# Halifax Harbour
# Water Quality Monitoring Program
# Quarterly Report #5

Prepared for:

**Jacques Whitford Limited**

Prepared by:

**AMEC Earth & Environmental**
7 Canal Street, 2nd Floor
Dartmouth, Nova Scotia
B2Y 2W1
Ph: (902) 463-7677
Fax: (902) 463-5696

November 2006

## DISCLAIMER

In conducting this study and preparing this report, AMEC has applied due diligence commensurate with normal scientific undertaking of a similar nature. In no event shall the consultant, its directors, officers, employees or agents be liable for any special, indirect or consequential damages, including property damage or loss of life, arising out of the use, interpretation or implementation of the data or any information enclosed in the report by any party, including without limitation, loss of profit, loss of production, loss of use, costs of financing, and liability to others for breach of contract.

# 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.

# Table of Contents

# List of Figures

# List of Tables

# 1 Introduction

This quarterly report is a summary of Halifax Harbour Water Quality Monitoring Project (HHWQMP) data collected from 21 Jun 05 to 14 Sep 05. The analysis presented here is an evolving presentation of the data. The data for the period are discussed in terms of compliance/exceedance of applicable water quality guidelines (Halifax Harbour Task Force, 1990), and how they affect recommendations for program modification. 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 which can occur as the project proceeds. 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) conducted by scientists with the Department of Fisheries and Oceans at Bedford Institute of Oceanography. This report discusses just the fifth quarter. Every fourth quarterly report includes an annual summary of data and trends over the previous four quarters.

# 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. This quarter the “profile” pages were rearranged slightly and the sampling site map was replaced with a more geographically correct version. This change occurred on Week 64 (6 Sep 05).

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

# 3 Sampling Program

Survey sampling is conducted on a weekly basis from one of two vessels based at the Armdale Yacht Club (AYC). The details of the sampling program are discussed in the introduction section of the project report binder and QR#1. The locations of the 31 regular sampling sites, as well as five intermittently occupied sites are included for reference in Figure 1.

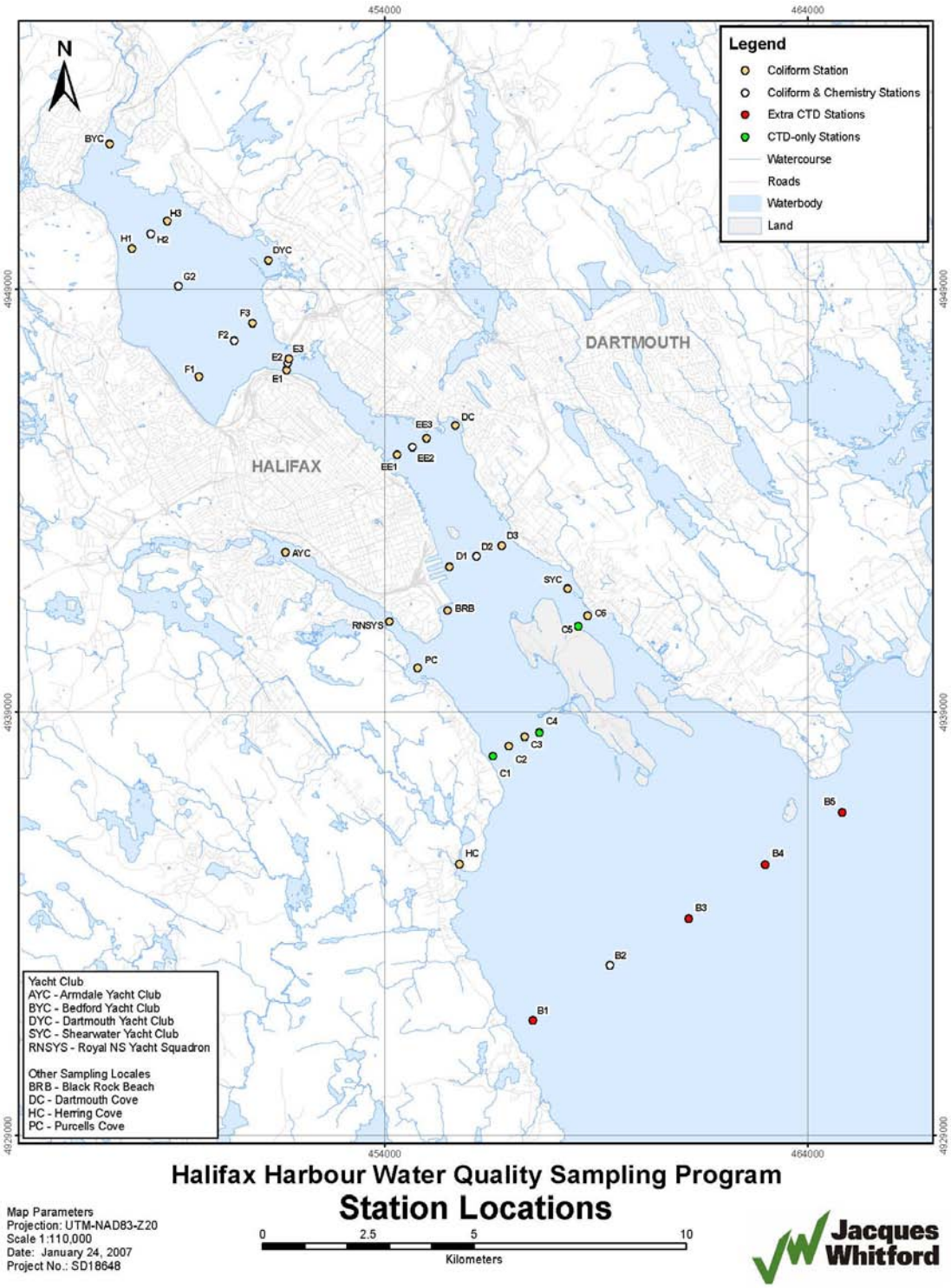


Figure 1. Halifax Inlet Sample Locations

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 are reiterated in Table 1. 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 five missed bacteria stations (1 and 10m depths), for a total of ten 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.

Table 1. Summary of measured parameters

| | EQL | | Harbour Task Force Guideline | Water Use Category | Sampling Stations (refer to Fig. 1) | Sampling frequency |
|---|---|---|---|---|---|---|
| | value | units | | | | |
| **Profile Data** | | | | | All | weekly |
| Salinity | n/a | PSU | n/a | n/a | | |
| Temperature | n/a | C° | n/a | n/a | | |
| Chlorophyll *a* | n/a | ug/L | n/a | n/a | | |
| | | | 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<br>200 | SA<br>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** | | | | | Chemical sites Supplemental sites | bi-weekly |
| Cadmium | 3 | ug/L | 9.3 | all | | |
| Chromium | 20 | ug/L | 50.0 | all | | |
| Copper | 20 | ug/L | 2.9 | all | | |
| Lead | 5 | ug/L | 5.6 | all | | |
| Manganese | 20 | ug/L | 100.0 | all | | |
| Nickel | 20 | ug/L | 8.3 | all | | |
| Zinc | 50 | ug/L | 86.0 | all | | |
| Aluminum | 100 | ug/L | none | | | |
| Antimony | 20 | ug/L | none | | | |
| Arsenic | 20 | ug/L | none | | | |
| Barium | 50 | ug/L | none | | | |
| Beryllium | 20 | ug/L | none | | | |
| Bismuth | 20 | ug/L | none | | | |
| Boron | 500 | ug/L | none | | | |
| Cobalt | 10 | ug/L | none | | | |
| Lithium | 20 | ug/L | none | | | |
| Iron | 500 | ug/L | none | | | |
| Molybdenum | 20 | ug/L | none | | | |
| Selenium | 50 | ug/L | none | | | |
| Strontium | 50 | ug/L | none | | | |
| Thallium | 1 | ug/L | none | | | |
| Tin | 20 | ug/L | none | | | |
| Titanium | 20 | ug/L | none | | | |
| Uranium | 1 | ug/L | none | | | |
| Vanadium | 20 | ug/L | none | | | |

### 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 fifth quarter is presented in Table 2.

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

| Date | 21-Jun-05 | 29-Jun-05 | 5-Jul-05 | 12-Jul-05 | 19-Jul-05 | 26-Jul-05 | 3-Aug-05 | 9-Aug-05 | 16-Aug05 | 23-Aug-05 | 30-Aug-05 | 6-Sep-05 | 14-Sep-05 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| survey | 53 | 54 | 55 | 56 | 57 | 58 | 59 | 60 | 61 | 62 | 63 | 64 | 65 |
| 1 | D3 | EE3 | PC | HC | D1 | C5 | HC | EE2 | D3 | B2 | D2 | BRB | B2 |
| 2 | SYC | EE2 | C2 | B2 | D2 | C6 | B2 | EE3 | EE3 | HC | D3 | D1 | HC |
| 3 | C6 | E3 | C1 | C1 | EE1 | SYC | C3 | D2 | E3 | C1 | SYC | EE1 | C1 |
| 4 | C5 | E2 | HC | C2 | E1 | D3 | C4 | D3 | F3 | C2 | C6 | E1 | C2 |
| 5 | C4 | F2 | B2 | PC | F2 | EE3 | C5 | SYC | DYC | PC | C5 | F1 | PC |
| 6 | C3 | F3 | C3 | RNSYS | F1 | E3 | C6 | C6 | H3 | RNSYS | C4 | G2 | RNSYS |
| 7 | B2 | DYC | C4 | AYC | G2 | F3 | SYC | C5 | BYC | AYC | C3 | H1 | AYC |
| 8 | HC | H3 | C5 | BRB | H1 | DYC | D3 | C4 | H2 | BRB | B2 | BYC | BRB |
| 9 | C1 | H2 | C6 | D1 | H2 | H3 | D2 | C3 | H1 | D1 | HC | H2 | D1 |
| 10 | C2 | BYC | SYC | D2 | BYC | BYC | EE3 | B2 | G2 | EE1 | C1 | H3 | D2 |
| 11 | PC | H1 | D3 | EE2 | H3 | H2 | EE2 | HC | F1 | E1 | C2 | DYC | EE1 |
| 12 | RNSYS | G2 | D2 | E2 | DYC | H1 | E3 | C1 | F2 | F1 | BRB | F2 | EE2 |
| 13 | AYC | F1 | EE3 | E1 | F3 | G2 | E2 | C2 | E1 | G2 | D1 | F3 | E1 |
| 14 | BRB | E1 | EE2 | F2 | E3 | F2 | F2 | PC | E2 | H1 | EE1 | E2 | E2 |
| 15 | D1 | EE1 | E3 | F1 | E2 | E1 | F3 | RNSYS | EE1 | BYC | E1 | E3 | F1 |
| 16 | D2 | D1 | E2 | G2 | EE3 | E2 | DYC | AYC | EE2 | H2 | F1 | EE2 | F2 |
| 17 | EE2 | BRB | F2 | H1 | EE2 | EE1 | H3 | BRB | D2 | H3 | G2 | EE3 | G2 |
| 18 | EE1 | AYC | F3 | H2 | DC | EE2 | H2 | D1 | D1 | DYC | H1 | D2 | H1 |
| 19 | E1 | RNSYS | DYC | BYC | D3 | D2 | BYC | EE1 | BRB | F3 | BYC | D3 | H2 |
| 20 | E2 | PC | H3 | H3 | SYC | D1 | H1 | E1 | AYC | F2 | H2 | SYC | BYC |
| 21 | F2 | C2 | H2 | DYC | C6 | BRB | G2 | F1 | RNSYS | E2 | H3 | C5 | H3 |
| 22 | F1 | C1 | BYC | F3 | C5 | C2 | F1 | G2 | PC | E3 | DYC | C6 | DYC |
| 23 | G2 | HC | H1 | E3 | BRB | C1 | E1 | H1 | C2 | EE2 | F3 | C4 | F3 |
| 24 | H1 | B2 | G2 | EE3 | C4 | C3 | EE1 | BYC | C1 | EE3 | F2 | C3 | E3 |
| 25 | H2 | C3 | F1 | D3 | C3 | C4 | D1 | H2 | HC | D2 | E3 | B2 | EE3 |
| 26 | BYC | C4 | E1 | SYC | C2 | PC | BRB | H3 | B2 | D3 | E2 | HC | D3 |
| 27 | H3 | C5 | EE1 | C6 | C1 | RNSYS | C2 | DYC | C3 | SYC | EE3 | C2 | SYC |
| 28 | DYC | C6 | D1 | C5 | PC | AYC | C1 | F3 | C4 | C6 | EE2 | C1 | C5 |
| 29 | F3 | SYC | BRB | C4 | RNSYS |  | PC | F2 | C5 | C5 | DC | PC | C6 |
| 30 | E3 | D3 | RNSYS | C3 | AYC |  | RNSYS | E2 | C6 | C4 | PC | RNSYS | C4 |
| 31 | EE3 | D2 | AYC |  |  |  | AYC | E3 | SYC |  | RNSYS | AYC | C3 |
| 32 | DC |  |  |  |  |  |  |  |  |  | AYC |  |  |

### 3.2 Sampling Bias

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

#### 3.2.1 Time of Day

Sewage flows have significant regular diurnal variations, which can affect the water quality in the harbour on short timescales. In addition to variations in sewage load, the most obvious diurnal variation is in sunlight. Sunlight is perhaps the major contributor to the die off of bacteria, and can have effects on other parameters, particularly chlorophyll (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 fifth quarter are shown in red. The sites are generally sorted from north to south. There are a few patterns which emerge. The stations at the north end of Bedford Basin have a smaller range of sampling times. This is because logistics dictates that the surveys never start or end in the Basin. In general, the range of sampling times increases with distance south. This is a function of travel time from the Armdale Yacht club in the Northwest Arm. Even if a distant site is sampled first, it takes a relatively long 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 probably not significant.

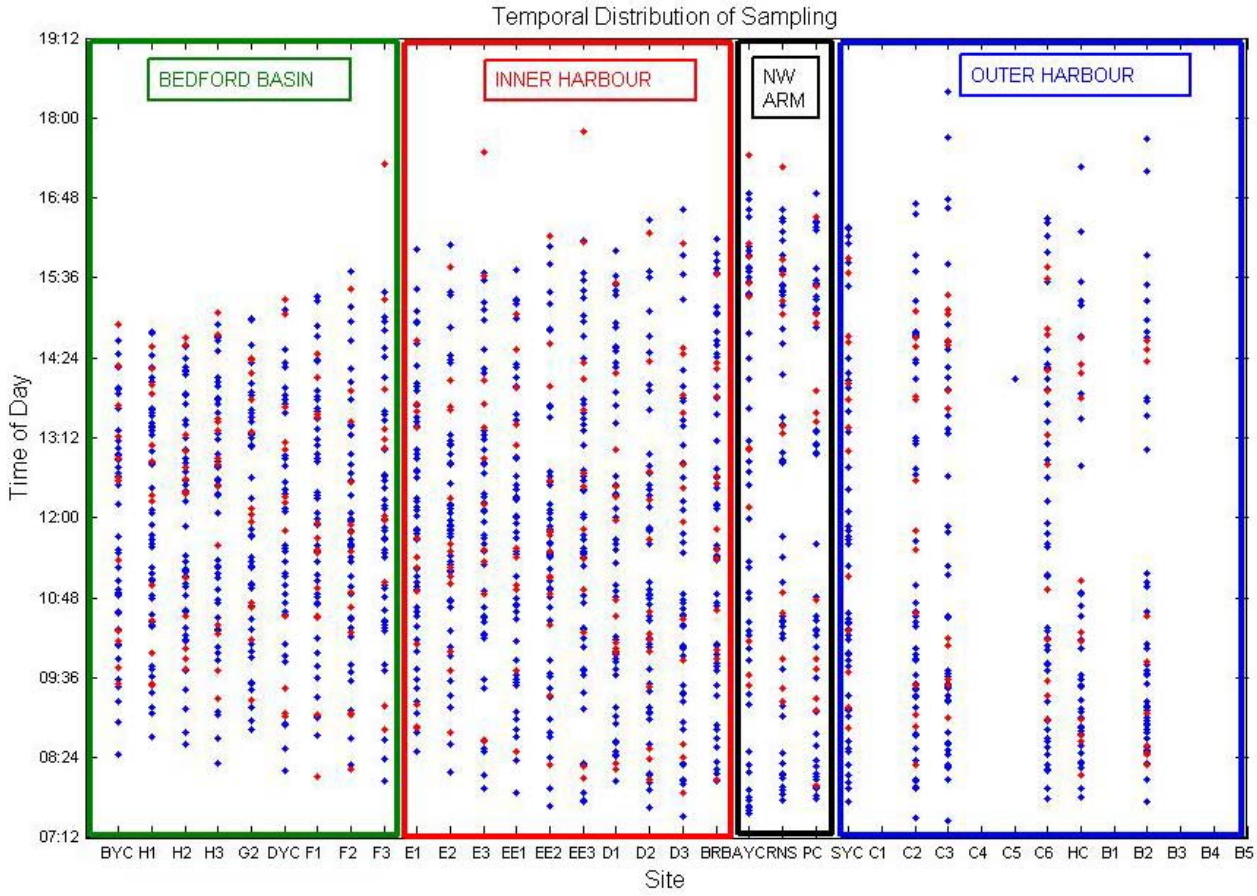


Figure 2. Temporal sampling distribution by site over entire program. Red markers denote points from this quarter.

### 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 tide direction) from the nearest outfall, and the variation in initial dilution 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 than the tides. Their effect on Harbour flushing can be significant and their impact on water quality may warrant investigation in the future. However, the occurrence of surges is 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.

A preliminary assessment of water level during sampling follows. The probability distribution of water level (above chart datum) as derived from the tide gauge at the Naval Dockyard in Halifax (CHS station 490) for the period June 2004 to August 2005 is shown in Figure 3**.** The red line is the baseline against which water levels during sampling will be compared. The overall water level distribution is slightly bi-modal. The central dip in probability roughly corresponds to the mean tide level. However the distribution is actually relatively flat, between 0.6 m and 1.8 m. In an ideal situation each site would be sampled in a distribution similar to the overall distribution.

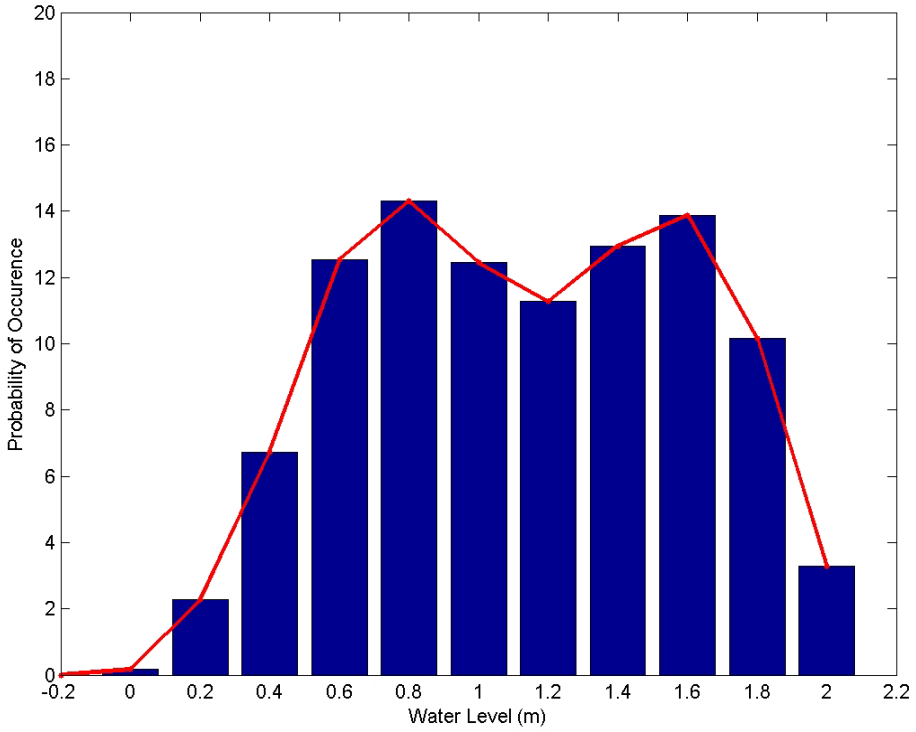


Figure 3. Probability distribution of water levels in Halifax, June 2004 to August 2005.

Figure 4 shows the distribution of water levels at the time of sampling compared to the overall water level distribution, for each sample site, since the start of sampling in June 2004. The sampling distributions show that a relatively full range of water levels has been sampled at each site. If anything, the higher water levels appear to be under-sampled at some stations, particularly in Bedford Basin. The reason for this is uncertain, but it is unlikely an issue because tidal currents in the Basin are very low (tidal

excursions are small) and large shallow water sewage outfalls do not exist there. There are some shallow water combined sewage overflows (CSO's), which periodically discharge to the Basin.

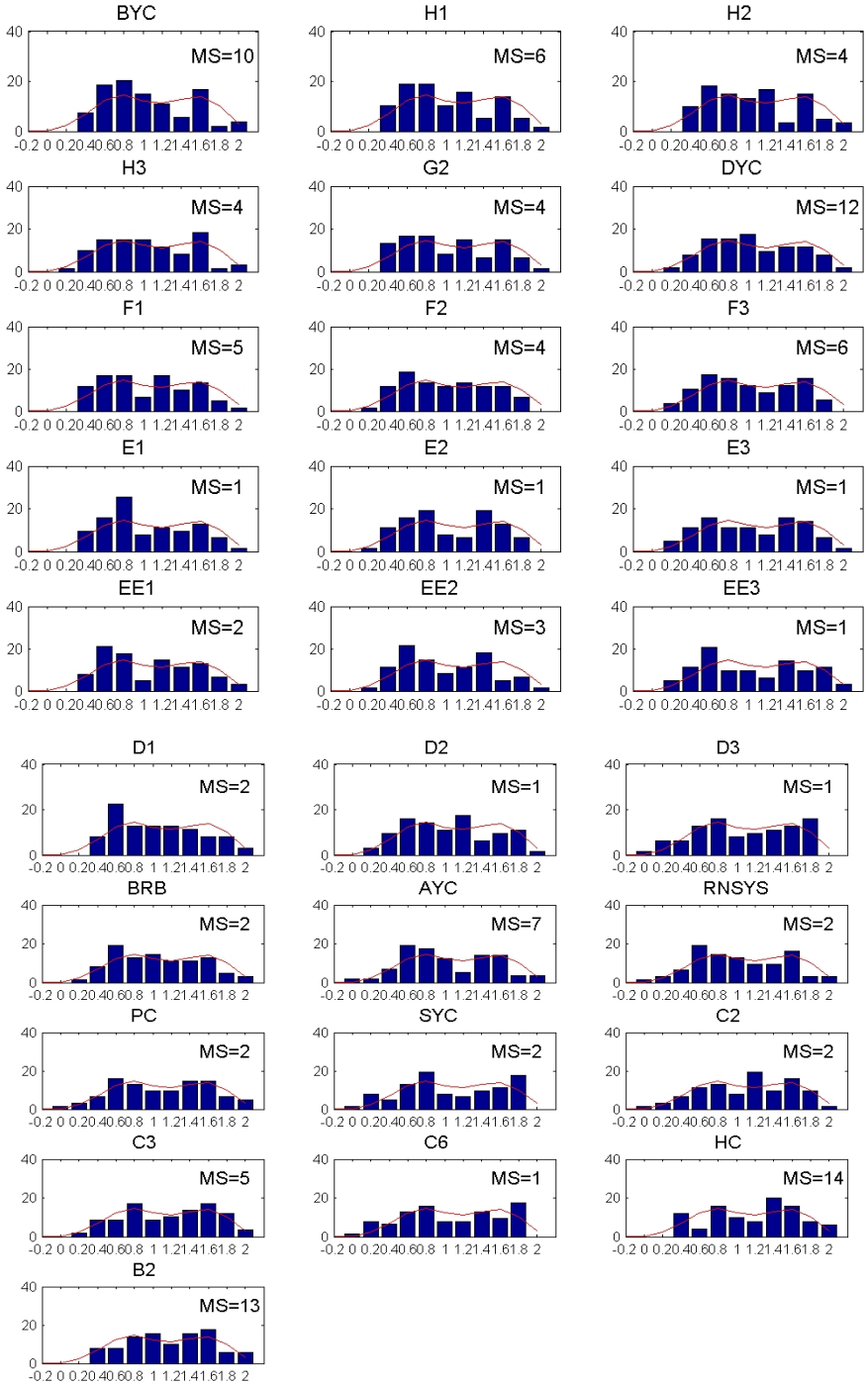


Figure 4. Water level distribution at each site during sampling June 2004 to Sept. 2005. Note: MS = Missed samples

### 3.2.3 Precipitation

Rainfall affects both the sewage loads and the dynamics of the Harbour. Following a rain event, effluent flow increases in a combined sewage system; collected material in the sewage pipes can be flushed; and the Harbour, in response to the increased fresh water input, can become more stratified, enhancing estuarine circulation. The combination of increased flow and stratification can have a great effect on the near field behaviour of the plumes from the outfalls. These effects lag the rainfall by some time and persist for some period after the rain stops. The duration of the impact, of course, depends on the magnitude of the rain event and the condition of the watershed. For purposes of discussion we have, somewhat arbitrarily, selected a three day precipitation window for our analysis. The red line in Figure 5 depicts the probability distribution of precipitation integrated over the current and previous two days for the entire program period (23 June 04 to 14 Sep 05). The blue bars on this plot represent a similar analysis performed for sampling days only. The plot indicates that our sampling is relatively unbiased with respect to precipitation. Over the entire twelve month period about 48% of days had precipitation less than 5 mm in the 72 hour window. The sampling day distribution includes 50% "dry days". On the other end, we generally have a good match given the limited number of samples. There were a few events with very high rainfall which were not sampled.

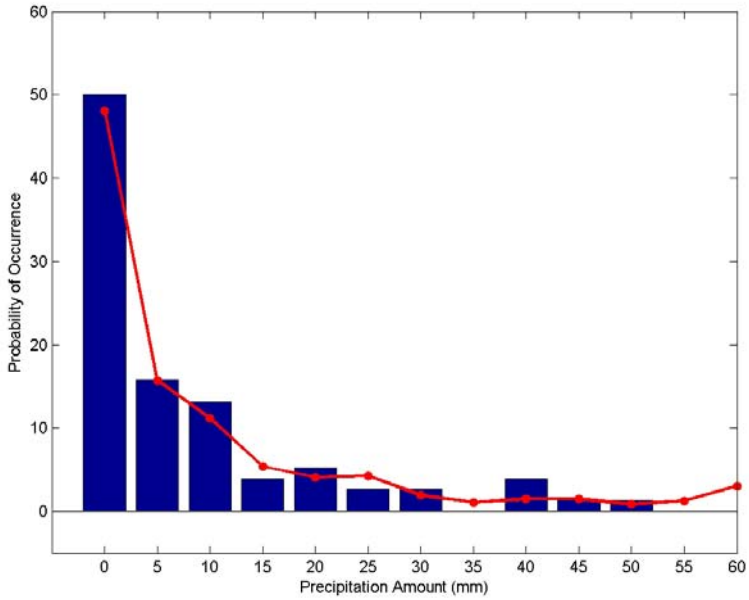


Figure 5. Probability distribution of cumulative 72 hour rainfall, June 2004 through September 2005

### 3.3 Program Changes

The only program change this quarter was the addition of a sample site at Dartmouth Cove (44° 39' 50.3" N, 63° 33' 33.0" W WGS84), in response to public concern. This site is sampled monthly during the summer, at a 1m depth, and analyzed for the full suite of chemical analyses.

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

## 4 Water Quality Results and Discussion

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

### 4.1 Fecal Coliform

The Guidelines for Canadian Recreational Water Quality (GCRWQ) (Health and Welfare Canada 1992) evaluate the compliance with water quality criteria based on geometric mean. The geometric mean, 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 fifth quarter are presented in Figure 6. In this figure, values in red exceed swimming guidelines (200 cfu/100 mL); values in blue exceed shellfishing guidelines (14 CFU/100 mL); and values

in black indicate suitability for either activity. Separate maps are presented for the 1 and 10m samples. In the following discussion it is helpful to refer to the station map (Figure 1).

For both the 1m and 10m samples, the coliform values are highest in the Inner Harbour. The maximum values at both depths occur in the EE section. Throughout the Inner Harbour the 1m mean values are higher than at 10m. This is consistent with the freshwater sewage discharges tending to rise to the surface. The distribution of high values is similar at both depths with high values at the surface corresponding to high values at depth. The fact that the distributions are not displaced relative to one another suggests that during this period, the net effect of layered flow is pretty neutral. There does appear to be some evidence of estuarine circulation in the Basin where the mean surface values are lower than the 10m values which could be caused by an up harbour flow of more contaminated water in a lower layer. In this quarter, mean values exceeding the swimming guidelines are restricted to the Inner Harbour. In the Basin and Outer Harbour the mean values meet swimming or even shellfishing levels.

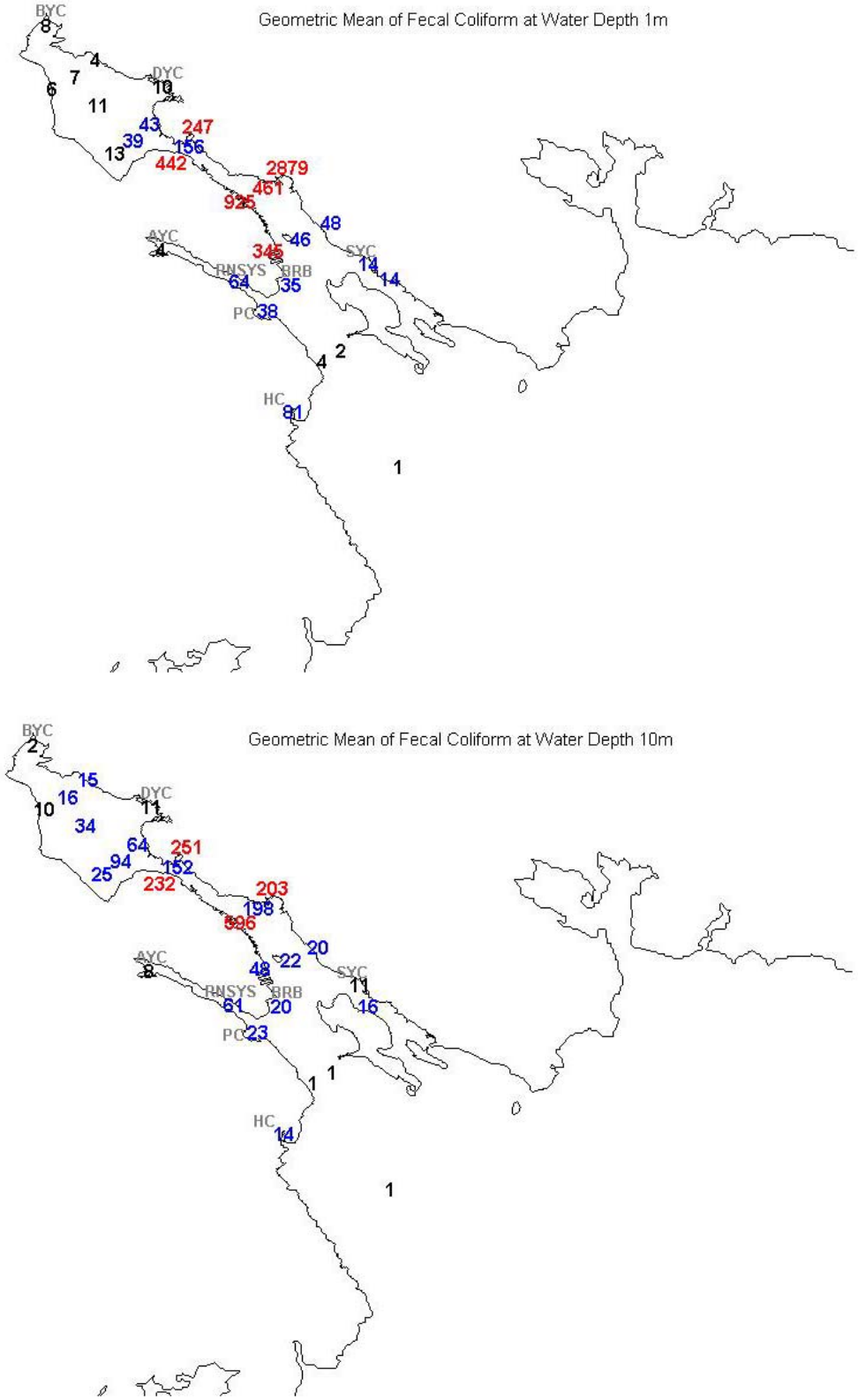


Figure 6. Fecal coliform geometric means (cfu/100mL), 21 June to 14 September 2005.

### 4.1.1 Guideline Exceedance

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

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

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

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

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

| | Outer Harbour | | | | Eastern Pass. | | Inner Harbour | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | B2 | HC | C2 | C3 | C6 | SYC | BRB | D1 | D2 | D3 | EE1 | EE2 | EE3 | E1 | E2 | E3 |
| Survey53 | 4 (3) | 92 (3) | 12 (5) | 10 (4) | 16 (5) | 17 (5) | 50 (5) | 338 (5) | 73 (5) | 114 (5) | 1359 (5) | 425 (5) | 909 (5) | 251 (5) | 109 (5) | 124 (5) |
| Survey54 | 3 (4) | 106 (4) | 7 (5) | 7 (5) | 3 (5) | 8 (5) | 25 (5) | 245 (5) | 36 (5) | 51 (5) | 857 (5) | 602 (5) | 816 (5) | 208 (5) | 83 (5) | 124 (5) |
| Survey55 | 2 (4) | 67 (4) | 5 (5) | 2 (5) | 1 (5) | 2 (5) | 8 (5) | 177 (5) | 18 (5) | 19 (5) | 484 (5) | 359 (5) | 407 (5) | 97 (5) | 75 (5) | 98 (5) |
| Survey56 | 1 (4) | 50 (4) | 2 (5) | 1 (5) | 1 (5) | 2 (5) | 9 (5) | 228 (5) | 16 (5) | 9 (5) | 395 (4) | 319 (5) | 224 (5) | 268 (5) | 153 (5) | 135 (5) |
| Survey57 | 1 (4) | 50 (4) | 4 (5) | 2 (5) | 3 (5) | 6 (5) | 20 (5) | 835 (5) | 29 (5) | 26 (5) | 549 (4) | 613 (5) | 467 (5) | 243 (5) | 207 (5) | 119 (5) |
| Survey58 | 1 (3) | 76 (3) | 4 (5) | 2 (5) | 7 (5) | 30 (5) | 34 (5) | 472 (5) | 42 (5) | 37 (5) | 600 (4) | 828 (5) | 1484 (5) | 797 (5) | 573 (5) | 588 (5) |
| Survey59 | 1 (3) | 72 (3) | 4 (5) | 2 (5) | 7 (5) | 30 (5) | 27 (5) | 748 (5) | 74 (5) | 37 (5) | 345 (4) | 387 (5) | 4116 (5) | 435 (5) | 385 (5) | 441 (5) |
| Survey60 | 1 (3) | 69 (3) | 2 (5) | 2 (5) | 8 (5) | 30 (5) | 27 (5) | 597 (5) | 70 (5) | 62 (5) | 278 (4) | 551 (5) | 7494 (5) | 826 (5) | 364 (5) | 394 (5) |
| Survey61 | 1 (3) | 76 (3) | 2 (5) | 2 (5) | 8 (5) | 17 (5) | 15 (5) | 269 (5) | 56 (5) | 154 (5) | 394 (5) | 638 (5) | 20062 (5) | 521 (5) | 222 (5) | 346 (5) |
| Survey62 | 1 (4) | 114 (4) | 1 (5) | 1 (4) | 16 (5) | 10 (5) | 13 (5) | 156 (5) | 37 (5) | 47 (5) | 183 (5) | 289 (5) | 13263 (5) | 440 (5) | 110 (5) | 242 (5) |
| Survey63 | 1 (5) | 119 (5) | 1 (5) | 1 (4) | 21 (5) | 9 (5) | 14 (5) | 216 (5) | 17 (5) | 22 (5) | 540 (5) | 347 (5) | 10956 (5) | 365 (5) | 75 (4) | 224 (5) |
| Survey64 | 1 (5) | 69 (5) | 1 (5) | 1 (4) | 39 (5) | 15 (5) | 21 (5) | 146 (5) | 18 (5) | 37 (5) | 1460 (5) | 447 (5) | 6069 (5) | 1160 (5) | 63 (4) | 243 (5) |
| Survey65 | 1 (5) | 86 (5) | 2 (5) | 1 (4) | 71 (5) | 17 (5) | 69 (5) | 288 (5) | 31 (5) | 35 (5) | 2606 (5) | 374 (5) | 5700 (5) | 782 (5) | 84 (4) | 405 (5) |

| | Bedford Basin | | | | | | | | | Northwest Arm | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | F1 | F2 | F3 | DYC | G2 | H1 | H2 | H3 | BYC | PC | RNSYS | AYC |
| Survey53 | 51 (5) | 59 (5) | 66 (5) | 23 (5) | 71 (5) | 51 (5) | 40 (5) | 18 (5) | 30 (5) | 44 (5) | 103 (5) | 6 (5) |
| Survey54 | 28 (5) | 53 (5) | 64 (5) | 10 (5) | 55 (5) | 16 (5) | 11 (5) | 5 (5) | 15 (5) | 14 (5) | 25 (5) | 3 (5) |
| Survey55 | 12 (5) | 28 (5) | 41 (5) | 5 (5) | 25 (5) | 7 (5) | 4 (5) | 3 (5) | 8 (5) | 12 (5) | 13 (5) | 2 (5) |
| Survey56 | 6 (5) | 18 (5) | 16 (5) | 4 (5) | 9 (5) | 3 (5) | 1 (5) | 1 (5) | 4 (5) | 14 (5) | 10 (5) | 1 (5) |
| Survey57 | 3 (5) | 17 (5) | 12 (5) | 9 (5) | 4 (5) | 2 (5) | 1 (5) | 2 (5) | 7 (5) | 23 (5) | 16 (5) | 3 (5) |
| Survey58 | 4 (4) | 32 (5) | 14 (5) | 15 (5) | 3 (5) | 2 (5) | 2 (5) | 2 (5) | 7 (5) | 20 (5) | 45 (5) | 3 (5) |
| Survey59 | 4 (4) | 18 (5) | 9 (5) | 15 (5) | 2 (5) | 2 (5) | 2 (5) | 2 (5) | 6 (4) | 20 (5) | 33 (5) | 4 (5) |
| Survey60 | 4 (4) | 26 (5) | 9 (5) | 15 (5) | 2 (5) | 2 (5) | 2 (4) | 2 (5) | 6 (4) | 15 (5) | 70 (5) | 4 (5) |
| Survey61 | 11 (4) | 26 (5) | 40 (5) | 25 (5) | 3 (5) | 4 (5) | 4 (4) | 3 (5) | 11 (4) | 8 (5) | 45 (5) | 3 (5) |
| Survey62 | 8 (4) | 14 (5) | 23 (5) | 4 (5) | 5 (5) | 2 (5) | 4 (4) | 1 (5) | 2 (4) | 17 (5) | 28 (5) | 2 (5) |
| Survey63 | 13 (5) | 37 (5) | 45 (5) | 4 (5) | 15 (5) | 5 (5) | 7 (4) | 2 (5) | 2 (4) | 19 (5) | 17 (4) | 4 (5) |
| Survey64 | 9 (5) | 20 (5) | 91 (5) | 5 (5) | 11 (5) | 5 (5) | 8 (4) | 3 (5) | 3 (5) | 60 (5) | 102 (4) | 4 (5) |
| Survey65 | 12 (5) | 51 (5) | 161 (5) | 8 (5) | 13 (5) | 5 (5) | 7 (5) | 3 (5) | 3 (5) | 192 (5) | 131 (4) | 5 (5) |

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

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

| | Outer Harbour | | | | Eastern Pass | | Inner Harbour | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | B2 | HC | C2 | C3 | C6 | SYC | BRB | D1 | D2 | D3 | EE1 | EE2 | EE3 | E1 | E2 | E3 |
| Survey53 | 1 (3) | 9 (3) | 3 (5) | 1 (4) | 18 (5) | 13 (5) | 21 (5) | 69 (5) | 22 (5) | 34 (5) | 231 (5) | 98 (5) | 191 (5) | 123 (5) | 113 (5) | 275 (5) |
| Survey54 | 1 (4) | 9 (4) | 2 (5) | 1 (5) | 5 (5) | 7 (5) | 10 (5) | 52 (5) | 16 (5) | 17 (5) | 258 (5) | 66 (5) | 139 (5) | 101 (5) | 81 (5) | 207 (5) |
| Survey55 | 1 (4) | 10 (4) | 1 (5) | 1 (5) | 2 (5) | 3 (5) | 6 (5) | 39 (5) | 12 (5) | 10 (5) | 427 (5) | 47 (5) | 156 (5) | 72 (5) | 61 (5) | 179 (5) |
| Survey56 | 1 (4) | 5 (4) | 1 (5) | 1 (5) | 3 (5) | 5 (5) | 7 (5) | 31 (5) | 7 (5) | 10 (5) | 434 (4) | 28 (5) | 98 (5) | 84 (5) | 93 (5) | 143 (5) |
| Survey57 | 1 (4) | 5 (4) | 1 (5) | 1 (5) | 5 (5) | 4 (5) | 10 (5) | 37 (5) | 9 (5) | 19 (5) | 971 (4) | 44 (5) | 127 (5) | 98 (5) | 65 (5) | 120 (5) |
| Survey58 | 1 (3) | 8 (3) | 1 (5) | 2 (5) | 10 (5) | 6 (5) | 16 (5) | 49 (5) | 20 (5) | 23 (5) | 2188 (4) | 200 (5) | 301 (5) | 366 (5) | 121 (5) | 223 (5) |
| Survey59 | 1 (3) | 9 (3) | 1 (5) | 2 (5) | 16 (5) | 7 (5) | 17 (5) | 42 (5) | 17 (5) | 27 (5) | 2229 (4) | 201 (5) | 404 (5) | 199 (5) | 119 (5) | 231 (5) |
| Survey60 | 1 (3) | 9 (3) | 1 (5) | 2 (5) | 40 (5) | 9 (5) | 22 (5) | 27 (5) | 13 (5) | 31 (5) | 1587 (4) | 244 (5) | 387 (5) | 444 (5) | 181 (5) | 239 (5) |
| Survey61 | 1 (3) | 22 (3) | 1 (5) | 2 (5) | 29 (5) | 6 (5) | 20 (5) | 23 (5) | 16 (5) | 16 (5) | 1420 (5) | 388 (5) | 471 (5) | 477 (5) | 123 (5) | 251 (5) |
| Survey62 | 1 (4) | 42 (4) | 1 (5) | 2 (4) | 26 (5) | 8 (5) | 26 (5) | 27 (5) | 27 (5) | 10 (5) | 984 (5) | 403 (5) | 478 (5) | 641 (5) | 198 (5) | 247 (5) |
| Survey63 | 1 (5) | 34 (5) | 1 (5) | 1 (4) | 20 (5) | 8 (5) | 19 (5) | 27 (5) | 19 (5) | 9 (5) | 807 (5) | 370 (5) | 337 (5) | 216 (5) | 167 (5) | 179 (5) |
| Survey64 | 1 (5) | 29 (5) | 1 (5) | 2 (4) | 25 (5) | 17 (5) | 19 (5) | 22 (5) | 26 (5) | 12 (5) | 398 (5) | 303 (5) | 148 (5) | 579 (5) | 264 (5) | 275 (5) |
| Survey65 | 1 (5) | 27 (5) | 1 (5) | 2 (4) | 18 (5) | 26 (5) | 36 (5) | 80 (5) | 46 (5) | 14 (5) | 467 (5) | 523 (5) | 125 (5) | 349 (5) | 305 (5) | 497 (5) |

| | Bedford Basin | | | | | | | | | Northwest Arm | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | F1 | F2 | F3 | DYC | G2 | H1 | H2 | H3 | BYC | PC | RNSYS | AYC |
| Survey53 | 62 (5) | 98 (5) | 53 (5) | 23 (5) | 53 (5) | 23 (5) | 28 (5) | 36 (5) | 4 (5) | 20 (5) | 36 (5) | 12 (5) |
| Survey54 | 40 (5) | 59 (5) | 33 (5) | 15 (5) | 46 (5) | 15 (5) | 13 (5) | 17 (5) | 2 (5) | 9 (5) | 29 (5) | 5 (5) |
| Survey55 | 46 (5) | 80 (5) | 22 (5) | 10 (5) | 30 (5) | 7 (5) | 7 (5) | 10 (5) | 1 (5) | 8 (5) | 30 (5) | 7 (5) |
| Survey56 | 33 (5) | 64 (5) | 20 (5) | 5 (5) | 26 (5) | 3 (5) | 4 (5) | 6 (5) | 1 (5) | 8 (5) | 22 (5) | 6 (5) |
| Survey57 | 30 (5) | 55 (5) | 16 (5) | 4 (5) | 19 (5) | 3 (5) | 3 (5) | 7 (5) | 2 (5) | 12 (5) | 23 (5) | 5 (5) |
| Survey58 | 26 (4) | 187 (5) | 31 (5) | 6 (5) | 18 (5) | 5 (5) | 4 (5) | 5 (5) | 2 (5) | 9 (5) | 45 (5) | 5 (5) |
| Survey59 | 11 (4) | 194 (5) | 33 (5) | 4 (5) | 9 (5) | 4 (5) | 4 (5) | 3 (5) | 1 (5) | 10 (5) | 36 (5) | 5 (5) |
| Survey60 | 4 (4) | 144 (5) | 41 (5) | 3 (5) | 9 (5) | 4 (5) | 6 (5) | 4 (5) | 1 (5) | 14 (5) | 49 (5) | 3 (5) |
| Survey61 | 4 (4) | 199 (5) | 38 (5) | 4 (5) | 10 (5) | 8 (5) | 10 (5) | 6 (5) | 1 (5) | 18 (5) | 67 (5) | 3 (5) |
| Survey62 | 7 (4) | 159 (5) | 47 (5) | 7 (5) | 23 (5) | 16 (5) | 30 (5) | 14 (5) | 1 (5) | 23 (5) | 78 (5) | 5 (5) |
| Survey63 | 9 (5) | 78 (5) | 93 (5) | 9 (5) | 30 (5) | 8 (5) | 36 (5) | 25 (5) | 1 (5) | 36 (5) | 110 (5) | 6 (5) |
| Survey64 | 20 (5) | 33 (5) | 204 (5) | 11 (5) | 39 (5) | 13 (5) | 64 (5) | 57 (5) | 2 (5) | 66 (5) | 156 (5) | 10 (5) |
| Survey65 | 31 (5) | 54 (5) | 244 (5) | 20 (5) | 93 (5) | 16 (5) | 53 (5) | 40 (5) | 2 (5) | 108 (5) | 152 (5) | 19 (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.

As seen in the tables, for this quarter, much of the surface water in the inner harbour would be deemed unacceptable for primary body contact most of the time. The distribution of sites with unacceptable water quality 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 Inner Harbour water at 10m is more variable, often unacceptable, but also frequently questionable or even acceptable. The exception is site EE1, which was unacceptable throughout the quarter. For this quarter, there are almost no sites outside the Inner Harbour with any occurrences of unacceptable water quality. The exception is the 10m sample at site F3, which experiences some high values, consistent with the estuarine circulation mentioned above. The 1m samples in the southern end of the Northwest Arm (PC and RNSYS) experienced periodic high values often resulting in a questionable rating. Except for the high values at F3, there are no unacceptable ratings in the Basin. The occurrence of questionable values in the Basin increase further south, and is more frequent in the 10m samples. The C section in Eastern Passage has no unacceptable ratings but has periodic questionable ratings. For this quarter all ratings in the outer harbour (outside and including the C section) are acceptable.

There does not appear to be a distinct trend in fecal coliform through the quarter in the 1m samples. In the 10m samples there seems to be a general decrease in water quality from the beginning of the quarter to the end. The mean values go from a split of 20/6/2 sites (acceptable/questionable/unacceptable), at the start of the quarter, to 17/5/6 at the end.

### 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. During this quarter, the only sample out of range was the 1m E2 sample on 30 Aug. This is the first out of range value at this site. This site also periodically experiences low (e.g. <= 10 fc/100 mL) values, so a shift in analysis resolution is not justified. This will continue to be monitored 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. Overall, in this quarter, 28% of samples had detectable levels of ammonium. There is no discernable systematic variation with depth, all mean and variation of values in the 1 and 10 m samples are similar, at least within the limits of the sparse data set. In this quarter, while there is week to week variability, it seems random and there appears to be no definite temporal trend. There is no strong correlation with meteorological events, as is

seen in the coliform data. There also is no clear spatial variability (Figure 7) with each site having between 3 and 5 values above the EQL. The means, computed with the <EQL values adjusted, are at about the EQL for all sites.

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** |
|---|---|---|---|---|---|---|---|---|---|
| 21-Jun-05 | 0.025 | 0.025 | 0.09 | 0.025 | 0.05 | 0.08 | 0.08 | 0.075 | 0.09 |
| 5-Jul-05 | 0.08 | 0.19 | 0.1 | 0.13 | 0.025 | 0.025 | 0.06 | 0.112 | 0.19 |
| 19-Jul-05 | 0.025 | 0.025 | 0.025 | 0.025 | 0.025 | 0.025 | 0.025 | 0.025 | 0.025 |
| 3-Aug-05 | 0.025 | 0.025 | 0.025 | 0.025 | 0.025 | 0.025 | 0.025 | 0.025 | 0.025 |
| 16-Aug-05 | 0.025 | 0.025 | 0.025 | 0.025 | 0.025 | 0.025 | 0.09 | 0.090 | 0.09 |
| 30-Aug-05 | 0.025 | 0.025 | 0.025 | 0.11 | 0.05 | 0.09 | 0.025 | 0.083 | 0.11 |
| 14-Sep-05 | 0.025 | 0.025 | 0.025 | 0.025 | 0.025 | 0.025 | 0.025 | 0.025 | 0.025 |
| mean | 0.03 | 0.05 | 0.05 | 0.05 | 0.03 | 0.04 | 0.05 | 0.04 | |
| max | 0.08 | 0.19 | 0.10 | 0.13 | 0.05 | 0.09 | 0.09 | | 0.19 |

| **10 m** | **B2** | **D2** | **EE2** | **E2** | **F2** | **G2** | **H2** | **mean** | **max** |
|---|---|---|---|---|---|---|---|---|---|
| 21-Jun-05 | 0.05 | 0.06 | 0.05 | 0.025 | 0.19 | 0.025 | 0.025 | 0.06 | 0.19 |
| 5-Jul-05 | 0.11 | 0.05 | 0.18 | 0.12 | 0.025 | 0.025 | 0.06 | 0.08 | 0.18 |
| 19-Jul-05 | 0.025 | 0.025 | 0.025 | 0.025 | 0.11 | 0.025 | 0.025 | 0.04 | 0.11 |
| 3-Aug-05 | 0.025 | 0.025 | 0.025 | 0.025 | 0.025 | 0.025 | 0.09 | 0.03 | 0.09 |
| 16-Aug-05 | 0.05 | 0.025 | 0.025 | 0.025 | 0.025 | 0.025 | 0.025 | 0.03 | 0.05 |
| 30-Aug-05 | 0.025 | 0.025 | 0.025 | 0.025 | 0.025 | 0.025 | 0.12 | 0.04 | 0.12 |
| 14-Sep-05 | 0.025 | 0.025 | 0.14 | 0.025 | 0.14 | 0.11 | 0.14 | 0.09 | 0.14 |
| mean | 0.04 | 0.03 | 0.07 | 0.04 | 0.08 | 0.04 | 0.07 | 0.05 | |
| max | 0.11 | 0.06 | 0.18 | 0.12 | 0.19 | 0.11 | 0.14 | | 0.19 |

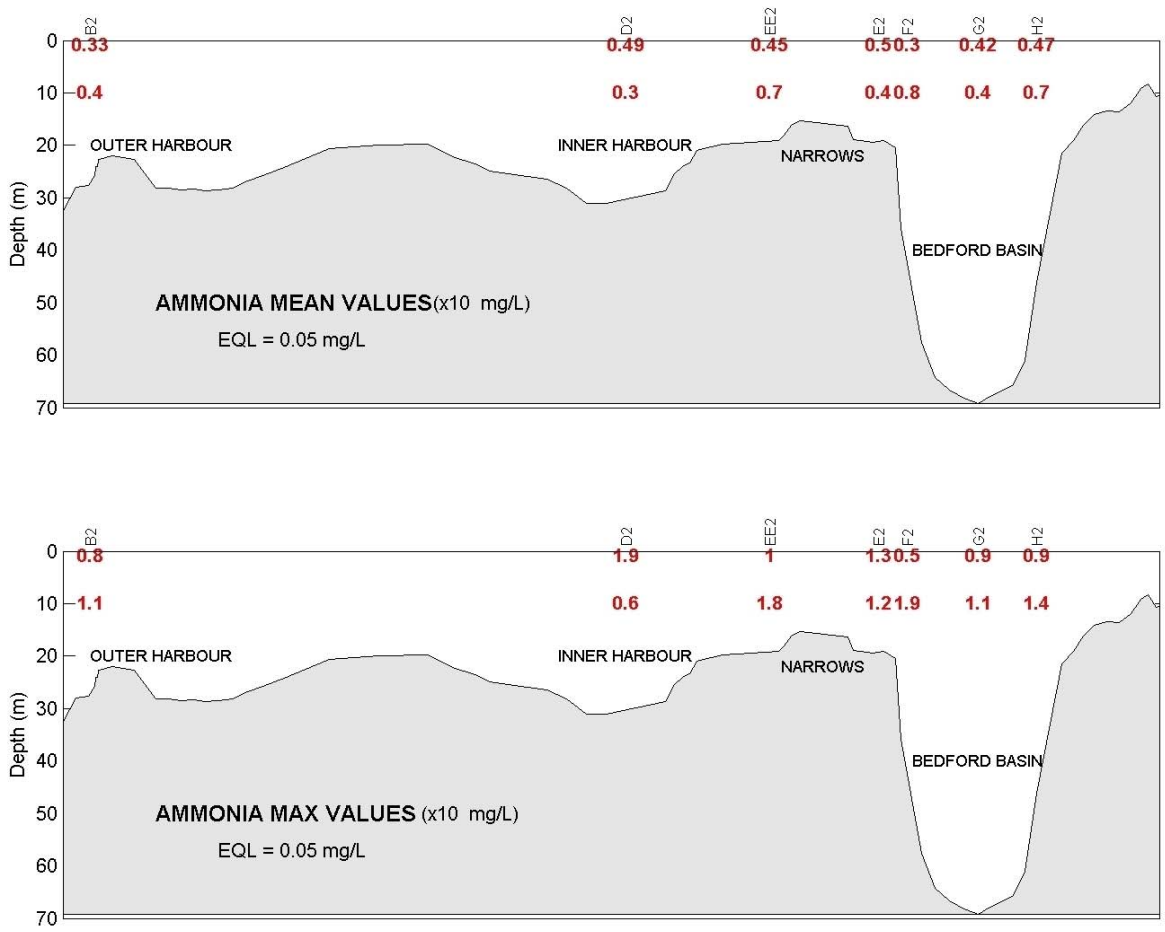


Figure 7. Mean and maximum value of ammonia nitrogen over all fifth quarter samples

## 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. For this quarter, there were two samples below the EQL of 2 mg/L. These samples were, the 1 and 10m samples at the control site B2, on 19 July. As with TN, the value of one half the EQL (1mg/L) is used for statistical purposes. The mean value over all surveys is approximately 11 mg/L. There is some systematic variation in these data both spatially and temporally. At most sites, the TSS values are at their maximums in the middle of the quarter (19 Jul through 16 August). This seems to correspond to a time of relatively low flushing (dry weather with relatively light wind), and increased productivity as seen in the fluorescence data. Spatially (Figure 8), on average, the lowest values tend to occur in the outer harbour at B2 and the highest values in the Narrows and southern Basin. However, relatively high values (>10 mg/L) can occur at any site.

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

| 1m | B2 | D2 | EE2 | E2 | F2 | G2 | H2 | mean | max |
|---|---|---|---|---|---|---|---|---|---|
| 21-Jun-05 | 8.7 | 3.8 | 8.8 | 6.8 | 12 | 17 | 12 | 9.9 | 17 |
| 5-Jul-05 | 7.2 | 4.4 | 15 | 3.2 | 13 | 9.3 | 12 | 9.2 | 15 |
| 19-Jul-05 | 1 | 9.5 | 14 | 8.8 | 9 | 7.7 | 15 | 10.7 | 15 |
| 3-Aug-05 | 10 | 8.4 | 13 | 11 | 22 | 12 | 13 | 12.8 | 22 |
| 16-Aug-05 | 8.4 | 17 | 13 | 14 | 17 | 16 | 4.2 | 12.8 | 17 |
| 30-Aug-05 | 4.4 | 11 | 14 | 10 | 13 | 13 | 14 | 11.3 | 14 |
| 14-Sep-05 | 6.6 | 14 | 11 | 13 | 8.3 | 9.1 | 11 | 10.4 | 14 |
| mean | 6.6 | 9.7 | 12.7 | 9.5 | 13.5 | 12.0 | 11.6 | 11.0 | |
| max | 10.0 | 17.0 | 15.0 | 14.0 | 22.0 | 17.0 | 15.0 | | 22.0 |

| 10m | B2 | D2 | EE2 | E2 | F2 | G2 | H2 | mean | max |
|---|---|---|---|---|---|---|---|---|---|
| 21-Jun-05 | 4.9 | 8.1 | 9.3 | 9.2 | 7.8 | 9.3 | 5.3 | 7.7 | 9.3 |
| 5-Jul-05 | 5.4 | 6.4 | 9.7 | 14 | 5.4 | 7.1 | 8.9 | 8.1 | 14.0 |
| 19-Jul-05 | 1 | 26 | 13 | 5.4 | 8.2 | 18 | 16 | 14.4 | 26.0 |
| 3-Aug-05 | 9.6 | 12 | 14 | 25 | 20 | 12 | 8.6 | 14.5 | 25.0 |
| 16-Aug-05 | 9.8 | 6.3 | 18 | 9.4 | 10 | 17 | 16 | 12.4 | 18.0 |
| 30-Aug-05 | 6.8 | 11 | 8.4 | 12 | 12 | 14 | 16 | 11.5 | 16.0 |
| 14-Sep-05 | 9.7 | 11 | 9 | 8.8 | 7.5 | 16 | 7.3 | 9.9 | 16.0 |
| mean | 6.7 | 11.5 | 11.6 | 12.0 | 10.1 | 13.3 | 11.2 | 11.2 | |
| max | 9.8 | 26.0 | 18.0 | 25.0 | 20.0 | 18.0 | 16.0 | | 26.0 |

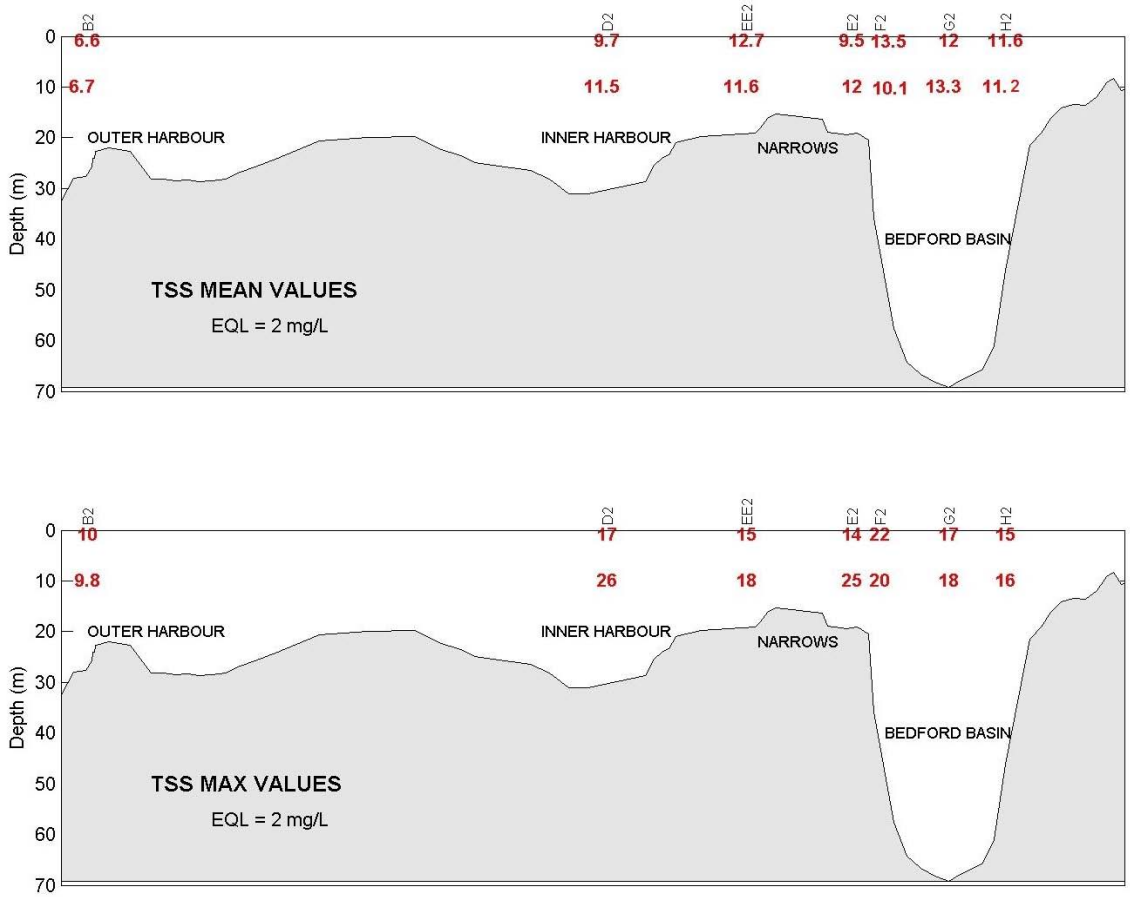


Figure 8. Mean and maximum values of total suspended solids (mg/L) over all fifth quarter samples.

## 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.

## 4.6 Metals

In the fifth quarter there have been twenty five independent measurements of metals of interest, i.e. metals for which water quality guidelines exist, in excess of laboratory EQL's. There were a total of 658 measurements (seven sites x two depths x seven surveys x seven metals, discounting two missed stations or four missed samples.). This equates overall to approximately 3.8% detectable values, or, conversely, greater than 96% non-detectable values. In addition to the regular samples, there was one QA/QC sample with detectable manganese. QA/QC samples are duplicate samples taken to verify the reference values and are therefore not independent. There were three values, one each, for zinc, copper and nickel, which exceeded applicable guidelines.

There were two surveys this quarter of particular note. The first, on 16 August, was remarkable in that there was a relatively high number (9 of 98 possible) of detectable metal values. There were four metals with detectable values and an exceedence in one sample for both zinc and copper. Four of the nine values occurred at site D2, including the only two guideline exceedences (zinc and copper, both in the 1m sample). The remainder of the samples were relatively dispersed from Bedford Basin to the outer harbour. The second survey of interest occurred on 14 Sep and had detectable levels of zinc in 11 of 14 samples (79%). The only levels below detection were in the three 10 m samples in Bedford Basin. In this survey, there was only one other detectable metal (nickel in the 10m sample at G2). Overall, these two surveys account for 21 of 25 (84%) positive metals determination for the quarter. The remaining five surveys had only four positive determinations. There is seemingly nothing remarkable about these surveys in other data sets.

The relevant fifth quarter metals values are summarized in Table 7, and are discussed briefly below.

Table 7. Summary of metal values >EQL from 21 June through 14 September 2005

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

| Survey Date | Value (µg/L) | Site | Depth(m) |
|---|---|---|---|
| 16-Aug-05 | 68 | B2 | 10 |
| | 180 | D2 | 1 |
| 14-Sep-05 | 53 | B2 | 1 |
| | 55 | B2 | 10 |
| | 54 | D2 | 1 |
| | 51 | D2 | 10 |
| | 53 | EE2 | 1 |
| | 56 | EE2 | 10 |
| | 62 | E2 | 1 |
| | 54 | E2 | 10 |
| | 51 | F2 | 1 |
| | 61 | G2 | 1 |
| | 57 | H2 | 1 |

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

| Survey Date | Value (µg/L) | Site | Depth(m) |
|---|---|---|---|
| 5-Jul-05 | 32 | F2 | 1 |
| 3-Aug-05 | 21 | D2 | 10 |
| | 32 | F2 | 1 |
| 16-Aug-05 | 33 | E2 | 10 |
| | 21 | EE2 | 1 |
| | 30 | G2 | 10 |
| | 44 | E2 (QA/QC) | 1 |

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

| Survey Date | Value (µg/L) | Site | Depth(m) |
|---|---|---|---|
| 19-Jul-05 | 21 | D2 | 1 |
| 16-Aug-05 | 31 | D2 | 1 |
| | 30 | D2 | 10 |
| | 32 | E2 | 1 |

**Nickel** EQL = 20 µg/L: Guideline=8.3 µg/L

| Survey Date | Value (µg/L) | Site | Depth(m) |
|---|---|---|---|
| 14-Sep-05 | 20 | G2 | 10 |

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

| Survey Date | Value (µg/L) | Site | Depth(m) |
|---|---|---|---|
| 16 Aug 05 | 22 | D2 | 1 |

**HR Copper** EQL = 1 µg/L : Guideline=2.9 µg/L

| Survey Date | Value (µg/L) | Site | Depth(m) |
|---|---|---|---|
| 30-Aug-05 | 1.3 | G2 | 1 |
| | <1 | B2 | 1 |
| | <1 | EE2 | 1 |

## Zinc

There were two surveys, and a total of thirteen samples, in which detectable concentrations of zinc occurred. On 16 Aug, there were two relatively high values, one (D2-1m at 180µg/L) that exceeded the 86 µg/L guideline. The remaining eleven positive results occurred on 14 Sept. In this survey, the values ranged from 51 to 62 µg/L, or just above the EQL of 50 µg/L, and all below the applicable guideline. There is nothing in the other data sets, including the analysis for other metal constituents, to indicate anything particularly unusual oceanographically or with overall sewage loads. It seems that this must represent some extraordinary source of zinc. This quarter, the data recovery rate for zinc (nearly 14%) is higher than that for manganese primarily due to the "event" on 14 Sept.

## Manganese

Manganese was present at detectable levels (>20 µg/L) on 3 out of 7 surveys, in a total of 6 samples. This amounts to about 6% of samples taken over the quarter. The concentrations ranged from 21 (EQL) to 33 µg/L. In no case was the guideline value of 100 µg/L exceeded. The only obvious pattern in the manganese data is that 5 of the 6 values occurred in two consecutive surveys, on 3 Aug and 16 Aug. There is not sufficient temporal resolution to draw any conclusions from this.

## Chromium

There were four samples with detectable levels, three of which occurred on the aforementioned 16 Aug survey. Of these, two occurred in the 1 and 10m samples at the D2 site. None of these samples exceeded the guidelines.

**Nickel**
Nickel had one sample with a positive result. This occurred in the 14 Sep survey at site D2 at 1m. Any detectable value of nickel exceeds criteria, as the EQL (20 μg/L) is greater than the guideline of 8.3 μg/L.

**Copper**
Copper had one sample with a positive result. This occurred in the 16 Aug survey at site G2 at 10m. Any detectable value of copper exceeds criteria, as the EQL (20 μg/L) is greater than the guideline of 2.9 μg/L.

**High Resolution Copper analysis**
Copper has been identified as a "key" contaminant (i.e. the concentration in the sewage effluent is the highest compared to the environmental guideline, so it is most likely to be violated by sewage contamination) and is under-resolved by the current analysis. This, and the general under-resolution of metals concentrations, has lead to ongoing discussion. As input to this discussion, three test samples were taken at depth 1m on 30 Aug. These were analyzed with a more detailed scan having an EQL of 1 μg/L. These results are also tabulated below. Of the three samples only one had a detectable level of copper (1.3 μg/L) at G2. This is relatively consistent with previous observations in the Harbour (Dalziel et al., 1989), though the maximum observed in that survey is 0.9 μg/L.

## 4.7 Temperature and Salinity

The Bedford Basin Plankton Monitoring Program (BBPMP) is a long standing program conducted by the Department of Fisheries and Oceans at the Bedford Institute of Oceanography. As part of the program, oceanographic profiles from the centre of Bedford Basin (near station G2) are collected on a weekly basis. The data consist of (among other parameters) temperature, salinity, fluorescence, and dissolved oxygen, which duplicates HHWQMP observations, and therefore provides an opportunity for crosschecking observations. Both sample sites are located near the deepest part of the Basin and are sampled weekly. The HHWQMP samples on each Tuesday, with contingency on Wednesday or sometimes Thursday, while the BBPMP usually samples on Wednesday. The BBPMP data, including more detailed phytoplankton data, are available on their website: www.mar.dfo-mpo.gc.ca/science/ocean/BedfordBasin.

The HHWQMP and BBPMP temperature and salinity data from 1 Jan 05 until the end of the fifth quarter (mid September 05) are presented in Figures 9 and 10. This quarter corresponds to days 172 to 257. The temperature data for each of the two programs show a nearly perfect correspondence.

The salinity data for this quarter also shows high degree of correspondence. Some of the fine detail varies, but this variation can be reconciled by missed data. The surface salinities show almost perfect correspondence. Both datasets show what appears to be a mid water intrusion of slightly saltier warmer water at about day 200 (19 Jul), but the evolution of the pattern is much smoother in the BBPMP data. The reason for this is

unclear but this is a subtle feature with very small salinity gradients. The reason could be due to a small difference in measured values, or the different contouring routines used to display the data for each of the two datasets.

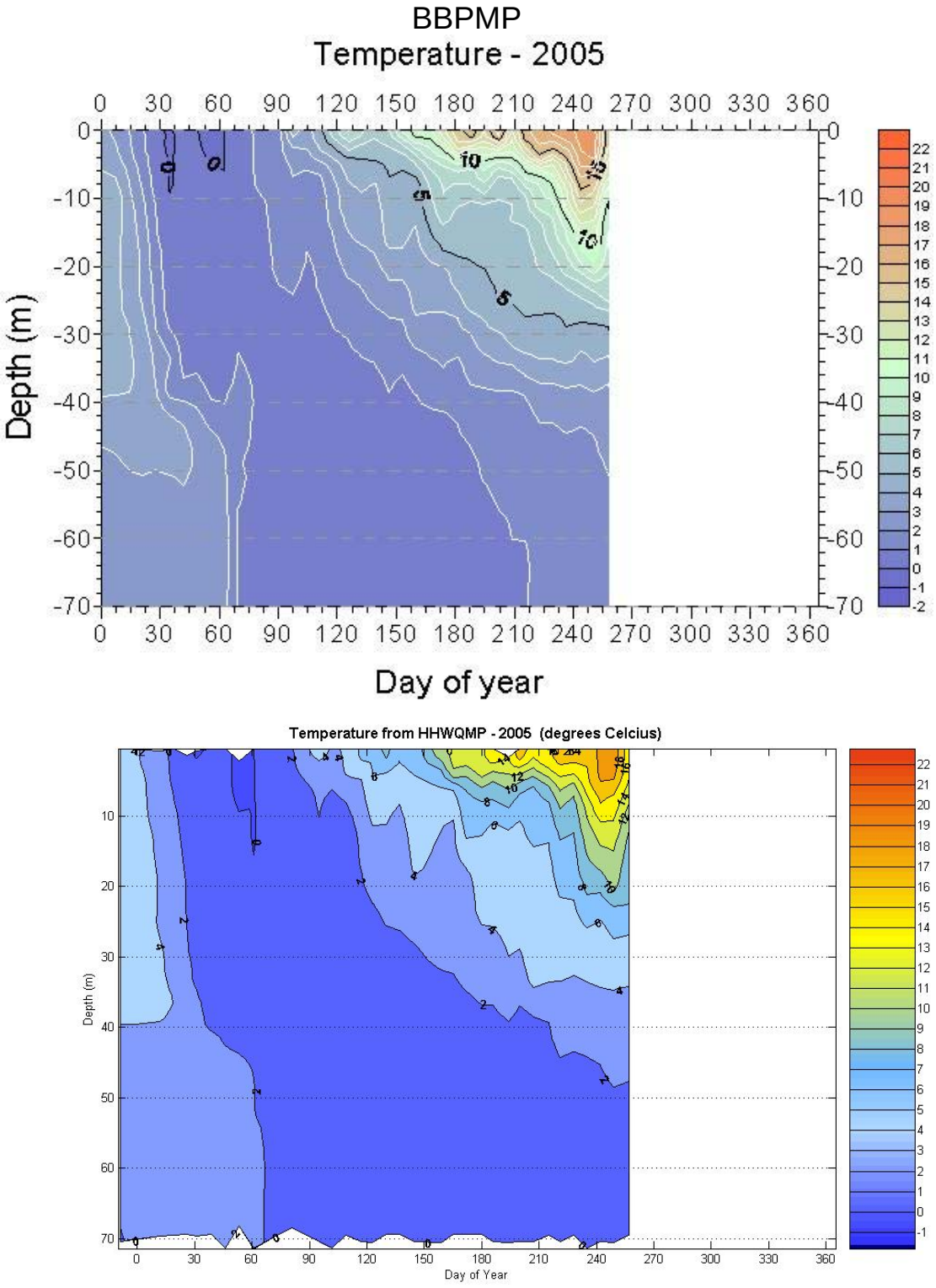


Figure 9. Comparison of BBPMP and HHWQMP temperature data from Station G2 (1 Jan to 14 Sep 2005).

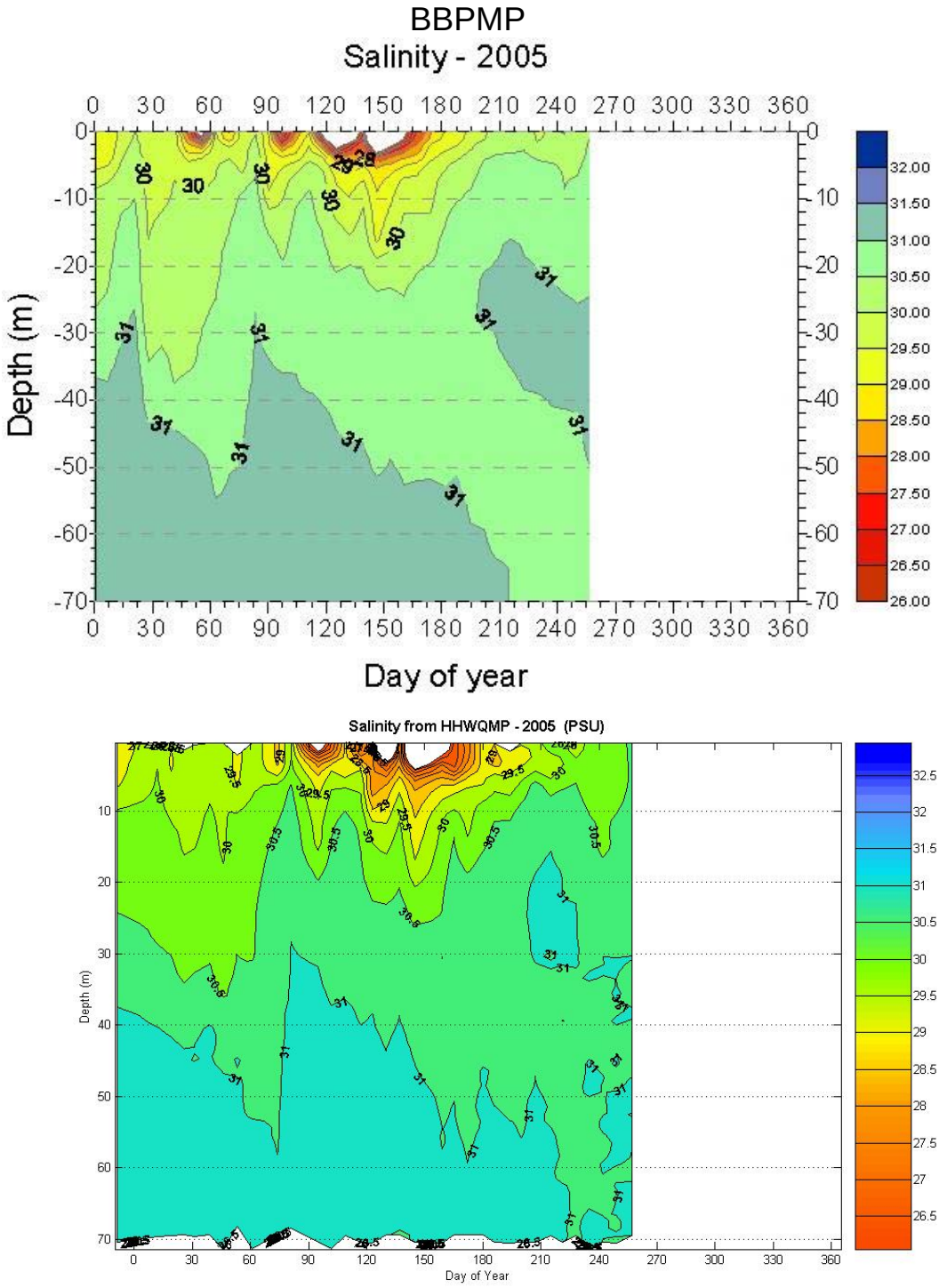


Figure 10. Comparison of BBPMP and HHWQMP salinity data from Station G2 (1 Jan to 14 Sep 2005).

## 4.8 Fluorescence

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

A comparison of HHWQMP fluorescence data with that of the BBPMP is presented in Figure 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. Both figures show a relative lull in fluorescence at the beginning of the quarter (day 172), followed by an increase in activity within several weeks, which continues sporadically for the remainder of the quarter. This activity at times approaches that of the spring bloom.

Interesting is spatial variation not captured in BBPMP data. The maximum fluorescence values in the Harbour generally occur in Bedford Basin but not usually at the G2 site. There are times when the profiles are quite uniform in the Basin, but more generally the maximum value varies in location around the Basin. It seems that the distribution varies quite smoothly and coherently among the Basin sites, apparently in response to oceanographic conditions, particularly estuarine and wind driven circulation. The maximum fluorescence values were observed, on different weeks, in the south, east and north of the Basin. The value at G2 was representative of the overall maximum value on only one week, when conditions were relatively uniform throughout the Basin. In other weeks the maximum value was up to four times that observed at G2. In all cases this quarter the fluorescence dropped quite markedly in the Inner Harbour and became quite low in the outer harbour as represented by Site B2. At this site the values are generally 1-2 $mg/m^3$, typical background values. There were a couple of instances where the value was as high as 4-5 $mg/m^3$.

In addition to the CTD profiles, the BBPMP collects water samples and does a rigorous analysis of the weekly plankton and nutrient conditions at their site.

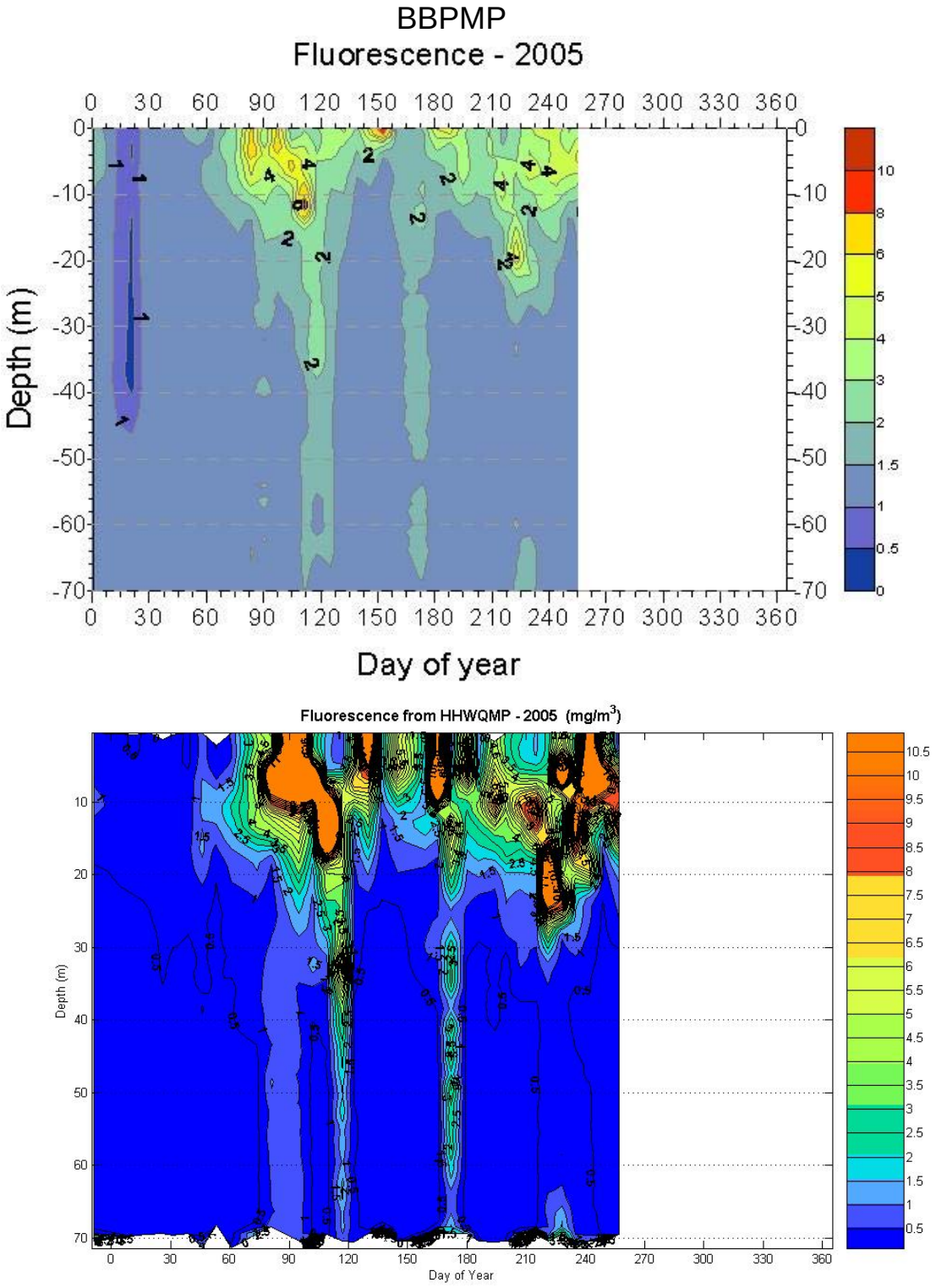


Figure 11. Comparison of BBPMP and HHWQMP fluorescence data from Station G2 (1 Jan to 14 Sep 2005).

### 4.9 Dissolved Oxygen

The dissolved oxygen data for the beginning of this quarter are generally above the applicable use-specific (SA, SB and SC) guidelines. The one exception is the Bedford Basin bottom water, which is oxygen deprived in its regular cycle of stagnation and renewal. At the start of the quarter, the minimum DO at the bottom was 6.5 mg/L, which is relatively high, due to a bottom water renewal in the previous quarter. This dropped through the quarter until it reached 3.1 mg/L by the end. Later in the quarter, starting at week 61 (16 Aug), the measurements indicate that the DO in the surface water started to drop below guideline levels. On that week, the measured DO in the surface water at site B2, dropped below the Class SA level of 8.0 mg/L. This exceedence at site B2 continued for the following week. The data in the next week, week 63 (30 Aug), indicate that the DO in the surface water (<20 m) dropped below 7 mg/L. This implies exceedences in all class SB waters (Basin, NW Arm, Eastern Passage and section C in outer Harbour) as well as the class SA exceedence at Site B2 in the Outer Harbour. The only area where guidelines are met is the Inner Harbour, which is classified SC and has a DO requirement of 6.0 mg/L which is never violated. This condition continues for the remaining two weeks of the quarter.

For the first part of the quarter, up to week 62, a Hydrolab oxygen probe was available to the field team and periodic near surface readings were taken. The purpose was to compare with the Seabird values as a possible ground truth. These readings were systematically higher, by 1-2 mg/L, than the corresponding values from the primary instrument, the Seabird CTD. The week to week variation in the Hydrolab data was significantly higher than the data from the Seabird. This trend is opposite from the comparison with the BBPMP data, discussed below.

Figure 12 represents a comparison of HHWQMP oxygen data with the BBPMP oxygen data from the beginning of the year to the end of this quarter (14 Sep 05). Note that the units for the HHWQMP plot are mL/L, rather than the mg/L, the units used in the weekly reports. These units correspond to the units of the published BBPMP data. The conversion factor from mg/L to mL/L is approximately 0.7.

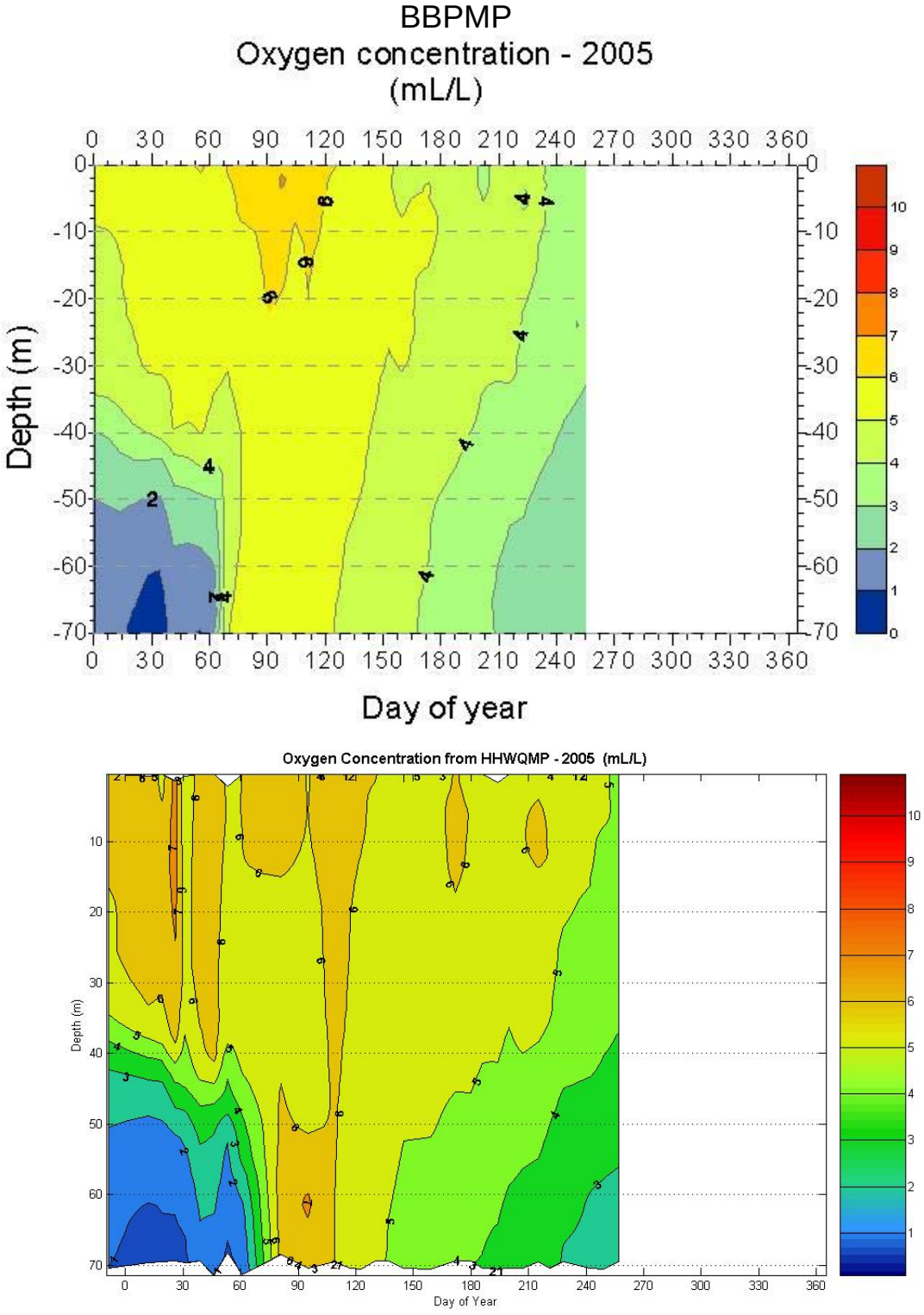


Figure 12. Comparison of BBPMP and HHWQMP dissolved oxygen data from Station G2 (1 Jan to 14 Sep 2005).

In this quarter, staring at Day 172, the data show very similar trends. Of interest is the fact that the surface DO at this point drops as the quarter progresses. This is consistent with the trend throughout the harbour documented above. Throughout the quarter the shape of the DO contours is similar. However, they are discrepancies in the magnitude of the data. The data seem to correspond quite closely at lower values, but the HHWQMP data tends to be relatively higher at higher values. At the bottom, the HHWQMP data are systematically higher by about 0.1-0.2 mL/L. At the surface, the HHWQMP data are again systematically higher but in this case by about 1 mL/L, which is significant. This suggests a proportional variation, i.e. the HHWQMP data is x% higher than the BBPMP data. Since both programs use similar, if not identical, DO sensors, the cause of this discrepancy is uncertain. Neither data set is ground-truthed, and dissolved oxygen sensors are relatively "finicky" sensors, which could result in some of the discrepancies. There are also data processing procedures necessary for the “alignment in depth” of the sensors along the sensor track which could account for some of the differences. Improved data quality can be achieved by adjusting the data a posteriori with independently determined high quality dissolved oxygen values. The BBPMP collects water samples for this purpose and analyzes them in the lab; however the published data presented here have not been adjusted. They are in the process of adjusting this data and have suggested that their data can be made available to HHWQMP for at least qualitative QAQC on DO data.

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

### 4.10 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* – Minor formatting changes. The “profile” pages were rearranged slightly and the sampling site map was replaced with a more geographically correct version. This change occurred on Week 64 (6 Sep 05).

*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.

*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 fourth quarter.

*Changes* –A sample site at Dartmouth Cove was added in response to public concern. This site is sampled monthly during the summer, at a 1m depth, and analyzed for the full suite of chemical analyses.

*Action*

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

## 5.3 Water Quality Parameters

### Fecal Coliform

*Summary Statement* – Overall, the fifth quarter fecal coliform levels indicate a time of relatively low flushing. On average, high values for both the 1m and 10m samples are similar, that is centered in the vicinity of Inner Harbour outfalls. There is not significant displacement of the distributions upstream or downstream from each other implying that the effect of layered currents mostly averages out, the distribution. High values are prevalent in the Inner Harbour but can occur at most any site during appropriate conditions. The variable analysis resolution scheme, implemented as a result of previous recommendations reduced the out-of-range values to only one this quarter, in the 1m sample at site EE-2 on 30 Aug 05. The analysis of high and low values to date at this site indicates that reducing the resolution would result in loss of data at the other end of the scale, so a change in resolution is not recommended.

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*
Ongoing (QR#1): Consider inclusion of enterococci as an alternate and/or additional tracer.

## Ammonia Nitrogen

*Summary Statement* – Ammonia nitrogen has detectable values in 28% of samples this quarter. This is down from the 58% of last quarter. Recognizing nitrogen as the key nutrient in marine systems, and the potential importance that nutrients have in the harbour oxygen dynamics, additional species of nitrogen continue to be considered for monitoring.

The BBPMP monitors nutrients at their site in Bedford Basin, including nitrate, silicate and phosphate, it is possible that the analysis of nitrate at an expanded number of sites could be included in 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* –Total suspended solids averaged 10-11 mg/L over the quarter, similar to the average of the previous quarter. The maximum observed value is 26 mg/L. The lowest values were two samples below the detection limit of 2 mg/L. Based on past data, it is expected that there will be future values below the detection limit.

*Changes* – None.

*Action*
Ongoing (QR#2,3): Change to larger water samples(1 L) to reduce EQL to 1.0 mg/L (currently 2.0 mg/L) (As of the writing of this report this has been changed.)

## 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* – None

*Action*
Consider dropping Total Oil and Grease analysis from regular sampling. It should be retained for supplemental samples, (As of the writing of this report this has been implemented)

## Metals

*Summary Statement* – There was three measured exceedances, one each of zinc, copper and nickel, of metals guideline over the period. There were twenty five values above detection limit (thirteen zinc, six manganese, four chromium, one nickel and one copper). All but four of these values occurred in two surveys, one with anomalously high values of several metals and one anomalously high in zinc (11 of 14 samples). The metals concentrations in the harbour are under-resolved by our present technique. To date the metals analysis has resulted in approximately 98% non-detectable values for metals for which guidelines exist.

*Changes* – None.

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

## 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 perform the required lab analyses to extend the utility of the fluorescence data.

Discussions are underway to investigate cooperation with the BBPMP to have chlorophyll analysis performed at selected HHWQMP sites throughout the Harbour.

*Changes* – None.

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

## Dissolved Oxygen

*Summary Statement* – To date, oxygen levels as measured in the program, are generally high in surface waters, and chronically low in the deep water of Bedford Basin. This is consistent with the existing understanding that Bedford Basin is a fjord, in which depressed oxygen in bottom water is typical. This quarter there was a period of three weeks where the HHWQMP data have indicated that guidelines were exceeded in all areas classified SA or SB by the Harbour Task Force (Halifax Harbour Task Force. 1990). The SC guidelines of 6 mg/L, which applies to the Inner Harbour, was not exceeded In situ oxygen measurements are particularly sensitive to a variety of factors. There is some discrepancy with data collected from other sources, other instruments deployed by HHWQMP and the monitoring data of BBPMP. Given this and the fact that dissolved oxygen is perhaps the most important indicator of the health of a water body, it is therefore very important to insure the quality of the collected data. If sewage load is contributing to oxygen depression in the harbour it 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.

# 6 References

Dalziel, J.A., P.A. Yeats and D.H. Loring, 1989. Dissolvedand particulate trace metal distributions in Halifax Harbour, In: H.B. Nicholls (ed.), Investigations of Marine Environmental Quality in Halifax Harbour, Can. Tech. Rep. Fish. Aquat. Sci. 1693.

Halifax Harbour Task Force. 1990. Halifax Harbour Task Force Final Report. Prepared for Nova Scotia Department of Environment, R. Fournier ed.

Health and Welfare Canada. 1992. Guidelines for Canadian Recreational Water Quality.

JWL and COA. 2004. Halifax Harbour Waster Quality Monitoring Program, Weekly and Quarterly Reports 2004 to 2008, report to the Halifax Regional Municipality, Harbour Solutions Project.