Combined work/quality assurance project plan (CW/QAPP) for plume tracking: 2001

Massachusetts Water Resources Authority

Environmental Quality Department
Report ENQUAD ms-58 (revision 1)

COMBINED WORK/QUALITY ASSURANCE PROJECT PLAN (CW/QAPP)

for

PLUME TRACKING: 2001
Tasks 11
MWRA Harbor and Outfall Monitoring Project

submitted to

MASSACHUSETTS WATER RESOURCES AUTHORITY
Environmental Quality Department
100 First Avenue
Charlestown Navy Yard
Boston, MA 02129
(617) 242-6000

prepared by

Ms. Elizabeth J. Bruce, Battelle
Mr. Carl S. Albro, Battelle
Dr. Carlton D. Hunt, Battelle
Ms. Heather K. Trulli, Battelle
Ms. Sheri A. Cheng, Battelle
Ms. Donna Pichiarallo, Battelle
Dr. Michael J. Mickelson, MWRA
Dr. Rocky Geyer, WHOI

submitted by

Battelle
397 Washington Street
Duxbury, MA 02332
(781) 934-0571

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CONCURRENCE AND APPROVALS

_____ _____
Dr. Carlton Hunt Date
Battelle Project Manager

_____ _____
Ms. Rosanna Buhl Date
Battelle Project QA Officer

_____ _____
Dr. Michael Mickelson Date
MWRA Project Manager
MWRA Water Column Project Area Manager

_____ _____
Ms. Wendy Leo Date
MWRA EM & MS Manager

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MWRA Harbor and Outfall Monitoring Project
Plume Tracking: 2001
Task 11

2.0 PROJECT REQUESTED BY

Massachusetts Water Resources Authority
Environmental Quality Department

3.0 DATE OF REQUEST

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4.0 DATE OF PROJECT INITIATION

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5.0 PROJECT MANAGEMENT

Dr. Andrea Rex	MWRA Director of Environmental Quality Department
Dr. Michael Mickelson	MWRA Harbor and Outfall Monitoring Project Manager
Mr. Kenneth Keay	MWRA Harbor and Outfall Monitoring Deputy Project Manager
Dr. Carlton Hunt	Battelle Project Manager for Harbor and Outfall Monitoring
Mr. Wayne Trulli	Battelle Field Manager for Harbor and Outfall Monitoring
Ms. Heather Trulli	Battelle Laboratory Manager for Harbor and Outfall Monitoring
Mr. Carl Albro	Battelle Task Leader for Outfall Plume Tracking Tasks

6.0 QUALITY ASSURANCE (QA) MANAGEMENT

Ms. Wendy Leo	MWRA EM & MS Manager
Ms. Rosanna Buhl	Battelle Project QA Officer

7.0 PROJECT DESCRIPTION

The Massachusetts Water Resources Authority (MWRA) is responsible for the operation and monitoring of the new sewage effluent outfall (Figure 1) from the Deer Island Wastewater Treatment Plant, which began discharging into Massachusetts Bay on September 6, 2000. The outfall is regulated under a National Pollutant Discharge Elimination System (NPDES) permit issued by the U.S. Environmental Protection Agency (EPA) and the Massachusetts Department of Environmental Protection (EPA/MADEP 1999) with an effective date of August 19, 2000. Part I, Section 18.e of the permit requires that MWRA "field test and certify whether the outfall's minimum dilution is equal to, or greater than, the predicted minimum dilution" specified in a hydraulic study published in 1993 (Roberts and Snyder (1993a,b). MWRA will address this permit condition in the summer of 2001 based on the activities described in this Combined Work/Quality Assurance Project Plan (CW/QAPP

Evaluation of effluent plume dilution characteristics and transport will be conducted using Rhodamine WT dye as a tracer. Data collected during the plume tracking exercise will be used to determine the location of the effluent discharge plume as it exits the diffuser and mixes with ambient waters. The dilution performance of the outfall will be evaluated and compared with results of the RSB model (Roberts and Snyder 1993a,b).

7.1 Objectives and scope

The primary objectives of the MWRA Plume Tracking Program are to 1) determine the initial dilution characteristics of the outfall and 2) to track the longer-term location and mixing dynamics of the outfall plume. To accomplish this, a tracer dye, Rhodamine WT, will be added to the effluent stream at Deer Island Treatment Plant over a period of 28 hours in the mid to late summer of 2001 to maintain a constant concentration. This will allow steady state release at the diffuser over two tidal cycles (25 hours). A suite of sensors will be towed through the water in Massachusetts Bay providing high-resolution, *in-situ* measurements of the Rhodamine WT dye (as well as salinity, temperature, density (calculated), turbidity, dissolved oxygen, and chlorophyll fluorescence) in the water surrounding the outfall. These data will be used to evaluate the initial dilution of the outfall and to verify that the NPDES permit dilution requirements are met (EPA/MADEP 1999).

In support of the interpretation of dilution assessments, current velocities within the study area will be measured using an Acoustic Doppler Current Profiler (ADCP) and density profiles will be measured with a CTD. The ADCP measurements will document the ambient currents (particularly tidal and wind-driven) that will affect the dilution and trajectory of the plume, assess the effectiveness of backscatter as a plume monitoring tool, and document the velocity anomalies at scales of 30 m to 2 km associated with the outfall.

Measurements of the Rhodamine WT dye plume will continue after the period of dye release from the outfall to demonstrate that the outfall plume continues to disperse and does not travel intact to resource areas. Discrete water samples will be collected for laboratory analysis to provide a secondary measure of dilution or to demonstrate the effectiveness of effluent treatment and dilution. In addition, a trained whale observer will report marine mammals sighted during the survey operations and report on any visible fronts, slicks, or discoloration. This CW/QAPP is revision 1 of the CW/QAPP originally published as Bruce *et al*. (2000) and reflects changes made in response to per review comments on Bruce *et al*. (2000), and information gained from preliminary efforts to track the plume in the fall of 2000 (Libby *et al*., In preparation). This Combined Work/Quality Assurance Project Plan (CW/QAPP) describes the sampling and analysis activities of MWRA's plume tracking program that will be conducted in 2001 under MWRA Contract S274. Many of the methods described in this plan are based on previous CW/QAPPs (Albro *et al*. 1993; Trulli and Albro 1998; Albro *et al.* 1998).

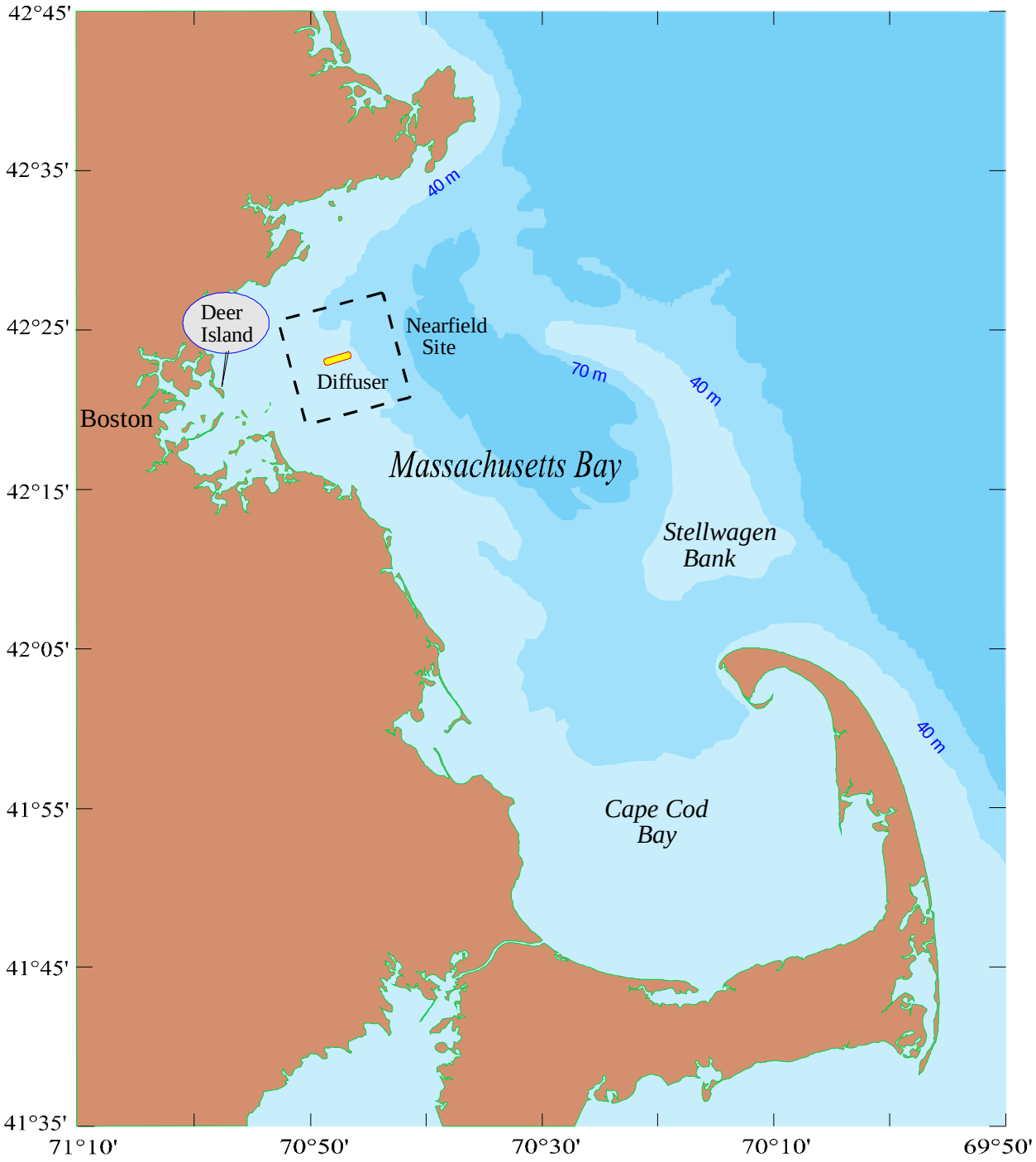

Figure 1. Location of MWRA effluent outfall in Massachusetts Bay

7.2 Technical approach

Two surveys are planned under this CW/QAPP. One will occur in the winter and one in the summer of 2001. The approach that will be followed to specifically address the permit requirement and certify the effluent dilution is first described. This survey will occur in mid summer and will collect data under strongly stratified water column conditions. Data from this survey will be used for the dilution certification. Prior to this survey a winter survey, which will occur in the late winter of 2001 will be conducted. This winter survey will be used to test (shakedown) the various protocols planned for the certification study and is designed to developed information on the effluent dilution during the winter (the period of maximum expected dilution).

The plume tracking exercise to certify the initial dilution is scheduled to occur within the year following the start of the new outfall and will occur during stratified conditions (see Table 1). This plume tracking exercise will span two tidal cycles (25h) to capture the effects of tidal fluctuations and changes in currents, and will be followed by a farfield survey to map lingering traces of the plume. The winter shakedown survey will include eight hours of dye addition and will practice field logistics and explore plume-tracking options.

Two separate teams, a Deer Island Treatment Plant (DITP) team and a field survey team, will be required for each plume tracking exercise. The Deer Island Treatment Plant team will operate the Rhodamine WT dye addition system and collect discrete samples from the effluent stream at the plant. The field team will operate on-board a vessel in Massachusetts Bay to collect a suite of *in-situ* measurements from the water column – including Rhodamine WT dye concentration. The field team will also collect a set of discrete samples from the water column for laboratory analysis. The technical approach to completing each of these exercises is discussed below.

Table 1. Schedule for plume tracking exercises

1st dye release	March, 2001	Winter conditions, unstratified, shakedown survey to test dye addition and field measurement protocols
2nd dye release	July, 2001	Summer stratification conditions, survey for effluent dilution certification and transport

7.2.1 Dye addition at Deer Island Treatment Plant

The tracer dye, Rhodamine WT, will be injected into the effluent stream at the Deer Island Treatment Plant (
Figure 2). Dye injection will be made upstream of the sodium hypochlorite injection point in the treatment process. Degradation of the dye by the free chlorine is not expected to be significant as the chlorine concentration is expected to be less than levels observed to cause dye degradation and rapid mixing and decay of the chlorine levels. The potential decay of the dye will be tested prior the study (see Section 12.1.1 and Section 14.1). The effluent is secondary-treated when flows are below 480 MGD; higher flows may be partly primary-treated. The dye addition will consist of a continuous flow-normalized input into the effluent at the Deer Island Treatment Plant for 28 hours. The start of the addition of the dye will be timed such that dye will begin to emerge from every riser of the diffuser and be released into seawater at low tide (Figure 3). The timing may be shifted to begin at high tide. Approximately 102 gallons of Rhodamine WT dye tracer stock solution will be released over 28h, assuming an effluent-flow rate of 350 MGD. The dye solution will thus be diluted 1:4 million (250×10^{-9}). Because the dye solution is assumed 20% w/v as active ingredient, this yields an effluent concentration of 50 µg/L (or ppb) as active ingredient. Dye flow will be paced with effluent flow to give a constant dye concentration in the effluent.

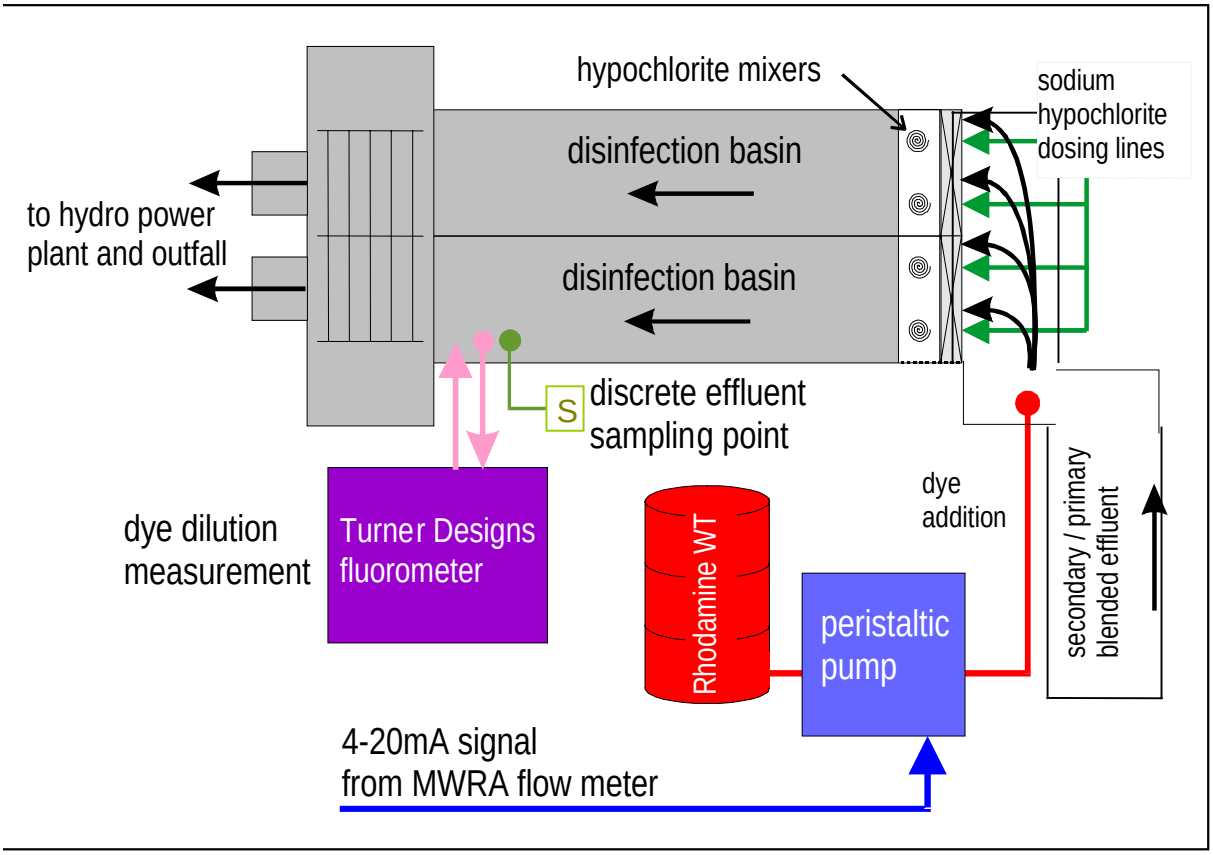

Figure 2. Schematic of Deer Island Treatment Plant dye addition and sampling locations.

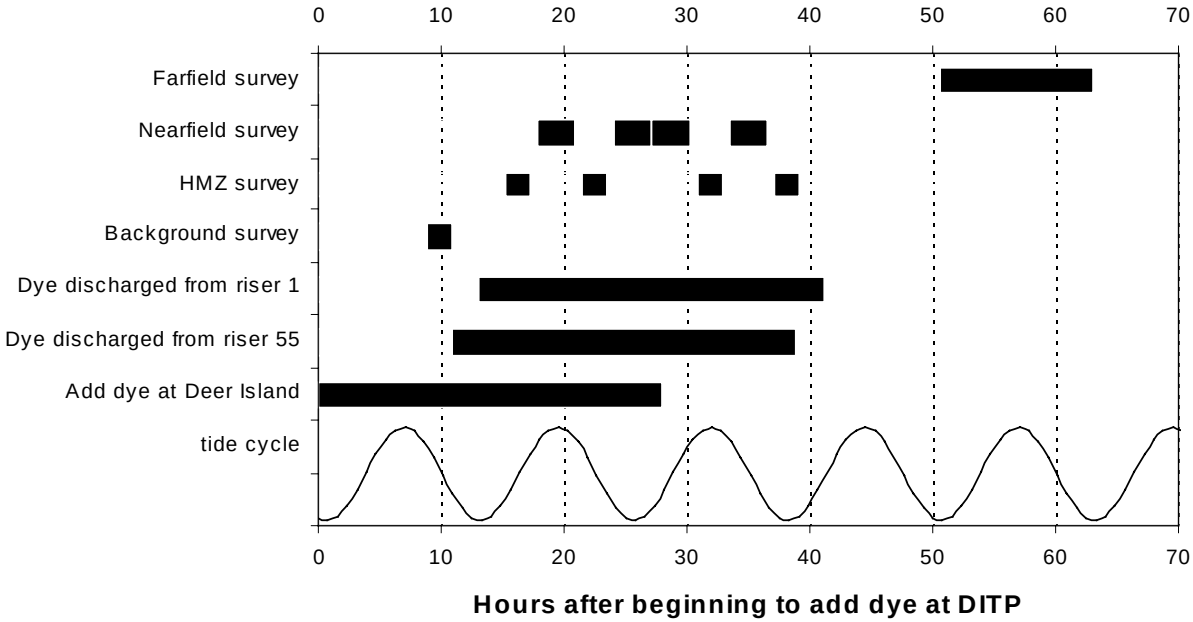

Figure 3. Timeline of dilution certification plume tracking survey

The transit time of the dye from the plant to the end of the diffuser ports will be estimated based on the specifications of the outfall tunnel and flow characteristics on the day of the survey. Assuming simple (plug) flow, the calculated transit time of the dye at a flow rate of 350 MGD is 10.8 h to the riser nearest to shore (riser #55) and 13.1 h to the most offshore riser (#1). The transit time calculation will be evaluated during the winter shakedown survey.

Dye concentration in the effluent will be continuously monitored using a Turner Designs flow-through fluorometer Model 10 AU during the period of dye addition (Table 2). The sampling location will be downstream of the point at which dye is added to the effluent. A submersible pump will deliver effluent continuously to the fluorometer. The temperature of the effluent will be monitored with a CTD to allow correction for temperature-dependent changes in fluorescence. The CTD will also give measurements of effluent salinity (expected to be less than two psu) for interpreting salinity patterns at the outfall.

Table 2. Summary of DITP instruments

Parameter	Lab	Units	Instrument	Reference
Effluent flow	MWRA process control	MGD	"Primary Flow Signal" venturi flowmeter, four in parallel, model 120" PFS-RECT	"Primary Flow Signal" manual (1991)
Dye flow	Battelle	mL/min	Masterflex L/S computer-compatible peristaltic pump, model 07550-10 with 07016-20 head	Masterflex manual (1999)
Rhodamine fluorescence	Battelle	µg/L	Turner Designs 10AU	Turner Designs manual (March 1997)
Conductivity	Battelle	mmhos/cm	OS200	Ocean Sensor manual (1999)
Temperature	Battelle	C	OS200	Ocean Sensor manual (1999)

7.2.2 Effluent characterization at Deer Island Treatment Plant

In addition to the continuous monitoring of the Rhodamine WT dye, a set of discrete effluent samples will also be collected at the Deer Island Treatment Plant. Grab samples will be analyzed for Rhodamine WT, chloride, total suspended solids, ammonium, phosphate, silver, copper, and fecal coliform/*Enterococcus*. Samples will be collected just prior to dye addition and then periodically over the 28-hour period that dye is released. Grab samples will be taken from approximately the same point at which the dye is monitored at the end of the disinfection basin. The samples will be analyzed by Battelle and/or by MWRA's Deer Island Laboratory (DIL). TSS and nutrients will be measured by both labs to allow comparison of standard-oceanographic to EPA-approved methods. Fecal coliform/*Enterococcus* will be sampled over a limited period to coordinate with field sampling and the short holding time of those samples. Table 3 indicates the sampling frequencies and distribution of effluent samples for analysis in Battelle and MWRA laboratories.

Table 3. Summary of discrete effluent samples collected at Deer Island Treatment Plant for the certification survey.

Sample	Number of samples for MWRA DIL	Number of samples for Battelle
Rhodamine WT	none	1 sample/ hour (29 total)
Chloride	2 samples/ hour (57 total)	none
Total Suspended Solids	2 samples/ hour (57 total)	1 sample/ hour (29 total)
NH_4 filtered	2 samples/ hour (57 total)	1 sample/ hour (29 total)
PO_4 filtered	2 samples/ hour (57 total)	1 sample/ hour (29 total)
Ag – Total	none	1 sample/ 4 hours (8 total)
Cu – Total	none	1 sample/ 4 hours (8 total)
Fecal Coliform/ *Enterococcus*	24 samples	none

7.2.3 Field program

The field program requires one vessel for the hydrography/fluorometry, ADCP measurements, and discrete sample collections. EPA is planning to provide a second vessel that will be used for NOAA's high-resolution measurements using a dual-frequency (20 kHz and 200 kHz) acoustical system. That system can image plume patterns and natural layering through backscatter from suspended solids and the abrupt small-scale density changes that occur when fresh and salt water mix. This plan addresses the activities of the first vessel; EPA and NOAA will prepare a separate plan to describe the activities of the second vessel. Table 4 provides a summary of the field measurements that will be acquired from the first vessel during each plume tracking exercise.

Table 4. Summary of shipboard instruments

Parameter	Lab	Units	Instrument	Reference
Rhodamine fluorescence	Battelle	µg/L	Chelsea Aquatracka Mark III	Chelsea manual (1991)
Conductivity	Battelle	mmhos/cm	OS200 CTD	Ocean Sensors CTD manual (1999)
Temperature	Battelle	C	OS200 CTD	Ocean Sensors CTD manual (1999)
Pressure	Battelle	m	OS200 CTD	Ocean Sensors CTD manual (1999)
Chlorophyll fluorescence	Battelle	µg/L	Wetstar WS-3-MF	Wet Labs manual (1998)
Transmissometry	Battelle	m-1	Seatech 20-cm (660nm)	Seatech manual (1998)
Altitude	Battelle	m	Datasonic PSA-916	Datasonic manual (1997)
Bottom depth	Battelle	m	Furuno FCV-52	Furuno manual (1998)
Navigational position	Battelle	degrees	Northstar 942X	Northstar manual (1998)
Ocean current velocity	Battelle	cm/sec	RD Instruments ADCP WHM600-I-UG6	RD Instrument manual (2000)
Sigma-T*	Battelle	no units	OS200 CTD	Fofonoff and Millard (1983)
Salinity*	Battelle	PSU	OS200 CTD	Fofonoff and Millard (1983)

* Sigma-T and salinity are calculated from conductivity, temperature, and pressure.

Plume tracking will be conducted using the Battelle Ocean Sampling System (BOSS) deployed from the survey vessel. The BOSS *in situ* sensor package will include: a Rhodamine fluorometer (Chelsea Aquatracka), a chlorophyll fluorometer (WET Labs WETStar), a CTD (which measures temperature, conductivity, and pressure (for depth)), and light transmission (Sea Tech transmissometer). A winch is used to control the depth of the towed sensor package. The BOSS sensor package can be raised or lowered using the winch at a rate of 0 - 1.0 meters/second.

Depending on the vessel's speed and winch operation, the system can operate in three different modes: vertical profile, constant-depth towing, or towyo. In vertical profiling mode, data is acquired as a

function of depth while the vessel remains stationary. In constant-depth mode, the BOSS system is towed through the water continuously at a single depth. During towyo mode the BOSS is operated in a vertically undulating (ascent and descent) pattern to obtain data continuously at different depths while underway. The plume tracking exercise will utilize BOSS in both the vertical profiling mode and the towyo mode.

Two different types of BOSS cables will be used during this experiment. During operations with discrete water sampling (using the pumped water system), an electrical-mechanical cable (200 ft long) with a Teflon tube down the middle of the cable will be used. For operations without discrete water sampling, a standard electrical mechanical cable (500 ft long) will be used. The maximum operational depths versus vessel speed are listed below:

Vessel speed (& mode)	Maximum depth pumped system	Maximum depth non-pumped system
0 knots (vertical profile)	45	135
2 knots (towyo)	40	120
4 knots (towyo)	25	70
8 knots (towyo)	NA	35

The vessel will also deploy a downward looking Acoustic Doppler Current Profiler (ADCP). This will provide real-time current measurements at 0.5 m or 1.0-m vertical increments between 2.5-m depth and 26 m depth (in 30 m of water). The ADCP will also provide relative backscatter amplitude through the whole water column at the same resolution.

The summer plume tracking exercise will include four different survey types, each with a different focus, to meet the overall objectives of the program. The exercise will include 1) one background survey, completed just prior to dye release from the diffuser, 2) four hydraulic mixing zone (HMZ) surveys[1] during dye release at the diffusers, 3) four nearfield surveys during dye release at the diffusers, and 4) one farfield survey after dye release has ended. See Figure 3 for a timeline of the plume tracking survey schedule. A brief description of each survey is provided below.

Background survey. *The objective is to obtain measurements of background fluorescence in the environment prior to dye release at the diffuser and to obtain discrete background water samples from locations outside region influenced by the effluent.* Background fluorescence is caused by any component of the water that naturally fluoresces in the same region of the spectrum as the Rhodamine WT excitation and emission wavelengths. Dissolved and colloidal organic matter may contribute to a background fluorescence signature (Smart *et al*. 1977). In addition, turbidity has been found to affect fluorescence readings (Albro 1994).

Measurements of background hydrographic data and fluorescence, using the BOSS system in towyo mode, will occur at a distance of approximately 60 meters around the centerline of the 2020-meter diffuser forming a loop 120 meters wide x 2140 meters long (Figure 4). Note this distance is based on a situation with no oceanic currents, which will occur only briefly during periods of slack tide. Thus, the

[1] Note: The term nearfield in this document refers to the general vicinity of the diffuser line. The term is not to be confused with the term near field used by plume modelers to mean the region in which mixing and dilution occur as a result of the turbulence generated by the discharge itself. This latter region is often refereed to as the initial mixing zone. We will refer to the modeler's near field as hydraulic mixing zone or HMZ. The term farfield is not to be confused with the modelers use of the term far field. The later is used to mean the region where plume mixing and dilution is due to oceanic turbulence. The farfield surveys described herein will encompass the modeler's farfield, as will most of the nearfield survey. It is the transition point between the hydraulic mixing zone and the farfield that initial dilution is set. Sampling this location will be the goal of the hydraulic mixing zone surveys.

spacing may be adjusted in the field depending upon the current regimes measured in real time with the ADCP as part of this activity. Note also that the position of the trackline may be adjusted to the north or south depending on the data received from this activity.

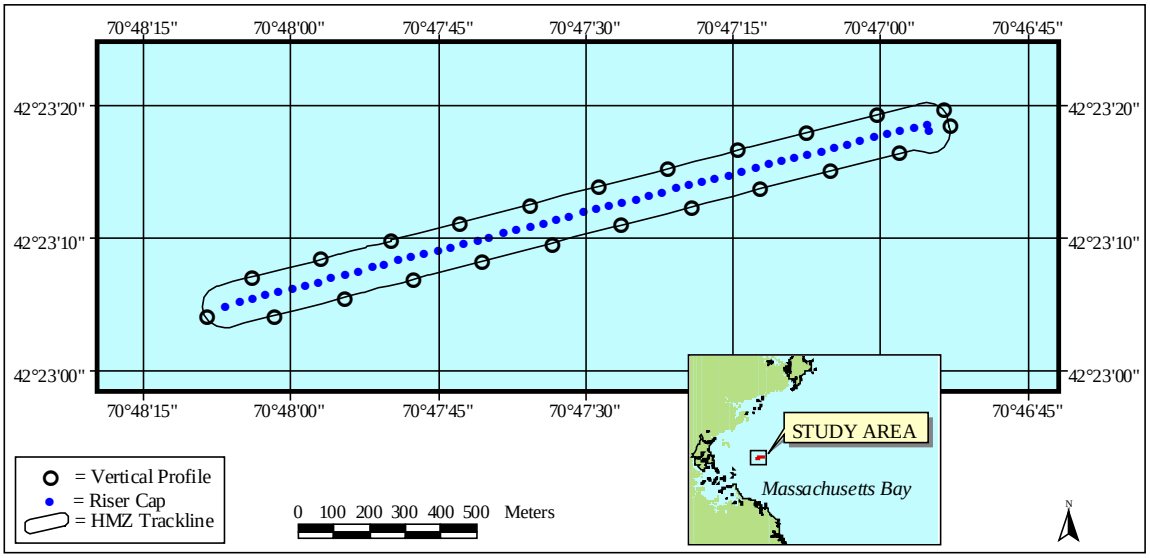

Figure 4. HMZ survey trackline.

During this background survey, a subset of discrete water samples will be collected using the BOSS water pumping system (Table 5). For collection of the discrete water samples, the towyo vessel will transit away from (~2000 meters) the effluent plume to seek waters *outside* of the effluent plume to provide a measure of background concentrations found in Massachusetts Bay. Sample depths will be collected relative to the expected depth of the effluent plume depending on season. These background measurements will be used to correct values of parameters used as dilution tracers. The exact location of the discrete sampling points will be determined during the survey in relation to real-time measurements of beam attenuation, temperature, and salinity.

Discrete samples will be collected as follows:

- One sample each TSS, NH_4, PO_4, and chlorophyll samples at four (4) separate locations outside of the effluent plume for correction/calibration purposes.
- No fecal coliform/*Enterococcus* samples will be collected during the background survey.
- One sample for silver and copper analysis at each of two (2) locations outside of the effluent plume

Discrete fluorescence samples at four (4) locations in addition to *in situ* background fluorescence at the Rhodamine dye wavelength.

Table 5. Summary of discrete water samples to be collected in the field during the certification survey.

Sample	Purpose	Total number of samples collected during the background survey	Total number of samples collected during HMZ surveys
Rhodamine WT	Compare field and DITP fluorometers	4 samples	36 samples (9 samples/ HMZ survey)
Total Suspended Solids	correct acoustic and optical measurements	4 samples	36 samples (9 samples/ HMZ survey)
NH_4 (dissolved)	Dilution tracer	4 samples	36 samples (9 samples/ HMZ survey)
PO_4 (dissolved)	Dilution tracer	4 samples	36 samples (9 samples/ HMZ survey)
Ag – Total	Dilution tracer	2 samples	8 samples (2 samples/ HMZ survey)
Cu – Total	Demonstrate compliance with WQC	2 samples	8 samples (2 samples/ HMZ survey)
Fecal Coliform/ *Enterococcus*	Demonstrate compliance with WQC	0 samples	24 samples (all in one HMZ survey)
Chlorophyll	calibrate *in-situ* fluorometer	4 samples	36 samples (9 samples/ HMZ survey)

Hydraulic Mixing Zone (HMZ) surveys. *The objective of these surveys is to measure dilution at the edge of the hydraulic mixing zone to determine compliance with the requirements of the NPDES permit*. The HMZ is defined as the distance required for initial mixing to be complete (see footnote 1). Initial mixing is mixing resulting from the momentum and buoyancy of effluent exiting the diffuser; it is characterized by vertical motion and is typically complete in a few minutes with the plume spreading about 2-4 times as wide as it is tall. After initial mixing, natural background currents (advection) slowly disperse the effluent plume over a scale of kilometers and days. The plume is not expected to reach the water surface when the water column is stratified (Roberts and Snyder 1993a, b.).

Four HMZ surveys will be performed within two tidal cycles. The first HMZ survey will occur when the rate of dye release is consistent along the entire length of the diffuser[2]. This will occur approximately 2 hours after the dye reaches riser #1 (the one furthest offshore). The HMZ surveys will occur at the following four points in the tidal cycle:

1. maximum flood current halfway between low and high tide (peak flood)
2. maximum ebb current halfway between high and low tide (peak ebb)
3. minimum current at high tide (slack flood)
4. minimum current at low tide (slack ebb)

Monitoring will occur along the edge of the HMZ boundary, which is defined by a loop extending approximately 60 meters on either side of the diffuser centerline under slack or no current conditions (see Figure 4). With the ship traveling at about 4 knots around the loop, the winch will towyo the *in situ* sensor suite through the water, focusing on the depths where dye concentrations exceed 0.1 µg/L active

[2] The field team will conduct exploratory plume tracking exercises between the completion of the background survey and the first HMZ survey to ensure the trackline spacing and location relative to the diffuser line are properly established. The depth range for the tow operations will also be established during this period.

ingredient (1:500 dilution of effluent). Approximately every 300 meters along the trackline the ship will slow and the towed BOSS system will descend to within 1 meter of the bottom. On two of the HMZ surveys, during slack flood and slack ebb, a center trackline (directly over the top of the diffuser axis) will also be included, but the BOSS system will not be allowed to descend closer than 5m to the sea floor (the tallest riser, #1, is 5m above the sea bed, Figure 5).

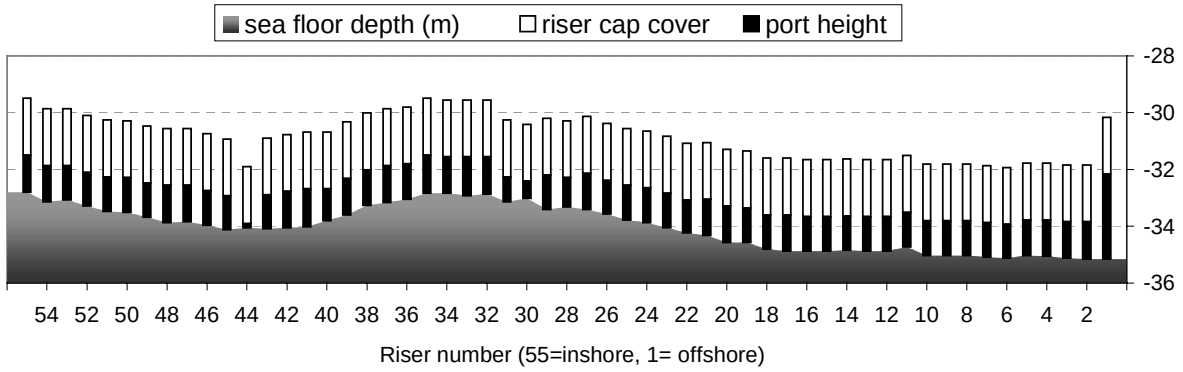

Figure 5. Height of riser caps

During the HMZ surveys the concentration of dye in the plume (C_{plume}) will be measured using an *in situ* rhodamine fluorometer (Chelsea); this will be used to determine dilution (S):

$$S = \frac{C_o}{C_{plume}}$$

where C_o is the concentration of dye in the effluent at the Deer Island Treatment Plant and Cplume is the concentration of dye in the plume in the ocean. As described in Section 7.2.1, C_O = 50 µg/L as active dye ingredient.

Discrete samples for measurement of other parameters will be collected as a secondary measurement of dilution and to demonstrate the effectiveness of effluent treatment and dilution. After completion of a 60-meter loop, a station along the HMZ trackline will be selected where dye concentrations appear to be relatively high. This location will be identified in the field from the towyo data. The vessel will then return to that station and conduct vertical profile operations. While profiling, the pumped system will collect discrete samples at selected depths as follows:

- Collect TSS, NH_4, PO_4, and chlorophyll samples at the depth of maximum dye concentration, minimum dye concentration, and at 7 other depths to obtain a range of values at different dye concentrations
- Collect bacterial indicator samples at the depth of maximum dye concentration, minimum dye concentration, and at four (4) other depths at each of four locations in the HMZ to obtain a range of values at different dye concentrations. These will be collected only on one HMZ survey to facilitate delivery of samples to the shore laboratory within the holding time.
- Collect samples for analysis of silver and copper at the depth of maximum dye concentration and one other depth of high dye concentration.

Nearfield Surveys. *The objective is to determine plume structure and behavior in the nearfield by examining the influence of tides and ambient stratification on its vertical and horizontal distribution.*

Four nearfield surveys will occur between the four planned HMZ surveys during the 28-hour dye release period (Figure 3: nearfield surveys 2 and 3 are back-to-back). Using the BOSS system in towyo mode (1-meter from the surface down to 5-meters from the bottom), monitoring will occur in a series of sequential loops around the diffuser, including a 60, 120, 240, and 480 meter loop (Figure 6). Four points (at a minimum) will be selected during each loop at locations where the maximum dye concentration is measured near the bottom. At these locations, the ship will slow down, allowing the BOSS to collect *in situ* hydrographic and dye data within 1-meter of the seafloor. This will be done to characterize the plume in the bottom waters.

Since no discrete samples will be acquired, the BOSS towed system will use the non-pumped cable. The ship velocity during these surveys will be approximately 8 knots (4 m/sec).

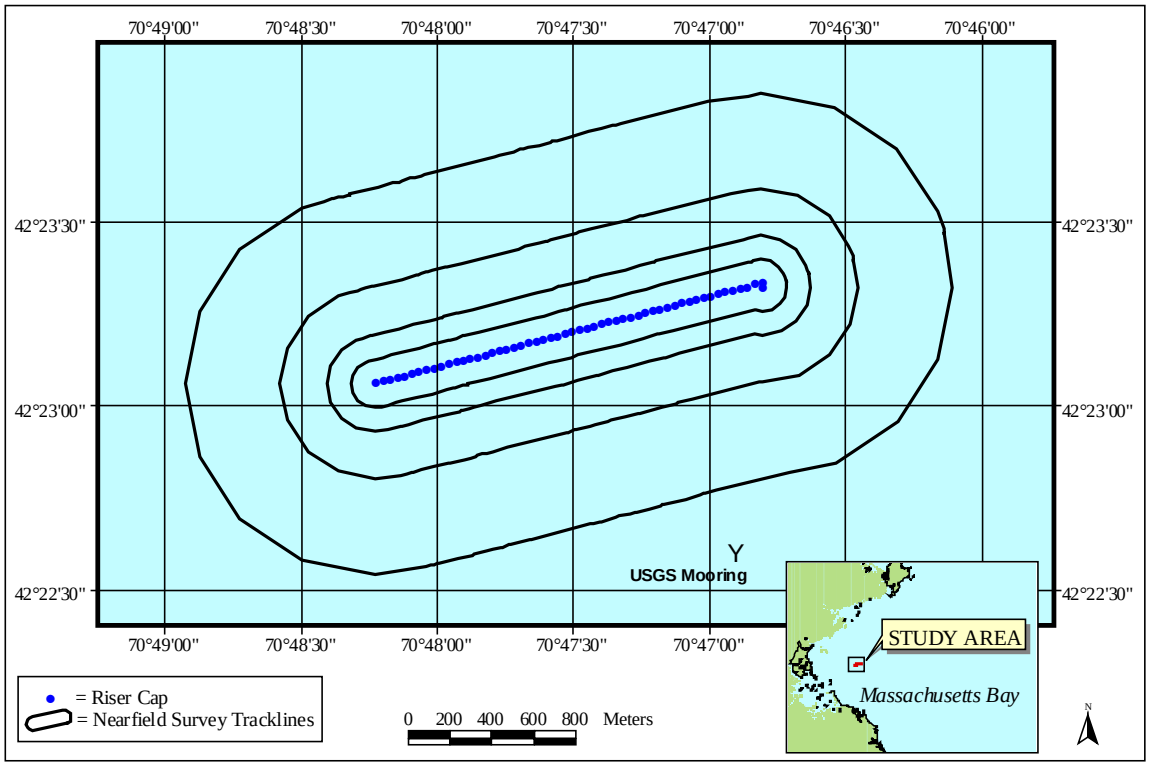

Figure 6. Nearfield survey tracklines with the location of the USGS long-term current meter mooring shown.

Farfield Surveys. *The objective is to determine plume structure and behavior in the Farfield by tracking the spread of the dye to dilutions of at least 1:500* (down to 0.10 µg/L active dye ingredient). The vessel will track along the boundary of the dye using the BOSS system (full suite of *in situ* sensed data) in towyo mode. The farfield survey will start approximately 9 hours after the dye stops entering the environment at the diffusers. The farfield survey will track (by adaptively changing the ship's course in real-time) the boundary of the dye plume for up to 12.5 hours. This survey will determine whether there are regions of reduced mixing or regions of penetration of the effluent into the near-surface waters (the plume is expected to surface during the December survey.) The survey will also document the influence of the ambient currents on the trajectory of the plume and its mixing. The principal product of the farfield survey will be to map the boundary of the effluent plume over scales of 5 to 10 km.

Additionally, at least four locations/hour will be selected at points where the dye concentration is found to be maximized near the bottom depths of the towyo pattern (about 5m above the sea floor). At these

points, the ship will slow down and the towed BOSS system will descend to within 1 meter of the bottom to further characterize the effluent plume in the bottom waters of Massachusetts Bay.

Since no discrete samples will be acquired, the BOSS towed system will use the non-pumped cable. The ship velocity during these surveys will be approximately 8 knots (4 m/sec).

7.2.4 Winter plume tracking and shakedown exercise

The winter shakedown exercise will occur in mid to late March of 2001, before thermal stratification sets up in Massachusetts Bay. During this exercise, dye (Rhodamine WT) will be added to the effluent for 6 hours at a constant concentration of 100 ppb (this will require 44 gallons of dye solution assuming a flow rate of 350 MGD). The dye will be released continuously at the Deer Island Treatment Plant as described in Section 7.2.1. The high dye concentration is planned to ensure the dye can be detected to a dilution of at least 500:1 in the unstratified water column. The planned concentration will also be used to check *in situ* dye detection levels in the face of potential natural interference on low-level, ambient dye concentrations. Results from this study will be evaluated to ensure the 50-ppb dye concentration planned for the summer certification study is adequate to ensure detection in Massachusetts Bay.

The tracer dye will be injected into the effluent stream at the Deer Island Treatment Plant as described in Section 7.2.1. The start of the addition of the dye will be timed such that dye will begin to emerge from every riser of the diffuser and be released into seawater at low tide. The timing may be shifted to begin the ambient surveys at high tide. Dye flow will be paced with effluent flow to give a constant dye concentration in the effluent.

Sampling for selected parameters (dye concentration, TSS, metals, nutrients, temperature, salinity, chlorophyll, chloride, bacterial samples) will also be tested at Deer Island Treatment Plant during this shakedown effort. Operation of the towyo system, *in situ* data collection plans, and the ambient water sampling system will be tested. Discrete samples will be collected for analysis of the same parameters planned for the certification survey from both the effluent and the ambient waters. This winter shakedown exercise will also provide an opportunity to confirm calculation of the dye transit time within the outfall tunnel.

The specifics of the ambient portion of the winter plume tracking will be kept flexible due to the lack of stratification in the water column in March, the expected high effluent dilution, and limited measurements on the actual plume dynamic in this system. The field team will be given flexibility to make adjustments in the survey protocols to ensure towed operations protocols are tested and optimized. The basic design described under the summer certification survey will be followed. That is, a background survey will precede the dye exiting the diffuser line and the *in situ* sensors will be towed near the diffuser to describe the dilution field. The field team will use the onboard ADCP to define the current fields and direction of plume drift. Two types of nearfield towing operations will be conducted (Figure 7). These will include a set of surveys with shortened towlines conducted near a subset of the diffusers (e.g. between diffusers 52 and 47 or 38 and 33 or 10 and 5). During these segment surveys, the *in situ* sampling system will be operated at a set of fixed depths sampled in rapid succession (Figure 8). Between these fixed depth studies, HMZ surveys will be conducted as described in Section 7.2.3. Prior to the first segment survey, transects extending from north or south of the diffuser line (perpendicular the diffuser) at fixed depths and under towyo operations will be conducted to define the gradients in the dye (thus effluent) field. Water samples will be collected from the effluent at the Deer Island Treatment Plant (Table 6) and from targeted effluent dilutions in the field for analyses in the laboratory (Table 7). The procedures for finding these dilutions in the field will be tested during this survey.

The initial trackline of each segment survey will be established based on the results of the perpendicular transects or field onboard data that is acquired during preceding segment surveys. The tracklines during

the first segment survey will overlap in space. For subsequent segment surveys the tracklines may be congruent in space or may be offset by the distance of the lateral drift of the water column to maximize the concurrence of the sampling in the plume. Field data will be used to determine which of these operational modes should be followed.

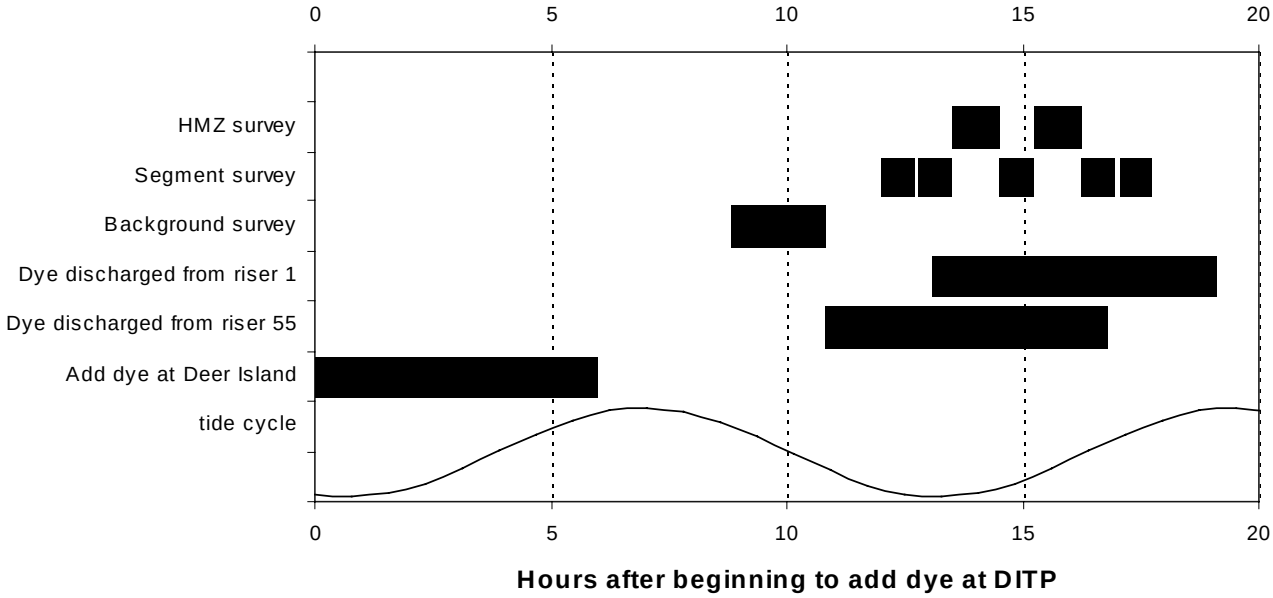

Figure 7. Timeline of winter shakedown survey.

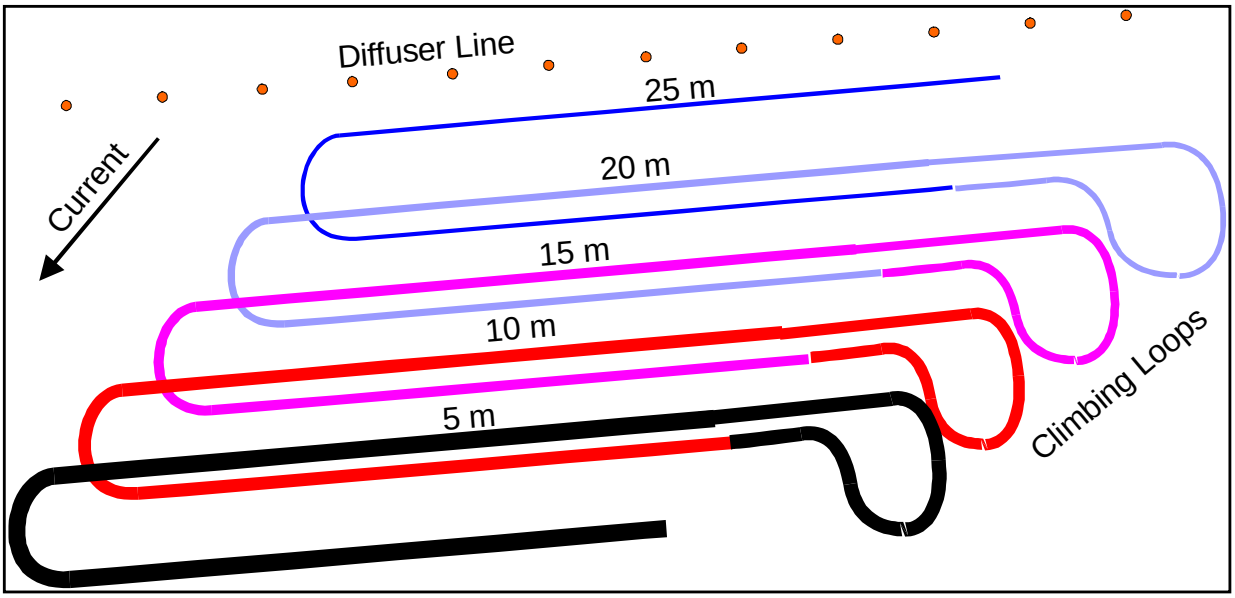

Figure 8. Schematic diagram of the trackline for the winter shakedown survey segment surveys. Loops may overlap exactly depending on field conditions.

Table 6. Summary of discrete effluent samples to be collected at Deer Island Treatment Plant during the winter shakedown survey.

Sample	Number of samples for MWRA DIL	Number of samples for Battelle
Rhodamine WT	none	1 sample/ hour (9 total)
Chloride	2 samples/ hour (9 total)	none
Total Suspended Solids	2 samples/ hour (9 total)	1 sample/ hour (9 total)
NH_4 filtered	2 samples/ hour (9 total)	1 sample/ hour (9 total)
PO_4 filtered	2 samples/ hour (9 total)	1 sample/ hour (9 total)
Ag – Total	none	1 sample/ hour (8 total)
Cu – Total	none	1 sample/ hour (8 total)
Fecal Coliform/ *Enterococcus*	9 samples	none

Table 7. Summary of discrete water samples to be collected in the field during the winter shakledown survey.

Sample	Purpose	Total number of samples collected during the background survey	Total number of samples collected during HMZ surveys
Rhodamine WT	Compare field and DITP fluorometers	4 samples	10 samples (3 samples/ HMZ survey)
Total Suspended Solids	correct acoustic and optical measurements	4 samples	10 samples (3 samples/ HMZ survey)
NH_4 (dissolved)	Dilution tracer	4 samples	10 samples (3 samples/ HMZ survey)
PO_4 (dissolved)	Dilution tracer	4 samples	10 samples (3 samples/ HMZ survey)
Ag – Total	Dilution tracer	2 samples	6 samples (2 samples/ HMZ survey)
Cu – Total	Demonstrate compliance with WQC	2 samples	6 samples (2 samples/ HMZ survey)
Fecal Coliform/ *Enterococcus*	Demonstrate compliance with WQC	0 samples	8 samples (all in one HMZ survey)
Chlorophyll	calibrate *in-situ* fluorometer	4 samples	10 samples (3 samples/ HMZ survey)

The track line separation and lateral movement is not expected to be large because the dominant forcing agents during the winter study will be tides and winds. The winds will be weak due to logistical and vessel constraints. Thus, conditions that will be most likely be encountered during wintertime plume tracking (wind stress is less than 1 dyn/cm^2 or less than 14 kt wind-speed). Under these conditions, current speeds of about 8 cm/s near-surface (5-m) and 5 cm/s near-bottom (33 m, in 35 m total depth) have been reported (Geyer *et al.*, 1992) for a mooring located near the Outfall Site (Lat. 42 22.6N, Long. 70 46.9 W). The instantaneous speed of these currents is mostly due to tidal currents, which are dominantly in the E-W direction. Similar near-bottom conditions are expected in the summer time (Geyer, personal communication, 2000).

The plume displacement based on these observed currents is estimated to be relatively small (Table 8). The information in this table shows average east-west and north-south displacements (in km) for time intervals between 6 and 48 hours. The E-W displacement dominates for the first 12 hours in the wintertime, with a magnitude of 1 km at the surface and around 0.7 km at the bottom. At longer time intervals, the N-S displacement becomes more prominent, and after 48 hours, the displacement of the dyed plume is likely to be about 3 km in both the E-W and N-S directions.

Table 8. Estimated short term east-west and north-south displacement of the dyed effluent plume under low wind stress.

Time interval	Depth (m)	E-W Displacement (km)	N-S Displacement (km)
6 hours	5	1.0	0.7
	33	0.7	0.3
8 hours	5	1.0	0.8
	33	0.7	0.3
12 hours	5	1.0	1.1
	33	0.6	0.5
24 hours	5	1.8	2.1
	33	1.1	0.7
48 hours	5	2.8	3.5
	33	2.0	3.0

The range of possible displacements of the dyed plume is indicated in Figure 9, which shows all of the trajectories for the mooring deployment interval for wind stresses less than 1 dyn/cm^2. Note that each of these dots represents an individual realization of the net transport over that time interval. Thus, the cloud of dots should not be considered as the "spreading" of the plume, but rather the aggregate of all possible net trajectories of the plume during calm, wintertime conditions. The small-scale dispersion of the plume cannot be determined by analysis of individual mooring data.

Figure 8 represents the segment loop size required for a 10 cm/sec current flowing diagonally to the diffuser line. The towed body will be raised incrementally in steps of 5 m until a set of data extending from near the seafloor to the ocean surface are obtained. These surveys will be repeated at selected segments and at least two locations along the diffuser line. If time allows, additional segment or HMZ surveys may be conducted.

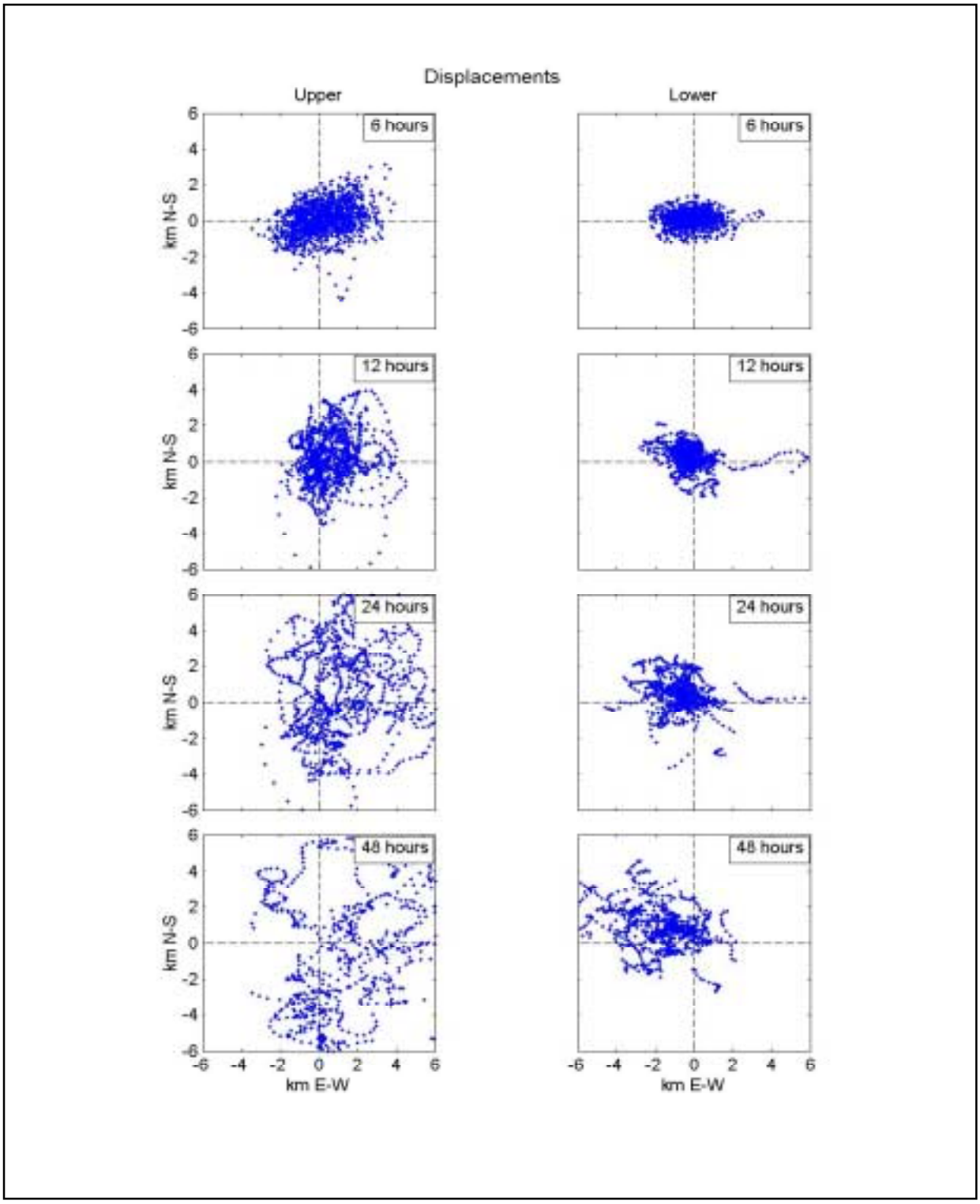

Figure 9. Estimated displacement of the dye plume in the upper and lower water column during the winter for time intervals from 6 and 48 hours after dye exits the diffuser system.

7.2.5 Laboratory program

Discrete water samples collected during the surveys will be analyzed to determine concentrations of dye, total suspended solids, ammonium and phosphate, silver, copper, chloride, fecal coliform/*Enterococcus*, and chlorophyll *a*. The sample analyses, for discrete samples collected both in the field and at the Deer Island Treatment Plant, are summarized in Table 9. Sampling and analytical methods are described in Section 12.

Table 9. Lab analysis of discrete samples collected at DITP and in the field

Parameter	Lab	Units	Instrument	Reference	Sample location
Rhodamine WT	Battelle	µg/L	Turner Designs fluorometer Model 10AU	Turner Designs Model AU-10 Manual (1997)	DITP and field
Chloride (effluent only)	DIL	mg/L	Mettler autotitrator	MWRA (1997c) SOP 10-ORNG-TAR-01.1	DITP
Total suspended solids	URI	mg/L	Mettler 5-place balance (0.01 mg)	Battelle SOP 5-053	Field and DITP
Total suspended solids	DIL	mg/L	Mettler 4-place balance (0.1 mg)	MWRA (1999) SOP 1012.0	DITP
Dissolved ammonium	URI	µM	Technicon Autoanalyzer II	Lambert and Oviatt (1986); Solorzano (1969)	Field and DITP
Dissolved ammonium	DIL	µM	Skalar autoanalyzer	MWRA (1998a) SOP 1005.0	DITP
Dissolved phosphate	URI	µM	Technicon Autoanalyzer II	Murphy and Riley (1962)	Field and DITP
Dissolved inorganic phosphorus	DIL	µM	Skalar autoanalyzer	MWRA (1998b) SOP 1006.0	DITP
Silver – total	Battelle	µg/L	inductively coupled plasma mass spectrometry (ICP-MS) or graphite furnace atomic absorption	EPA Method 200.8, 200.9 (EPA 1991); EPA Method 1638 and EPA 1640 Battelle MSL SOP I-022; Battelle MSL SOP I-029	DITP and field
Copper – total	Battelle	µg/L	inductively coupled plasma mass spectrometry (ICP-MS)) or graphite furnace atomic absorption	EPA Method 200.8 , 200.9 (EPA 1991); EPA Method 1638 and EPA 1640 Battelle MSL SOP I-022; Battelle MSL SOP I-029	DITP and field
Fecal Coliform/ *Enterococcus*	DIL	#/100 mL	microscope	MWRA (1996a) and MWRA (1996b)	DITP and Field
Chlorophyll a/phaeopigments	UMD	µg/L	Turner Designs fluorometer Model 10AU	Arar and Collins (1992); Battelle SOP 5-265	Field

7.2.6 Data management

Figure 10 illustrates the data processing steps that must be performed to allow data entry into the MWRA Environmental Monitoring and Management System (EM&MS).

7.3 Data usage

The data will be used to evaluate that the initial dilution characteristics of the effluent in Massachusetts Bay and determine if the dilution meets the MWRA NPDES permit requirements. Data will also be used to evaluate short and intermediate term transport behavior of the plume and to identify variability within the plume. To do this, the following data will be examined.

The Plume Tracking Plan focuses on the environment in the immediate vicinity of the outfall location in Massachusetts Bay with additional monitoring of the plume. The planned tracklines of the towyo vessel will provide measurements of Rhodamine WT dye that will indicate the vertical and horizontal distribution of the effluent and its dilution. The combined data from the HMZ and nearfield surveys will be used to provide contours of dilution over relatively small scales in the immediate vicinity of the outfall.

Data collected during the farfield surveys will be used to demonstrate the dispersion of the plume over longer time scales. Contour plots of temperature, salinity, and Rhodamine WT dye will be used for visualization of the data.

Data collected during the plume tracking exercise will be used as input to the environmental discharge model RSB (described in Baumgartner *et al*. 1992). RSB was developed based on experiments on multiport diffusers in density-stratified currents. This model predicts the spread of the plume and calculates the minimum dilution and the flux-average dilution based on the physical characteristics of the outfall, diffuser flow rate, effluent density, ambient water density, and the current speed at one depth.

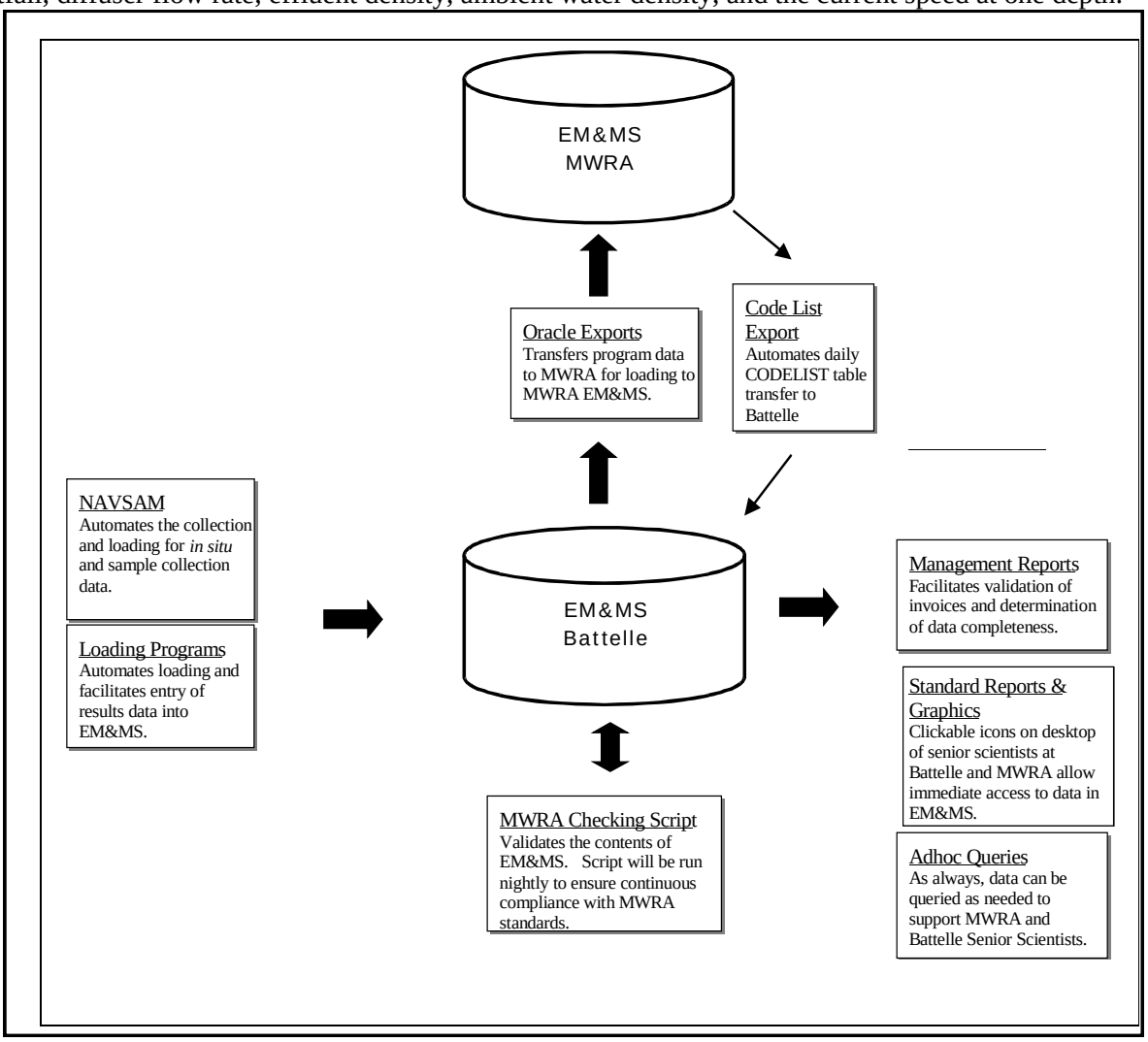

Figure 10. Data Processing Steps for Entry into MWRA EM&MS

RSB model predictions of dilution will be compared to the estimates calculated from actual measurements of dye concentration in the field. Dilution will also be evaluated with secondary parameters: salinity, NH_4, PO_4, Cu and Ag.

The ADCP and hydrographic data collected during the surveys will be available for comparison with the United States Geological Survey (USGS) mooring, located in the nearfield region, which provides hydrographic and current measurements for bottom, mid-depth, and occasionally surface waters. In

addition, NOAA maintains a weather buoy which provides wave field and wind information. Battelle will evaluate that information as well as that from the MWRA's Harbor and Outfall Nearfield survey hydrocast data collected prior to and after the plume tracking surveys.

8.0 PROJECT FISCAL INFORMATION

This project is being carried out under the Harbor and Outfall Monitoring contract (Contract No. S274) between MWRA and Battelle.

9.0 SCHEDULE OF ACTIVITIES AND DELIVERABLES

Table 10 lists the delivery schedule and milestones for the various plume-tracking activities.

Table 10. Schedule of data reports, data exports, and synthesis reports

Deliverable or Milestone	Survey Period	Due Date
Survey-Related Reports[1]		
Survey Plans	Each survey	4 weeks prior to survey
Surveys	Winter/shakedown survey Plume tracking survey.	March 2001 July 2001
Survey Reports – Draft	Each survey	4 weeks after survey
Survey Reports – Final	Each survey	2 weeks after receipt of comments
Data Reports and Exports		
Sensor Data Processing Report	Each survey	within 60 days of survey
Discrete Sample Data Reports	Each survey	within 60 days of survey
Data Exports	Each survey	1 month after Data Report
Modeling Reports		
Modeling report	Each survey	1 month after data report
Interpretive Reports[2]		
Report Outline	Each survey	within 120 days of survey
Draft Report		within 150 days of survey
Final Report		within 2 weeks of comment

[1] All survey reports will include some interpretive results including identification of the value of minimum dilution and notification of possible exceedance of the Contingency Plan warning level.
[2] Revised from scheduled inclusion in Task 33.02 Semiannual and 33.03 Annual Water Column Report

10.0 PROJECT ORGANIZATION AND RESPONSIBILITIES

The plume tracking tasks will be accomplished through the coordinated efforts of several organizations (Figure 11). Dr. Mike Mickelson is the MWRA Project Manager and the MWRA Water Column Project Area Manager. He will be informed of all matters pertaining to work described in this CW/QAPP. Mr. Ken Keay is the MWRA Deputy Project Manager and will serve as a backup to Dr. Mickelson. Ms. Wendy Leo is the MWRA EM&MS Database Manager.

Dr. Carlton Hunt is the Battelle Project Manager and is responsible for the overall performance of this project. The Battelle Quality Assurance Officer for the project is Ms. Rosanna Buhl. For this task, Ms. Buhl is responsible for reviewing data reports and QA for completeness and adherence to the CW/QAPP. She is also responsible for reviewing the data reports for accuracy and completeness. Mr. Wayne Trulli is the Battelle Field Manager responsible for all Battelle field collections. Ms. Heather Trulli, Battelle's Laboratory Manager, is responsible for overseeing all laboratory activities in the contract. Ms. Ellie

Baptiste-Carpenter is Battelle's Database Manager. The key contacts at each of the supporting laboratories are shown in Figure 11. Addresses, telephone (and fax) numbers, and Internet email addresses, as well as specific project roles and responsibilities are defined in detail in the HOM3 Program Management Plan (Battelle 1998). Mr. Carl Albro is the Task Leader. He is responsible for all technical work conducted in support of the plume tracking studies.
A Chief Scientist will be assigned to each survey and a team leader to each shift making dye additions. The Chief Scientist will have authority to make field decisions relative to the plume tracking effort. Each Chief Scientist will be a senior scientist with experience in towyo operations and will be thoroughly familiar with the goals and objectives of the plume tracking study. Each Chief scientist assigned to this project will participate in the winter survey to ensure familiarity with tracking systems, field protocols, and project requirements. Dye addition team leaders will conduct the dye additions during the winter survey to gain familiarity with overall operations of the process.

Dr. R. Geyer and Mr. Paul Dragos will be responsible for the ADCP operations, data collection, ADCP portions of the sensor data reports, and interpretive sections of synthesis reports. Mr. Dragos will be responsible for the plume modeling and model report

11.0 DATA QUALITY REQUIREMENTS AND ASSESSMENTS

To ensure that all data generated during the conduct of surveys, analyses, and reporting are of the highest quality, data will be examined in terms of precision, accuracy, completeness, comparability, and representativeness. These terms are defined in the HOM3 Quality Management Plan (Battelle 1998). The application of these data quality measures is described below.

11.1 Dye addition and monitoring

11.1.1 Precision and accuracy

Precision and accuracy objectives for the fluorometer and flows at Deer Island treatment Plant are presented in Table 11. Section 12 provides details on relevant sampling procedures to ensure data quality, and Section 14 details instrument calibration methods and specifications. The manual for the plant venturi flowmeter claims 0.5% accuracy; for four flowmeters in parallel this would be 1%. Plant flow is recorded to 0.1 MGD. The manual for the peristaltic pump claims accuracy of 0.5%, with readability to 1 mL/min. We anticipate that actual performance will be less than ideal, and that is reflected in Table 8. Based on 5% accuracy in the flow of stock dye solution and 5% accuracy in the flow of effluent, the accuracy of the ratio is 7%. The concentration of dye in effluent is related to this ratio, and with other interfering factors we anticipate that the dye concentration in effluent can be controlled to 10%, or 50 ± 5 µg/L.

11.1.2 Completeness

Dye will be added continuously over a 28h period, and the resulting dye content will be recorded from a time before dye is added until after it disappears from the waste stream. Flow and concentration will be recorded at 1-minute intervals. The goal of the study is continuous addition of dye over the full 28 hours. Any event that affect the ability to continuously add dye for the full 28 hours will discussed with the Project Managers for action.

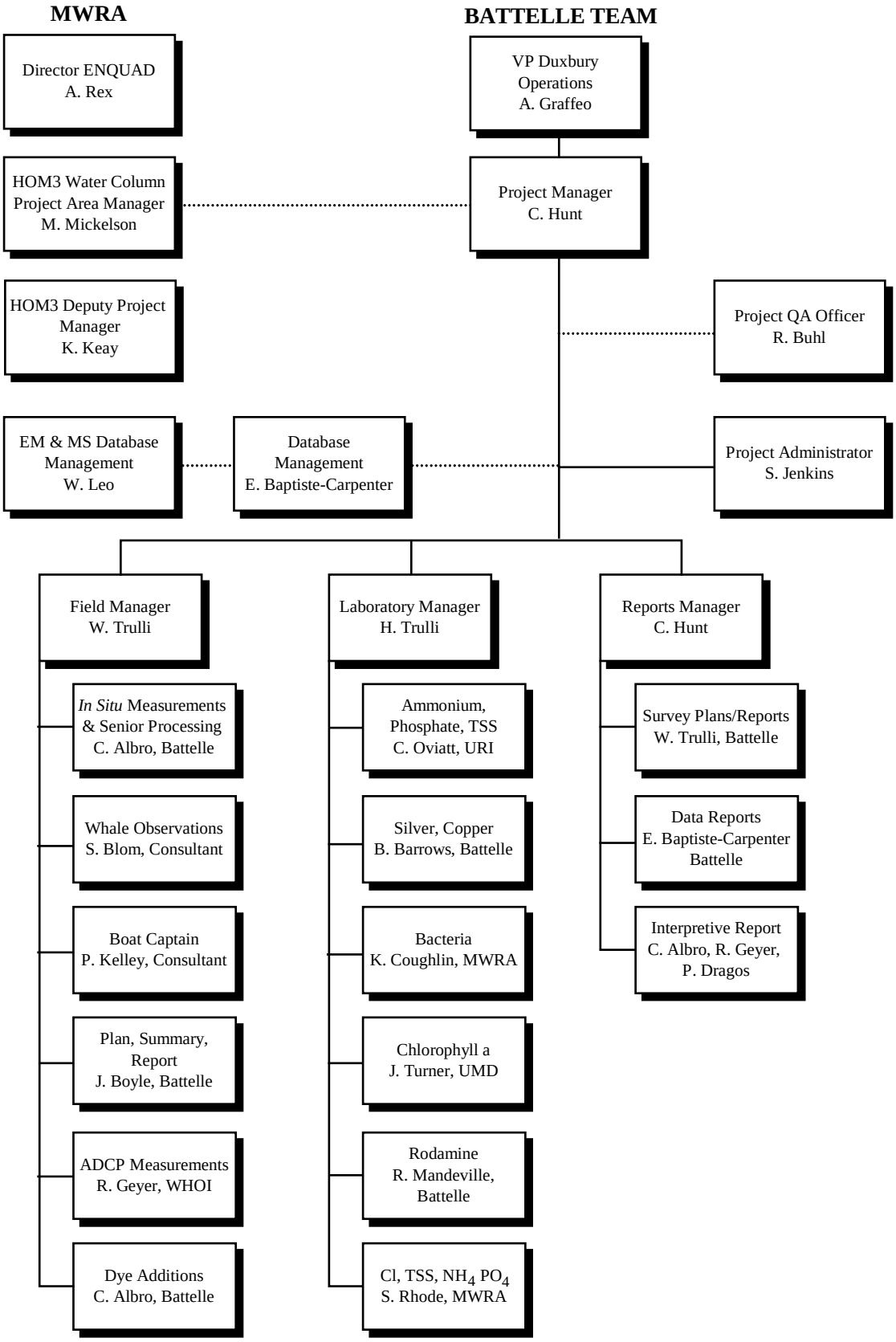

Figure 11. Project Organization Chart

11.1.3 Comparability

The dye stock solution from the manufacturer will be assumed to be exactly 20% w/v as active ingredient, and the rhodamine fluorometers will be standardized to that dye stock. This is acceptable because dilution is calculated from relative concentration. The method of dye addition and monitoring is comparable to that of other studies. It is conventional practice (Turner Designs, pers. comm.) to ignore the label on the barrel which specifies the stock density (typically 1.12) and actual concentration (typically 213g/L).

11.1.4 Representativeness

The cross-sectional variability of dye concentration will be checked during the experiment. Effects of temperature, chlorine, and turbidity on dye fluorescence will be evaluated in preliminary studies. If more that one barrel of dye is used, steps will be taken to ensure the barrels have uniform concentration.

Table 11. Accuracy and precision of DITP instruments

Instrument	Reporting Units	Range	Accuracy	Precision
Plant flow meter	MGD	0 to 1440 MGD	5%	0.1 MGD
Peristaltic pump	mL/min	8 to 480 mL	5%	1 mL
Conductivity	mmhos/cm	0.5 to 65	0.021	0.01
Temperature	C	-2 to 30	0.015	0.01
Rhodamine fluorometer (Turner)	µg/L	0.1 to 100	0.1	0.01

11.2 Navigational and hydrographic data

11.2.1 Precision and accuracy

Based on manufacturer specifications or Battelle's experience, precision and accuracy objectives for navigation and hydrographic samplings are presented in Table 12. Field operations will be managed such that the impact of adverse weather is minimized. Field operations will generally be conducted in seas less than 5 feet. The towyo operations and navigation system will enable the vessel captain to adhere to within ±15 m of the preplanned tracklines under these weather conditions. Section 12 provides details on relevant sampling procedures to ensure data quality. Section 14 describes instrument calibration methods and specifications.

11.2.2 Completeness

Battelle's navigation software system outputs navigation positions at an interval of two per second. The software system will display all position fixes and save these fixes in an electronic file during towing and sampling operations. The project's time interval requirement for obtaining positions during sampling is 1 per minute. Thus, even with a few bad data streams from the DGPS navigation system to the computer, the software will provide enough fixes within each 1-minute period for 100% data collection. During transit, the software system will save vessel coordinates in an electronic file every five minutes.

Because hydrographic and ADCP data are acquired electronically and monitored in real time, no loss of data is expected. With the sampling rates of the CTD (4 Hz), ADCP (1 reading per 15 sec) and navigation systems (0.5 Hz), sufficient data will be acquired to map the dye concentrations and current velocity structure along the specified survey tracklines. Horizontal resolution from the *in situ* sensors used for the towed operations is expected to provide 0.4-meter spatial resolution at a 3 knots towing speed and 1 m resolution at 8 knots. Moving averages at 4 Hz will be used for data processing. If instrument malfunctions occur and operations are modified or suspended during any survey day, a decision on modification of activities for that survey will be made with consultation and agreement of MWRA,

Table 12. Accuracy and precision of field instrument sensors

Sensor	Reporting Units	Range	Accuracy	Precision
Rhodamine fluorometer (Chelsea)	µg/L	0.05 to 100	0.1	0.01
Conductivity	mmhos/cm	0.5 to 65	0.02	0.01
Temperature	ºC	-2 to +30	0.015	0.01
Pressure (depth)	m	0 to 300	0.60	0.01
Transmissometer (20-cm)	m^{-1}	0 to 50	0.20	0.01
Echosounder (depth)		0 to 200	2	0.1
ADCP	cm/sec	-500 to 500	±5	0.2
Chlorophyll fluorometer	µg/L	0.1 to 100	50% of reading*	0.01
Altimeter	m	0 to 100	1	0.1
DGPS Navigation	Degrees	Coastal	1.8×10^{-5} degrees	1.8×10^{-5}

*When compared to wet chemistry results.

whenever possible. A 10% loss of hydrographic, *in situ* dye concentration, and navigation data over the entire program is not expected to compromise the objectives of the program. The plume dilution certification exercise will be considered complete if the pre-dye survey, and 3 of the 4 HMZ surveys are successfully accomplished. The winter shakedown survey will be considered complete if five hours of towing operations are successfully completed.

11.2.3 Comparability

Latitude/longitude positions will be recorded. The position recording system will be comparable to positions obtained by previous MWRA monitoring activities as well as by other researchers that have used or are using differentiated GPS. The vessel position will be monitored and adjusted to be within 15 meters of planned tracklines.

The electronic measurement instruments that will be used during the plume tracking surveys are similar to the instruments that have been used by MWRA contractors from 1992 through 1997 (Albro *et al.* 1993, Bowen *et al.* 1998) and currently in use (Albro *et al*. 1998). To maintain comparability post-calibration methods for chlorophyll referenced in Albro *et al*. (1998) will be used. Thus, the data should be consistent with and comparable to previous studies. During review and synthesis of the survey data, the results will be compared with the general ranges of water property data obtained from previous MWRA studies.

An RD Instruments ADCP will be used during the surveys. The RD-manufactured shipboard ADCP is the de facto standard in the oceanographic community and has been used previously by MWRA in outfall monitoring studies. In addition, RD-manufactured ADCPs are routinely used by National Oceanic and Atmospheric Administration (NOAA), United States Geological Survey (USGS), and research institutions for physical oceanographic measurements. Thus, the data will be consistent with and comparable to previous studies. As a quality control check of the comparability of the ADCP data, the results will be compared with the general ranges of current data obtained from past studies in the outfall area. ADCP data will also be compared to the current data from the USGS moorings operating in the area during the surveys.

11.2.4 Representativeness

The representativeness of the overall outfall monitoring program sampling design is detailed in the Outfall Monitoring Plan (MWRA 1997b). The sampling program itself plus the measurements of dilution

along the entire length of the diffuser, in both stratified and unstratified conditions, are considered adequate to represent the effluent plume dilution achieved by the outfall. Representativeness will also be ensured by proper handling, storage, and calibration of equipment so that the materials analyzed reflect the collected material.

11.3 Sample collection

11.3.1 Precision and accuracy

Precision and accuracy of water and effluent sampling procedures are not directly quantified, but are ensured by the collection procedures and dilution criteria used to target sampled depths. The sampling objective is to obtain uncontaminated samples representative of their location. Each sample will be clearly labeled with a unique sampling identifier (survey ID and sample number) that will allow the sample to be traced from collection through analysis to reporting. All samples will be handled and stored according to the appropriate protocols.

11.3.2 Completeness

Each survey will be considered complete if 80% of all planned water samples are collected. In the event of sample loss or equipment malfunction, the Chief Scientist will determine the need for appropriate corrective action (*e.g.*, resampling) and will record such action in the survey notebook.

11.3.3 Comparability

Sampling results of this survey will be comparable to data from other recent surveys of the study area because standardized sampling procedures will be employed. Reporting of the units of concentration will follow standard convention for most oceanographic studies.

Comparability of the sampling procedures with previous studies will be achieved through adherence to procedures that are based on documented standard methods (*e.g.*, EPA or ASTM methods) or on methods previously described in the scientific literature or HOM monitoring program documents. Comparability throughout the project will be achieved through adherence to this CW/QAPP.

11.3.4 Representativeness

The study is designed to examine the representativeness of the outfall behavior, thus the plume mapping and the targeted dilution criteria will ensure that the discrete samples represent the dilution environment at the outfall. Discrete water samples will be collected, handled, and transported using procedures that will ensure that resulting data represent the sample material collected. Flow of waste through the treatment plant smoothes short scale transient changes in effluent inflow. Sampling effluent samples every half-hour will ensure the data represent the effluent condition during the studies.

11.4 Laboratory program

11.4.1 Precision and accuracy

Table 13 summarizes the laboratory data quality objectives for the plume tracking exercise. Section 12 provides additional details on the analytical procedures (*e.g.*, prepared standards) that will ensure data quality, and Section 14 describes instrument calibration methods.

11.4.2 Completeness

It is expected that 100% of the samples collected and intended for analysis will be analyzed. However, a sample loss of <10% per survey will not compromise the objectives of the plume tracking exercise.

11.4.3 Comparability

Data will be directly comparable to results obtained previously at the same or similar sites in Massachusetts Bay water column monitoring program (Albro *et al.* 1998), because field program design and analytical procedures are similar or identical. In addition, the use of written standardized procedures ensures that sample preparation and analyses will be comparable throughout the project and with other projects.

11.4.4 Representativeness

Representativeness is addressed primarily in sampling design. The laboratory measurements that will be made during the task have already been used in many systems to characterize nutrient, metals, and bacteria in effluent and the water column and therefore are considered to yield data representative of the study area. The sample collection strategy is designed to collect samples that represent the plume as it is being diluted and to allow extrapolation of discrete sample data to the continuously collected measured dye and hydrographic data. Representativeness will be ensured also by proper handling, storage (including appropriate preservation and holding times), and analysis of samples so that the material analyzed reflects the material collected as accurately as possible.

Deviations from the analytical scheme described in this CW/QAPP will be noted in the laboratory records associated with analytical batches and in the QA statements and will be discussed in the quarterly QA/QC Corrective Action reports.

11.4.5 Sensitivity

Sensitivity is the capability of methodology or instrumentation to discriminate among measurement responses for quantitative differences of a parameter of interest. The method detection limits (MDL) (Table 14) provide the sensitivity goals for the proposed procedures.

Table 13. Data Quality Objectives

Quality Control sample type	Lab	Frequency	Data Quality Indicator	Corrective Action
Procedural blanks				
Total suspended solids	URI	3/day	<5 times MDL	Examine and document
Total suspended solids	DIL	1 per batch of 20	< 1 mg/L	Examine and document
Ammonium and phosphate	URI	1 per batch of 20	<5 times MDL	Examine and document
Ammonium and phosphate	DIL	1 per batch of 20	< Reporting limit	Examine and document
Silver	Battelle	1 per batch of 20	<5 times MDL	Examine and document
Copper	Battelle	1 per batch of 20	<5 times MDL	Examine and document
Chloride	DIL	1 per batch of 20	< MDL	Examine and document
Rhodamine	Battelle	1 per batch of 20	<MDL	Examine and document
Filter blanks				
Total suspended solids	URI	1 per batch of 20	<5 times MDL	Examine and document
Chlorophyll a	UMD	Once daily	<5 times MDL	Examine and document
Fecal coliform and *Enterococcus*	DIL	Once daily	<5 times MDL	Examine and document
Prepared standards and SRM				
Total suspended solids	DIL	1 per batch of 20	85-115% recovery	Retest affected samples
Ammonium and phosphate	URI	Twice per year	85-115% recovery	Examine and document
Ammonium	DIL	1 per batch of 20	88-110% recovery	Retest affected samples
Phosphate	DIL	1 per batch of 20	90-110% recovery	Retest affected samples
Copper and silver	Battelle	1 per batch of 20	<20% RPD	Examine and document
Chloride	DIL	1 per batch of 20	95-105% recovery	Retest affected samples
Chlorophyll a	UMD	1 per batch of 20	<15% RPD	Examine and document
Fecal coliform and *Enterococcus*	DIL	Once daily	colony growth	Examine and document
Laboratory duplicates				
Total suspended solids	URI	Every sample	<10% RPD	Examine and document
Total suspended solids	DIL	2 per batch of 20	<20% RPD	Retest affected samples
Rhodamine	Battelle	1 per batch of 20	<5% RPD	Examine and document
Chlorophyll a	UMD	1 per batch of 20	<15% RPD	Examine and document
Laboratory triplicates				
Ammonium and phosphate	URI	All samples	<2% RSD	Examine and document
Copper and silver	Battelle	1 per batch of 20	<30% RSD	Examine and document
Matrix spike				
Ammonium	DIL	1 per batch of 10	35-128% recovery	Examine and document
Phosphate	DIL	1 per batch of 10	65-133% recovery	Examine and document
Copper and silver	Battelle	1 per batch of 20	90-110% recovery	Examine and document
Chloride	DIL	1 per batch of 10	63-132% recovery	Examine and document
Matrix spike duplicate				
Ammonium	DIL	1 per batch of 20	<11% RPD	Examine and document
Phosphate	DIL	1 per batch of 20	<9% RPD	Examine and document
Copper and silver	Battelle	1 per batch of 20	20% RPD	Examine and document
Chloride	DIL	1 per batch of 20	<3% RPD	Examine and document

NA: Not Applicable
Percent Recovery =[(amount recovered - amount in background matrix)/amount spiked] x 100%.
Relative Percent Difference (RPD) = [(absolute value (replicate 1 - replicate 2) x 2/(replicate 1 + replicate 2)] x 100%.
Relative standard deviation (RSD) = Coefficient of Variation (CV) = (standard deviation of the sample concentration / mean sample concentration) x 100%.
Examine and document: Results examined by subcontractor lab manager, task leader, or project manager. Corrective action (e.g., re-extraction, reanalysis, data qualifier) is documented.

Table 14. Method Detection Limits

Analysis	Lab	MDL
Rhodamine WT	Battelle	0.01µg/L
Chloride	DIL	20 mg/L
Total suspended solids	URI	0.1 mg/L
Total suspended solids	DIL	1 mg/L
Ammonium	URI	0.02µM
Ammonium	DIL	0.1 mg/L (0.7µM)
Phosphate	URI	0.01µM
Phosphate	DIL	0.01 mg/L (0.3µM)
Silver	Battelle	0.01 µg/L (effluent and seawater)
Copper	Battelle	0.02/0.05 µg/L (effluent/seawater)
Chlorophyll a (EDL)	UMD	0.036µg/L
Fecal coliform and *Enterococcus*	DIL	1 colony per volume filtered

EDL: Estimated Detection Limit

12.0 SAMPLING AND ANALYTICAL PROCEDURES

Methods for dye addition, field measurements, and the collection and analysis of samples are described in the following sections. Analyses will be performed by DIL, Battelle, UMD, and URI as defined below.

12.1 Deer Island Treatment Plant

12.1.1 Dye addition and monitoring

Rhodamine WT dye solution (20% active ingredient) will be added to the primary/secondary blended effluent channel just prior to the mixers at the entrance to the disinfection basin. The mixers are used to thoroughly mix the effluent with chlorine (sodium hypochlorite; pre-diluted to ~500 mg/L). The addition of the dye at this location allows the dye to be vigorously mixed with the effluent and allows measurement of the dye concentration at the end of the disinfection basin before the effluent travels into the diffuser tunnel where it cannot be sampled. The chlorine concentration in the effluent just after the hypochlorite mixers ranges from 5 to 7 mg/L. According to Deaner (1973), a chlorine concentration of 2-9 mg/L in the effluent should not significantly alter the fluorescent properties of the dye. Studies at Battelle, prior to the plume tracking exercise, will test for up to 72-hours whether chlorine would reduce the fluorescence response of the dye over the duration of the survey (see also Section 14.3.4).

A peristaltic pump will be used to add the dye to the primary/secondary blended effluent channel. The pump speed will be controlled by a 4-20 mA signal provided by the Deer Island Treatment Plant's process control computer. The signal will be proportional to the "official plant flow" which is the sum of the four main venturi flowmeters in the primary treatment tanks. The DITP process control computer will smooth and lag the signal by a few minutes as appropriate to approximate flow at the point of dye injection. The dye feed line from the pump will branch into two lines at either side of the channel in a manner to optimize uniform mixing.

The rate of Rhodamine WT dye addition will vary with the effluent flow rate to maintain a constant concentration of 50µg/L as active dye ingredient in the disinfection basin. To achieve this concentration the tracer stock dye solution, containing a nominal 20% active ingredient w/v, will be diluted 250x10-9, or 250 nL/L. Thus, assuming an effluent flow of 350 MGD (Deer Island average), dye will be added to

the mixers at the rate of 230 mL/min, and for the planned 28 hour dye release the total amount of dye needed is 102 gallons. That calculation is as follows:

350 MGD * E6 G/MGD * 250E-9 dilution * 28 h * 1 day/24 h = 102 G, and
350 MGD * 2628.758 LPM/MGD * 250E-9 dilution * 1000 mL/L = 230 mL/min.

The dye solution and the pump will be shielded from temperature extremes which might change pumping characteristics. If more than one container of dye stock is used, they will be blended beforehand to ensure uniformity. The dye stock solution being pumped will be gently mixed each hour. The total volume of dye used over the 28h period will be checked using the weight of the dye added.

Dye concentration will be monitored at the downstream end of the disinfection basin. A submersible pump will raise effluent through a hose to the level of a Turner Designs fluorometer equipped with a flow-through cuvette to continuously measure the concentration of the dye. The outlet return hose will have an air break to allow sampling from the return stream and to prevent possible negative pressure which could cause bubbles in the cuvette. The fluorometer will be temperature-compensated for rhodamine and will be shielded from temperature extremes. A CTD will be placed in the pumping line or suspended in the disinfection basin to measure effluent temperature and conductivity.

Effluent will be monitored at a single depth (1 meter below the surface) until readings stabilize, signaling that the initial mixing of the dye is complete. This should occur about 30 minutes after the start of dye addition. After stabilization, the dye concentration should remain constant. To confirm that the dye is mixed homogeneously throughout the effluent, the dye concentration will be measured and recorded at five depths within the 25-foot deep basin at least once per hour.

The specific details of the dye addition system and protocols for operation will be included in the Survey Plan – which will be written prior to the first plume tracking exercise.

12.1.2 Effluent sampling

For discrete sampling of ammonium and phosphate, and total suspended solids, effluent from one of the MWRA sampling points along the disinfection basin will be transferred to one to four 1-Liter opaque polyethylene jars. Sample bottles will either be lowered on a built-in sampling rack or filled from the fluorometer flow return line. These transfer jars will be rinsed three times before filling with sample water up to the neck of the jar. The water for metals will be collected directly into pre-cleaned polyethylene bottles. The filtration apparatus (for NH_4, PO_4, and TSS) will be rinsed between sampling by using deionized water. The filtrate sample bottles will be rinsed three times with filtrate prior to filling. Sample volumes, containers, and storage conditions are listed in Table 15. The grab samples for Rhodamine provide a check for uniformity and for comparison with field samples.

Table 15. Sample volumes, containers, and processing for effluent samples.

Parameter	Lab	Sample Volume (Target) (mL)[a]	Sample Containers	DITP Processing/ Preservation[c]	Maximum Holding Time to Analysis
Rhodamine WT	Battelle	200	250 µL polyethylene bottles	Store at 4°C	28 days
Chloride	DIL	350	500 mL polyethylene bottles	Store at 4°C	28 days
Total suspended solids	URI	300 – 500 (500)	Nuclepore filter in a Petri dish	Pass sample through a Nuclepore filter within 72 hours. Store filter in petri dish at room temperature.	6 months
Total suspended solids	DIL	400	500 mL polyethylene bottles	Refrigerate. Store at 4°C.	7 days
Ammonium and phosphate	URI	40	60-mL polyethylene bottle	Pass through a Nuclepore membrane filter. Freeze until analysis.	28 days
Ammonium	DIL	150	500 mL polyethylene bottles	Add 2mL H2SO4 per liter of sample and refrigerate.	24 days
Phosphate	DIL	150	500 mL polyethylene bottles	Store at 4°C.	48 hours
Silver and copper	Battelle	500	pre-cleaned 500 mL polyethylene bottles	Store refrigerated; acidify at analytical laboratory for 72 hours before sample processing	6 months
Fecal coliform and *Enterococcus*	DIL	200	250 mL sterile polyethylene	Store at 1-4°C.	6 hours

[a]Volume processed for analysis.
[c]Name brand items (*e.g.*, Nuclepore, Whatman) may be substituted with comparable items from a different manufacturer.

12.2 Field sampling and measurements

12.2.1 Navigation

Vessel positioning during sampling operations will be accomplished with the BOSS navigation system. This system consists of a Northstar DGPS interfaced to the BOSS computer. The GPS receiver has six dedicated channels and is capable of locking onto six different satellites at one time. To correct the GPS calculations, the Northstar DGPS will receive correction data from one of three United States Coast Guard DGPS broadcast sites: Montauk Point, NY, Chatham, MA, or Portsmouth Harbor, NH (Figure 12). This capability ensures strong signal reception, and accurate and reliable positioning with 2-second updates.

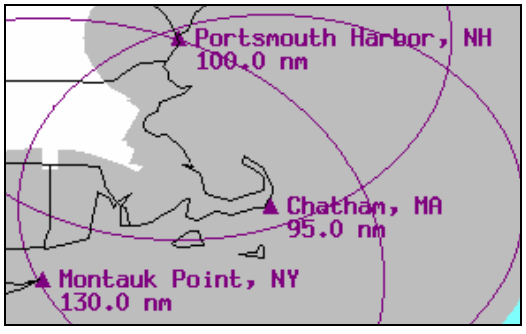

Figure 12. DGPS master stations coverage

12.2.2 Vessel handling

Boston Harbor, Massachusetts Bay, and Cape Cod Bays are heavily trafficked by commercial, fishing, and recreational vessels. Endangered species, as well as numerous other marine mammals seasonally frequent the Bays. The licensed boat captain will operate the vessel in a professional manner at all times during surveys to minimize the possibility of collisions with other traffic or with marine mammals. Also required by National Marine Fisheries Service's rules, the vessel will maintain a minimum distance of 500 yards from right whales (right whales are rare in the Nearfield area). If a right whale is within 500 yards of a sampling trackline, the vessel will wait for the right whale to move out of range or the station will be sampled as close to nominal as possible while maintaining the minimum required distance from right whales. During towyo operations, tracklines will be adjusted to avoid whales to ensure that operations continue.

12.2.3 Hydrographic measurements

The hydrographic sampling equipment and data acquisition equipment consists of the following apparatus and instruments.

- Battelle-designed and fabricated winch with a split drum containing 150 m of 9-conductor and 60m Teflon tubing/12-conductor cable
- Battelle Ocean Sampling System Towed Body
- Submersible pumping system
- Ocean Sensors OS200-CTD (Conductivity, Temperature, and (Pressure) Depth) equipped with the following:
  - Sea Tech 20-cm-pathlength transmissometer that provides *in situ* measurements of optical beam transmission (related to the concentration of suspended matter in the water at the point of measurement)
  - Chelsea fluorometer configured for Rhodamine WT dye
  - WET Labs WetStar chlorophyll a fluorometer
- Data Sonic altimeter provides a measurement of underwater unit height from the bottom
- Furuno FCV-52 Color video echosounder (200 kHz) to provide bathymetric measurements during vertical and horizontal profiling operations
- Computer with custom data-acquisition software (NAVSAM©)
- Color printer

Battelle's software, NAVSAM© acquires data from all electronic sampling systems and navigation systems at the rate of four times per second. Once per second the software, NAVSAM©, displays all of the information on a color monitor. The screen is split to show sensor data on the left and navigation data on the right. Once the data are acquired, they are automatically written to a data file and logged concurrently with position data from the navigation system. The navigation portion of the display will show the position of the vessel compared to the coastlines digitized from standard NOAA charts, navigation aids, preset sampling locations, and vessel track. A second monitor will be furnished to the helmsman as a steering display. During towing operations, position fixes will be electronically recorded at 2-second intervals. During transit (during non-towing operations) position fixes will be electronically recorded at 5-minute intervals.

12.2.4 Acoustic measurements

A 600kHz Acoustic Doppler Current Profiler (ADCP) will be used to obtain velocity measurements at 1-m depth increments below the vessel. The beam angle for the ADCP is 20 degrees. The ADCP measures

both the current velocity relative to the vessel and vessel velocity relative to the earth (by bottom tracking) to determine absolute current velocities. A mounting pole is attached to the side of the vessel. The acoustic transducer is attached to the pole such that when the pole is vertical, the acoustic transducer will be placed just below the water surface. With an initial range-gate-blanking window to eliminate surface noise, the depth range of the instrument will be effectively from 1m below the surface to 0.75m above the bottom. Raw velocity data will be recorded every 5 seconds, and these data will be averaged over 15 seconds to yield reliable velocity estimates with errors of several cm/s. With ship speed of 0-8 kts, the resulting spatial resolution in the along-track direction will be 30-45 m. At speeds greater than 8 kts, the transducer will be pivoted out of the water. Navigation data from the NAVSAM© system will be recorded along with the ADCP data on the ADCP computer system.

12.2.5 On-board discrete water sampling

Water samples for ammonium, phosphate, copper, silver, chlorophyll, bacteria, and TSS will be obtained using the submersible pumping subsystem of the BOSS. The internal gear pump is located on the towed body. The pump provides a flow rate of 14 Lpm which translates into a 28-second transit time for the water to go from the pump inlet to the outlet onboard the vessel. This lag time will be verified using an onboard flow-through transmissometer. The NAVSAM© software will be used to record the hydrographic data at the selected location of the discrete sample. The NAVSAM© software will also printout corresponding labels for the collection bottles and sample log form once the exact location is selected. The software will calculate the hose-transit lag time that is required before collection of the actual water sample on deck. With 10-20 seconds left on the countdown, the sampling technician will be instructed to rinse the suite of bottles to be used for that sampling event. When the countdown is finished the sampling technician will be instructed to collect water.

For onboard processing of ammonium, phosphate and total suspended solids, water from the pumping system will be collected in 1-L opaque polyethylene jars. These transfer jars will be rinsed three times with pumped water immediately before filling with water up to the neck of the jar. The water for metals and fecal coliform/*Enterococcus* will be collected directly into the appropriate bottles.

The filtration apparatus will be rinsed between samples by using deionized water. The filtrate sample bottles will be rinsed three times with filtrate prior to filling. Sample volumes, containers, and storage conditions are listed in Table 16.

12.2.6 Whale observation

If the survey is between December and May 15, a trained whale observer will conduct sighting watches while on station and during transit between stations. The sighting operations will occur during daylight hours and when the vessel is in Massachusetts Bay. The observer will scan the ocean surface by eye for a minimum of 40 minutes every hour. All sightings will be recorded on standardized marine mammal field sighting logs (Figure 13). Header fields for sighting logs include observer name, date and time, weather, wind speed, sea state, vessel name, heading and speed. In addition, the observer will record the vessel position every 20 minutes, time of sighting, observer position on vessel, sighting event code (on or off watch, transiting or on station), relative bearing to mammal, species name, and number of animals sighted on the sightings logs. The sampling vessels will operate according to protocols mandated by the Commonwealth of Massachusetts regarding right whales (Appendix A).

Table 16. Sample volumes, containers, and processing for field samples

Parameter	Sample Volume (Target) (mL)[a]	Sample Containers[c]	Shipboard Processing/ Preservation[c]	Maximum Holding Time to Analysis
Rhodamine WT	200	250-mL polyethylene bottle	Store in cooler at 4°C	28 days
Hydrographic tows[b]	NA	NA	Record data to floppy diskette.	NA
Total suspended solids	100 – 500 (500)	Nuclepore filter in a Petri dish	Pass sample through a Nuclepore filter. Store in petri dish at room temperature.	6 months
Ammonium and phosphate	40	60-mL polyethylene bottle	Pass through a Nuclepore membrane filter. Freeze until analysis.	28 days
Silver and copper	500	pre-cleaned 500 mL polyethylene bottle	Store refrigerated; acidify at analytical laboratory for 72 hours before processing	6 months
Chlorophyll	100 –300	Whatman GF/F in foil	Pass water sample through filter. Fix with saturated $MgCO_3$ solution, freeze filter until analysis	4 weeks
Fecal Coliform/ *Enterococcus*	250	pre-cleaned 250 mL polyethylene bottle	Store in cooler at 1-4°C	6 hours

[a]Volume processed for analysis.
[b] Conductivity, temperature, pressure, chlorophyll a fluorescence, transmissometry, bottom depth, navigational position, ADCP
[c]Name brand items (*e.g.*, Nuclepore, Whatman) may be substituted with comparable items from a different manufacturer.

12.3 Laboratory sample processing and analysis

12.3.1 Rhodamine

Samples will be analyzed for Rhodamine concentrations with a Turner Designs Fluorometer. The fluorometer will be calibrated (five point) by volumetrically adding known amounts of Rhodamine dye to ambient waters. This calibration curve will include seawater samples with no dye added to ensure any natural fluorescence is taken into account. Rhodamine levels in the samples will be quantified against this calibration curve. All processing will be at a constant temperature using a batch (cuvette) calibration process.

12.3.2 Total suspended solids

URI. Samples for total suspended solids (TSS) determination will be processed by URI in a particulate-free area according to Battelle SOP No. 5-053, *Suspended Particulate Matter Measurements (Total Suspended Solids [TSS])*. Using a vacuum-filter system, up to five 100-mL aliquots of a seawater sample will be passed through a pre-cleaned and pre-weighed 0.4 μm pore size Nuclepore 47-mm diameter membrane filter. Filters will be weighed using a five-place balance. Should the filtration rate slow substantially, the rest of the unused aliquots will be discarded. The lesser volume will be noted. The filter will then be rinsed three times with pH 8 deionized water to remove salt. Duplicate filters will be processed in parallel for each sample. Filters will be folded in quarters, placed in petri dishes, and stored at room temperature until analyzed. The filters will be dried in a clean bench for at least 48 hours. Sample-laden filters will then be re-weighed. A 5-place balance will be used for all TSS measurements. TSS will be calculated as the net filter weight normalized to the volume filtered. The TSS concentration will be reported as the mean of the duplicate samples.

Effluent samples will be processed as above. However, smaller volumes of sample (25 to 50 mL) will be used to ensure filter clogging does not affect the measurement. Samples will be refrigerated and filtered as soon as possible but within 7 days of sample collection per EPA methods.

DIL. The MWRA Deer Island Laboratory will analyze for TSS following EPA-approved methods. Samples will be refrigerated and filtered as soon as possible but within 7 days of sample collection. Pass 200 mL of effluent sample through a Whatman 934-AH glass fiber filter. Wash with 30 mL distilled water. Discard any large debris (rare with secondary treatment). Dry to constant weight at 103º C. Weigh with a 4-place balance. The balance is annually calibrated but daily calibration allows up to 0.2 mg difference on a reference weight.

12.3.3 Ammonium and phosphate

URI. A 60 mL syringe will be used to inject sample water from a transfer jar, through an in-line filter (Nuclepore 47 mm diameter, 0.4 μm membrane-fiber filter) and into a 60 mL white polyethylene bottle. After rinsing the bottle three times, 40 mL of the remaining sample will be filtered into the bottle for analysis. The sample bottle will be labeled and the sample will be frozen. The samples will remain frozen until analyzed.

Lambert and Oviatt (1986) described the analysis of ammonium and phosphate. The filtrate concentrations of ammonium and phosphate will be measured colorimetrically on a Technicon II Autoanalyzer, which automates standard manual techniques for the analysis of ammonium and phosphate. The analysis of ammonium will be based on the technique of Solorzano (1969) in which the absorbance of an indophenol blue complex is measured at 630 nm. The analysis of phosphate will be based on the molybdate blue procedure of Murphy and Riley (1962).

DIL. The MWRA Deer Island Laboratory will analyze for ammonium and phosphate following EPA-approved methods. The procedures are similar to Battelle's except the sample is not frozen and filtration is in the lab.

12.3.4 Silver and copper

Battelle. Water samples are pre-concentrated according to a reductive precipitation procedure described in EPA Method 1640 (EPA 1996). Iron (Fe) and palladium (Pd) are added to each sample aliquot followed by a sodium tetrahydroborate solution to form a precipitate. The precipitate is then filtered and dissolved with nitric and hydrochloric acids, and the resulting acid mixture is analyzed by inductively coupled plasma mass spectrometry (ICP-MS) following EPA Method 200.8 (EPA 1991). Silver in seawater samples, which does not always respond well to ICP-MS analysis because of interferences may be analyzed by graphite furnace atomic absorption (GFAA) following EPA Method 200.9 (EPA 1991).

12.3.5 Chloride

DIL. The MWRA Deer Island Laboratory will analyze for chloride following EPA-approved methods, using a Mettler autotitrator that is annually calibrated and checked each day. A measured volume of sample is titrated against a standard solution of silver nitrate to a potentiometric endpoint. The concentration of titrant and the volumes of sample and titrant are used to calculate the concentration of chloride in the original sample.

Marine Mammal Sightings Log

Task: Type: Date: Page ___ of ___ Observer:

Date	Time	Position at Sighting		Vessel Heading		Mammal Sighting				Weather Conditions							Glare	
mmddyy	24-h clock	Latitude (°N)	Longitude (°W)	Direction	Speed	Species	Angle Rel. to Boat	Head. Distance (m)	No. in Group	Sea State	Wind Speed	Swell	Visibility	Cloud Cover	Rain	Fog	Angle from Boat Head.	Glare Code

Code List

Species	
Mn	Humpback whale
Bp	Finback whale
Eg	Right whale
Ba	Minke whale
Lag	Atlantic whitesided dolphin
Pp	Harbor porpoise
Gn	Pilot whale
Bn	Blue whale
Bp	Sei whale
Lal	Whitebeaked dolphin
Pv	Harbor seal
G	Gray seal
H	Hooded seal
Ha	Harp seal
UB	Unidentified baleen whale
UO	Unidentified Odontoceti
UP	Unidentified Phocid

Sea State			
0	Glass	3	1.5 - 3 ft
1	Catpaw	4	3 - 6 ft
2	3 in - 1.5 ft	5	> 6 ft.

Wind Speed (knots)			
0	0 – 5	3	15 – 20
1	5 – 10	4	20 - 25
2	10 – 15	5	> 25

Swell (feet)			
0	None	2	3 – 6
1	1 – 3	3	> 6

Glare			
0	None	2	Moderate
1	Mild	3	Severe

Visibility (miles)			
0	None	4	3 – 5
1	< ¼	5	5 – 10
2	¼ - 1	6	10
3	1 - 3	7	Unlimited

Figure 13. Example of Marine Mammal Sightings Log and relevant codes

12.3.6 Fecal coliform/*Enterococcus*

DIL. The MWRA Deer Island Laboratory will analyze all samples for fecal coliform and *Enterococcus*. Samples will be tested according to DIL's Standard Operating Procedures (MWRA 1996a,b). Seawater sample filtration will occur onboard the survey vessel, lab space permitting. If lab space or logistics do not allow this, samples will be transferred to the DIL for processing well before the holding time for this measurement expires. This will be tested as part of the shakedown survey.

DIL and Battelle will coordinate on the fecal coliform and *Enterococcus* sample collection effort. DIL will email the DIL-sample-IDs to Battelle and will mail the sample bottles, sample labels, and the DIL chain-of-custody form directly to Battelle in advance of the survey. Battelle will create Battelle sample-IDs and Battelle chain-of-custody forms. Battelle will complete both the DIL and the Battelle chain-of-custody forms. DIL and Battelle will retain a copy of all forms.

12.3.7 Chlorophyll

UMass Dartmouth. Samples for chlorophyll *a*/phaeophytin determination will be processed and analyzed by UMD according to Battelle SOP No. 5-265, *Extraction and Analysis of Chlorophyll* a *and Phaeophytin* a *in Seawater using a Turner* [Designs] *Model 10AU Fluorometer*. Samples for chlorophyll *a* analysis will be collected on Whatman 47-mm-diameter GF/F using a vacuum-filter system. A saturated solution of $MgCO_3$ will be added to the sample during filtration to aid retention and buffer the sample against low pH (which converts chlorophyll to phaeophytin). The filter will be stored frozen until analyzed.

13.0 SAMPLE CUSTODY

Samples collected in the field (including those collected at the treatment plant) will be identified by a unique eight character *Sample ID* which is a concatenation of a five character *Event ID* and a three-character hexadecimal number (*Sample_Marker*). The *Sample ID* will identify the water collected in the sampling bottles. The five character *Event ID* will be unique to each plume tracking exercise, such as PL991, with "PL" indicating that it is a plume tracking survey, "99" indicating the survey year, and "1" signifying the first survey of the year. The *Sample_Marker* is a non-repeating (within a survey) number generated by the NAVSAM© software at specific events - including the collection of discrete samples during towed operation.

Each portion of a sample separated for analytical purposes will be assigned a unique *Bottle ID*, composed of the 8 character *Sample ID* plus a 3 character suffix designating the nature and replicate number. For example, "FE2" indicates that the subsample is the second replicate for fecal coliform/*Enterococcus* analyses (see Table 17) for two-letter codes. Information relating to each sub-sample will then be recorded in the *Bottle* table in the EM&MS database.

Any samples collected or analyzed by the Deer Island Laboratory (DIL) will also be assigned an MWRA LIMS sample ID (LIMS_ID) by DIL and have a LIMS label affixed. If LIMS_IDs are not used as SAMPLE_IDs, Battelle will be record them in the ANALYTICAL_RESULTS.LAB_SAMPLE_ID field. Battelle will match up the LIMS_IDs and NAVSAM© -generated SAMPLE_IDs and BOTTLE_IDs using the barcodes on the LIMS and NAVSAM© sample labels.

Before the field surveys are initiated, a table of all samples to be collected will be prepared. The information in those tables are used to generate the station logs (Figure 14) and to generate a planned-bottle table (Table 18) for use during the surveys.

The scientific crewmember operating the data collection system will insert a sample label on the log form for each sampling event. These logs will be put into a survey notebook prior to the survey. The log includes fields for entering pertinent information about sample and general comments. During the towing operations CTD data will be logged and stored electronically on the computer's hard disk. When discrete water samples are collected, the operator will enter the Group ID and mark an event into the CTD data file and the survey electronic log.

After marking an event, sample marker information is joined with the planned bottle table to generate log label and bottle labels. The bottle label will include the Bottle ID in text and barcode (3 of 9 format), date, time, latitude/longitude, depth for the sample, and analysis code. The data files saved by the software will also be used later as entry into the EM&MS database (see Section 15.0 for more information). Bottles to be analyzed by DIL will also have a MWRA LIMS sample label affixed.

Table 17. Analysis Codes used in *Bottle ID* and LIMS codes

Analysis Codes	LIMS Codes	Description	Laboratory
DY	not applicable	Dye	Battelle
TS	not applicable	Total suspended solids	URI
SS	TSS-AQGRV	Total suspended solids	DIL
AH	not applicable	Ammonium and Phosphate	URI
AD	NH3-AQAAN	Ammonium	DIL
PD	PO4-AQAAN	Phosphate	DIL
TM	not applicable	Silver	Battelle
TM	not applicable	Copper	Battelle
Cl	CL—AQTAR	Chloride	DIL
FE	FCOLSWMFL and ECOCSWMFL	Fecal Coliform/*Enterococcus*	DIL
CH	not applicable	Chlorophyll a	UMD
AE	not applicable	Aesthetics	Battelle

Table 18. Planned-bottle table structure

Field Name	Description
Group ID	Group ID based on set of subsamples which is used by NAVSAM© to determine how a sample is to be subdivided
Analysis ID	Two-letter analysis code list in Table 17
Rep Number	Replicate number (1 through 6)

After all of the samples for a survey are collected, chain-of-custody forms (Figure 15 and Figure 16) for each type of sample will be generated. Using the chain-of-custody forms, the samples will be inventoried before the samples are transferred. When the custody of samples is transferred, the custody form will be signed by both the staff member that relinquishes custody and the staff member assuming custody for the samples. The relinquishing staff member will retain a photocopy of the signed COC. After the analysis is completed, the original (signed) COC will be given to the Laboratory Manager to be placed in the project files. Bottles to be analyzed by DIL will also have a MWRA chain-of-custody form. The Battelle Laboratory Manager and Deer Island Laboratory Manager will each receive a copy of both the MWRA and Battelle COC for such samples. DIL will forward copies to the EM&MS database administrator in MWRA's ENQUAD.

SAMPLING LOG	
For BOSS Towing/Submersible Pumping Operations	
Project Name: Harbor and Outfall Monitoring MWRA Contract No. S274	
Event ID: WN98D	Weather Observations
Tow Track ID:	General:
	Seas:
	Wind:
Comments related to sampling	Labels or sampling information area
Comments	Group ID
	Time
	Latitude
	Longitude
	CTD Depth
	Marker No
Comments	Group ID
	Time
	Latitude
	Longitude
	CTD Depth
	Marker No
Comments	Group ID
	Time
	Latitude
	Longitude
	CTD Depth
	Marker No
Comments	Group ID
	Time
	Latitude
	Longitude
	CTD Depth
	Marker No
Comments	Group ID
	Time
	Latitude
	Longitude
	CTD Depth
	Marker No

Figure 14. Sample Station Log

13.1 Custody of electronic data

Field custody of electronic data will be the responsibility of the survey chief scientist or shift leader for the dye addition effort. These persons will be identified for each survey. The field custody of the electronic data consists of creating floppy-disk backups of all electronic data generated each day. Each floppy disk label will include a survey ID, date, name of person creating the backup files, and a disk number. When the equipment is returned to Battelle, a second complete backup labeled as "Set 2", will be generated on floppy disks. The backup will be in the custody of Mr. Albro. The survey chief scientist or shift leader maintains the original.

Mr. Albro of Battelle, URI, and UMD will produce electronic data generated under this task. The electronic files for chlorophyll a data will remain in the custody of the Task Leader at UMD. TSS data will remain in the custody of the URI Task Leader. Data will be in the custody of these individuals until all analyses are completed and data have been accepted by Battelle data management and QAU. The data will be entered into a loading application that contains the data integrity checks for the EM&MS. The data from the loading application will be subjected to QA audit for analytical processing. Two copies of each type of electronic file will be made. Set 1 will remain in custody of the Task Leader in the Task notebook. Set 2 will be transferred the HOM3 Database Manager for entry into the MWRA database.

Electronic data will remain in the custody of laboratory managers [Dr. Candace Oviatt (URI); Dr. Dave Borkman, UMD] until an independent QA audit has been completed. Once the data have passed the independent laboratory QA audit, three copies of each type of electronic file will be made. Set 1 will remain in the custody of the subcontractor custodians and Sets 2 and 3 will be sent to Battelle. Set 2 will be stored in the Task notebook and Set 3 will be given to the Battelle Database Manager for entry into the MWRA database.

Electronically recorded data from the ADCP and navigation-data-acquisition systems will be recorded on computer hard disk and backed up on 3.5-in. computer diskettes at the end of each survey day and, when possible, during breaks in survey operations. A data-file log will be maintained throughout the survey operations and serves as a sample-transfer record. It contained computer data-file names, the date and time they were opened, and any observations or notations otherwise not recorded on computer diskette. Project name, site designation, data type, and data format will be recorded as headers in each data file on diskette. Field custody of electronic data will be the responsibility of Dr. R. Geyer. Dr. Geyer will also be responsible for the analysis of these data. Therefore, he will retain custody of the diskettes until the project is complete. Upon completion of the interpretive report, the electronic files from the ADCP will be provided to Battelle. Data recording practices in the field follow standard operating procedures of documentation. All data will be collected on computer diskette, in field notebooks, or on established forms. All notes will be written in ink. The data-acquisition software assigns a unique data filename to each horizontal transect made during the survey. The time, date, and position of the start and end of each data file are also determined and stored on computer disk.

MWRA Harbor and Outfall Monitoring Program

Contract No. S274

Chain-of-Custody Form

Today's Date : 6/9/98 9:09:07 AM

Chain-of-Custody # : WN985-BS-0146
Survey ID : WN985
Analysis ID : BS
Analysis Description : Biogenic silica

Laboratory : Chesapeake Biological Laboratory
Nutrient Analytical Services
Box 38
Solomons MD 20688
Dr. Carl Zimmerman
410-326-7252 (Phone) 410-326-7209 (Fax)

Bottle ID :	Bottle ID :	Sampling Date :	Station ID :	Ck 1	Ck 2	Ck 3	Ck 4
[redacted]	WN98500BBS1	5/1/98 8:13:44 AM	N04	☐	☐	☐	☐
[redacted]	WN98500BBS2	5/1/98 8:13:44 AM	N04	☐	☐	☐	☐
[redacted]	WN98500DBS1	5/1/98 8:16:38 AM	N04	☐	☐	☐	☐
[redacted]	WN98500DBS2	5/1/98 8:16:38 AM	N04	☐	☐	☐	☐
[redacted]	WN98500FBS1	5/1/98 8:18:46 AM	N04	☐	☐	☐	☐
[redacted]	WN98500FBS2	5/1/98 8:18:46 AM	N04	☐	☐	☐	☐
[redacted]	WN985030BS1	5/1/98 10:22:29 AM	N18	☐	☐	☐	☐
[redacted]	WN985030BS2	5/1/98 10:22:29 AM	N18	☐	☐	☐	☐
[redacted]	WN985032BS1	5/1/98 10:25:17 AM	N18	☐	☐	☐	☐
[redacted]	WN985032BS2	5/1/98 10:25:17 AM	N18	☐	☐	☐	☐
[redacted]	WN985034BS1	5/1/98 10:27:04 AM	N18	☐	☐	☐	☐
[redacted]	WN985034BS2	5/1/98 10:27:04 AM	N18	☐	☐	☐	☐
[redacted]	WN985059BS1	5/1/98 12:11:34 PM	N10	☐	☐	☐	☐
[redacted]	WN985059BS2	5/1/98 12:11:34 PM	N10	☐	☐	☐	☐
[redacted]	WN98505BBS1	5/1/98 12:13:53 PM	N10	☐	☐	☐	☐
[redacted]	WN98505BBS2	5/1/98 12:13:53 PM	N10	☐	☐	☐	☐
[redacted]	WN98505DBS1	5/1/98 12:16:18 PM	N10	☐	☐	☐	☐
[redacted]	WN98505DBS2	5/1/98 12:16:18 PM	N10	☐	☐	☐	☐

Shipping Condition - Room Temperature: _____ Cold(ice): _____ Frozen(dry ice): _____
Received Condition - Room Temperature: _____ Cold(ice): _____ Frozen(dry ice): _____

Relinquished By / Date / Time / Company / Transport-Airbill #	Received By / Date / Time / Company

Figure 15. Example of water chemistry Chain-of-Custody Form

DATE: MWRA CHAIN OF CUSTODY FOR MISCELLANEOUS SAMPLES .... PAGE:1 OF 1

SAMPLE LOC.	SAMPLE ID	DATE COLLECTED	TIME	SAMPLE LOCATION DESCRIPTION	PLANT	TYPE/TESTS/PRESERVATIVE/BOTTLE
						G C CG GS/FCOLSWMFL/ /P G S G C CG GS/ECOCSWMFL/ /P G S
						G C CG GS/FCOLSWMFL/ /P G S G C CG GS/ECOCSWMFL/ /P G S
						G C CG GS/FCOLSWMFL/ /P G S G C CG GS/ECOCSWMFL/ /P G S
						G C CG GS/FCOLSWMFL/ /P G S G C CG GS/ECOCSWMFL/ /P G S
						G C CG GS/FCOLSWMFL/ /P G S G C CG GS/ECOCSWMFL/ /P G S
						G C CG GS/FCOLSWMFL/ /P G S G C CG GS/ECOCSWMFL/ /P G S
						G C CG GS/FCOLSWMFL/ /P G S G C CG GS/ECOCSWMFL/ /P G S
						G C CG GS/FCOLSWMFL/ /P G S G C CG GS/ECOCSWMFL/ /P G S
						G C CG GS/FCOLSWMFL/ /P G S G C CG GS/ECOCSWMFL/ /P G S
						G C CG GS/FCOLSWMFL/ /P G S G C CG GS/ECOCSWMFL/ /P G S
						G C CG GS/FCOLSWMFL/ /P G S G C CG GS/ECOCSWMFL/ /P G S
						G C CG GS/FCOLSWMFL/ /P G S G C CG GS/ECOCSWMFL/ /P G S

COMMENTS: ____

____

____

****

SAMPLED BY: ____________________________ DATE: ________________________

RELINQUISHED TO: _______________________ DATE: ________________________

RECEIVED BY: ___________________________ DATE: ________________________ (AT LAB)

Figure 16. Example of MWRA bactriological cample Chain-of-Custody Form

13.2 Custody of effluent and water samples

During collection of discrete samples at Deer Island Treatment Plant and in the field, COC forms will be completed and labels will be affixed to the sample containers, thereby creating a link between the sample and data recorded on the COC form. The COC forms will have the same alphanumeric code as the corresponding label on the sample container, ensuring the tracking of sample location and the status. Bottles to be analyzed by DIL will also have MWRA LIMS sample labels and a MWRA chain-of-custody form.

The samples will remain in the custody of the Sample Custodian (designated by the Chief Scientist for each survey) while in the field. COC forms will accompany the samples when transferred from the field to the laboratory. All samples will be distributed to the appropriate laboratory personnel by hand or by Federal Express or to a locked sample-delivery location at Deer Island. Battelle staff will collect and store the effluent samples until the samples can be delivered to DIL (first-floor sample-receiving area or the locked sample-receiving location) at the end of the experiment; DIL staff will visit the Battelle sampling site once or twice during daylight hours to take custody of available stored samples. Samples for analysis by Battelle or subcontractors will be shipped on ice or frozen via overnight delivery. When samples arrive at each laboratory, custody will be relinquished to the Laboratory Custodian. Upon receipt of the samples at Battelle, or DIL, or at Battelle's subcontractors, the Sample Custodian will examine the samples, verify that sample-specific information recorded on the COC is accurate and that the sample integrity is uncompromized. The samples will be logged into the laboratory tracking system and the custody forms completed and signed to complete the transfer of custody. Any discrepancies between sample labels and transmittal forms, and unusual events or deviations from the project CW/QAPP will be documented in detail on the COC and the Task Leader and Project Manager notified. The original COC forms will be submitted to the Battelle Laboratory Manager and maintained in the MWRA project files. The Deer Island Laboratory Manager and the Battelle Laboratory Manager will each receive a copy of both the MWRA and Battelle COC for DIL-analyzed samples. Sample numbers that include the complete field ID number will be used to track the samples through the laboratory. Alternately, unique laboratory IDs may be assigned by each laboratory for use during their sample analyses, but the data will be reported to the database by using the field-generated sample number.

Samples that have been analyzed and have passed their holding times will be discarded. No samples will be archived.

14.0 CALIBRATION PROCEDURES AND PREVENTIVE MAINTENANCE

Instrument maintenance and repair logs will be stored in the instrument files maintained by Battelle and by the subcontractors. Maintenance of and repairs to instruments will be in accordance with manufacturers' manuals. Any deviations to this policy will be noted.

14.1 Dye addition and monitoring

14.1.1 Effluent flow

Effluent flow information will be provided by the Deer Island process control computer. It is based on the sum of flow through four parallel venturi flowmeters in the primary treatment tanks. The flowmeters are calibrated by plant staff each year.

14.1.2 Dye pump

A peristaltic pump will used to add dye stock solution to the effluent. The performance characteristics will be fully evaluated in relation to the 4-20mA controlling signal, hose type, fatigue, and temperature. Appropriate adjustments will be made to allow a well-controlled $250*X10^{-9}$ dilution of dye in effluent.

14.1.3 Dye solution

The dye stock solution will be assumed to be 20% w/v as active ingredient. The details on the manufacturer label will be noted in the field notebook. If more than one container must be used, containers will be blended beforehand.

14.1.4 Rhodamine fluorometer (Turner Designs)

The Turner Designs fluorometer used for Rhodamine WT dye analysis at Deer Island Treatment Plant, will be calibrated in the laboratory. The Turner Designs fluorometer has a peak excitation of 550 nm and an emission wavelength range of 570 - 700 nm. The Rhodamine temperature-compensation settings will be used.

The Turner Designs fluorometer will be calibrated at the same time as the *in situ* Rhodamine fluorometer (Section 4.2.5). A small pump will circulate sample water from the 15L-test tank, through the fluorometer, back into the tank. This will allow for inter-calibration of the two fluorometers. The calibration criteria defined in Section 14.2.5 apply.

14.1.5 Temperature and conductivity sensors

The software gain and offset of the temperature and conductivity of the Battelle sensors are calibrated annually at the factory and the factory calibration settings are not changed. A review of the calibration coefficients for the CTDs shows that they are quite stable from year to year. Based on factory calibrations of the Ocean Sensors CTD, the annual amount of drift is: 0.018 °C for temperature; 0.042 mmhos/m for conductivity; 0.055 PSU for salinity; and 0.046 for Sigma-T.

14.2 Hydrographic profiling equipment

14.2.1 Pressure (depth) sensor

At the beginning of each survey, the software offset of the Ocean Sensors CTD depth sensor is set to read zero when the sensor is on deck. The offset is entered into the equipment setup file. The offset of the pressure reading is affected by the atmospheric pressure.

14.2.2 Temperature and conductivity sensors

The software gain and offset of the temperature and conductivity sensors are calibrated annually at the factory and the factory calibration settings are not changed. A review of the calibration coefficients for the CTDs shows that they are quite stable from year to year. Based on factory calibrations of the Ocean Sensors CTD, the annual amount of drift is: 0.018 °C for temperature; 0.042 mmhos/cm for conductivity; 0.055 PSU for salinity; and 0.046 for Sigma-T.

14.2.3 Echosounder and altimeter

The echosounder and altimeter acoustic devices are initially calibrated at the factory before delivery and the manufacturer does not recommend recalibration. These devices are not used as precision bathymetry systems. Pre-survey checks include verification of the instrument setup and informal comparison with the navigation chart depths at the dock.

Maintenance and calibration of these acoustic devices will be documented, including dates of most recent servicing. The lack of moving parts or need to open the devices for setup or data retrieval minimizes maintenance requirements. Routine maintenance is limited to transducer head inspection, applying grease to the I/O connector and cleaning external surfaces.

14.2.4 Transmissometer

The transmissometer is calibrated annually in the laboratory at Battelle. This calibration consists of obtaining voltage readings under the three following conditions:

V_o = voltage when the light path is blocked
V_a = voltage in air
V_w = voltage in distilled water.

Beam attenuation for the 20-cm path length is calculated using the following equation:

$$c = A - 5 \ln (V_m - V_o)$$

where c = beam attenuation
A = offset coefficient
V_m = measured *in situ* voltage.

Knowing that the beam attenuation of clear distilled water is 0.364/m (Sea Tech Inc, Transmissometer Manual), the value of *A* is calculated as follows:

$$A = 0.364 + 5 \ln (V_w - V_o).$$

A review of the calibration coefficients for the transmissometer show that it is stable from year to year. The drift of the transmissometer is dependent on the amount of time it is operated. For example, in 1992 the transmissometer drift was approximately 0.01/m after 288h of operation. Transmissometer operation is checked each day of survey by reading the signal with the light path fully blocked (expected response > 40/m) and with the light path unobstructed (expected response < 0.5/m) readings in air. Readings are displayed using the NAVSAM© program.

14.2.5 *In situ* Rhodamine fluorometer (Chelsea)

The Chelsea fluorometer has a peak excitation wavelength of 500 nm and a peak emission wavelength of 590 nm and has a built in temperature compensation circuit for correcting the dye signal for temperature effects. The Chelsea fluorometer, used for *in situ* Rhodamine WT dye analysis, will be calibrated in the laboratory prior to the first plume tracking survey. The Chelsea fluorometer will be immersed in a test tank with 15L of distilled water. A dye stock of 10,000µg/L will be prepared by adding 50µL of Rhodamine WT (20% active ingredient) to 1L of distilled water.

The calibration will be conducted by immersing the Chelsea fluorometer in the deionized water without any dye. Dye will be added incrementally to the tank. Dye additions will be volumetrically added to the tank using Class S glassware. The entire contents of the labware will be rinsed into the tank. The final concentration will be 50µg/L (100µg/L for the winter survey). Each dye concentration will be calculated based on the following:

$$\text{Dye Concentration} = \frac{10{,}000\mu g/L * \text{Total Dye Mixture Volume Added}}{\text{Initial Tank Volume} + \text{Total Dye Mixture Volume Added}}$$

Dye additions will be small (*e.g*., a total of 75 mL of dye stock will be required to raise the concentration to 50 µg/L) relative to the initial volume in the tank volume. After each interval of dye addition the tank will be stirred and the fluorometer voltage reading will be recorded once it is stable. Up to five calibration points will be used. These data will be used to establish a calibration curve. The linear regression must have a correlation coefficient (r) $\geq$0.90.

14.2.6 *In situ* chlorophyll *a* fluorometer

Based on manufacturer's recommendations, the software gain and offset of the fluorometer are set annually. The fluorometer data, displayed with the NAVSAM© program, will approach 0.0 Φg/L when the instrument is on deck. As daily maintenance, the fluorometer will be rinsed with deionized water.

The fluorescence readings will be corrected using the measured chlorophyll *a* data from discrete bottle samples. These data will be used to develop a linear regression and correction slope and intercept.

The regression will be based on the following equation:

Chl. conc. (from sensor) = slope *x* (Chl conc. (bottle value) + intercept)

Those values of slope and intercept will be used to correct CTD value in the database:

Corrected sensor Chl conc. = (Chl conc. (from sensor) – intercept)/slope

The calibration will be acceptable if the significance of F (confidence interval) is #0.05, and will be qualified as failed if the significance is >0.05.

14.2.7 Acoustic Doppler Current Profiler (ADCP)

The ADCPs are initially calibrated at the factory before delivery and the manufacturer does not recommend any recalibrations. Pre-deployment checkout of ADCP in a still tank verified proper instrument operation. Pre-deployment checks include verification of the instrument setup; verification of the transducer operation, continuity and noise level; verification of proper operation of the CPU and internal clock; and compass calibration check. The results are recorded in the field log.

Maintenance and calibration of the ADCP and/or specific sensors will be documented, including dates of most recent servicing. The lack of moving parts or need to open the ADCP for setup or data retrieval minimizes maintenance requirements. Routine maintenance is limited to transducer head inspection, applying grease to the I/O connector and cleaning external surfaces.

14.3 Dye interference

14.3.1 Background fluorescence

Background fluorescence is considered any fluorescing matter in the sample, which may contribute signal at the Rhodamine WT fluorescence wavelengths. Blue-green algae or dissolved organic matter may contribute to the background fluorescence level. This background value must be accounted for in the measurement of Rhodamine WT fluorescence, otherwise concentration values will be artificially high.

Background fluorescence in the Massachusetts Bay receiving environment will be examined by measuring the fluorescence of at least 10 water samples collected during a routine Water Column Monitoring Survey prior to the first Plume Tracking Exercise. The *in situ* Chelsea fluorometer will be used for these measurements. This will enable characterization of the expected variability in the background fluorescence. In addition, the Chelsea fluorometer will be used to characterize background

fluorescence in Massachusetts Bay during each background survey. These surveys occur immediately prior to the appearance of Rhodamine WT dye at the diffuser. Background concentrations in the absence of dye will be used to correct for natural chromophor interference on the dye fluorescence.

The background fluorescence of Deer Island effluent will be measured using the Turner Designs fluorometer, although it is expected to be insignificant (<1µg/L). The background fluorescence of the effluent will be measured at the Deer Island Treatment Plant immediately prior to dye addition. The background fluorescence value of the effluent will be subtracted from the fluorescence value of the effluent with the dye added. Discrete samples of effluent will be collected during the test exercise (prior to the actual plume tracking exercise) to confirm that the background fluorescence of the effluent does not vary significantly daily.

14.3.2 Turbidity

Previous work (Albro 1994) has shown that "false" fluorometer readings are proportional to transmissometer (turbidity) readings. To remove these "false" readings, the towed body will be towed in and out of the effluent plume several times before the dye appears in the discharge plume. Using the relationship between the fluorometer readings to transmissometer readings, an equation relating the "false" reading to turbidity will be determined using linear regression

$$\text{Beam Attenuation Effect (BAE)} = A_{ba} + B_{ba} * \text{Beam Attenuation Reading}$$

where A_{ba} and B_{ba} are constants determined by linear regression

Based on the BAE, dye experiment fluorometer readings will be corrected for turbidity interference. This corrected fluorometer reading will be compared to the true dye concentration to develop a dye concentration equation as a function of fluorometer and transmissometer readings. The equation will be determined using linear regression:

$$\text{Dye Concentration} = B_f * (\text{Fluorometer Reading} - \text{BAE})$$

where B_f is a constant determined by linear regression.

To examine the potential interference of turbidity in the Deer Island effluent samples, experiments will be performed in the laboratory, prior to the winter survey exercise, using the Turner fluorometer. At least five samples of effluent (at the end of the disinfection basin with minimal chlorine residual) will be taken from Deer Island and a known dilution of dye will be added. The sample will be measured using the Turner Designs fluorometer, immediately before and after the sample has been allowed to settle out (4-6 hours). If turbidity is found to affect the true dye fluorescence reading in effluent, then the same technique as described below will be applied to correct for the effects of particles on the dye concentration.

14.3.3 Photodegradation

The possible effects of dye photodegradation – due to direct sunlight - over the survey period (2-3 days) needs to be characterized prior to the start of the survey. A 15L test tank of 50 µg/L concentration will be set in direct sunlight to simulate worst case conditions. Readings will be taken with the Chelsea fluorometer every 4 hours during daylight hours for at least 3 days. Light (PAR) will be measured at mid depth of the tanks during the experiment. The tank will be stirred prior to taking dye readings. The effects of photodegradation will be characterized from these readings, and correction factors will be derived for the plume tracking exercise if necessary.

14.3.4 Dye loss

Loss of dye can occur from several possible due causes. These include chlorine in the effluent, bromide ion in seawater, adsorption by dissolved and particulate organic matter in the effluent, and fluorescence quenching (see also 12.1.1). The potential loss will be tested prior to the first plume tracking exercise. For the effluent test, a known volume of dye solution (dye stock) at a known concentration will be added to a known volume of effluent collected from the head of the Deer Island Treatment plant disinfection basin. The tests will be run at the Deer Island Treatment Plant. The target concentration will be a 50 µg/L dye solution. The same volume will also be added to a known volume of deionized water and to a known concentration of seawater from Massachusetts Bay, each at a targeted 50 µg/L dye solution. Samples will be stored in the dark at 20 °C to eliminate effects of photodegradation. Fluorescence values of each test solution will be measured immediately upon dye addition and homogenization and twice per hour over the first 12 hours of the experiment using the Turner Designs fluorometer. After 12 hours, the measurement rate will decrease to three per 12-h period over a duration of 60 hours. If the dye concentration does not change significantly after 12 hours, the experiment may be ended. If the fluorescence value is found lower in the effluent or seawater sample than in the deionized water or the dye concentration decreases as a function of time, the rate of dye loss will be characterized and a method for correction of the dye concentration will be developed.

14.3.5 Temperature

Temperature has an important effect on Rhodamine fluorescence. Both Rhodamine fluorometers have built-in temperature compensation, and this will be tested in the lab by varying the temperature of a test solution.

14.3.6 Dye interference with ammonium and phosphate analyses

The effect of 50µg/L dye on colorimetric analyses of ammonium and phosphate in the effluents and at lower dye concentrations in seawater will be evaluated and corrected for if necessary.

14.4 Navigation equipment

Once the 12V DC-power supply for the Northstar DGPS navigation system has been switched on, there is typically no other setup interaction necessary between the NAVSAM© operator and the navigation system. The GPS will also conduct an automatic self-test. Once the DGPS has acquired at least one satellite, the green LED on the front panel will start flashing. When the DGPS has acquired at least three satellites to give a correct position, the green LED will remain lighted constantly. The DGPS will display a latitude-longitude (L/L) position once the system has acquired an acceptable fix. The DGPS system provides guaranteed position accuracy of 10 meters 95% of the time.

Position calibration will be performed twice per day as follows:

1. An absolute position is obtained from published charts with a position accuracy approaching 2 sec (approx. 40 m).
2. The NAVSAM© program is set to calibration-navigation mode.
3. Thirty fixes are obtained by the program, averaged, and then compared to the absolute position entered by the operator.
4. If a printer is connected to the system, a printout of the calibration is obtained. Otherwise, the data are manually entered into the first or last station log for that day.

To test the navigation system at the diffuser, the survey vessel will be directed along the centerline of the diffuser using the visual display of the NAVSAM©. The visual display will show diffuser cap location. As the vessel goes over each diffuse cap, the 200 kHz echo sounder should indicate a bottom object 3-4 meters high. The success of this test will be recorded.

14.5 Laboratory instruments

Calibration procedures for laboratory instruments are summarized in Table 19. All laboratory calibration records will be reviewed by analysis task leaders and maintained in laboratory notebooks.

For all instruments used in metals analyses, a four-point calibration (minimum) is performed just prior to sample analysis. A calibration check standard is analyzed after every 10 authentic samples to ensure that the instrument remains in calibration over the course of sample analysis. If the percent difference is greater than the acceptability criteria, remedial maintenance will be performed on the instrument, a new initial calibration will be performed, and the affected batch of samples will be reanalyzed at the discretion of the analyst and project management. Deviations from calibration or data objectives will be documented in the project files.

The ICP-MS is tuned as described in Battelle SOPs MSL-I-022, which is based on EPA Method 200.8. The tuning solution used includes ^{24}Mg, ^{103} Rh, and ^{208} Pb to determine the resolution of the instrument for low, medium and high masses. Routine maintenance is performed by the manufacturer twice yearly or as needed, and any daily maintenance is recorded in a logbook. Calibration procedures for the GFAA are described in Battelle SOPs MSL-I-029.

15.0 DOCUMENTATION, DATA REDUCTION, AND REPORTING

15.1 Data recording

All data (excluding the ADCP data) will be initially recorded either (1) electronically onto computer storage media from BOSS or other laboratory systems or (2) manually into bound laboratory notebooks or onto established data forms. All notes will be written in black ink. Corrections to hand-entered data will be initialed, dated, and justified. Corrections to electronically captured data (*e.g.*, electronic "spikes") will be documented on a hard-copy plot of the data. Completed data forms or other types of hand-entered data will be signed and dated by the individual entering the data. Direct-entry and electronic data entries will indicate the person collecting or entering the data. It will be the responsibility of the laboratory managers to ensure that all data entries and hand calculations are verified in accordance with procedures described in Section 16. In addition to these documentation procedures, station logs associated with field and laboratory custody and tracking will be kept in survey notebook for each survey. These notebooks will be stored in the physical oceanography laboratory under the supervision of Mr. Wayne Trulli until archival.

All ADCP measurements are internally recorded and are transferred from instrument memory to computer hard disk, with translation from internal instrument formats to calibrated engineering units using algorithms provided by the manufacturer.

Table 19. Calibration procedures for laboratory instruments

Parameter	Lab	Instrument type	Initial calibration			Continuing calibration		Corrective action
			No. Stds	Acceptance Criteria	Frequency	Acceptance Criteria	Frequency	
Rhodamine	Battelle	Turner Designs fluorometer	4-5	r ≥ 0.995	Prior to analytical run	PD from initial 10%	Twice daily	Investigate, recalibrate
Chloride	DIL	Mettler autotitrator	NA	NA	NA	PD less than 5%	Every 5 samples	Investigate, reanalyze
Total Suspended Solids (TSS)	URI	Mettler 5- Place Balance	NA	Professionally Calibrated to Agree with NIST traceable Calibration Weights	Annually	PD less than 1% from reference weights	Daily	Professional Service requested for PD over 5%
Total Suspended Solids (TSS)	DIL	Mettler 4- Place Balance	NA	Professionally Calibrated to Agree with NIST traceable Calibration Weights	Annually	PD less than 2% from reference weights	Daily	Professional Service requested for PD over 5%
Ammonium and phosphate	URI	Technicon II Autoanalyzer	4-5	r ≥0.999	Prior to analytical run	PD from initial 15%	Every 10 samples	Investigate, recalibrate
Ammonium	DIL	Skalar autoanalyzer	4-5	r ≥0.997	Prior to analytical run	PD from initial 15%	Every 10 samples	Investigate, recalibrate
Phosphate	DIL	Skalar autoanalyzer	4-5	r ≥0.997	Prior to analytical run	PD from initial 15%	Every 10 samples	Investigate, recalibrate
Silver and copper	Battelle	ICP-MS	≥2	r ≥ 0.99	Prior to analytical run	PD from initial 15%	Every 10 samples	Discuss with project manager. Remedial maintenance, new initial calibration, or reanalyze samples. Document and justify.
Silver and copper	Battelle	GFAA	≥4	r ≥ 0.99	Prior to analytical run	PD from initial 15%	Every 10 samples	Discuss with project manager. Remedial maintenance, new initial calibration, or reanalyze samples. Document and justify.
Chlorophyll a	UMD	Model 10AU Turner Fluorometer	6	r ≥ 0.995	Prior to analytical run	PD from initial 10%	Twice daily	Investigate, recalibrate

15.2 Data reduction

15.2.1 Dye addition and monitoring

The flow data from the Deer Inland process control computer will be recorded, both as MGD and as the 4-20mA signal used to control the dye pump. The 4-20mA signal will be translated into pump flow as mL/min using known pump characteristics. The ratio of dye flow to effluent flow will be graphed versus the Turner Design rhodamine fluorescence to visualize the effectiveness of the constant-concentration dosing and monitoring system. Dye fluorescence readings will be corrected for effects of background fluorescence, turbidity, photodegradation, chlorine degradation, adsorption by dissolved and particulate organic matter, temperature, and fluorescence quenching.

15.2.2 Hydrographic and navigation data

The hydrographic data generated during the survey will consist of rapidly sampled, high-resolution measurements of conductivity (salinity), temperature, pressure (depth), transmissometry, chlorophyll a fluorescence, Rhodamine WT dye, altitude above bottom, bathymetry, and navigation. The BOSS data-acquisition software assigns a unique data filename to each towyo or vertical profile made during the survey. All data will be electronically logged with date, time, and concurrent GPS/LORAN vessel-position data. Battelle's NAVSAM© software will be used to convert the raw engineering data into concentration units using factory or laboratory calibration coefficients. The converted data will be plotted in high resolution, parameter versus time graphic form for visual inspection of data representativeness. NAVSAM© will create a Microsoft Access database file consisting of two tables. One table will contain the two-second averaged data. A second table includes the data corresponding to the average of the data within +/- 5 seconds of collecting water at each sampling event. The database file will serve as an export file to the EM&MS database. The data reductions are described by Weiss (1970) and Fofonoff and Millard (1983).

15.2.3 Acoustic Doppler current profiler (ADCP) data

The ADCP rejects points where bottom tracking is poor, signal-to-noise ratio is low, or where a mean velocity cannot be determined over the measurement volume (areas of strong gradients and large-scale turbulence). Only a few points are expected to be rejected. During post-processing, the current data will be rotated into a true north and east coordinates system. The velocity data will cleaned based on percent-good ping return and measurements less than 1 m above the bottom. Using the clean data set, depth-averaged velocities and fluxes will be calculated. The choice of averaging interval will be chosen based on the measurements of water properties and dye. The appropriate vertical scale will be determined by the spreading of the effluent, which should be revealed by the vertical dye distribution and/or other water-column parameters (*e.g.*, T-S anomalies). The vertical averaging of the ADCP data will be for the purpose of rendering the data to a form that is more easily interpreted than the fully resolved vertical structure. For the purpose of describing the vertical structure, we will take advantage of the maximum resolution of the instrument (0.5 m is probably the optimum for the 600 kHz workhorse ADCP). The data will also be sorted into spatial bins in the along-transect direction with 25, 50- or 100-meter spacing.

15.2.4 Subcontractor laboratory data

All data generated by Battelle's subcontractors will be either electronically transferred from the instrument or manually read from the instrument display and entered into a loading application, provided by the Battelle Data Management team. Data in laboratory notebooks will be manually entered into the loading application. All data reduction will be performed electronically either by the instrument software or in a spreadsheet and will be validated according to procedures described in Section 16. The format for final data submission is described below.

15.3 RSB modeling using field data

The RSB model is based on experimental studies by Roberts, Snyder, and Baumgartner (Roberts and Snyder 1993a,b). The model will produce data that will provide MWRA with the information they need to decide if the outfall meets the EPA NDPES permit requirements. The RSB model will be used to predict the outfall's minimum dilution, rise height, and plume thickness. The outfall's physical characteristics will be entered along with the assumed effluent density, the ambient water density profile, and the average current speed (in meters/sec) over the mixing height. At a minimum, the model will be run for a set of ambient conditions – based on an hourly interval – taken from the field data measured during the HMZ and nearfield surveys during the plume tracking exercise. This would include a minimum of 25 model runs for each plume tracking exercise.

15.4 Reporting data to be loaded into the database

All field and laboratory data to be loaded into the EM&MS will be submitted to Battelle in electronic format. The field data will be available for data loading directly off the ship. The laboratories will be supplied a loading application that will increase data quality and efficiency. These applications eliminate the need for data reporting formats and deliver many of the quality control checks upstream to the laboratories.

15.4.1 Dye addition and DITP monitoring

Effluent flow, dye flow, and Turner Designs rhodamine fluorescence will be loaded into the database (Table 20), as well as data from the CTD used at DITP. Data will be recorded at one-minute intervals.

Table 20. Database codes for dye addition and monitoring parameters

Parameter	Param_Code	Unit_Code	Instr_Code	Meth_Code
Effluent flow	EFF_FLOW	MGD	VENTURI	VENTURI
Dye flow	DYE_FLOW	mL/min	PERIPUMP	PERIPUMP
Rhodamine dye fluorescence	RWT	ug/L	TDDYE	BRUCE00
Temperature	TEMP	C	CTD5	BOSS
Conductivity	CONDTVY	mmhos/cm	CTD5	BOSS
Salinity	SAL	PSU	CTD5	BOSS
Density as measured by Sigma_t	SIGMA_T		CTD5	BOSS

15.4.2 Navigation and sample collection data

Navigation and sample collection data will be processed on-board the survey vessel and be ready for loading into EM&MS upon arrival at Battelle. A database application developed as part of the NAVSAM© system will query the on-board database tables for the fields necessary to populate the *Event, Station, Sample* and *Bottle* tables. The data will be loaded into the EM&MS database by clicking a button. All database constraints developed by MWRA will be applied to the tables so that the data are checked during the insert.

15.4.3 Hydrographic data

Battelle will also load into the database the following type of data collected with the BOSS sensor package:

- Date, time, location, and corrected sensor data associated with each water sample

Two additional data sets will be electronically archived:

- Date, time, location, and corrected sensor data that has been bin-averaged into 2-second bins (towyo data)
- Date, time, location, and corrected Acoustic Doppler Current Profiler data (ADCP)

A database application will be used to load the hydrographic data from the processing database directly into the EM&MS database. Table 21 shows the database codes for the hydrographic parameters. Towyo and ADCP data will be loaded into an Oracle database with structure currently under development by MWRA. Data will be supplied to MWRA as a database export. Database constraints will be in place to provide an initial check of the data integrity and validity.

15.4.4 Analytical and experimental data

15.4.4.1 Subcontractor laboratories

The data reporting for analytical and experimental data begins with the Battelle Data Management Team who populate a loading application that is then sent to the laboratory for their data entry. As defined above, the collection data from field activities are delivered to the data manager as an Access database. Sample IDs and analysis protocols are extracted from this database and used to populate a database within the loading application. A separate loading application is prepared for each data deliverable (Figure 17). Data contributors open the database and are presented with a form that already contains the Sample IDs and analyte list for their data submittal (Figure 18). The laboratory enters the results and other supporting information such as qualifiers. All entries are constrained by the rules of EM&MS. Errors are caught on

Table 21. Database codes for hydrographic and ADCP parameters

Parameter	Param_Code	Unit_Code	Instr_Code	Meth_Code
Conductivity	CONDTVY	mmhos/cm	CTD5	BOSS
Rhodamine dye fluorescence	RWT	ug/L	CHDYE	BOSS
Water Pressure	PRESSURE	m	CTD5	BOSS
Salinity	SAL	PSU	CTD5	BOSS
Density as measured by Sigma_t	SIGMA_T	unitless	CTD5	BOSS
Temperature	TEMP	C	CTD5	BOSS
Chlorophyll a fluorescence	FLUORESCENCE	ug/L	WETSTAR	BOSS
Transmissivity	TRANS	m-1	TR20	BOSS
East current speed	E_CURRENT	cm/s	ADCP1	ADCP
North current speed	N_CURRENT	cm/s	ADCP1	ADCP

entry and fixed by the data contributor. Primary keys are in-place so duplication can not occur. Entry applications are developed on an individual laboratory basis. Laboratory staff receives one day of training on the application prior to their first set of samples. When data entry is complete, the database is sent back to Battelle. Laboratories with existing data processing capability will be supplied a loading application that can import their final spreadsheet and then run the quality control checks. The laboratory will have to meet the specified format for the data to load successfully

The loading application gives the laboratory several function buttons. These include hardcopy report, quality control checks, exception report, and analysis summary. The hardcopy report allows the laboratory to create a hardcopy report to check for entry errors and to submit a final report to Battelle with the data deliverable. The quality control checks are comprised of the applicable sections of EM&MS check and constraints scripts and checks for outliers. This report gives the data contributor a chance to

confirm the reasonableness of their data prior to submission to Battelle. The exception report checks the data that was expected against the results loaded. The data contributor must account for any entries in the exception report. The analysis report produces a report of the number of analyses by analyte. A copy of this report is included with the data deliverable and with the invoice for the analyses. Within the loading application, the data entered by the laboratory is translated into the correct codes and inserted into database tables with the same structure as the matching EM&MS table.

Table 22 shows the qualifiers to be used by the laboratory. Table 23 shows the analytical parameters, codes, and units of measure for the analytes collected under this task. The database codes are described in Table 24. The laboratory will have the ability to add additional codes to describe their results, but the new qualifiers will be highlighted in the exception report. Battelle will notify MWRA concerning the new qualifier and will adjust the code table in the application to agree with any changes to the EM&MS code list table. MWRA has the responsibility for maintaining the code list for the EM&MS.

15.4.4.2 MWRA

MWRA ENQUAD staff will import effluent flow data from Deer Island Process Control into the MOOR_INSTR and MOORING tables in EM&MS. MWRA will send these data as Oracle export files to Battelle within four days of each plume tracking exercise. Battelle will import the data into their local copy of EM&MS.

Deer Island Laboratory staff will prelog their samples into LIMS, including sample ID, project facility, location, sample type, and anticipated test codes. DIL will preprint labels and chain of custody forms. Battelle will use these as well as Battelle labels and chain of custody forms. DIL will scan the LIMS barcodes of samples delivered by Battelle; this marks samples as ready for testing. DIL staff will manually enter test results into LIMS subject to validation approval (a separate test- and sample-level review).

ENQUAD staff will retrieve the data via Oracle from the LIMS data warehouse into the ANALYTICAL_RESULTS table in EM&MS. These data will be sent to Battelle as Oracle export files within six weeks of each plume tracking exercise where the data will be imported into Battelle's local copy of EM&MS.

Battelle will log in data submitted to Battelle upon receipt and maintain a copy on file under the login_id. Battelle will run the MWRA check script on the database as a batch job each night. Any issues will be sent by Battelle to the data manager and MWRA via email. MWRA will make any necessary corrections and resubmit the data to Battelle before Battelle incorporates them into Battelle's copy of EM&MS. Corrected data will under go analysis and be re-export once corrections are complete and verified.

15.5 Loading analytical and experimental data into the Harbor and Outfall Studies Database

Data submissions from the laboratory are the final loading applications. The submissions are logged in upon receipt and a copy is maintained on file under the login ID. Data are loaded into a temporary table space by a button on the application. A transfer script will copy the data into the proper table in Battelle's copy of the EM&MS. Data from the laboratories receive a quality assurance review after the data has been synthesized into a data report. Any issues are corrected in the database and the well-documented script is supplied to MWRA with the export of the database. The MWRA check script will be run on each database export. The data manager and MWRA will resolve any issues. The output file of the check scripts will also be submitted to MWRA with the data export.

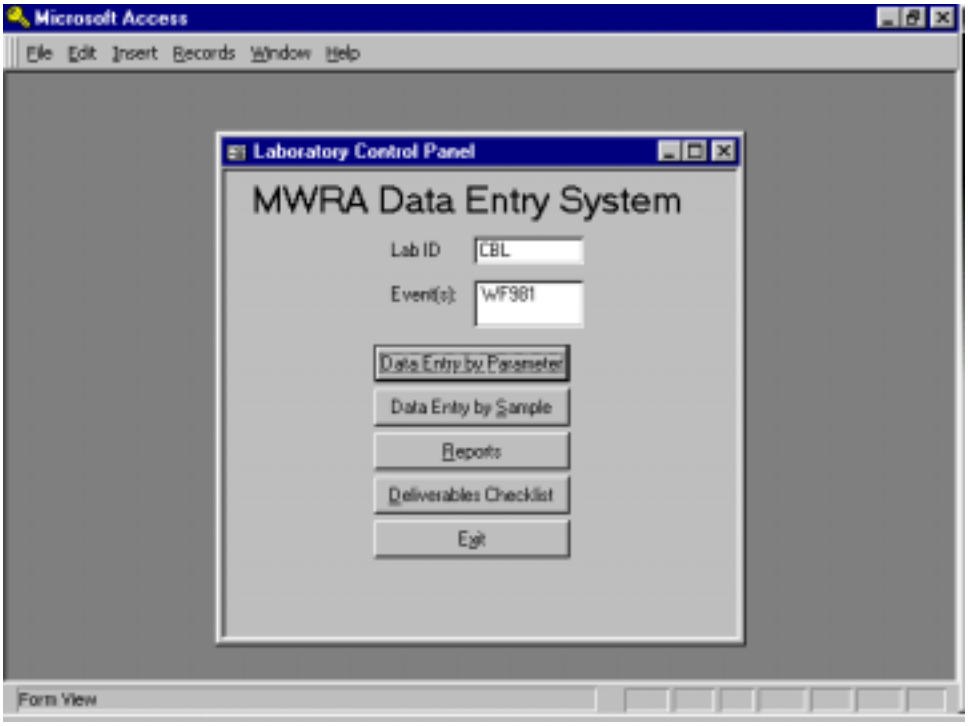

Figure 17. Loading Application Function Buttons Window

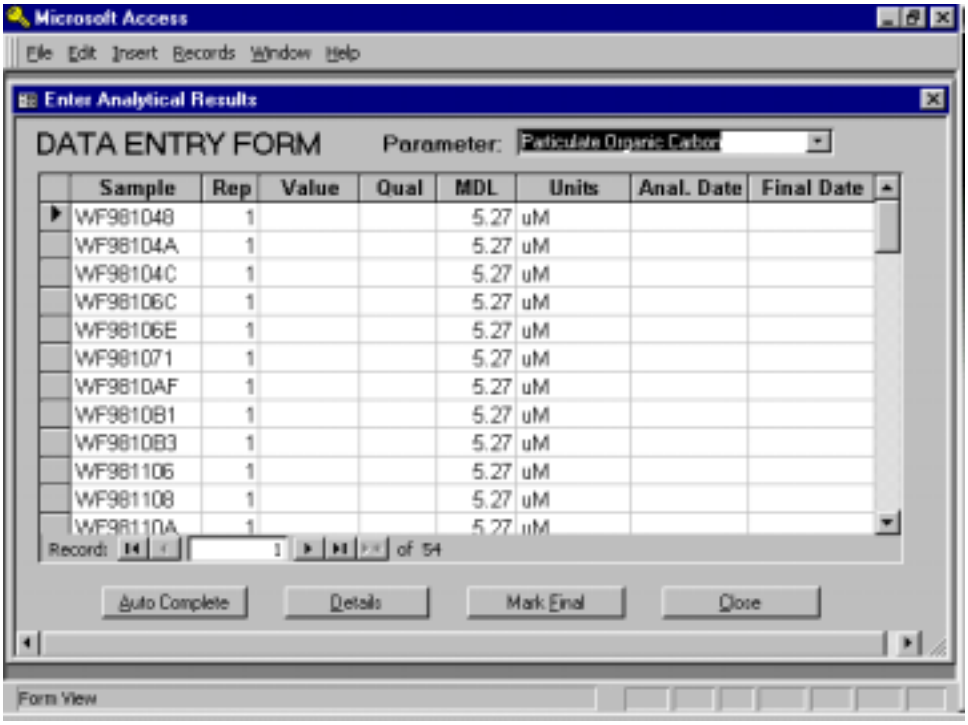

Figure 18. Form containing Sample Ids and Analyte List

Table 22. Laboratory qualifiers

Qualifier	Description	Value reported?
	Value is not qualified	yes
a	Not detected, value reported as negative or null	yes
A	Over maximum detection limit (TNTC)	yes
B	Blank-corrected, blank >=5x MDL	yes
B5	Blank-corrected, blank <5x MDL	yes
b	Not blank corrected, blank >= 5x MDL	yes
E	Calibration level exceeded	yes
e	Results not reported, value given is NULL. Explanation in COMMENTS	no
f	Value reported below MDL	yes
g	Recovery outside data objectives	yes
h	Below standard curve 0	yes
I	Interferant from standard	yes
j	Estimated value	yes
L	Analytical concentration reported from dilution	yes
o	Value out of normal range, judged fit for use by principal investigator	yes
p	Lab sample bottles mislabeled - caution data use	yes
r	Precision does not meet data quality objectives	yes
s	Suspect/invalid (not fit for use) explanation in COMMENTS	yes
T	Holding time exceeded	yes
u	Useable profile reading, not calibrated against bottle measurement	yes
v	Arithmetic mean	yes
x	Matrix interference	yes
q	Possibly suspect/invalid and not fit for use. Investigation pending. Only MWRA has authority to apply this qualifier	yes

Table 23. Database codes for chemistry analytical and experimental parameters

Parameter	Param_Code	Unit_Code	Anal_Lab_ID	Instr_Code	Meth_Code
Rhodamine WT (effluent and seawater discrete samples)	RWT	µg/L	BOS	TDDYE	BRUCE00
Total Suspended Solids (TSS)	TSS	mg/L	URI	MET5PLACE	SOP5-053
Total Suspended Solids (TSS)	TSS	mg/L	DIL	MAE200	TSS-AQGRV
Ammonium	NH4	µM	URI	T2A	SOL69
Ammonium	NH4	µM	DIL	SKALAR	NH3-AQAAN
Phosphate	PO4	µM	URI	T2A	MURPH62
Phosphate	PO4	µM	DIL	SKALAR	PO4-AQAAN
Silver	7440-22-4	µg/L	MSL	ICPMS, GFAA	200.8. 200.9
Copper	7440-50-8	µg/L	MSL	ICPMS	200.8
Chloride	MWRA12	mg/l	DIL	METITR	4500CL-B
Fecal Coliform	FCOL	#/100 ml	DIL	MICR	MFFC
Enterococcus	ECOC	#/100 ml	DIL	MICR	MFEC
Chlorophyll a	CHLA	µg/L	UMD	FLU5	ARAR92

Table 24. Description of database codes

Field_Name	Code	Description
ANAL_LAB_ID	BOS	Battelle Ocean Sciences, Duxbury, MA
ANAL_LAB_ID	DIL	MWRA Central Lab
ANAL_LAB_ID	MSL	Marine Sciences Laboratories, Battelle, Sequim, WA
ANAL_LAB_ID	URI	Univ. Of Rhode Island – MERL
ANAL_LAB_ID	UMD	Univ. of Mass. Dartmouth
INSTR_CODE	ADCP1	ADCP 600 kHz
INSTR_CODE	CHDYE	Chelsea Fluorometer configured for dye
INSTR_CODE	CTD1	SEABIRD 9 CTD
INSTR_CODE	CTD5	OS200 CTD
INSTR_CODE	FLU5	Turner Designs 10-AU Fluorometer
INSTR_CODE	GFAA	GRAPHITE FURNACE ATOMIC ABSORPTION
INSTR_CODE	ICPMS	Inductively coupled plasma mass spec
INSTR_CODE	MAE200	Mettler AE200 4-place balance (0.1 mg)
INSTR_CODE	MET5PLACE	Mettler 5-place balance (0.01 mg)
INSTR_CODE	METITR	Mettler autotitrator
INSTR_CODE	MICR	Microscope
INSTR_CODE	PERIPUMP	Peristaltic pump
INSTR_CODE	SKALAR	Skalar autotitrator
INSTR_CODE	T2A	Technicon II Autoanalyzer
INSTR_CODE	TDDYE	Turner Designs model 10-AU configured for dye
INSTR_CODE	TR20	WET Labs 20 cm Transmissometer
INSTR_CODE	VENTURI	Venturi flowmeter
INSTR_CODE	WETSTAR	WET Labs WetStar chlorophyll a fluorometer
METH_CODE	200.8	EPA Method 200.8 and EPA (1991)
METH_CODE	200.9	EPA Method 200.9 and EPA (1991)
METH_CODE	4500CL-B	4500-CL- B Argentometric method for chloride. Standard Methods 20th Ed.
METH_CODE	ADCP	Acoustic Doppler currrent profiler
METH_CODE	ALB93	Albro *et al*. (1993)
METH_CODE	ARAR92	Arar and Collins (1992)
METH_CODE	BOSS	Battelle Ocean Sampling System
METH_CODE	BRUCE00	Bruce *et al*. 2000, CW/QAPP for plume tracking: 2000-2001
METH_CODE	GFAA	Graphite furnace atomic absorption
METH_CODE	ICPMS	Inductively coupled plasma mass spec.
METH_CODE	MFEC	Membrane filter procedure (Apha 1989, Section 9230 C) for Enterococcus
METH_CODE	MFFC	Membrane filter procedure (Apha 1989, Section 9222 D) for fecal coliform bacteria
METH_CODE	MURPH62	Murphy and Riley (1962)
METH_CODE	NH3-AQAAN	Wastewater autoanalyzer method for Ammonium
METH_CODE	PERIPUMP	Peristaltic pump
METH_CODE	PO4-AQAAN	Wastewater autoanalyzer method for Phosphate
METH_CODE	SOL69	Solorzano (1969)
METH_CODE	SOP5-053	Battelle Ocean Sciences SOP No. 5-053
METH_CODE	TSS-AQGRV	Wastewater gravimetric analysis for TSS
METH_CODE	VENTURI	Venturi flowmeter
UNIT_CODE	C	Degrees Celsius
UNIT_CODE	cm/s	centimeters per second
UNIT_CODE	m	meters
UNIT_CODE	m-1	Inverse meters
UNIT_CODE	mg/L	Milligrams per liter
UNIT_CODE	MGD	Million gallons per day
UNIT_CODE	mL/min	Milliliters per minute
UNIT_CODE	mmhos/cm	Millimhos per centimeter
UNIT_CODE	PSU	Practical salinity units
UNIT_CODE	ug/L	Micrograms per liter
UNIT_CODE	uM	Micromoles per liter

15.6 Reporting data to MWRA

The data contained in each hard copy data report are submitted to MWRA as a database export. The supporting documentation files are included with the data submission. Data deliverables will be combined only with permission from MWRA.

16.0 DATA VALIDATION

The data validation procedures for this project are defined in the HOM3 Quality Management Plan. As a part of data validation, each Task Leader ensures that:

- Any data that are hand-entered (*i.e.*, typed) are validated by qualified personnel prior to use in calculations or entry into the database.
- All manual calculations are performed by a second staff member to verify that calculations are accurate and appropriate.
- Calculations performed by software are verified at a frequency sufficient to ensure that the formulas are correct, appropriate, and consistent, and that calculations are accurately reported. All modifications to data reduction algorithms are verified prior to submission of data to the Authority.
- Electronic submissions are loaded to temporary files prior to incorporation into the database, and are analyzed selectively using methods such as scatter plots, univariate and multivariate analyses, and range checks to identify suspect values. Routine system back-ups are performed daily.
- Once data have been generated and compiled in the laboratory, senior project scientists review data to identify and make professional judgments about any suspicious values. All suspect data are reported with a qualifier. These data may not be used in calculations or data summaries without the review and approval of a knowledgeable Senior Scientist. No data measurements are eliminated from the reported data or database and data gaps are never filled based on other existing data. If samples are lost during shipment or analysis, it is documented in the data reports to the Authority and noted in the database.

17.0 PERFORMANCE AND SYSTEM AUDITS

The Battelle QA Officer for the Harbor and Outfall Monitoring Project is Ms. Rosanna Buhl. She will direct the conduct of at least one systems audit to ensure that Task 11 (and related) plume tracking activities are carried out in accordance with this CW/QAPP. A systems audit will verify the implementation of the Quality Management Plan and this CW/QAPP for the work conducted in the Water Quality monitoring.

Tabular data reported in deliverables, and associated raw data generated by Battelle will be audited under the direction of the Project QA Officer. Raw data will be reviewed for completeness and proper documentation. For electronically acquired data (*e.g.*, navigational data), Ms. Buhl will verify that computer software used to process the data has been validated. Errors noted in data audits will be communicated to analysts and corrected data will be verified.

Audits of the data collection procedures at subcontractor laboratories will be the responsibility of the Subcontractor. Each subcontractor is fully responsible for the QA of the data it submits. Data must be

submitted in CW/QAPP-prescribed formats; no other will be acceptable. During the time work is in progress, an inspection will be conducted by the subcontractor QA Officer or their designee to evaluate the laboratory data-production process. All data must be reviewed by the subcontractor QA Officer prior to submission to the Battelle Database Manager and must be accompanied by a signed QA statement that describes the types of audits and reviews conducted and any outstanding issues that could affect data quality and a QC narrative of activities.

The Battelle QA Officer will conduct an initiation audit and, as needed, a laboratory inspection to access compliance with the Quality Management Plan and this CW/QAPP. Performance audits, procedures used to determine quantitatively the accuracy of the total measurement system or its components, will be the responsibility of the subcontractor laboratory and may include internal performance evaluation samples and participation in external certification programs.

18.0 CORRECTIVE ACTION

All technical personnel share responsibility for identifying and resolving problems encountered in the routine performance of their duties. Dr. Carlton Hunt, Battelle's Project Manager, will be accountable to MWRA and to Battelle management for overall conduct of the Harbor and Outfall Monitoring Project, including the schedule, costs, and technical performance. He is responsible for identifying and resolving problems that (1) have not been addressed timely or successfully at a lower level, (2) influence multiple components of the project, (3) necessitate changes in this CW/QAPP, or (4) require consultation with Battelle management or with MWRA.

Identification of problems and corrective action at the laboratory level (such as meeting data quality requirements) will be resolved by laboratory staff or by Subcontractor Managers. Issues that affect schedule, cost, or performance of the plume tracking tasks will be reported to the Task Leader or to the Battelle Project Manager. They will be responsible for evaluating the overall impact of the problem on the project and for discussing corrective actions with the MWRA Project Manager. Problems identified by the QA Officer will be reported and corrected as described in Section 17.0 and will be listed in the QA/QC Corrective Action Log described in the QMP (Battelle 1998).

19.0 REPORTS

19.1 Survey-related reports

For each plume tracking exercise, one survey plan and one survey report will be prepared. The shakedown survey report will be expanded to include results and discussion of the shakedown exercise, both dye addition and field survey, and will include recommendations and modifications for the full surveys.

19.1.1 Survey Plans

A survey plan will be prepared for each plume tracking exercise. The following sections, established by U.S. Environmental Protection Agency for surveys using the OSV *Anderson*, will be presented. Each survey plan will be submitted as a final unbound, double side copy on 3-hole paper at least two weeks prior to the start of the exercise.

- Purpose, background, and data use for survey
- Schedule of operations

- Specific survey tracklines
- Survey/sampling methods
- Navigation and positioning control
- Vessel, equipment, and supplies
- Scientific party
- Documentation of any deviations from this CW/QAPP
- Predicted tide and tidal currents for each survey day (determined 0.2 nm south of Boston Light using Micronautics, Inc. Tide.1 and Tide.2 software)

19.1.2 Survey Reports

Survey reports will describe the survey conducted, measurements made, samples collected, problems experienced, general observations of water quality, and summarize observations made by the certified whale observer. Each survey report will include some interpretive results including identification of the value of minimum dilution and notification of possible exceedance of the Contingency Plan warning level (MWRA 1997a). Survey reports are expected to be 5-10 pages of text with accompanying station maps and sample collection table. The winter shakedown survey report will include results and discussion of the shakedown exercise plus any recommendations for changes to the summer survey.

The sample collection table will be a tabular summary of sampling locations and samples collected. These data will be generated directly from the Battelle HOM3 database. Any deviations from this CW/QAPP, not known at the time of survey plan preparation, will also be incorporated into the survey reports. Two unbound, single-sided copies of the draft survey report will be submitted to MWRA no later than two weeks after the completion of each survey. MWRA's comments on the report will be due to Battelle two weeks after receipt of the draft report. The final survey report, addressing MWRA's comments, will be due to MWRA two weeks after receipt of the comments. If MWRA does not submit comments within the two-week period, the draft survey report will be considered final.

19.2 Data Reports

Four plume tracking data reports will be submitted to MWRA. One report for each survey will include discrete sample results and one will include the sensor data fully calibrated to the discrete samples where appropriate. Each report is final. The data reports are formatted to provide a user-friendly view of the data. The data reports are created directly from the Battelle version of the EM&MS. The format and the content of the data report are reviewed with the MWRA technical task leader prior to the submission of the first set. All subsequent reports are submitted in this format.

The discrete sample data reports will contain tabular summaries of concentrations of all measurements including Rhodamine, ammonium, phosphate, silver, copper, chlorophyll and pheopigments, and TSS for each sample collected and analyzed. MWRA will report the chloride and fecal coliform/Enterococci. The sensor report will present hydrographic data (position, salinity, temperature, density, depth, Rhodamine WT dye fluorescence, chlorophyll fluorescence, and optical transmittance), ADCP data (current and direction by depth bin) and meteorological data from Deer Island.

19.3 Modeling Reports

The field data will be used to develop modeling reports. These reports will describe the data used in the models and the model output. The dilution performance of the outfall will be evaluated and compared with results of the RSB model A draft and final report for each survey will be prepared. The results will be included in the syntheses reports developed for each survey. Each modeling report will address the following areas:

- Executive Summary
- Introduction (report purpose, report organization)
- Data Sources and Overview of Modeling Objectives
- Summary of Methods and Data used for the Modeling
- Results (RSB Model data)
- Discussions

  Compare RSB model output to the physical model of Roberts and Snyder (1993a, b)
- Conclusions & Recommendations
- References

19.4 Interpretive Reports

A plume tracking interpretive report will be developed for each survey. Each plume tracking interpretive report will address the following areas:

- Executive Summary
- Introduction (program overview, report purpose, report organization)
- Data Sources and Overview of Plume Tracking Objectives
- Summary of Methods
- Results (Effluent data, Field data and RSB Model data)
  - The combined data from the HMZ and nearfield surveys will be used to provide contours of dilution over relatively small scales in the immediate vicinity of the outfall.
  - Data collected during the farfield surveys will be used to demonstrate the dispersion of the plume over longer time scales.
  - Contour plots of temperature, salinity, and Rhodamine WT dye will be used for visualization of the data in the data report.
  - Parameter-parameter plots will show co-dilution of the constituents measured and identify characteristics of endmember water masses mixing in the nearfield.
  - The results of the RSB model runs will be included in the data report, including the input parameters used for modeling and the output of the model for each run.
- Discussions
  - Comparison of the 2 plume tracking exercises
  - Comparison of actual data compared to the RSB model output
- Conclusions & Recommendations
- References

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APPENDIX A

Right Whale Guidance Protocol for Vessels Operated/Contracted by the Commonwealth of Massachusetts (21 November 1997)

Guidance Protocol on the Interaction with Whales Specifically Northern Right Whales for Vessels Operated/Contracted by the Commonwealth of Massachusetts

Introduction

The northern right whale is the most endangered large whale in the world. In the western north Atlantic the population is estimated to be about 300 animals. Massachusetts coastal waters are part of the range of the northern right whale and Cape Cod Bay has been designated a critical habitat for the whale under the federal Endangered Species Act because of its high use by the species in the late winter and early spring for feeding. The Great South Channel, east of Cape Cod, has also been designated critical habitat because of its importance to the right whale as a feeding area. It has been determined that the most significant human induced causes of mortality are ship strike and entanglements in fishing gear.

Purpose

The purpose of this protocol is to give guidance to the vessels owned by the Commonwealth and those operating under contract to the Commonwealth as to proper operational procedures if the vessels should encounter whales - *i.e.* sighting and reporting procedures, and entanglement and carcass reporting protocol.

Applicability

This protocol will apply to all vessels owned by the Commonwealth of Massachusetts and/or contracted out by the Commonwealth of Massachusetts.

Geographic Scope/Operational Scope

This protocol applies to all applicable vessels operating in or adjacent to Commonwealth waters. When vessels are operating in the designated critical habitat areas (Cape Cod Bay or the Great South Channel) heightened operation is applicable, especially during the late winter and spring when the right whales are expected to be located in these areas.

Sightings of Right Whales

The Executive Office of Environmental Affairs and the National Marine Fisheries Service is interested in receiving reports from individuals who observe right whales during vessel operations. Reports should be made to the National Marine Fisheries Service Clearinghouse. Patricia Gerrior, NMFS Right Whale Early Warning System Coordinator, who manages the Clearinghouse and her numbers are 508-495-2264 (work), 508-495-2393 (fax) and pager 508-585-8473. Please report your name, agency and phone numbers at which you can be contacted. The vessel's name, the date, time and location of the sighting, the numbers of whales sighted and any other comments that may be of importance. If a camera or video camera is available please take some photographs. These photographs should be provided to Pat Gerrior or Dan McKiernan, Massachusetts Division of Marine Fisheries. They will in turn send copies to the New England Aquarium for comparison to the Right Whale Photo Identification Catalog. **Please remember that Massachusetts has Right Whale Conservation Regulations (322 CMR 12:00) which establishes a 500 yard buffer zone surrounding a right whale. Vessels shall depart immediately from any buffer zone created by the surfacing of a right whale.**

Physical Contact with a Whale

If a vessel owned by the Commonwealth of Massachusetts or under contract with the Commonwealth of Massachusetts comes into physical contact with any whale it should be noted in the vessel's logbook. The vessel's logbook should include the time and location of the incident; weather and sea conditions; vessel speed; the species of whale struck if known; the nature of any injures to crew, and/or the whale, and/or damage to the vessel. Also, record the name of any other vessels in the area that may have witnessed the incident or can provide information about circumstances. A copy of the vessel's log for the entire trip should be submitted to the Director of the Division of Marine Fisheries, the Director of the Division of Law Enforcement, the Secretary of Environmental Affairs and the National Marine Fisheries Service, Northeast Region in Gloucester.

If after hitting the whale, the animal is incapacitated or appears to have life threatening injuries and the vessel is safe and secure, immediately call the Center for Coastal Studies, entanglement hotline at 800-900-3622 or via their pager at 508-803-0204 and the Massachusetts Environmental Police Communications Center at 800-632-8075 or 617-727-6398. Stay with the whale until the Coast Guard or Center for Coastal Studies arrives on scene.

Entanglements

If the vessel comes upon or entangles a right whale, immediately notify the Center for Coastal Studies' entanglement hotline at 800-900-3622 or via their pager at 508-803-0204 and the Massachusetts Environmental Police Communications Center at 800-632-8075 or 617-727-6398. Do not attempt to remove any debris from the whale, stay on station with the whale or follow at a safe distance. As relocating an entangled whale can be extremely difficult, staying on station or following the animal is very important. However, if following the whale is not possible contact, the Coast Guard and/or the Center for Coastal Studies and note the last direction the animal was heading and any other pertinent information that would assist in relocating the whale.

Stranded Whales

For a stranded right whale please notify the Stranding Network immediately call Connie Merigo or Howard Krum, New England Aquarium, Central Wharf, Boston, MA 02110. The standing Network's hotline is 617-973-5247 (pager) or as a second resort call 617-973-5246/6551.

QUICK REFERENCE

Sightings & Photographs

Patricia Gerrior, NMFS Right Whale Early Warning System Coordinator, manages the Clearinghouse and her numbers are 508-495-2264 (work), 508-495-2393 (fax) and pager 508-585-8473

Photographs

Dan McKiernan, Massachusetts Division of Marine Fisheries, 19th Floor, 100 Cambridge Street, Boston, MA 02202. 617-727-3193 ext. 369.

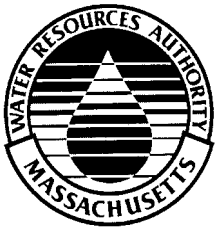
Entanglements or Injured whales

Center for Coastal Studies, entanglement hotline at 800-900-3622 or pager at 508-803-0204

Massachusetts Environmental Police Communications Center at 800-632-8075 or 617-727-6398.

Stranded Animals

The standing Network's hotline is 617-973-5247 (pager) or as a second resort call 617-973-5246/6551.



Massachusetts Water Resources Authority
Charlestown Navy Yard
100 First Avenue
Boston, MA 02129
(617) 242-6000
http://www.mwra.state.ma.us