable" water quality punctuated by events of lower bacterial water quality, similar to section C on the other side of McNabs Island.

10 m Samples

Referring to Table 5, as with the 1m samples, the values at sections E and F are generally "unacceptable" at the end of the quarter, likely at least in part due to the sewage diversion from Duffus St to Fairview Cove. Aside from these, the 10m floating geometric means are generally at "acceptable" levels. There are periodic high values at some sites that trigger "questionable" or "unacceptable" means. A major exception is the 10m sample at EE1 that consistently has "unacceptable" values. The reason is uncertain but may be related to the relatively nearby Duke St. outfall that is located at the Harbour bottom off Historic Properties. This relatively deep outfall may at times introduce bacteria deeper in the water column.

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 site. The Outer Harbour is the only region classified SA. This has a lower requirement (14 cfu/100 mL) than the swimming criteria. The only sites within the Task Force "Outer Harbour" boundaries are B2 and HC. HC (Herring Cove) never meets the SA criteria. 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				Eastern Pass.		Inner Harbour									
	B2	HC	C2	C3	C6	SYC	BRB	D1	D2	D3	EE1	EE2	EE3	E1	E2	E3
Survey105	15 (3)	295 (3)	173 (3)	249 (3)	93 (3)	201 (3)	387 (3)	1098 (3)	475 (3)	1590 (3)	2475 (3)	1860 (3)	19672 (3)	18 (3)	63 (3)	71 (3)
Survey107	6 (3)	343 (3)	45 (3)	167 (3)	19 (3)	54 (3)	931 (3)	2513 (3)	633 (3)	1251 (3)	3145 (3)	2064 (3)	3541 (3)	21 (3)	130 (3)	566 (3)
Survey108	6 (2)	448 (2)	31 (2)	54 (3)	24 (3)	22 (3)	335 (3)	846 (3)	305 (3)	1086 (3)	2699 (3)	5421 (3)	1938 (3)	107 (3)	464 (3)	1254 (3)
Survey109	6 (2)	58 (2)	18 (2)	61 (2)	11 (2)	16 (2)	472 (3)	537 (2)	216 (3)	800 (2)	1915 (3)	4624 (3)	2366 (2)	486 (3)	358 (3)	2049 (2)
Survey110	1 (2)	27 (2)	5 (2)	4 (2)	340 (2)	36 (2)	115 (3)	498 (2)	170 (3)	404 (2)	1361 (3)	4717 (3)	2470 (2)	4692 (3)	2686 (3)	2615 (2)
Survey111	1 (2)	71 (3)	3 (3)	1 (2)	418 (2)	26 (2)	51 (3)	56 (2)	41 (3)	7 (2)	928 (3)	802 (3)	475 (2)	4692 (3)	1438 (3)	3291 (2)
Survey112	1 (1)	268 (2)	2 (3)	1 (2)	112 (3)	25 (3)	27 (3)	396 (3)	20 (3)	19 (3)	861 (2)	907 (3)	609 (3)	3767 (3)	1959 (3)	1887 (3)

	Bedford Basin									Northwest Arm		
	F1	F2	F3	DYC	G2	H1	H2	H3	BYC	PC	RNSYS	AYC
Survey105	11 (3)	32 (3)	27 (3)	57 (3)	15 (3)	72 (3)	20 (3)	25 (3)	62 (3)	138 (3)	36 (3)	9 (3)
Survey107	11 (3)	20 (3)	45 (3)	54 (3)	37 (3)	42 (3)	36 (3)	38 (3)	62 (3)	165 (3)	392 (3)	7 (3)
Survey108	47 (3)	77 (3)	20 (3)	80 (3)	20 (3)	22 (3)	20 (3)	60 (3)	135 (3)	45 (3)	436 (3)	4 (3)
Survey109	215 (3)	86 (3)	7 (2)	40 (2)	7 (3)	5 (3)	7 (3)	32 (3)	54 (3)	18 (2)	868 (2)	2 (2)
Survey110	868 (3)	1348 (3)	77 (2)	15 (2)	16 (3)	7 (3)	7 (3)	17 (3)	217 (3)	6 (2)	414 (2)	3 (2)
Survey111	178 (3)	626 (3)	653 (2)	11 (2)	17 (3)	2 (3)	3 (3)	2 (3)	30 (3)	3 (2)	1165 (2)	15 (2)
Survey112	61 (3)	990 (3)	400 (3)	14 (3)	31 (3)	3 (3)	7 (3)	5 (3)	7 (3)	10 (3)	246 (3)	12 (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				Eastern Pass.		Inner Harbour									
	B2	HC	C2	C3	C6	SYC	BRB	D1	D2	D3	EE1	EE2	EE3	E1	E2	E3
Survey105	1 (3)	53 (3)	6 (3)	6 (3)	9 (3)	15 (3)	22 (3)	7 (3)	53 (3)	22 (3)	107 (3)	37 (3)	725 (3)	92 (3)	23 (3)	40 (3)
Survey107	1 (3)	110 (3)	3 (3)	16 (3)	7 (3)	26 (3)	161 (3)	14 (3)	57 (3)	60 (3)	310 (3)	95 (3)	262 (3)	66 (3)	63 (3)	317 (3)
Survey108	1 (2)	266 (2)	3 (3)	13 (2)	20 (3)	78 (3)	102 (3)	31 (3)	72 (3)	71 (3)	455 (3)	126 (3)	148 (3)	138 (3)	143 (3)	404 (3)
Survey109	1 (2)	394 (2)	21 (3)	160 (1)	20 (2)	71 (2)	106 (3)	38 (3)	27 (3)	15 (2)	409 (3)	113 (3)	47 (2)	348 (3)	215 (3)	1138 (2)
Survey110	1 (2)	98 (2)	10 (3)	1 (1)	167 (2)	36 (2)	20 (3)	66 (3)	24 (3)	21 (2)	216 (3)	134 (3)	511 (2)	472 (3)	268 (3)	704 (2)
Survey111	1 (2)	105 (3)	10 (3)	1 (2)	184 (2)	37 (2)	16 (3)	137 (3)	27 (3)	6 (2)	263 (3)	261 (3)	648 (2)	512 (3)	340 (3)	2893 (2)
Survey112	1 (1)	59 (2)	3 (3)	2 (3)	102 (3)	18 (3)	30 (3)	183 (3)	27 (3)	15 (3)	607 (3)	452 (3)	731 (3)	575 (3)	959 (3)	1703 (3)

	Bedford Basin									Northwest Arm		
	F1	F2	F3	DYC	G2	H1	H2	H3	BYC	PC	RNSYS	AYC
Survey105	20 (3)	34 (3)	21 (3)	5 (3)	32 (3)	4 (3)	21 (3)	27 (3)	4 (3)	8 (3)	48 (3)	9 (3)
Survey107	17 (3)	12 (3)	12 (3)	3 (3)	33 (3)	4 (3)	15 (3)	187 (3)	4 (3)	57 (3)	111 (3)	7 (3)
Survey108	36 (3)	16 (3)	15 (3)	5 (3)	45 (3)	9 (3)	12 (3)	106 (3)	5 (3)	65 (3)	191 (3)	4 (3)
Survey109	35 (3)	6 (3)	12 (2)	6 (2)	23 (3)	5 (3)	5 (3)	39 (3)	13 (3)	50 (2)	141 (2)	3 (2)
Survey110	65 (3)	46 (3)	117 (2)	22 (2)	23 (3)	15 (3)	15 (3)	9 (3)	13 (3)	6 (2)	92 (2)	4 (2)
Survey111	47 (3)	57 (3)	402 (2)	29 (2)	27 (3)	26 (3)	20 (3)	16 (3)	6 (3)	9 (2)	277 (2)	25 (2)
Survey112	105 (3)	345 (3)	313 (3)	37 (3)	46 (3)	62 (3)	50 (3)	72 (3)	4 (3)	13 (3)	226 (3)	31 (3)

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

4.2 Ammonia Nitrogen

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

Ammonia nitrogen has consistently been present at levels that are around the detection limit of 0.05 mg/L. In this quarter, at 1 m, 8.7 % of samples had detectable levels of ammonia and at 10 m, 24 % of samples had detectable levels. There were no detectable levels after the 1 August 06 (109) survey. Over time, there has been discussion of patterns in the data but the variability is large and the detectability is marginal. The detectable levels at 1 m occur at stations D2 and EE2, and at 10 m they occur at all stations except B2 but the highest values and most frequent occurrence tend to occur in the Narrows (E2) and Bedford Basin (H2) consistent with a sewage/runoff source. In this quarter, the highest mean values occurred at site D2 at 1 m and E2 at 10 m, though the levels are only slightly lower both up and down Harbour from this site.

In this quarter, while there is week-to-week variability, it again seems relatively random, though there may be a temporal trend as there were no detectable levels for the last three surveys (15, 29 August and 13 September). In the first 4 surveys there is no particular station or survey with an overall mean level that varies greatly from another. 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.

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

1m	B2	D2	EE2	E2	F2	G2	H2	mean	max
105 (21 Jun 06)	ND	ND	0.05	ND	ND	ND	ND	0.029	0.050
107 (4 Jul 06)	ND	0.1	0.05	ND	ND	ND	ND	0.039	0.100
108 (18 Jul 06)	missed	ND	ND	ND	ND	ND	ND	0.025	0.025
109 (01Aug 06)	ND	0.06	ND	ND	ND	ND	ND	0.030	0.060
110 (15 Aug 06)	ND	ND	ND	ND	ND	ND	ND	0.025	0.025
111 (29 Aug 06)	missed	ND	ND	ND	ND	ND	ND	0.025	0.025
112 (13 Sep 06)	missed	ND	ND	ND	ND	ND	ND	0.025	0.025
mean	0.025	0.041	0.032	0.025	0.025	0.025	0.025	0.028	0.044
max	0.025	0.100	0.050	0.025	0.025	0.025	0.025	0.039	0.100

10m	B2	D2	EE2	E2	F2	G2	H2	mean	max
105 (21 Jun 06)	ND	ND	0.06	0.06	0.05	0.05	0.05	0.046	0.060
107 (4 Jul 06)	ND	0.07	ND	0.07	ND	ND	0.06	0.043	0.070
108 (18 Jul 06)	missed	ND	ND	0.14	ND	ND	ND	0.044	0.140
109 (01Aug 06)	ND	ND	ND	ND	ND	0.05	0.07	0.035	0.070
110 (15 Aug 06)	ND	ND	ND	ND	ND	ND	ND	0.025	0.025
111 (29 Aug 06)	missed	ND	ND	ND	ND	ND	ND	0.025	0.025
112 (13 Sep 06)	missed	ND	ND	ND	missed	ND	ND	0.025	0.025
mean	0.025	0.031	0.030	0.053	0.029	0.032	0.040	0.035	0.059
max	0.025	0.070	0.060	0.140	0.050	0.050	0.070	0.046	0.140

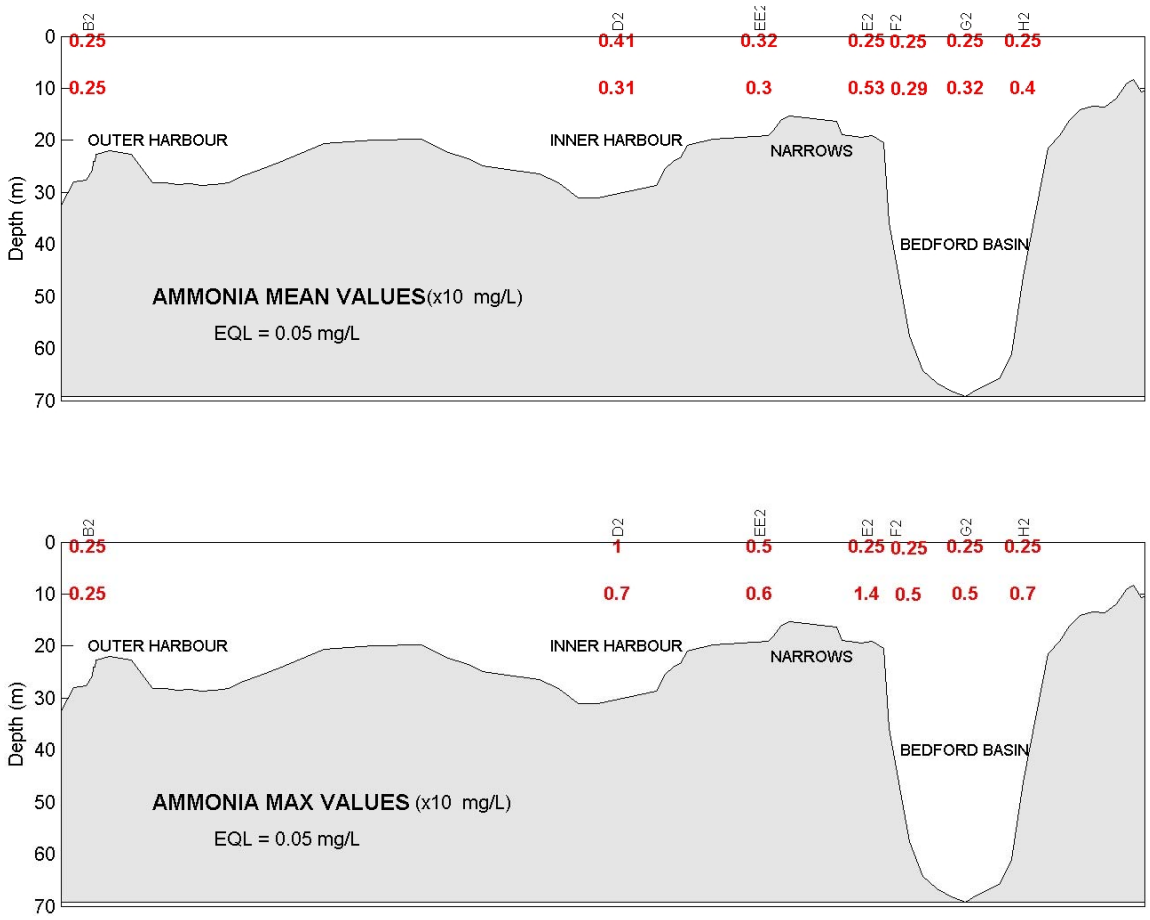

Figure 7. Mean and maximum value of ammonia nitrogen (X10 mg/L) over all ninth quarter samples

4.3 Carbonaceous Biochemical Oxygen Demand

Further to a recommendation in Quarterly Report 2, $CBOD_5$ analysis for regular samples ceased in survey 49 (25 May 2005), due to lack of detectable values. $CBOD_5$ analysis continues for supplemental samples, where there have been detectable values. The $CBOD_5$ analysis was performed on the last survey of this quarter at stations F1 and F2. The levels were below the 5 mg/L detection limit. The supplemental sample at Chain Rock Outfall in the Northwest Arm (survey 110) was also analyzed for $CBOD_5$ and the level was 5 mg/L, just at the detection limit.

4.4 Total Suspended Solids

A summary of the TSS values for this quarter is shown in Table 7. There were no samples that were below the EQL of 1 mg/L. The quarterly mean and max values are plotted by station in Figure 8. This quarter's site average values were in the range of 3.2 to 6.5 mg/L. The maximum values, by site, ranged from 5-15 mg/L. Figure 8 suggests that there may be a tendency for higher values at F2 and G2 (10 m). This is pattern is uncertain as the statistics are biased by single high values from survey 107 (4 July).

Overall, as with Ammonia, there does not appear to be a strong correlation between TSS concentrations and meteorological events/oceanographic conditions. There are occasional higher values that seem to be associated with more extreme events (e.g. storms, plankton blooms etc). These events are generally identifiable visually and are usually documented in field notes. In this quarter there was one such event in survey 107. This was in a period of visibly reduced water quality that was correlated with a rainfall/storm event and relatively high phytoplankton activity. This survey had the highest TSS values of the quarter.

Table 7. TSS Summary (mg/L).

1m	B2	D2	EE2	E2	F2	G2	H2	mean	max
105 (21 Jun 06)	3	4	3	4	4	4	2	3.43	4.00
107 (4 Jul 06)	7	5	8	5	7	4	5	5.86	8.00
108 (18 Jul 06)	missed	2	3	5	3	4	6	3.83	6.00
109 (1 Aug 06)	2	3	3	6	2	2	3	3.00	6.00
110 (15 Aug 06)	5	5	7	7	6	7	4	5.86	7.00
111 (29 Aug 06)	missed	2.3	2.9	4.1	4.2	5.1	4.1	3.78	5.10
112 (13 Sep 06)	missed	1.3	2.1	2.1	1.9	2.6	2.4	2.07	2.60
mean	4.25	3.23	4.14	4.74	4.01	4.10	3.79	3.98	5.53
max	7.00	5.00	8.00	7.00	7.00	7.00	6.00	5.86	8.00

10m	B2	D2	EE2	E2	F2	G2	H2	mean	max
105 (21 Jun 06)	3	2	4	3	3	4	6	3.57	6.00
107 (4 Jul 06)	7	5	7	3	12	15	6	7.86	15.00
108 (18 Jul 06)	missed	2	3	3	5	3	2	3.00	5.00
109 (01Aug 06)	7	3	4	3	3	4	3	3.86	7.00
110 (15 Aug 06)	4	5	5	3	8	5	6	5.14	8.00
111 (29 Aug 06)	missed	3.5	4	5.5	7.7	5	3.6	4.88	7.70
112 (13 Sep 06)	missed	1.9	3	3.1	missed	2.9	2.4	2.66	3.10
mean	5.25	3.20	4.29	3.37	6.45	5.56	4.14	4.42	7.40
max	7.00	5.00	7.00	5.50	12.00	15.00	6.00	7.86	15.00

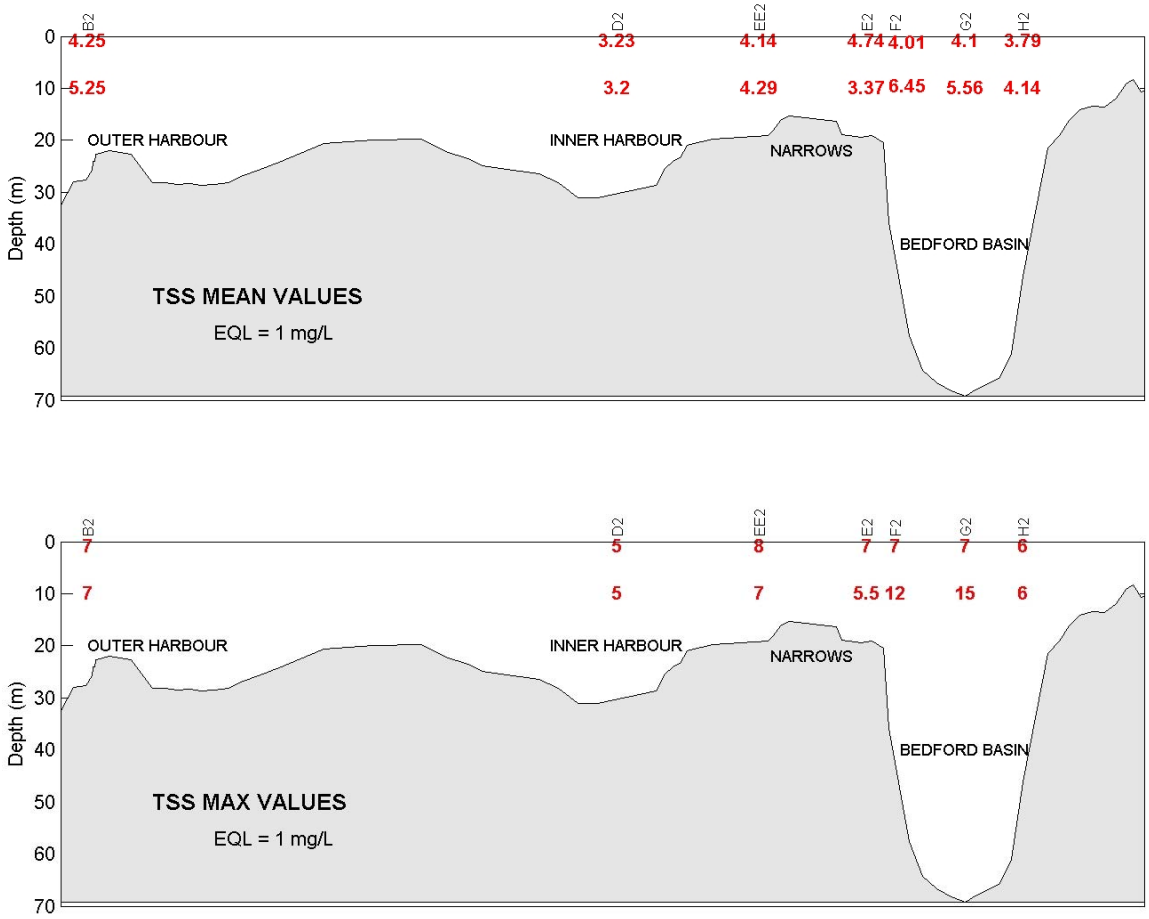

Figure 8. Mean and maximum values of total suspended solids (mg/L) over all ninth quarter samples.

4.5 Total Oils and Grease

Based on recommendations in Quarterly Report 5 regular sampling for Total Oil and Grease was discontinued in, survey 75 (23 Nov 06). The analysis is retained for supplemental samples. The supplemental sample at Chain Rock Outfall in the Northwest Arm (survey 110) was analyzed for Total Oil and Grease and had non-detectible levels.

4.6 Metals

As discussed in Section 3.1, a high resolution metals analysis began on survey 111 (29 Aug 06). This replaces the low level metals scan that was discontinued in survey 73 (23 Nov 06). Therefore, in this quarter there is metals data for only the last two surveys (111, 112). There were a total of 24 samples collected. The results of these are summarized in Table 8. The mean values consider only detectable levels. This table shows that of the metals with guidelines, copper and zinc were present in detectable levels in almost all of the samples. Manganese is detectable in somewhat less than half the samples. 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.

Table 8. Metals concentration summary (surveys 111 and 112).

Metal	EQL (µg/L)	Number >EQL	Mean (µg/L)	Range (µg/L)	Task Force Guideline (µg/L)
Cadmium	0.1	0	-	-	9.3
Cobalt	0.1	0	-	-	n/a
Copper	0.1	24	0.6	0.2-1.2	2.9
Iron	1	24	7.5	3 - 10	n/a
Lead	0.1	3	.17	0.1-0.2	5.6
Manganese	1	10	1	1	100
Mercury	0.01	0	-	-	0.025
Nickel	0.5	2	0.6	0.6	8.3
Zinc	1	23	5.2	1 - 32	86

4.7 Profile Data

The Seabird CTD used in this program measures continuous profiles of temperature, salinity, fluorescence and dissolved oxygen with depth. In the past, the profile data has been 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. Unfortunately as noted in Section 2, BBPMP has discontinued the analysis used for comparison. 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 (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. Phytoplankton blooms tend to start in the Basin and migrate outward to the rest of the harbour. The profile maximum values generally decrease in magnitude and occur lower in the water column further out of the harbour. The data in the Basin generally represents the maximum concentrations observed and is representative of the timing of phytoplankton activity in the remainder of the harbour. During this quarter there was relatively consistent phytoplankton activity with maximum levels of 10-20 mg/m^3. The highest levels observed during the quarter (maximum levels of > 30 mg/m^3), were in survey 107, (4 July 06).

4.7.3 Dissolved Oxygen

Comparison between dissolved oxygen determinations by different methods/instruments has proven uncertain. Part of this uncertainty is due to the vagaries of the instruments themselves. Additionally, small variations in processing procedures, particularly with “alignment” procedures, that assign depths to the DO measurements obtained with the CTD, can add uncertainty. The CTD sensors are quite stable, but tend to lose sensitivity with time. Due to the nature of the CTD itself, they cannot be user calibrated. The BBPMP routinely collects water samples for ground truthing their CTD DO measurements. The samples are analyzed with a well calibrated bench top DO meter. This data can be used to adjust the profile data. 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 9, below. Note that the BBPMP station is approximately 125 m east of the HHWQMP site G2 and that BBPMP samples are generally collected on the day following the HHWQMP samples, so direct correspondence is not to be expected.

Table 9. 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
105 (21 Jun 06)	7.3	6.6	6.4	6.3	0.88	0.95
106 (27 Jun 06)	-	-	7.1	6.3	-	-
107 (4 Jul 06)	7.6	6.9	7.9	6.1	1.03	0.89
108 (18 Jul 06)	8.6	6.9	6.4	6.4	0.75	0.93
109 (01Aug 06)	7.5	6.8	7.1	5.7	0.95	0.84
110 (15 Aug 06)	7.8	6.5	7.0	6.3	0.90	0.97
111 (29 Aug 06)	7.1	6.3	6.9	6.3	0.97	1.00
112 (13 Sep 06)	6.5	6.1	6.7	6.3	1.03	1.03

The data generally exhibits good correspondence. The HHWQMP data on average is slightly higher than the BBPMP data, but within uncertainty given the differences in time and location.

In general in this quarter the DO levels are relatively low compared to the applicable guidelines. Part of this is due to water temperature. The temperature range at the surface at G2 is 11 to 18° C with the corresponding DO saturation levels being approximately 8-9 mg/L. The levels are at times at or near saturation, but still there are times that the concentrations drop below guidelines, particularly in deeper water.

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 measured dissolved oxygen in the harbour surface water meets the applicable guidelines most everywhere. An exception is the first survey (105) where the whole water column is just below the class SA (8.0 mg/L) guideline at B2. Also, near the end of the quarter (survey 110, 29 Aug 06) the DO at station B2 again dropped just below the 8.0 mg/L guideline throughout the water column. B2 was not sampled in surveys 111(29 Aug 06) and 112(13 Sep 06), but the DO levels throughout the harbour appear to have dropped and by survey 112 the DO was below the 7 mg/L guideline throughout the water column in all SB areas, and the 6 mg/L class SC guideline is exceeded in the bottom water in the Inner Harbour. The bottom water in the Basin throughout the quarter does not meet the 7.0 mg/L class SB guideline. This is typical for the Basin where the bottom water is replaced only sporadically. Other than this at the start of the quarter the DO at the bottom of the

NW Arm was below the 7.0 mg/L guideline. In the last half of the quarter, the bottom water did not meet guidelines anywhere in the Harbour.

4.8 Supplemental Sample

During this quarter there was one supplemental sample (survey 110, 15 Aug 06) in a particularly large visible plume from the Chain Rock Outfall in the Northwest Arm. This plume was visible from a distance (Figure 9) and extended completely across the NW Arm. There were visible fronts at the northern and southern edges. The source of the plume was the Chain Rock outfall. This outfall is in relatively shallow water and often results in a visible boil with an agglomeration of birds. This day it was particularly evident (Figure 10). Inside the plume the water was visibly turbid with significant amounts of detritus (Figures 11 and 12). The sample was taken at 1522 ADT at approximately 50 m east southeast (parallel to shore) from the outfall. The sample coordinates are 44º 37.159´ N, 63º 34.318´ W (NAD83). The northern edge of the plume from inside the plume is shown in Figures 13 and 14.

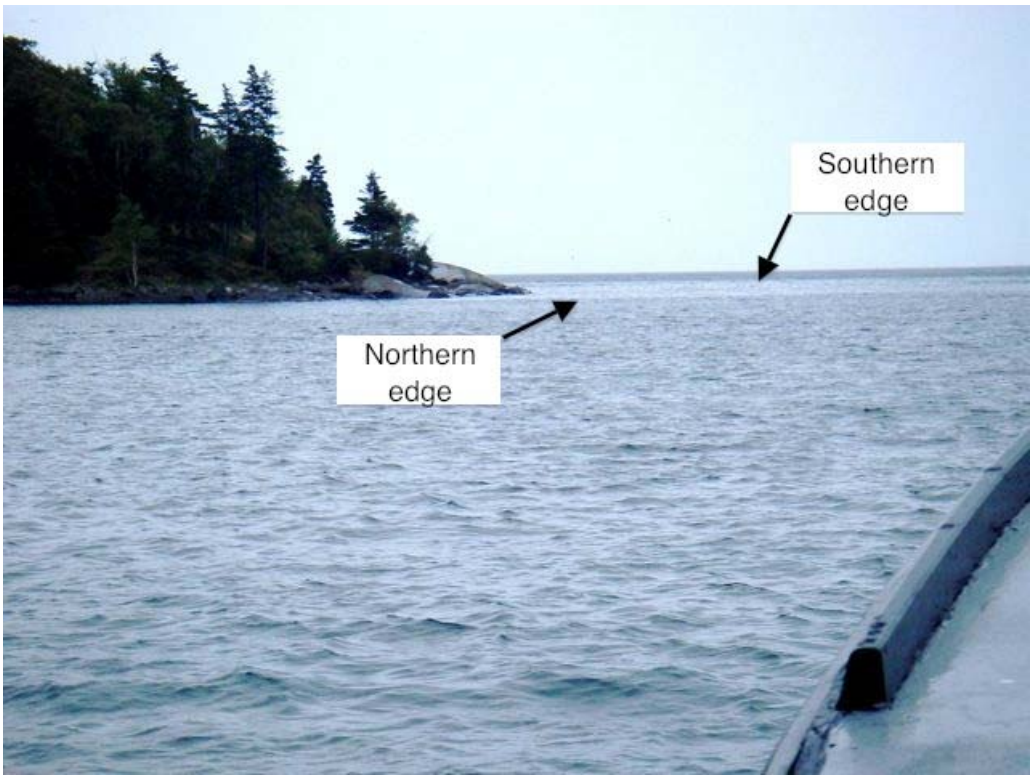

Figure 9. Approaching the plume from the North.

Figure 10. Chain Rock outfall boil and birds.

Figure 11. Turbid water shoreward of sample site.

Figure 12. Close up of turbid water showing detritus.

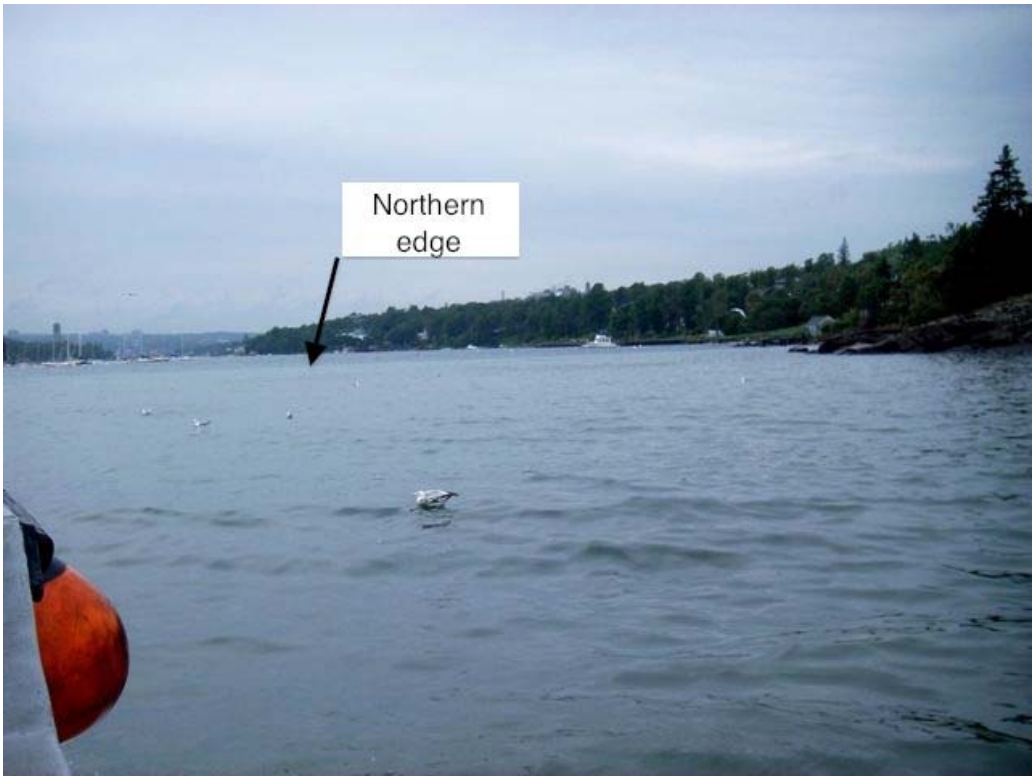

Figure 13. Northern edge of plume from within the plume.

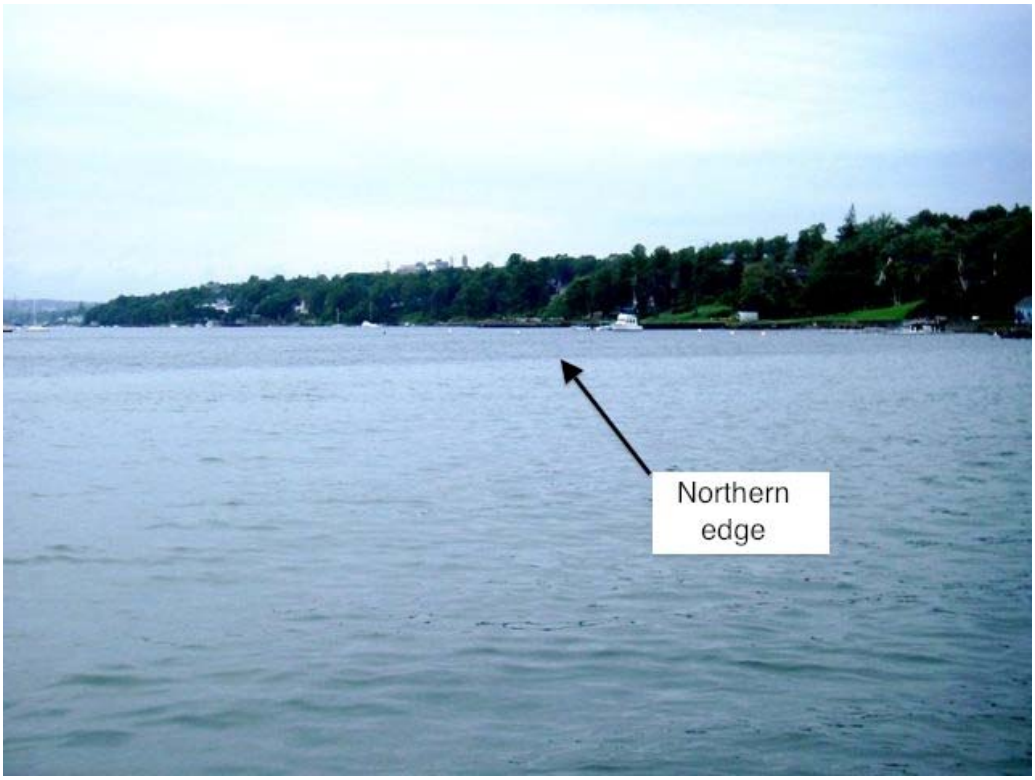

Figure 14. Approaching northern edge of plume.

The near surface salinity was about 29.5 PSU, that compares to 30.2 and 30.7 PSU for the nearest sites, PC and RNSYS respectively. This suggests that the sewage (fresh water) is probably diluted 20:1 or more with the surrounding seawater. The remainder of the CTD measurements were unremarkable compared with nearby values. The results of the lab analysis are presented in Table 10. These suggest that at the sample site, the surface water was poorly diluted sewage. The bacteria levels are high (out of range). The $CBOD_{5,}$ very seldom detectable in the harbour, is 5.0 mg/L, and the ammonia nitrogen at 0.66 mg/L is more than four times higher than any other sample this quarter. The TSS is also elevated (12 mg/L) but is similar to the maximum values observed this quarter in other samples. The metals scan indicated no values above detection limits. This was the low resolution scan and does not guarantee that levels of copper (guideline 2.9 ug/L) or zinc (guideline 8.3 ug/L) did not exceed guidelines.

Table 10. Supplemental sample lab results.

	UNITS	VALUES	RDL
BACTERIA			
Fecal Coliform	cfu/100 mL	>10,000	1
INORGANICS			
Carbonaceous BOD	mg/L	5	4
Nitrogen (Ammonia Nitrogen)	mg/L	0.66	0.05
Total Suspended Solids	mg/L	12	1
OIL & GREASE			
Total Oil & Grease	mg/L	ND	5
METALS WITH GUIDELINES			
Cadmium (Cd)	ug/L	ND	3
Chromium	ug/L	ND	20
Cobalt (Co)	ug/L	ND	10
Copper (Cu)	ug/L	ND	20
Iron (Fe)	ug/L	ND	500
Manganese (Mn)	ug/L	ND	20
Nickel (Ni)	ug/L	ND	20
Zinc (Zn)	ug/L	ND	50
METALS WITH NO GUIDELINES			
Aluminum	ug/L	ND	100
Antimony	ug/L	ND	20
Arsenic	ug/L	ND	20
Barium	ug/L	ND	50
Berylium	ug/L	ND	20
Bismuth	ug/L	ND	20
Boron	ug/L	3300	50
Cobalt (Co)	ug/L	ND	10
Lead (Pb)	ug/L	ND	5
Lithium	ug/L	140	20
Selenium	ug/L	ND	50
Strontium	ug/L	5600	50
Thallium	ug/L	ND	1
Tin	ug/L	45	20
Titanium	ug/L	3	20
Uranium	ug/L	ND	1
Vanadium	ug/L	ND	20

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 weekly reporting frequency was changed to biweekly in July 2006 after survey 107(4 Jul 06).
- Metals analysis is included for the chemistry sites starting in survey 111 (29 Aug 06) therefore metal plots are included at the end of each survey report starting with survey 112 (13 Sep 06).

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. The documentation of sampling/sample handling/lab procedures/ data analysis remains incomplete.

Changes

- The graphical comparison of CTD data in Bedford Basin with the Bedford Basin Phytoplankton Monitoring Program (BBPMP) has been discontinued due to changes in data presentation by BBPMP.
- A point comparison of dissolved oxygen at 1-10 m has been added for quality control purposes.

5.2 Sampling Program

The sampling route selection continues as per the eighth quarter. As of that time the routes were modified to always either start or end in the Northwest Arm, where the survey boat is based. This was done based on travel time considerations and does introduce an early morning /late afternoon bias into the data. The morning sampling may coincide with the peak diurnal sewage flows and may result in a bias in water quality samples near the chain rock outfall (e.g. RNSYS, PC). This is also a function of the plume trajectory at the time of sampling. This should be considered in a detailed analysis of RNSYS, and to a lesser extent, PC water quality data.

Changes
- As of survey 111(29 Aug 06) a high resolution metals analysis is included for all "chem." stations.

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Ongoing item (Quarterly Report 3): Consider additional/or substituted sampling sites to address Herring Cove (Hospital Point) STP and Tribune Head outfall. Additional sampling around Hospital Point will begin next quarter, closer to the commissioning of the Hospital Point STP, the last of the three plants to be commissioned.

5.3 Water Quality Parameters

Fecal Coliform

In general, the geometric mean coliform values are well above primary contact guidelines in the Inner Harbour. Outside of the Inner Harbour high values are more sporadic. The occurrence of high values outside the Inner Harbour are primarily dependant on oceanographic conditions, that may transport water from the Inner Harbour either up or down harbour, and secondarily dependant on loading events (e.g. storms) that may increase loads thereby raising levels everywhere. Both of these often act together. Near the end of this quarter the normal spatial pattern was disrupted by a temporary, but potentially protracted, diversion of sewage from the Duffus St. outfall in the Narrows to the Fairview Cove outfall in the southern Basin. This has resulted in higher than normal bacteria levels in sections E and F. 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, dependant 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 were all in sites affected by the sewage diversion. Without the diversion these sites periodically experience low values and a decrease in resolution, and commensurate increase in resolution of high values, at these sites could result in a loss of resolution at on the lower detection limit. 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 around the detection limit of 0.05 mg/L. Overall, in this quarter, 16 % of samples had detectable levels of ammonia. There were two higher measurements in regular samples that were about 2-3 times the detection limit. The supplemental sample (section 4.8) had an ammonia level (0.66 mg/L) that is > 13 times the detection limit. Ammonia nitrogen is an attractive tracer as it is routinely monitored in sewage treatment facilities and, therefore, has quantifiable source strength in sewage. Recognizing nitrogen as the key nutrient in marine systems, and the potential importance that nutrients have in the Harbour oxygen dynamics, additional species of nitrogen should continue to be considered for monitoring.

Changes
- None

$CBOD_5$

Based on recommendations in Quarterly Report 2, $CBOD_5$ was dropped from regular analysis in survey 49 (25 May 2005). Until that time there were an insignificant number of regular samples with detectable $CBOD_5$ at the 5 mg/L level. $CBOD_5$ has been retained as a tracer for the supplemental sampling program.

The $CBOD_5$ analysis was performed at stations F1 and F2 in the last survey of this quarter (survey 112). The levels were below the 5 mg/L detection limit. The supplemental sample (section 4.8) was also analyzed for $CBOD_5$ and had the barely detectable level of 5 mg/L

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 does seem to be 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. In this quarter there was one such event in survey 107(4 Jul 06). This quarter's site average values were in the range of 3.2 to 6.5 mg/L with site maximum values of 5 to 15 mg/L.

Changes:
- At the end of the quarter the EQL of the TSS analysis was reduced to 0.5 mg/L

Total Oils and Grease

Based on recommendations in Quarterly Report 5, analysis for total oil and grease was dropped from regular analysis in survey 75 (23 November 2005), due to lack of detection. It is retained in supplemental sample analysis. The supplemental sample at Chain Rock Outfall in the Northwest Arm (survey 110) was analyzed for total oil and grease and had non-detectable levels.

Changes
- None

Metals

Initial results from two surveys indicate that the newly instituted higher resolution metals analysis will result in meaningful data on the concentrations of several heretofore unresolved metals in the Harbour. This data did not indicate any guideline exceedances.

Changes:
- A modified metals analysis has been instituted and metals analysis is included for the chemistry sites starting in survey 111 (29 August 2006).

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.

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. During this quarter there was relatively consistent phytoplankton activity with maximum levels of 10-20 mg/m^3. The highest levels observed during the quarter (maximum levels of > 30 mg/m^3), were in survey 107, (4 July 06).

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, in addition to the Basin bottom water there were a number of guideline exceedances. At the start of the quarter they occurred in the deeper water of the NW Arm and throughout the water column in the Outer Harbour (class SA). At the end of the quarter, the DO tended to drop everywhere, leading to widespread exceedances, including the surface water throughout the Harbour. 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 good correspondence.

Changes

- None

6 References

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