WP012

SUMMER PLUME TRACKING SURVEY REPORT

FOR

WATER QUALITY MONITORING
Task 11
MWRA Harbor and Outfall Monitoring Project

Submitted to

MASSACHUSETTS WATER RESOURCES AUTHORITY
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TABLE OF CONTENTS – WP012

LIST OF TABLES

LIST OF FIGURES

1.0 Introduction

On July 16-20, 2001 the Summer Plume Tracking survey WP012 was conducted at Deer Island Treatment Plant (DITP) and Massachusetts Bay. The summer plume tracking survey was conducted to collect *in situ* data on dye added to the effluent, other *in situ* parameters, and discrete samples within the MWRA outfall plume. The results from this survey will be used to certify the dilution of the MWRA plume as required under the NPDES Permit in a report due in April 2002. Estimates of initial dilution of the DITP effluent were developed based on dye concentration in discrete samples from the effluent and within the dye plume near the diffuser in Massachusetts Bay. The survey also tracked the dispersion of the effluent plume away from the diffuser line. Rhodamine WT dye was added at MWRA's Deer Island Treatment Plant (DITP) and traced offshore for three days. The *R/V Aquamonitor,* a 45-foot research vessel, served as the sampling platform during the offshore survey. Mobilization efforts were conducted while the vessel was docked at Hewitt's Cove Marina in Hingham, Massachusetts.

Additional surveys were performed during the study by the United States Environmental Protection Agency and National Oceanic and Atmospheric Administration. Offshore efforts were coordinated. Results developed by EPA are not included in this report.

1.1 Personnel

Mr. Bob Ryder captained the vessel. Table 1 lists the scientific crews at each location. Dr. Phil Roberts observed the offshore operations, as did Dr. Michael Mickelson of MWRA.

Table 1. Survey Personnel for Summer Plume Tracking Survey WP012.

Activity: **Date:** **Location:**	Mobilization 7/13/01 Hingham & DITP	Dye Addition 7/16-17/01 DI Plant	Nearfield Day 7/17/01 Diffuser area	Farfield Day 7/18/01 Mass Bay	Farfield Day 7/19/01 Mass Bay	Demobilization 7/20 Hingham & DITP
Battelle						
Chief Scientist	A. Mansfield	NA	A. Mansfield	A. Mansfield	A. Mansfield	A. Mansfield
NAVSAM / ADCP Operator	B. Mandeville	B. Mandeville	C. Albro	C. Albro	C. Albro	C. Albro
Principal investigator	--	--	C. Hunt	--	--	--
Technician	T. Kaufman	T. Kaufman	B. Curtis	B. Curtis	B. Curtis	B. Curtis
Technician	--	L. Gilday	N. Jenkins	--	--	--
Contractors						
Captain	--	--	B. Ryder	B. Ryder	B. Ryder	--
Observer	--	--	P. Roberts	P. Roberts	P. Roberts	--
MWRA Observer	--	M. Mickelson	M. Mickelson	--	--	--
At-sea Totals	NA	NA	8	5	5	NA

1.2 Activities

Mobilization for the survey was conducted on Friday, July 13th. On Monday July 16, and Tuesday July 17, 2001, the Dye Addition portion of the Summer Plume Tracking was successfully completed. The Nearfield portion of the Summer Plume Tracking survey was conducted on July 17th. The Farfield portion was conducted on July 18th and 19th.

The 2001 Summer Plume Tracking was broken into two major survey components: 1) Deer Island Treatment Plant and 2) the offshore field program. The offshore component was comprised of four distinct surveys types 1) a background survey, 2) exploratory surveys, 3) three hydraulic mixing zone (HMZ)[1] surveys, and 4) a farfield tracking survey. The first three activities occurred on day 1. The farfield surveys took place on the second and third field days. During the surveys, both *in situ* and discrete samples were collected. The details of each of these components are given below.

2.0 Dye Addition and Monitoring Activities at DITP

Activities conducted at DITP included 1) dye addition, 2) *in situ* effluent monitoring, and 3) collection of discrete effluent samples.

2.1 Methods

2.1.1 Dye Addition:

Rhodamine WT dye solution (20% w/v active ingredient) was added to the primary/secondary blended effluent channel at the Deer Island Treatment Plant downstream of the secondary clarifiers (Figure 1) at a location of vigorous mixing (near the riser shaft for clarifier B). This provided vigorous mixing before the flow split into two streams leading to the sodium hypochlorite dosing points, the hypochlorite mixers and the two disinfection basins. The hypochlorite mixers blend the effluent with chlorine (as sodium hypochlorite (NaOCl); pre-diluted to ~500 mg/L). The addition of the dye upstream of the hypochlorite mixers allowed vigorous mixing of the dye and effluent. The target dye concentration was 75 µg/L (75 ppb).

Rhodamine WT dye purchased from Keystone Aniline Corporation at a concentration of 20% wt/vol was transferred from the shipping container to the primary/secondary blended effluent channel using a Masterflex L/S computer-compatible peristaltic pump (model 07550-10 with dual 07016-20 heads). The dye was injected directly into the effluent. The pump speed was controlled by a 4-20 mA signal provided by the DITP's process control computer. The signal was proportional to the "official plant flow" which is the sum of the four main venturi flow meters in the primary treatment tanks. The DITP process control computer smoothed and lagged the signal by three minutes to approximate flow at the point of dye injection and reduce rapid fluctuation of the pump RPM. The dye injection rate, i.e. pump speed, was

[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 refered 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.

recorded periodically throughout the dye addition, and on each occasion the plant flow rate was verified by the DITP operators.

2.1.2 Dye Monitoring (*in situ* sampling)

The dye-dosed effluent was monitored with *in situ* instrumentation and sampled at the most downstream end of the west disinfection basin. Dye fluorescence, temperature, conductivity, density, and turbidity were continuously measured at this point (just prior to effluent entering the effluent tunnel). An Ocean Sensors OS200 CTD package with a Seapoint rhodamine WT fluorometer[2] and Seapoint turbidity meter[2] were suspended in the disinfection basin. Data was collected from the sensors by the Battelle Ocean Sampling System (BOSS). Prior to dye addition and approximately 1 hour after the start of dye addition, vertical profiles were conducted within the west disinfection basin. Each time profiles were conducted at three locations: 1) at 5' from the west wall, 2) in the center of the basin and 3) at 5' from east wall of the basin. At each location the sensors were lowered to 2.5-3 meters, then brought back to the surface. The dye concentration appeared to be uniform across all locations and depths sampled. As a result, *in situ* monitoring was conducted at the center of the west basin at approximately 2m depth for the remainder of the survey. See section 4.2.1 for dye concentrations.

2.1.3 Discrete Effluent Sampling

In addition to the continuous *in situ* monitoring of the effluent, a set of discrete effluent samples was collected at DITP. Samples were obtained for analysis of Rhodamine WT, chloride, total suspended solids (TSS), ammonium (NH_4), phosphate (PO_4), silver (Ag), copper (Cu), and fecal coliform/*Enterococcus*. Samples were collected just prior to dye addition and then periodically (Table 2) over the 6-hour period that the dye was released. A submersible pump was placed near the east wall of the west basin and discrete samples were collected as grabs from the pump flow. Samples were also collected from the east basin for Rhodamine analysis only. These samples were collected as grabs along the western edge of the east basin. The samples were analyzed by either Battelle or by MWRA's Deer Island Laboratory (DIL). TSS and nutrients were measured by both labs to allow comparison of standard-oceanographic to EPA-approved methods. Table 2 lists all samples collected at Deer Island Treatment Plant.

[2] Note: this is a change from the CW/QAPP (2000). The *in situ* rhodamine fluorometer replaced the Turner designs 10-AU flow-through fluorometer. The *in situ* turbidity sensor was added. The changes were approved in advance by MWRA.

Figure 1. Schematic of DITP Dye Addition and Sampling Locations.

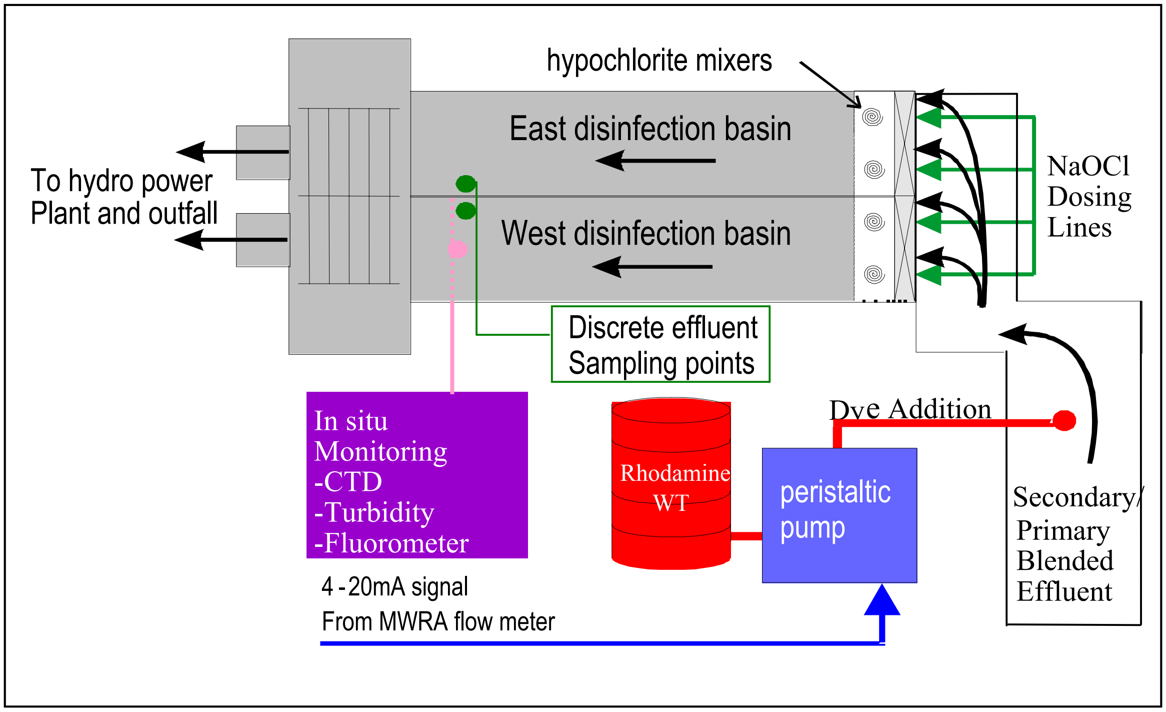


Table 2. Samples Collected For Analysis From the West Basin* During the Dye Addition Survey at DITP.

Parameter	Planned Samples		Actual Samples	
	For MWRA DIL	For Battelle	For MWRA DIL	For Battelle
Rhodamine WT	None	1 sample/ 1/2 hour from each basin (26 total)*	None	26
Chloride	1 sample/ 1/2 hour (13 total)	None	13	None
TSS	1 sample/ 1/2 hour (13 total)	1 sample/ hour (7 total)	13	7
NH_4/PO_4	--	1 sample/hour (7 total)	--	7
NH_4	1 sample/ 1/2 hour (13 total)	--	13	--
PO_4	1 sample/ 1/2 hour (13 total)	--	13	--
Ag/Cu	None	1 sample/ hour (7 total)	None	7
Fecal Coliform/ *Enterococcus*	1 sample/ hour (7 total)	None	7	None

*Note: Rhodamine samples were collected from each basin; all other samples were collected from the west basin only

2.2 Chronology of Dye addition activities at DITP

All times in this report are Eastern Daylight Time (EDT) except for Appendix 1 which is in Eastern Standard Time (EST).

Monday, July 16, 2001

1830	Dye addition team loads equipment at Battelle and departs for DITP.
2000	Arrive at DITP begin equipment set-up.
2045	Run test of dye addition pump, with no dye.
2124	All equipment set up and in place. Testing complete, systems check out.
2126	1st profile of disinfection basin conducted (pre-dye). West side of west basin, ~5' from west wall. Profile to 3 m deep.
2130	2nd profile of disinfection basin conducted (pre-dye). Mid-way across west basin. Profile to 2.5 m deep. CTD Serial# 521 not working, switch to serial# 464. 464 is due for calibration.
2132	3rd profile of disinfection basin conducted (pre-dye). East side of west basin, ~5' from east wall.
2135	Background samples collected. (1st "hourly" sample set)
2145	Dye addition begins.
2202	First detection of dye at monitoring point.
2245	Collect "half-hourly" sample set.
2252	Profile of disinfection basin conducted. East side of west basin, ~5' from east wall. Profile to 2.5 m deep.
2256	Profile of disinfection basin conducted. West side of west basin, ~5' from west wall.
2257	Profile of disinfection basin conducted. Mid-way across west basin. Profile to ~2 m deep. Leave sensors at mid basin ~2m deep for remainder of monitoring.
2259	Collect "hourly" sample set.
2329	Collect "half-hourly" sample set.
2358	Collect "hourly" sample set.

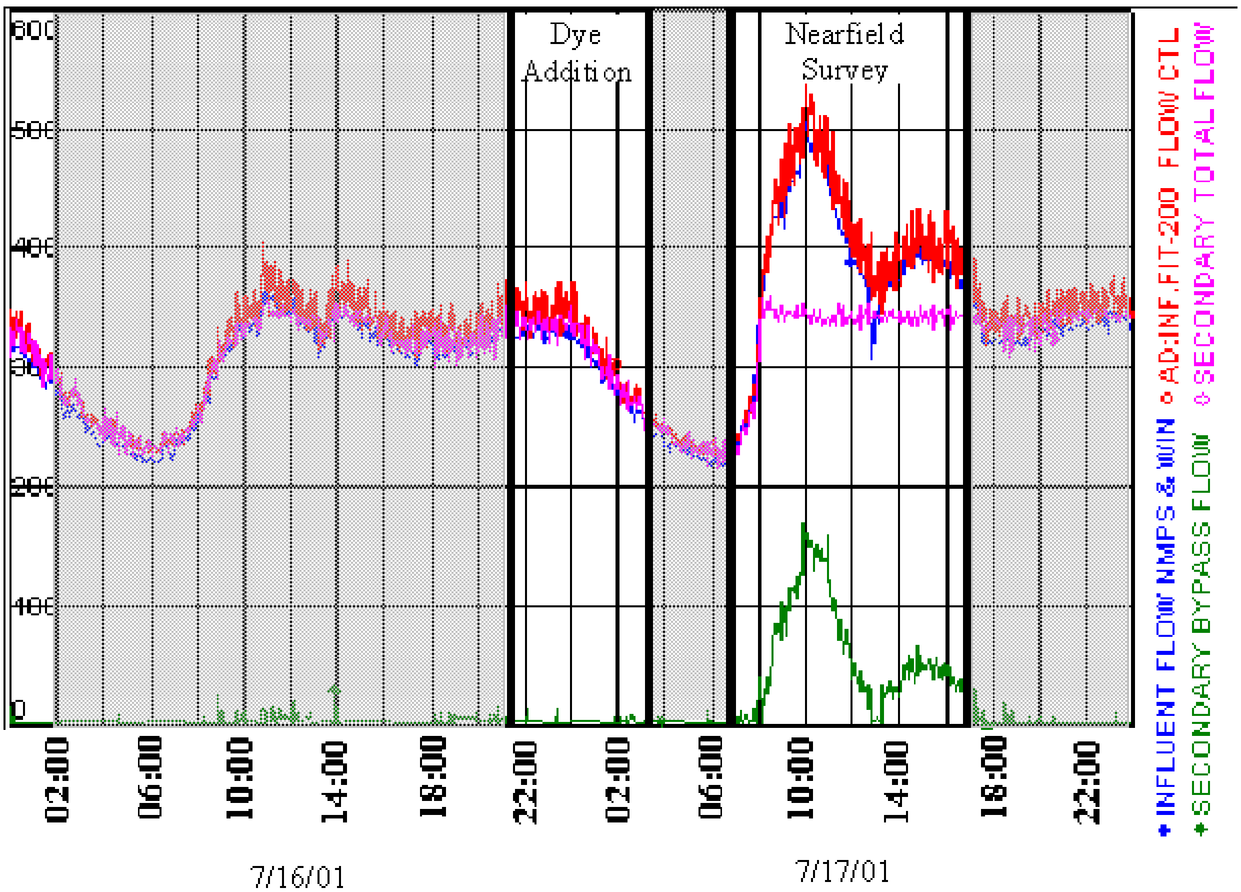
Tuesday, July 17, 2001 Dye addition activities at DITP continued

0029	Collect "half-hourly" sample set. Samples delivered to DITP sample bank drop-off refrigerator.
0102	Collect "hourly" sample set.
0130	Collect "half-hourly" sample set.
0158	Collect "hourly" sample set.
0226	Collect "half-hourly" sample set. Samples delivered to DITP sample bank drop-off refrigerator.
0258	Collect "hourly" sample set.
0328	Collect "half-hourly" sample set.
0345	Dye addition terminated
0413	Noticeable decline in dye concentration.
0540	Final "hourly" sample set collected. Equipment demobilized.

2.3 Results of DITP monitoring

The DITP effluent flow rate varied from 346 MGD at the start of dye injection, to a peak of ~370 MGD at midnight, to 254 MGD at the end of dye injection. Figure 2 shows the DITP plant flows during the hours of the dye addition and the nearfield survey (0.3 inches of rain caused an increased flow on 7/17/01).

Figure 2. DITP Flow Rates During the Survey Period[2]



The discrete dye samples collected from the disinfection basins during dye addition were analyzed at Battelle on 8/6/01. Figure 3 depicts the DITP dye concentrations throughout the addition period; discrete sample values are also shown. All *in situ* data was collected in the west disinfection basin. Discrete samples from both the east and west basins are shown in the figure. Table 3 shows rhodamine concentrations measured from discrete sample collections for each disinfection basin, highlighted values were not included in the averages as they represent increasing or decreasing, rather than stable dye concentrations in the effluent. Discrete samples collected in the east basin had slightly higher (0.22 µg/L) concentrations than those in the west basin.

[2] Data provided by MWRA

Figure 3. DITP *in situ* and Discrete Dye Concentrations

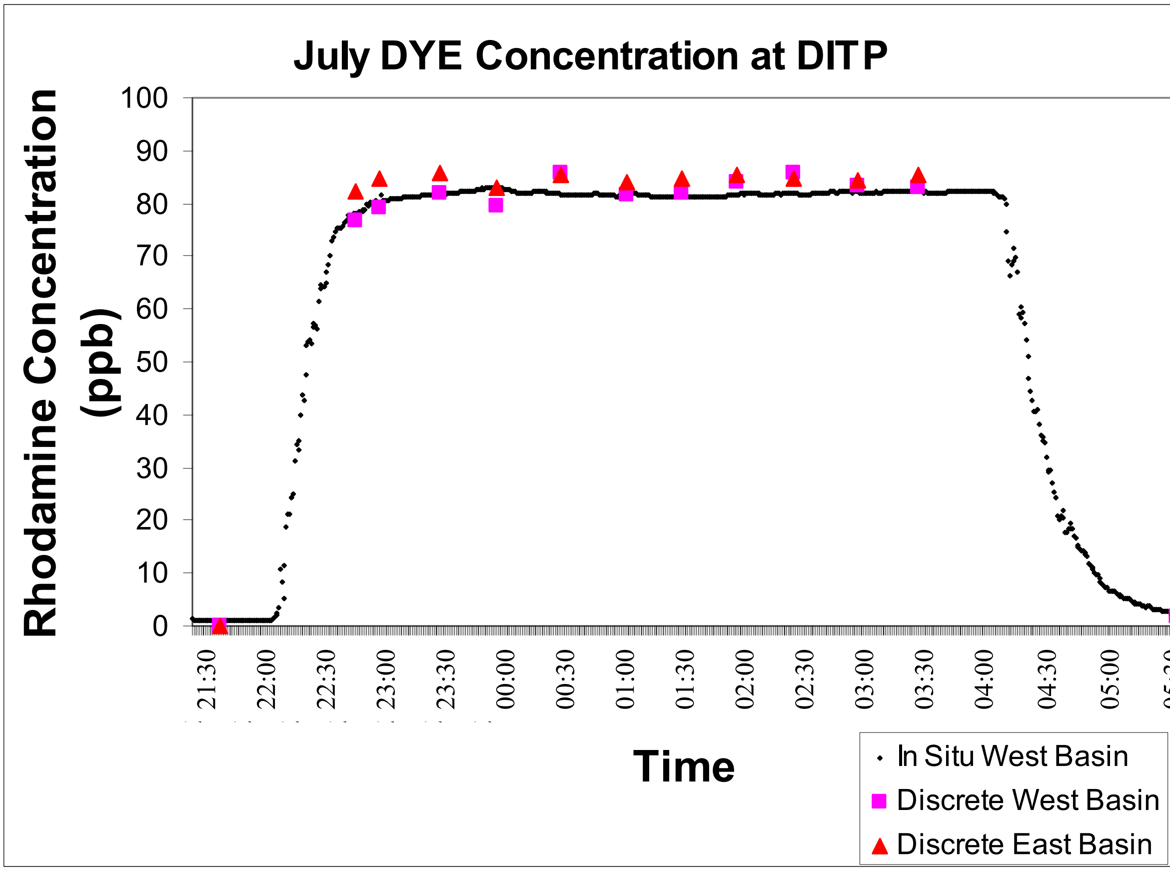


Table 3. Dye concentrations (µg/L) in the East and West Disinfection Basins

	Dye east basin	Dye west basin
	0.13	0.12
	82.13	76.77
	84.81	79.06
	85.74	82.06
	82.84	79.42
	85.36	85.64
	83.99	81.48
	84.83	82.02
	84.16	85.56
	84.80	85.71
	84.55	83.45
	85.25	82.82
	3.48	1.77
Mean	**84.41**	**82.18**
STDEV	**1.09**	**2.92**
CV%	**1.29**	**3.55**
	Overall mean	***83.3***

Four 30-gallon (capacity) barrels of Rhodamine WT dye were purchased and available for the dye addition. Of the four dye barrels, two were from Keystone lot #566 and two were from lot #209 (only the barrels from lot #209 were used during the dye addition). Each barrel was assigned a number (1-4), which was written on the side and top. On Monday, July 16, 2001 each of the four dye barrels was weighed at DITP. Following the survey (11/7/01) each of the barrels was again weighed at DITP. Table 4 lists the initial and final weights of the dye barrels as well as the total weight added to the effluent stream from each barrel. The total weight of Rhodamine WT dye added to the effluent during the 6-hour dye addition was 288.5 lbs. This total weight is within 10% of preliminary calculations based on DITP and dye flow rates. Over the 6-hour dye addition period, effluent flow rate at DITP fluctuated from 256 to 350 MGD with an average of 314 MGD. Based on these flow rates and a dye addition rate which maintained an average of 83.3 µg/L in the effluent, the overall weight used would be 308 lbs. This is a rough calculation, a more detailed analysis will be included in the synthesis report.

Table 4 Weight of Rhodamine Dye Barrels

	Lot #566		**Lot #209**	
Barrel #	**1**	**3**	**2**	**4**
Initial weight (lbs)	270	269	275	269
Final weight	270	269	137	118.5
Weight of dye added	0	0	138	150.5

3.0 Offshore Activities

The offshore survey consisted of three separate survey types 1) Background surveys to measure conditions without dye, 2) a "Nearfield" conducted in the immediate vicinity of the outfall diffuser as dye emerged and 3) a "Farfield" following the dye plume as it was transported away from the diffuser area. The Nearfield survey included exploratory measurements to determine initial dye behavior and a series of three hydraulic mixing zone studies to map the characteristics of the dye field and collect discrete samples. The farfield survey was conducted over the course of two days. Each portion is described in detail in the following sections. Section 3.4 contains a chronology of all offshore activities.

3.1 Methods

3.1.1 *In situ* data collection

Plume tracking was conducted using a second Battelle Ocean Sampling System (BOSS) deployed from Battelle's *R/V Aquamonitor*. The BOSS *in situ* sensor package included: a Rhodamine fluorometer (Seapoint), a CTD (which measures temperature, conductivity, and pressure (for depth)), and light transmission (Sea Tech transmissometer). Depth of the towed sensor package was controlled by vessel speed and by winch. The BOSS sensor package was paid out off the stern of the vessel using the winch at a rate of 0 - 1.0 meters/second. The plume tracking exercise utilized the BOSS in three sampling modes 1) vertical profile, 2) constant-depth towing, and 3) towyo. In vertical profiling mode data was acquired as a function of depth while the vessel remained stationary. During towyo mode the BOSS was operated in a vertically undulating (ascent and descent) pattern to obtain data continuously at different depths while underway.

The vessel also deployed a downward looking Acoustic Doppler Current Profiler (ADCP). This provided 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 also provided relative backscatter amplitude through the whole water column at the same resolution.

3.1.2 Discrete sample collection

An electrical-mechanical cable (200 ft long) with a Teflon tube down the middle of the cable was used for the towing operations described above. This system allowed collection of discrete water samples during the background and hydraulic mixing zone surveys. This cable was used during the entire survey.

During the background and hydraulic mixing zone surveys discrete samples were collected for analysis of TSS, NH_4, PO_4, rhodamine, chlorophyll, silver and copper. On the 2^{nd} and 3^{rd} HMZ transects samples were also collected for bacterial indicators (Fecal Coliform/ *Enterococcus*).

Discrete samples were obtained using the submersible pumping subsystem of the BOSS. Water is pumped to a sample collection station onboard the vessel by an internal gear pump located on the towed body. The pump provided a flow rate of 14 Lpm, which translates into a 29-second transit time from pump inlet to collection onboard. This lag time was verified using an onboard flow-through transmissometer. The transmissometer readings (inboard and outboard) were compared to ensure that the discrete sample is representative of the parcel of water measured by the *in situ* sensors. Collection procedures were as follows: 1) The towed body was lowered to the appropriate sampling depth, 2) the NAVSAM operator marked the start of the sampling event and began a countdown based on the hose transit time, 3) with 10-20 seconds left on the countdown, the sampling technician was instructed to rinse the suite of bottles used for that sampling event, 4) when the countdown reached zero, the sampling technician was instructed to collect the sample water, 5) the start and finish of discrete collections were marked by the NAVSAM operator.

Samples for NH_4/PO_4 and Chlorophyll were filtered onboard. Water samples for TSS, metals and Fecal Coliform/ *Enterococcus* were collected but not processed onboard. Following the survey, all samples were transferred to the appropriate laboratories for analysis. The Fecal Coliform/ *Enterococcus* samples were delivered to the DITP laboratory at the end of the survey day. All holding times were met. Table 5 lists all samples collected during the offshore surveys.

Table 5. Samples Collected For Analysis During the Nearfield Survey WP012.

	Planned Samples		**Actual Samples**			
Parameter	**From Background Survey**	**From each HMZ survey**	**From Background Survey**	**From HMZ #1**	**From HMZ #2**	**From HMZ #3**
Rhodamine WT	4	9	4	3	9	9
TSS	4	9	4	3	9	9
NH_4/PO_4	4	9	4	3	9	9
Ag/Cu Total	2	2	2	2	3	3
Fecal Coliform/ *Enterococcus*	0	9 (last 2 surveys only)	0	0	9	9
Chlorophyll	4	9	4	3	9	9

3.2 Nearfield Surveys

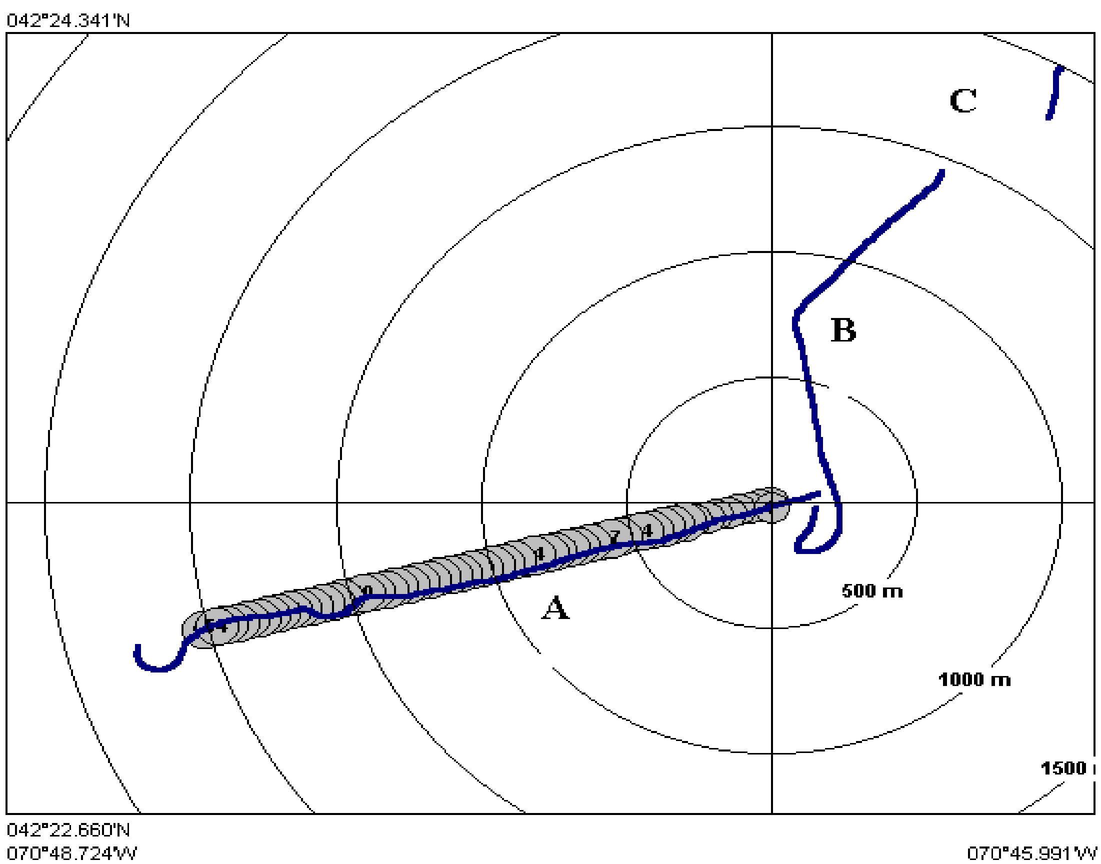
The nearfield portion of the MWRA summer plume tracking survey was conducted on July 17 between 0800 and 1700. The three survey types, 1) background, 2) exploratory and 3) HMZ, are described in detail in the following subsections.

3.2.1 Background Survey

The objective of the background survey was 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 the region influenced by the effluent.

The background survey was conducted prior to dye emergence from the outfall diffusers. The tracklines of the background survey are shown in Figure 4. Upon arriving in the diffuser area, a towyo trackline was conducted from west to east directly down the diffuser line (labeled "A" in Figure 4). This trackline was conducted to collect *in situ* background values within the effluent plume area and to determine the direction of currents in the area. Section "B" of the background transect was a towyo operation away from the diffuser area to a location outside of the effluent plume. The direction was established because currents were slightly to the west and the tide stage was approaching high flood. Section "C" of the background survey was the location for collection of discrete background samples. Samples collected during the background survey are listed in Table 5.

Figure 4. Background survey Transect.



3.2.2 Exploratory Surveys

Exploratory transects were conducted before the dye emerged from the first diffuser to define the hydrographic gradients in the water column near the diffuser line and current direction and velocity before emergence of dye. Once dye was detected, additional exploratory transects were conducted to define the behavior of the dye. Transects were conducted west of and perpendicular to the diffuser line before dye emerged from riser #55 (the furthest inshore). Figure 5 shows the pre-dye exploratory transects. Figure 6 shows a profile of the water column from the combined pre-dye exploratory transects. This includes the initial detection of dye at 10:27 AM over riser #55. Once dye began to emerge from the diffuser, perpendicular transects were continued around the west end of the diffuser line (between 55 and 51). This served two purposes: 1) it allowed time for the dye emergence to reach a steady state and 2) it provided a general characterization of the dye plume, prior to conducting the HMZ transects and sample collection. These transects were conducted in the dye (thus effluent) field and were conducted perpendicular to the diffuser line at both fixed depths and under towyo operations. Figure 7 shows the post-dye emergence exploratory transects and a general indication of the early plume dispersion; the start time of each trackline is included. The transects shown in Figure 7 were collected under Towyo conditions; dye concentrations are from variable depths. Figure 8 shows a profile of the water column from the combined post-dye exploratory transects. Results from these transects were used to help determine the location, duration and direction of the HMZ transects. No discrete samples were collected during the exploratory transects.

A fairly strong stratification, typical of Mass Bay summer conditions, was observed in the water column in the diffuser area. The pycnocline was located between 5 and 10 meters deep and was mostly temperature driven. Temperatures in the surface waters were ~15.5° while waters below 10 m were generally less than 8°C.

Figure 5. Pre-Dye Exploratory Survey Tracklines

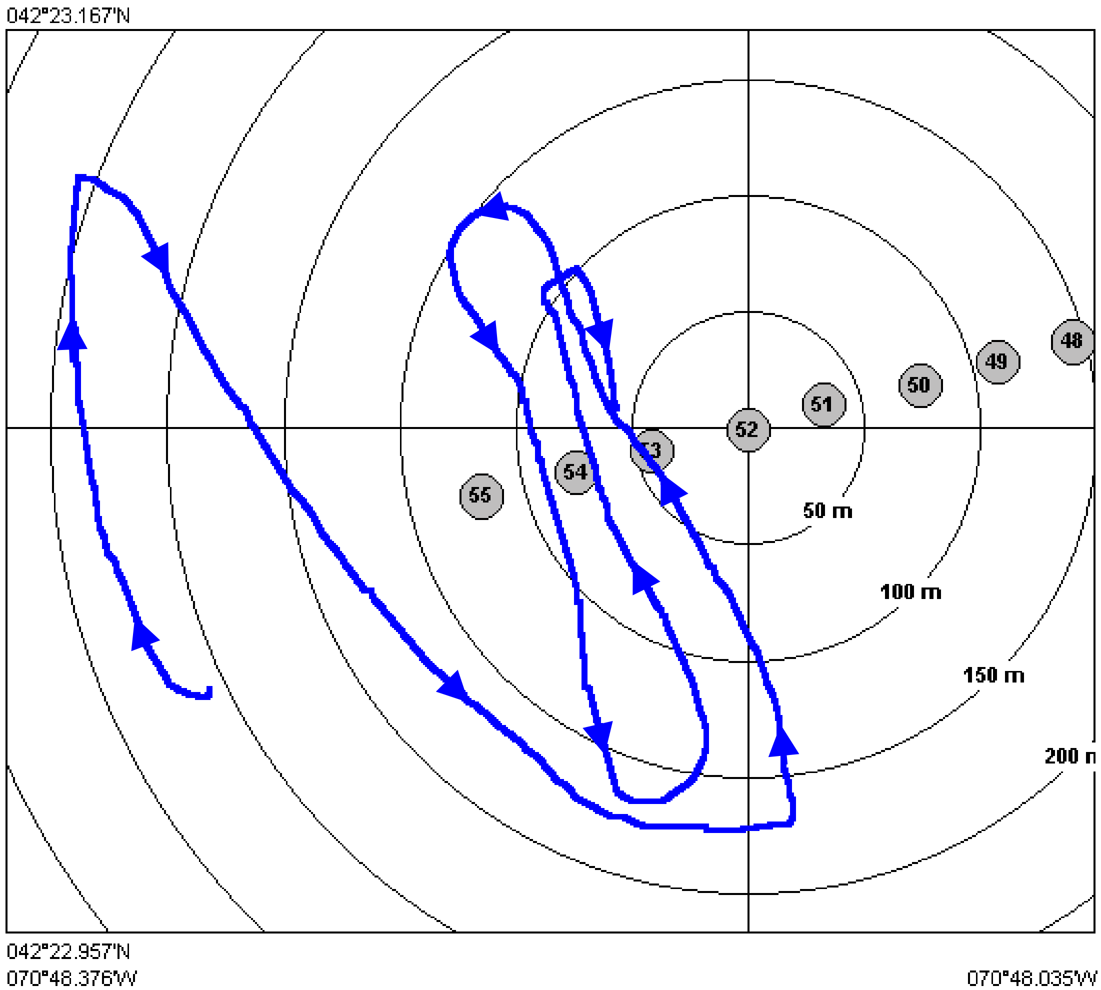


Figure 6. Pre-Dye Exploratory Hydrographic Profile

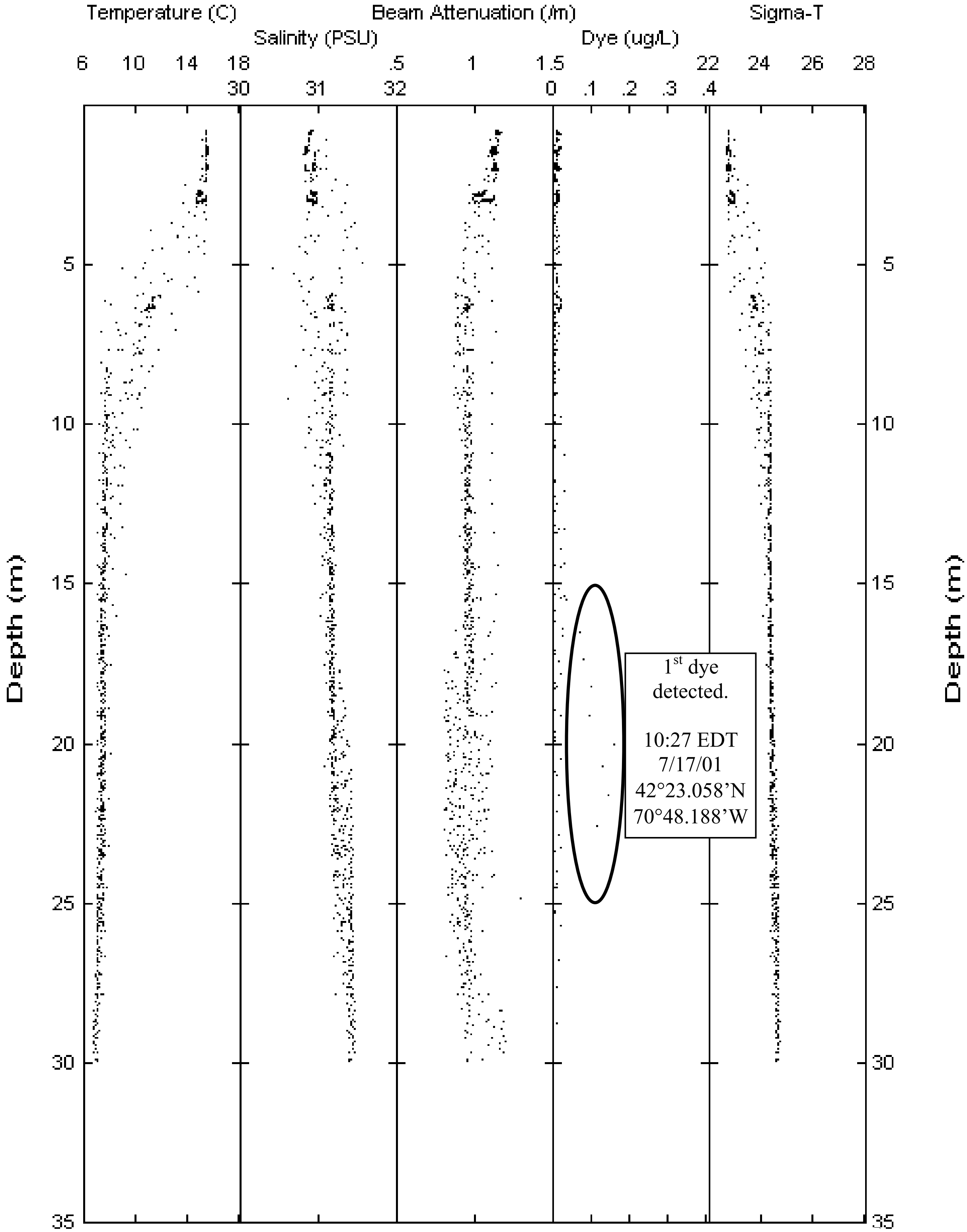


Figure 7. Post-Dye Emergence Exploratory Survey Tracklines

(Start time of each transect is shown. Color scale indicates dye concentration range)

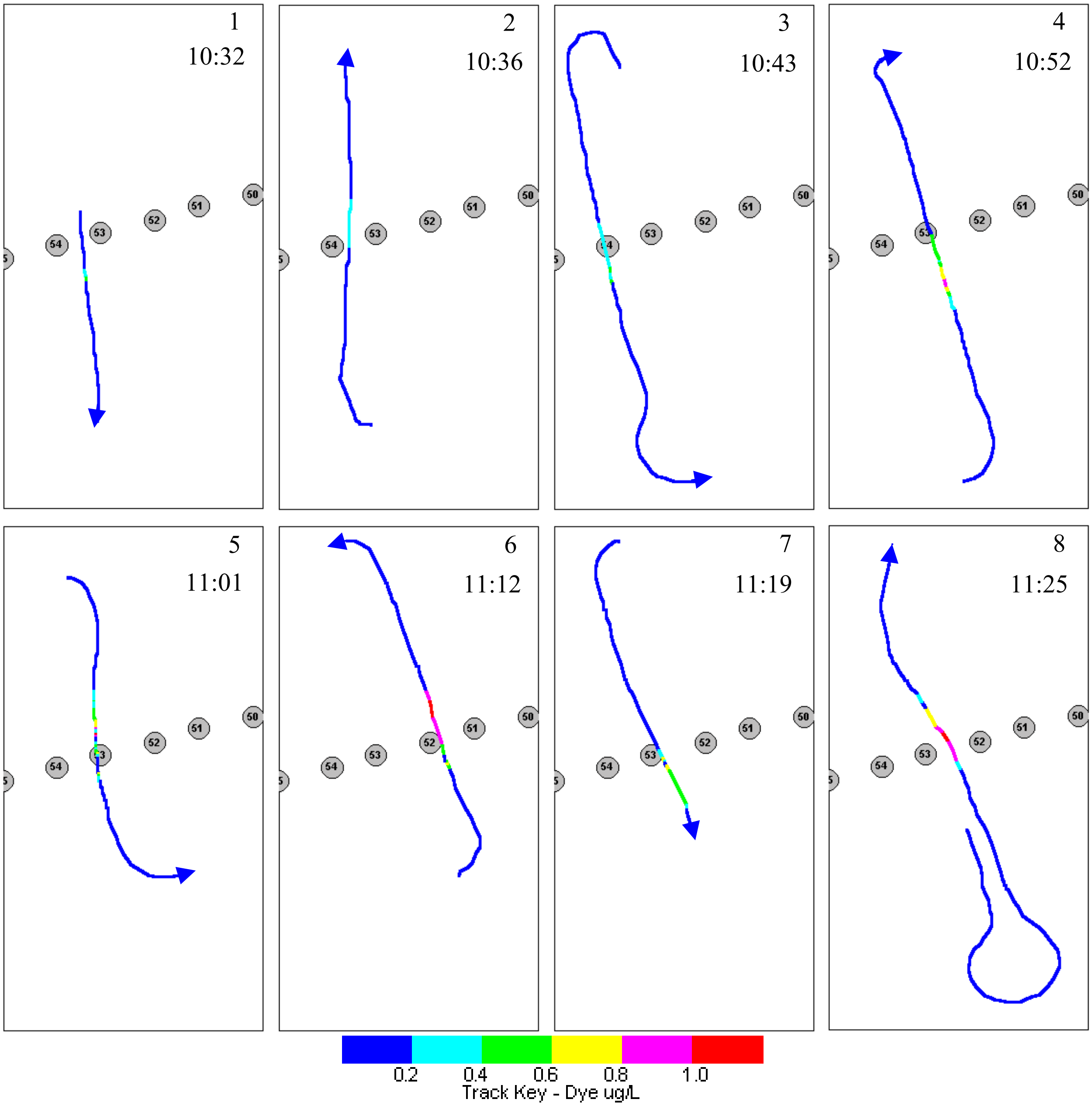
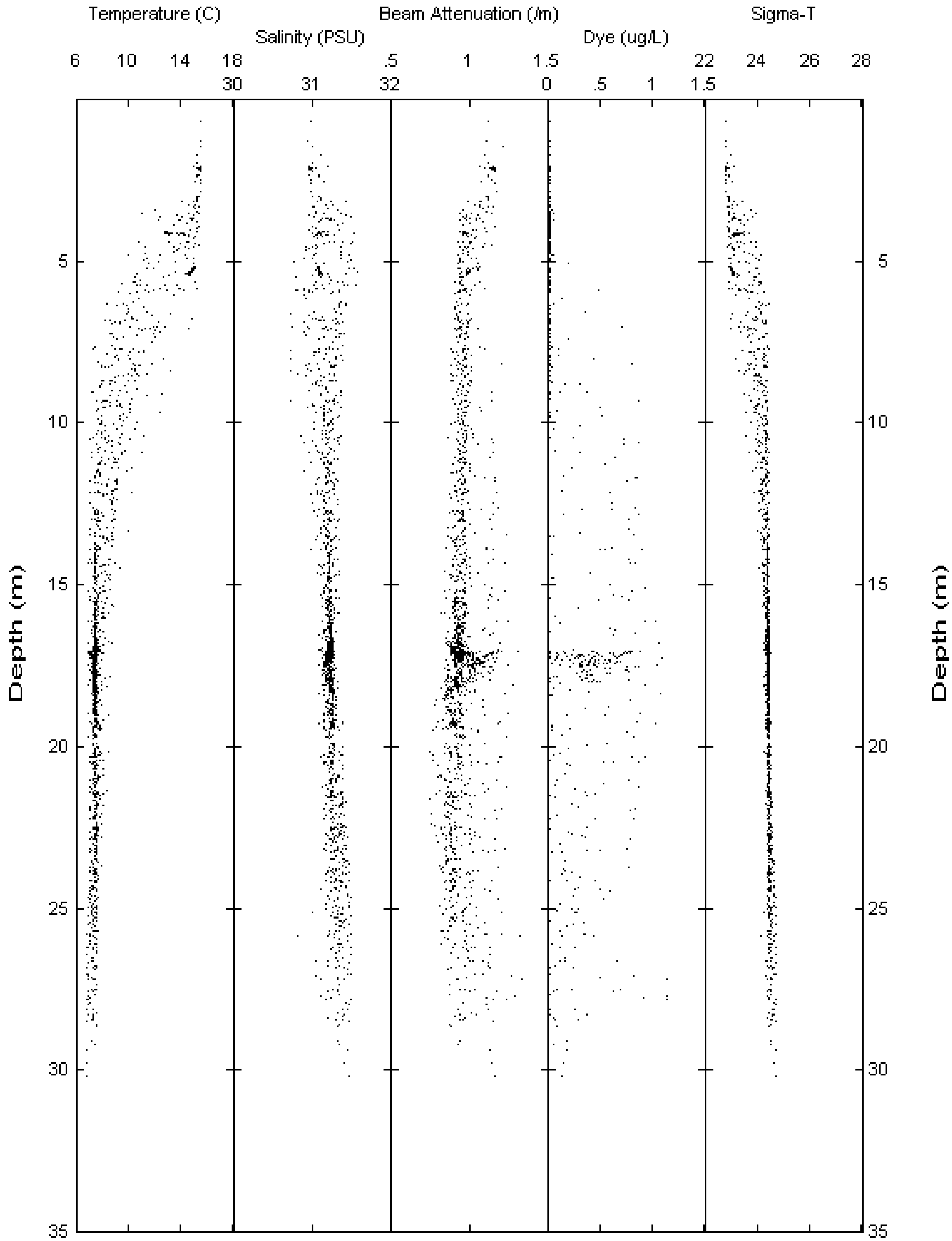


Figure 8. Post-Dye Emergence Exploratory Hydrographic Profile



The exploratory transects revealed that the effluent plume was approximately centered on the diffuser line and moving toward the offshore end of the diffuser. This was consistent with ADCP readings collected during this time. The nearfield ADCP data is discussed in section 3.2.4

3.2.3 Hydraulic Mixing Zone (HMZ) Surveys –

The objective of the HMZ surveys was to measure dilution at the edge of the hydraulic mixing zone to determine compliance with the requirements of the NPDES permit.

Three HMZ surveys were conducted. Because the currents were essentially parallel to the diffuser line and the dye emerged at the start of ebb tide, it was determined by the field team that the HMZ surveys should be conducted at at least three locations along the diffuser (the original plan was to sample two locations with repetition of one or both locations depending on time). The decision was predicated on the fact that the flow down the diffuser would cause a spreading plume that ultimately would extend beyond the east end of the diffuser line. HMZ #1 was conducted approximately 1.5 hours after dye emerged (to ensure steady state dye in the emerging effluent) at the West end of the diffuser between risers 51 and 52. The second HMZ was conducted midway down the diffuser line between risers 25 and 26 approximately 3.5 hours after dye emergence. The third HMZ survey was conducted approximately 110 meters off the east of the diffuser approximately 6 hours after dye emergence. Discrete samples were collected during each of the HMZ surveys. Collected samples are listed in Table 5.

3.2.3.1 HMZ #1

Prior to collecting samples, two transects were conducted perpendicular to the diffuser line to assess the dimension of the dye plume and identify ideal sampling locations. Figures 9 and 10 show the HMZ #1 tracklines, plume structure and discrete sample locations. At the west end of the diffuser line, the plume was approximately 125 meters wide. The plume was basically centered around the diffuser axis with slight tendency to set to the south. Maximum dye concentrations observed in the dye plume during these transects was ~1.0 µg/L.

Note that in Figures 10, 12, and 14 the plume appears to "spikey" in the vertical direction. This may be a result dye entrainment inside the sensor package, data averaging, current direction, layer of discharges from individual risers, or some other cause. Further evaluation is necessary to determine the cause and exact vertical boundaries of the plume. It is presumed that the true plume edges are smoother and somewhat more compact than shown in these figures.

Figure 9. HMZ #1 Trackline and Discrete Sample Locations (arrows)

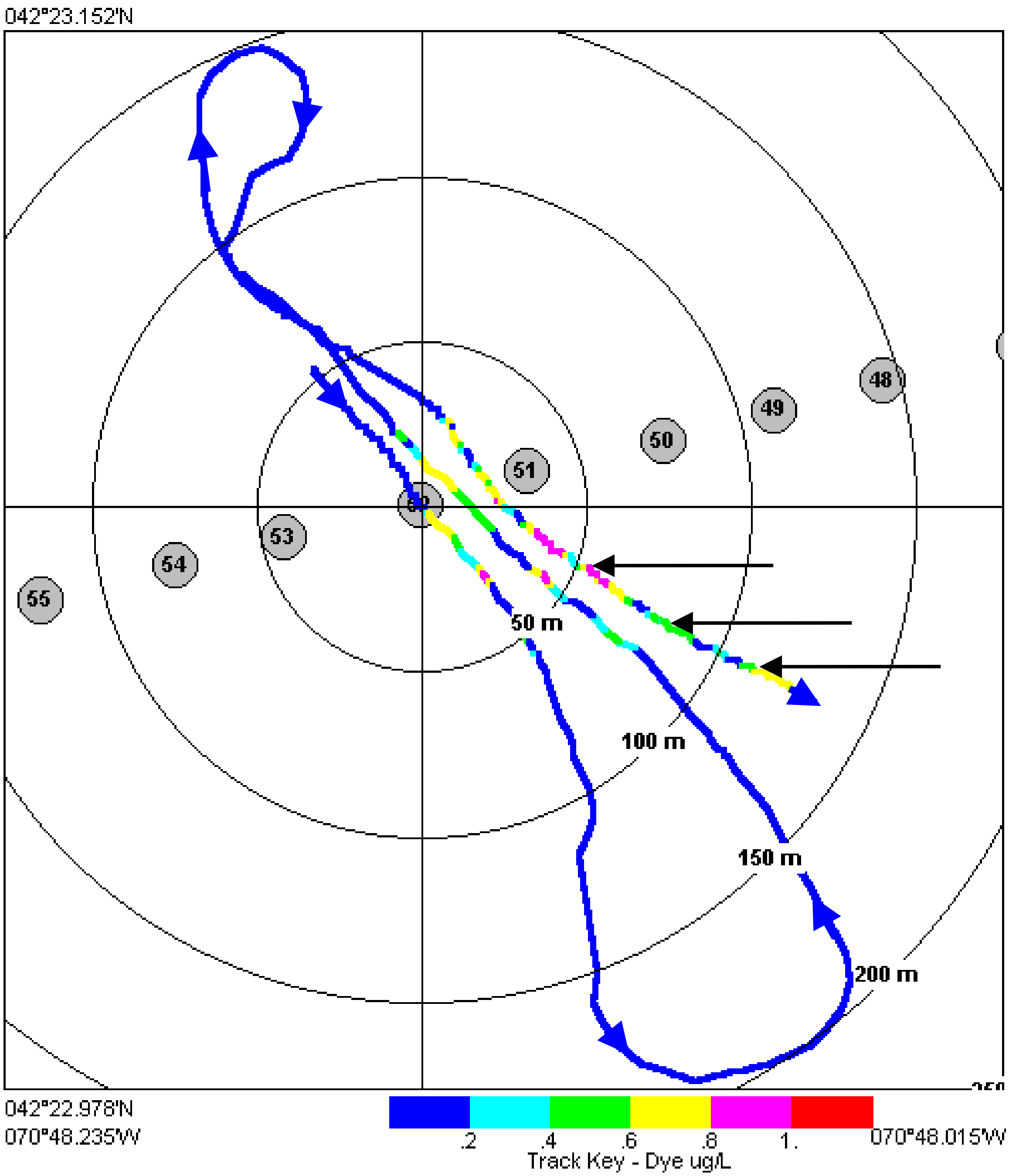
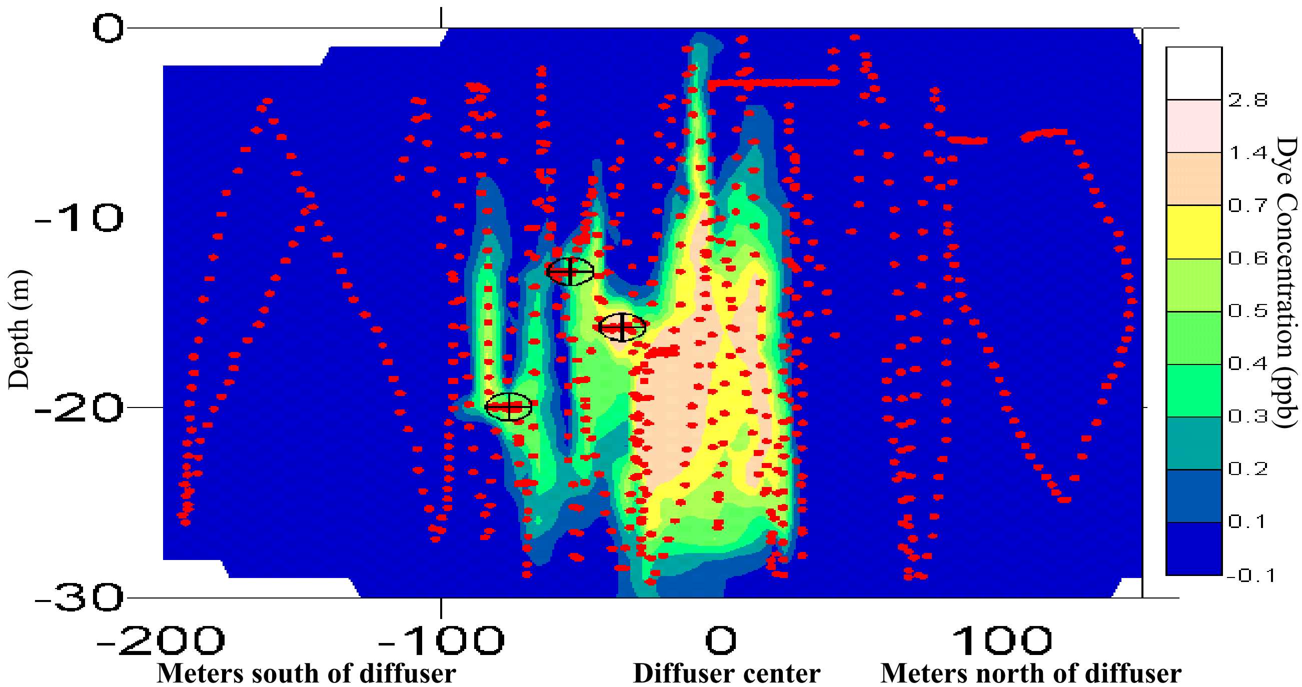


Figure 10. HMZ #1 Profile and Sample Locations



Note: Profile viewed down diffuser line from east to west.

3.2.3.2 HMZ #2

The second hydraulic mixing zone survey was conducted near the center of the diffuser line between risers 25 and 26. Prior to collecting samples, two transects were conducted perpendicular to the diffuser line to assess the dimension of the dye plume and identify ideal sampling locations. Figures 11 and 12 show the HMZ #2 tracklines, plume structure on the third transect and discrete sample locations. At the center of the diffuser line, the plume was approximately 550 meters wide. The plume was basically centered around the diffuser axis with a slight southerly offset. Maximum dye concentrations observed in the dye plume during these transects was ~1.7 µg/L. This concentration was found deep in the water column just above a diffuser head.

Figure 11. HMZ #2 Trackline and Discrete Sample Locations (arrows)

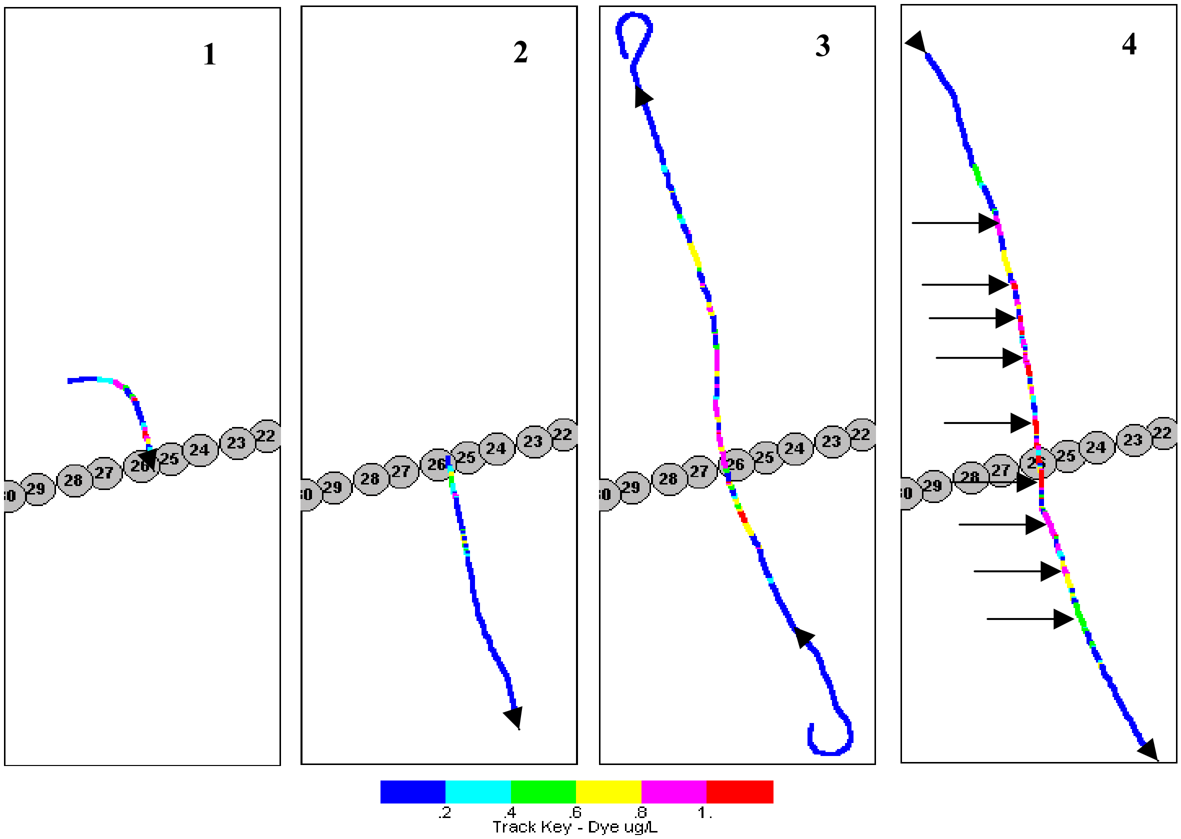
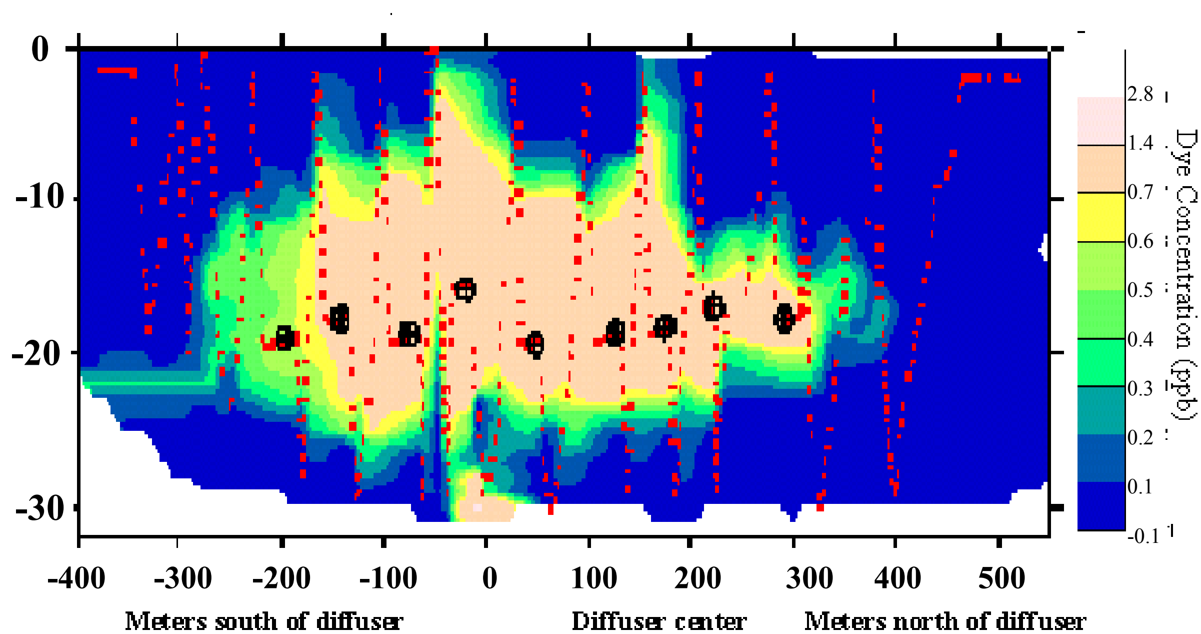


Figure 12. HMZ #2 Profile and Sample Locations

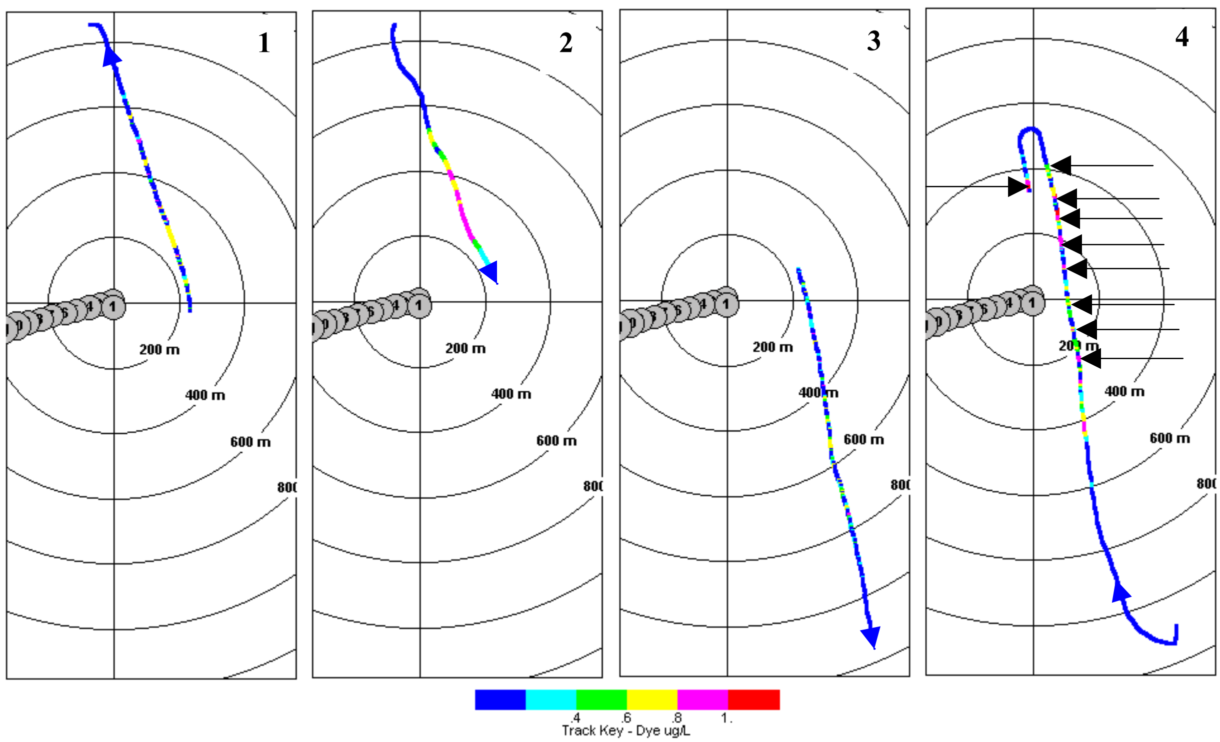


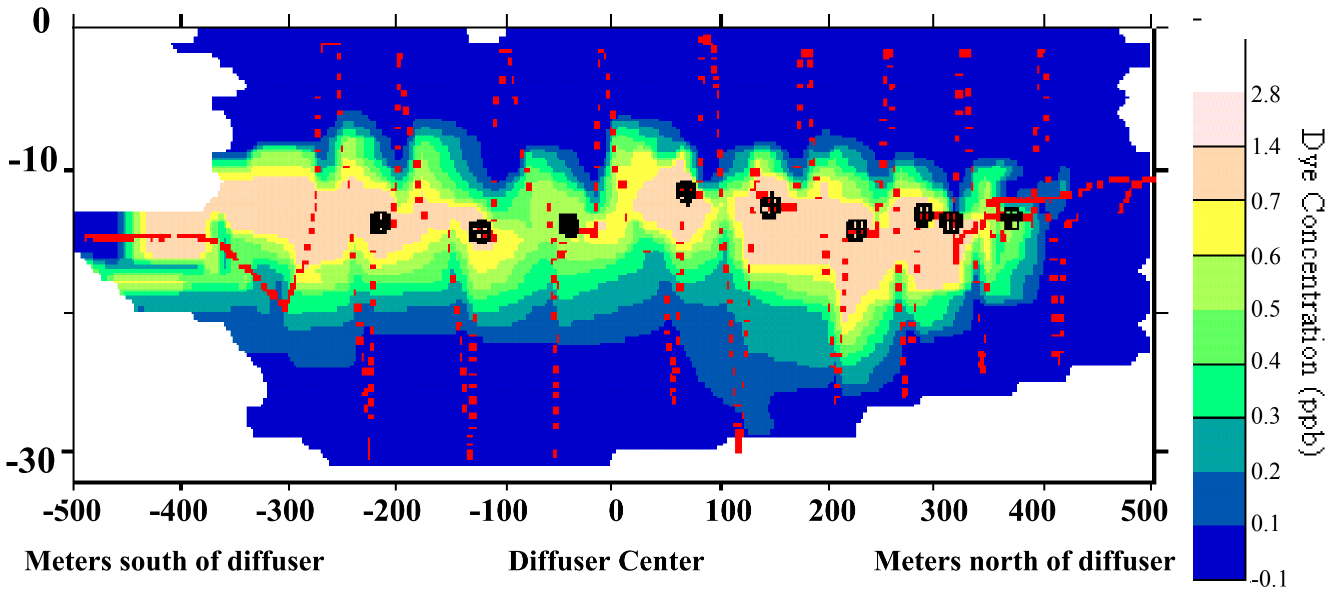
Note: Profile viewed down diffuser line from east to west

3.2.3.3 HMZ #3

The third hydraulic mixing zone survey was conducted east of the diffuser array. Prior to collecting samples, two transects were conducted perpendicular to the diffuser line to assess the dimension of the dye plume and identify ideal sampling locations. The first transect extended from the centerline of the diffuser to the north. This transect was used to define the northern extent of the dye plume. The second extended to the south and includes panels 2 and 3 of Figure 13. Figures 13 and 14 show the HMZ #3 tracklines, plume structure on the third transect and discrete sample locations. Beyond the east end of the diffuser array, the plume was approximately 850 meters wide. The plume, while extending east of risers #1 an #2, was still basically centered around the diffuser axis. Maximum dye concentrations observed in the dye plume during these transects was ~1.1 µg/L.

Figure 13. HMZ #3 Trackline and Discrete Sample Locations (arrows)





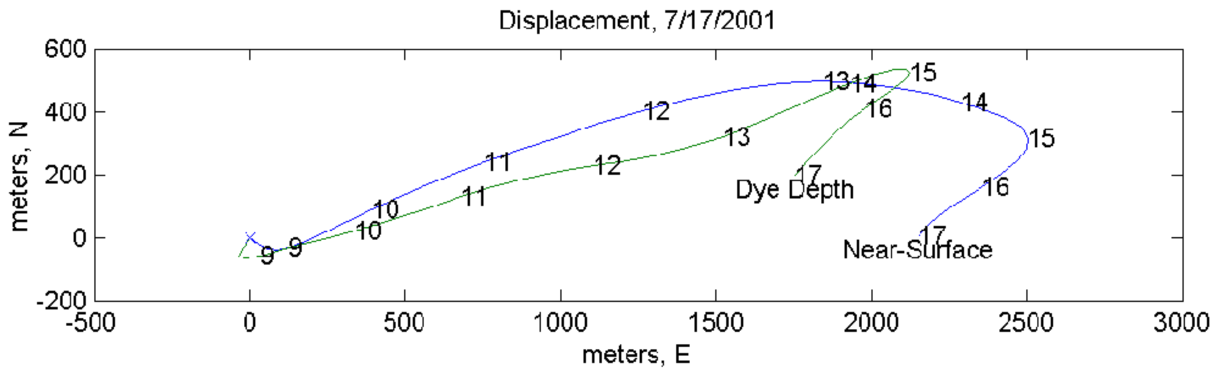
Note: Profile viewed down diffuser line from east to west

Figure 14. HMZ #3 Profile and Sample Locations

3.2.4 ADCP Data From Nearfield Day

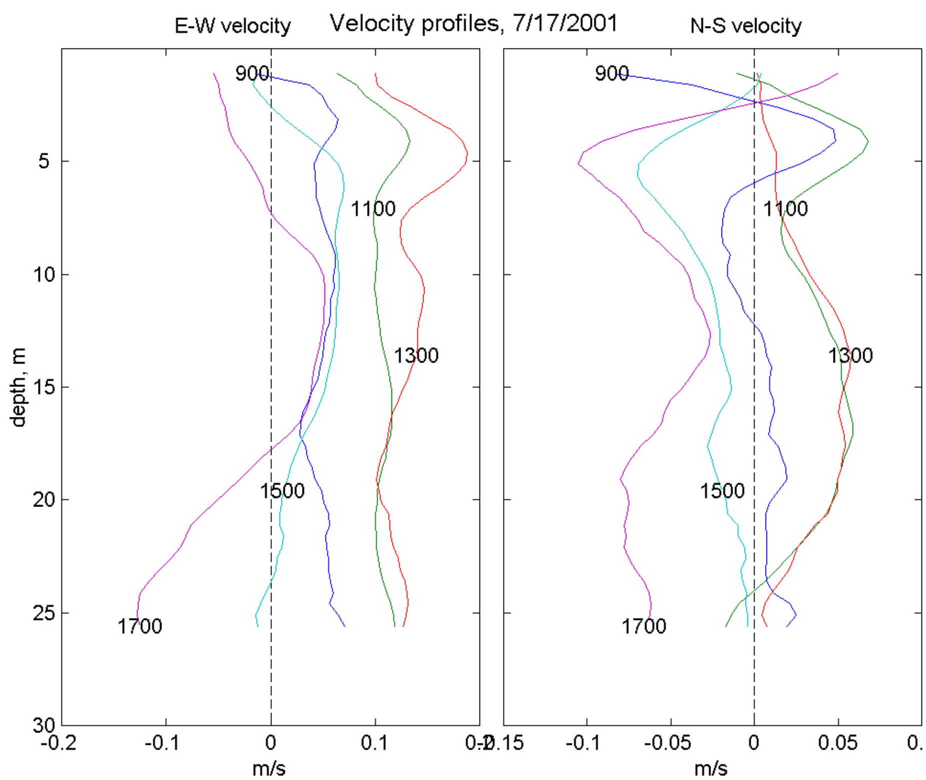
Figures 15 and 16 show the net movement of the water and the current velocities in the water column throughout the nearfield day. From 09:00 to approximately 15:00 the overall current direction at the dye depth was ENE. This direction runs almost directly down the diffuser axis. These currents were driven primarily by tidal action. Maximum flood tide on 7/17/01 was at 08:51 and maximum ebb tide was at 14:54. This tidal cycle and predominant current direction provided consistent conditions for nearly the entire nearfield sampling day (08:07 – 16:57). Near the end of the nearfield survey day, the tidal currents began to switch around to a southwesterly direction. This was especially abrupt at the depth of the dye cloud. This coincided with the change from ebb to flood tide. Current direction and velocities were fairly consistent vertically throughout the water column, although the change in current direction with tidal change was exaggerated at ~5m (“dye-depth”). This resulted in a slight offset between near-surface currents and currents at the depth of the dye (just below the pycnocline).

Figure 15. Water displacement Over Time During the Nearfield Day



Note: Numbers (9-17) refer to time of day.

Figure 16. Current Velocities in the Water Column on the Nearfield Day



Note: Numbers (0900-1700) refer to time of day

3.3 Farfield Survey

The objective of the farfield survey was to determine plume structure and transport beyond the period of initial mixing. This was accomplished by tracking the dye to dilutions of at least 1:1000 (down to 0.10 µg/L active dye ingredient) on July 18 and 19, 2001.

The farfield surveys were entirely conducted in towyo mode. No discrete samples were collected during the farfield surveys. Farfield survey tracklines were intended to characterize both the three dimensional structure of the plume, as well its net movements.

3.3.1 Farfield Day 1

The first farfield survey was conducted on Wednesday, July 18, 2001. The survey vessel was driven directly to the MWRA outfall diffuser area. Over 12 hours had passed since the end of the nearfield survey on 7/17. The EPA vessel *OSV Peter W. Anderson* remained in the diffuser area overnight and maintained contact with the dye plume during the majority of this time. Based on information from the crew aboard the *Anderson*, tide state, and ADCP current data from the previous day, it was assumed that the dye plume would be found near the diffuser line and likely to the east. However, it was also acknowledged that the shift in current direction at the end of the nearfield day might have brought the dye back towards the southwest. Tracklines expanding out from the center of the diffuser were planned to "fish" for the dye plume.

Figure 17 shows the initial tracklines run on the first farfield day and the identification of the northern boundary of the dye plume. The trackline in Figure 17 is labeled and referred to in the following text. Upon arrival at the center of the diffuser array, the sensors were placed in the water and a towyo transect was driven approximately parallel to and just to the north of the diffuser line. Dye at ~0.25 μg/L was detected 190 m to northeast of riser #2 at ~12 m deep (**A**). This initial trackline was continued over 1500 m past the east end of the diffuser although dye extended only to ~350m from riser #2. After reaching the east end of this trackline the vessel was turned and a parallel line was run 500 m north of the original line (**B**). No dye was detected during this entire 3.3 km transect. A trackline was then run 500m south of the original trackline (**C**). Dye was found along a large portion of this transect. Another parallel trackline was run to the south of line "C" (**D**). Dye was found along large portions of "D". These transects showed that the plume was south of the diffuser and did not extend to the north.

Figure 17. Initial Tracklines to Identify Farfield Plume Location.

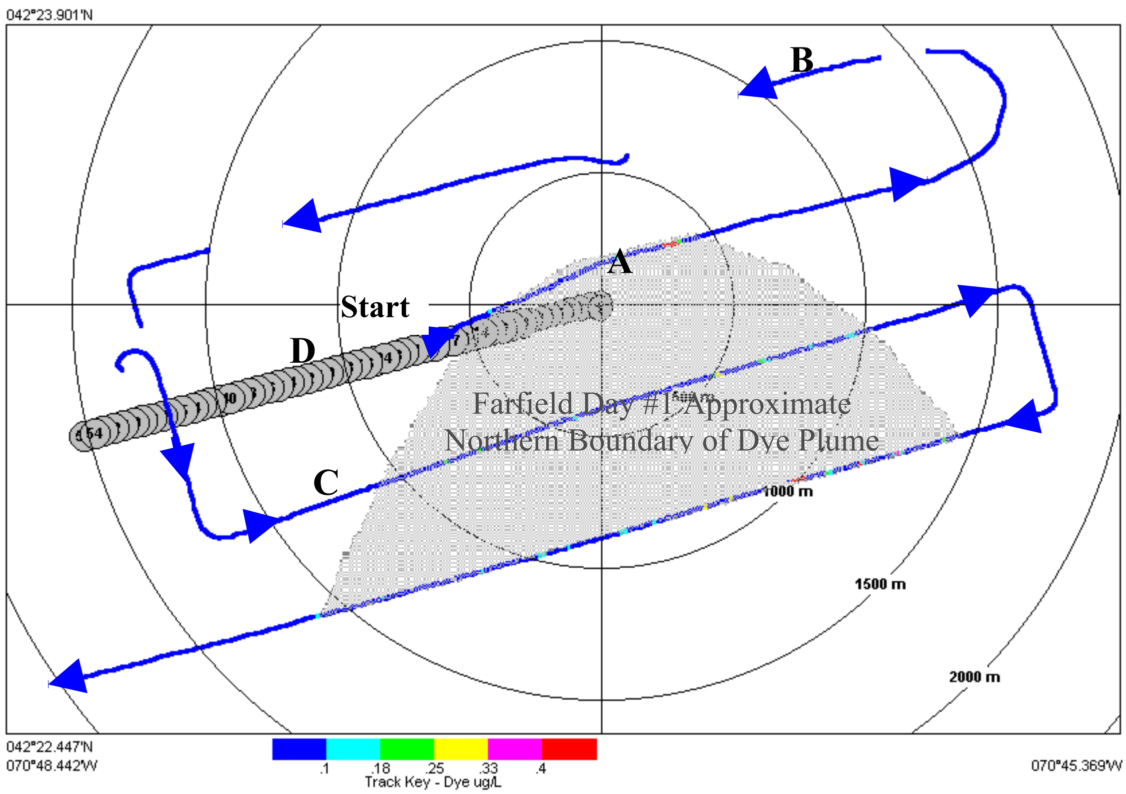
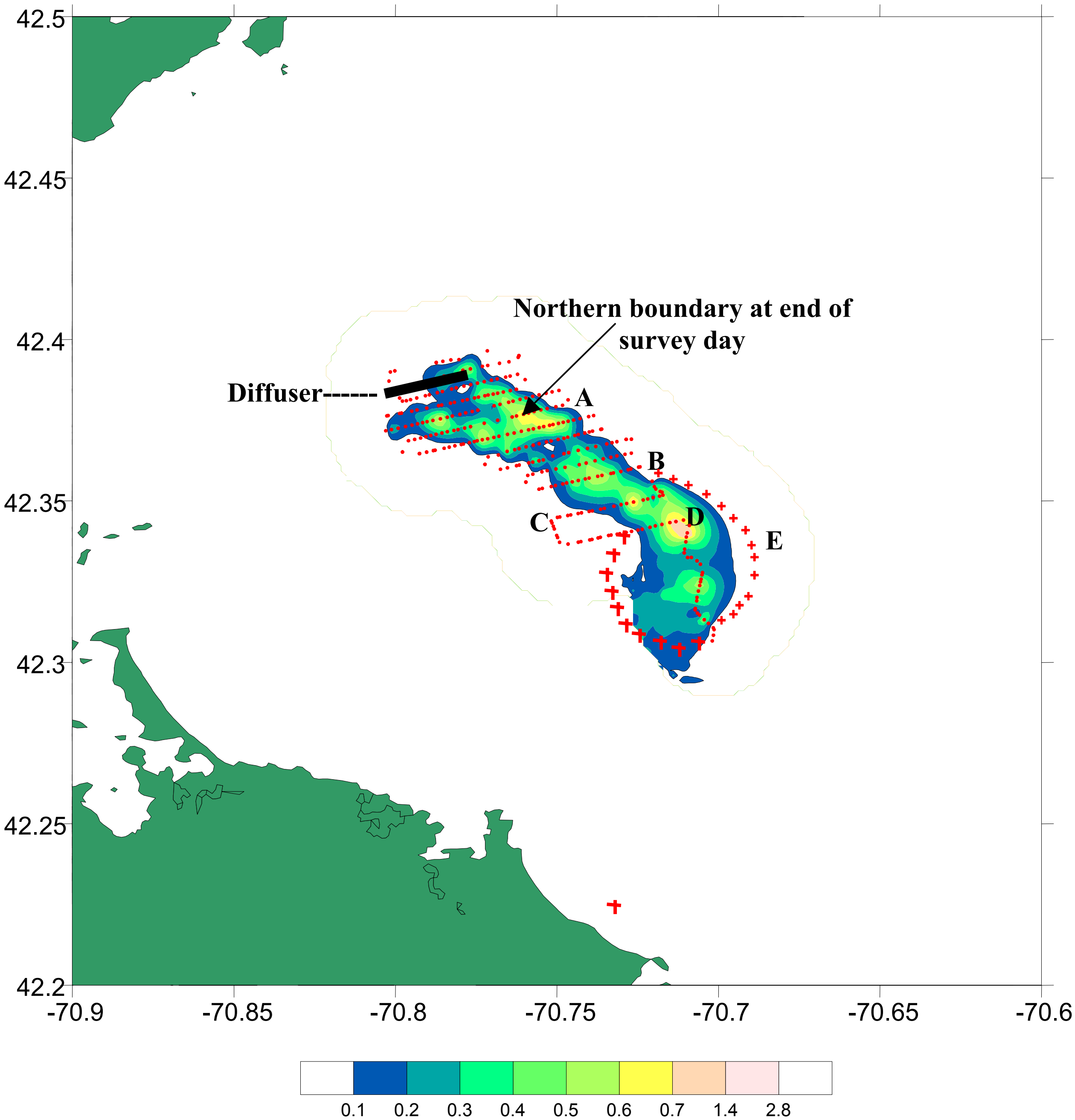


Figure 18 continues on the initial tracklines (Fig. 17) and shows the entire farfield day #1 trackline and measured dye concentrations. The letters on the figure mark specific portions of the survey and are referred to in the following text. Transects were continued, under towyo operations, running parallel to and south of the diffuser line (**A**). Each transect was conducted approximately 500m south of the previous line. Transects were extended well beyond the last point of detected dye to ensure that the entire plume was being mapped. This mapping protocol was continued for 10 transects and found the plume over 4.5 km to the southeast of the diffuser. Dye concentrations were still high (>0.5 µg/L) this far from the diffuser (**B**). At this point concern developed that the entire dye plume could not be mapped during the day. The field team decided to increase the transect spacing to 1000 m to capture as much of the plume as possible (**C**). Two transects were conducted at this spacing bringing the survey line 7.2 km south east of the diffuser at ~4PM. A decision was then made to follow the current trackline to the approximate center axis of the plume, then conduct a "zigzag" transect towards the SSE (**D**). This was conducted to capture the southern extent of the dye plume. One reason for the rapid zigzag transect was a concern that currents were driving the dye plume towards the SSE more quickly than could be captured by the east/west transect pattern. This transect ran out of the dye plume at 10.8 km SSE of the diffuser. Because this final zigzag pattern did not allow the eastern and western boundaries to be measured, the plume boundary shown as plus marks in Figure 18 is an estimation of the southern edges (**E**). Once the southerly edge of the plume was reached, a transect was conducted back to the north towards the diffuser (transect not shown in Figure 18 but plotted in the survey chronology of Section 3.4). At this time the northern boundary of the plume was found approximately 2000m to the south of where the northern boundary of the plume had been located nine hours earlier (the diffuser itself is useful for scale, being 2020m long). Based on this shift, it may be assumed that the entire plume depicted in Figure 18 is exaggerated by as much as 2000m in comparison to its actual size at a given time.

Figure 18. Farfield Day 1 Plume Boundaries

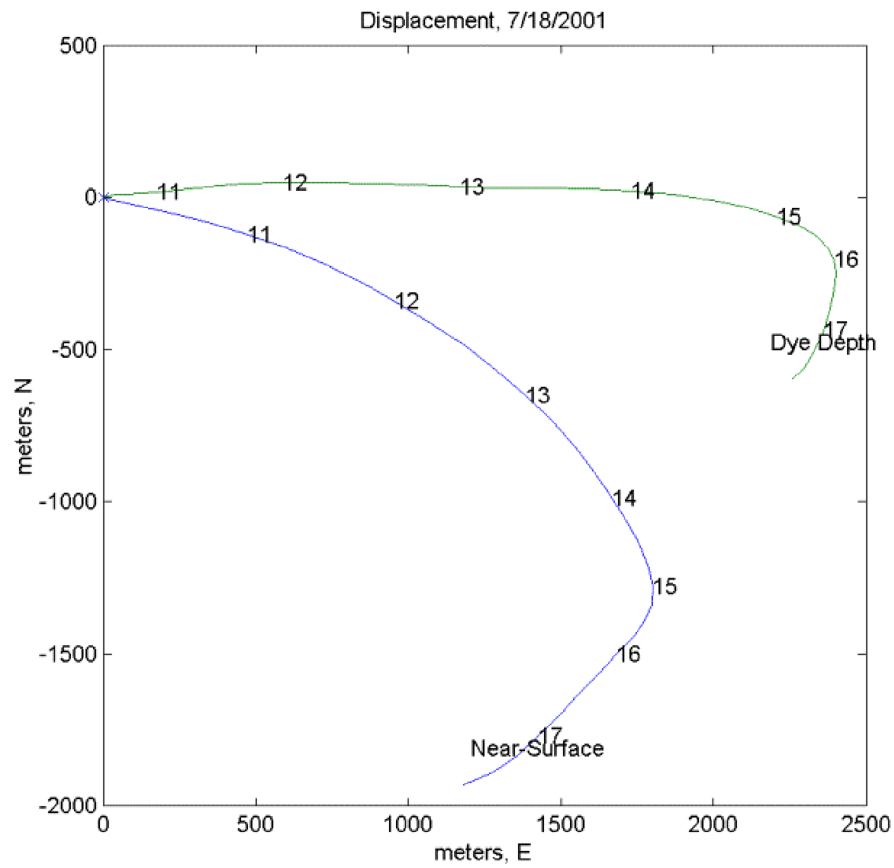


The rhodamine dye plume was entrained below the pycnocline at approximately 11m throughout the entire survey area. The maximum observed dye concentration was 0.79 µg/L at 6.3 km SSE of the diffuser, although more typical high concentrations were around 0.5 µg/L.

3.3.2 Farfield Day #1 ADCP Data

ADCP data from the first farfield day shows the majority of current direction at the dye depth to be in the easterly direction with a shift to the south late in the day (Figure 19). The current direction and net movement during the first farfield day are similar to the previous day. Current data from both days were dominated by tides. It is assumed that the turning of the tide at the end of the nearfield day pushed the plume towards the southwest and shoreward as the tide flooded. The following ebb tide, which occurred around 5 AM on the 18th, probably set the plume back towards its initial position at the end of the first day, but with a southerly translation. By the time of the farfield survey, the dye plume had experienced two such cycles. The farfield survey was conducted primarily during ebb tides, which means the previous flood tides had pushed the plume towards the west. Further detailed analysis of these data are required to understand factors causing the southerly movement of the plume.

Figure 19. ADCP data from Farfield Day #1



3.3.3 Farfield Day 2

On Thursday, July 19, 2001 the second farfield survey was conducted. As on the first farfield day, finding the dye plume required "fishing" for a dye signal. Based on the movement of the plume and the ADCP data from the previous two days, the vessel was driven towards the southern end of the previous day's plume location, see start on Figure 20 which shows the entire farfield day #2 trackline and measured dye concentrations. The letters mark specific portions of the survey and are referred to in the following text. A broad "zigzag" transect towards the SSE was initially conducted. Dye was first detected approximately 1800 meters due west of the southern most point from farfield day 1. After completing the initial zigzag transect (**A**), a transect was driven west to identify if the plume had moved towards the shore. This transect was continued until dye was no longer detected (**B**). The vessel was then pointed southeast in an attempt to run back into the plume and begin mapping the southwestern edge (**C**).

No dye was detected along this transect after running for over 7 km. The vessel was then turned to the ESE in an attempt to find the southern end of the plume. Again, no dye was detected after traveling for nearly 3 km. Having detected dye to the north and east of these transects it appeared that, unless the plume had split, dye had not traveled beyond this point to the southwest. The vessel was then turned back to the northwest (**D**). Dye was observed along this trackline which was continued until dye was no longer detected (**E**). Due to the large and unknown size dimensions of the plume, there was concern that the entire area would not be mapped by the end of the survey day. As on the first farfield day, the field team was concerned that the plume itself was moving faster than the vessel could effectively map. It was therefore decided that if only one boundary of the plume could be thoroughly mapped, the most important would be the southwest. With this in mind, the next two transects were run to the west and south from point "**E**". Once it was verified that the plume had not traveled this far southwest, the vessel was turned east back towards the highest previously detected dye concentrations. In this area (**F**) dye concentration reached 0.42 µg/L. In an attempt to capture the net movement of the dye plume on farfield day #2, the vessel surveyed north and east towards the starting point of the day. A long transect (9.8 km) was then run to the southeast through the entire plume area (**G**). The survey day was ended at point "**G**".

3.3.4 ADCP Data from Farfield Day 2

Net current movement at the dye depth during the second farfield day was predominately to the southeast. This may have resulted in a dye plume that extended further to the east than was mapped by the farfield day #2 transects. Figure 21 shows the net movement of the water at the dye depth and near the surface on the second farfield day. Further analysis is required to confirm this speculation and to understand if other currents were also affecting the transport of the plume.

Figure 22 shows the tidal cycles during the three offshore survey days.

Figure 20. Tracklines from Farfield Day #2

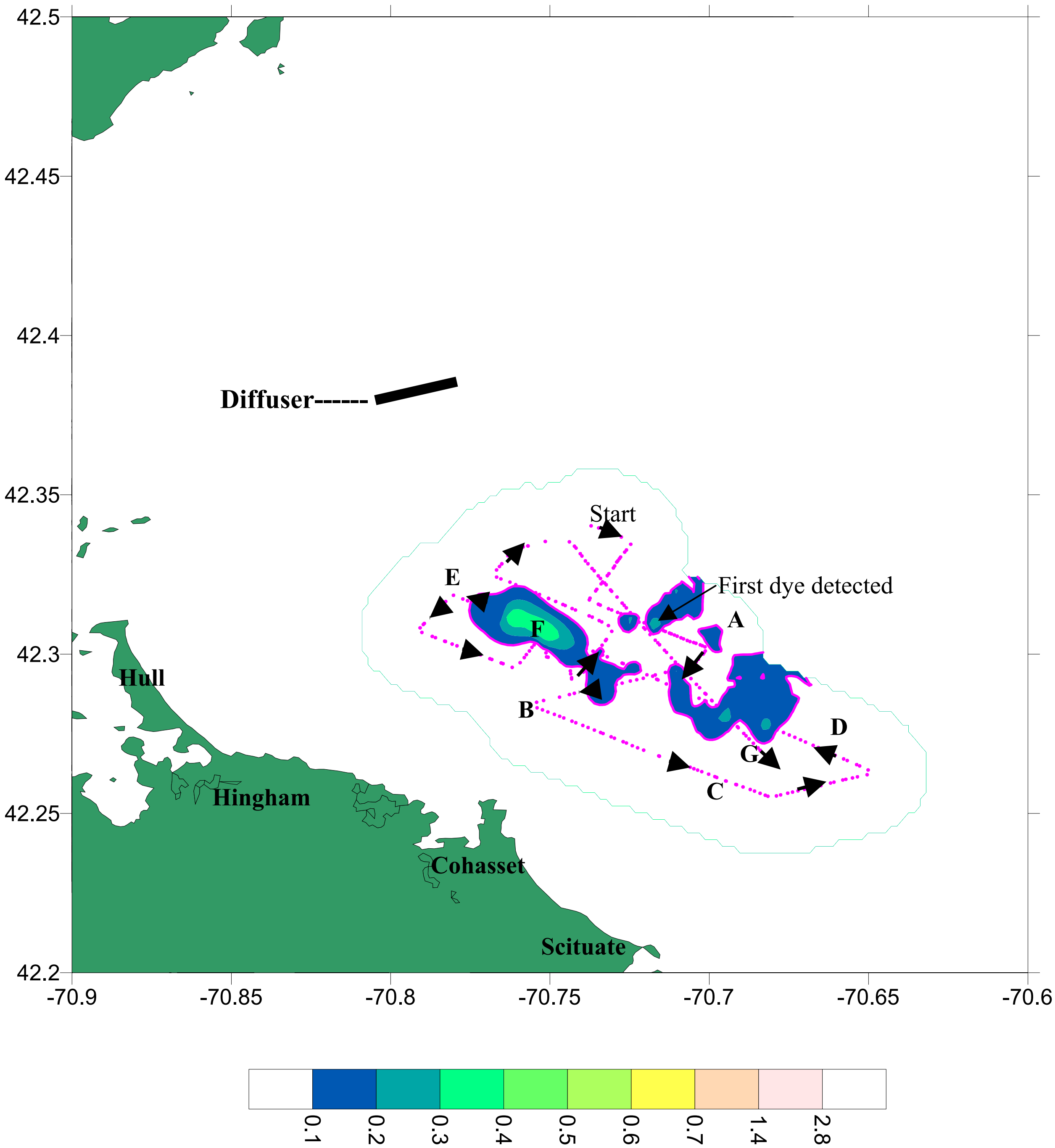


Figure 21. ADCP data from Farfield Day #2

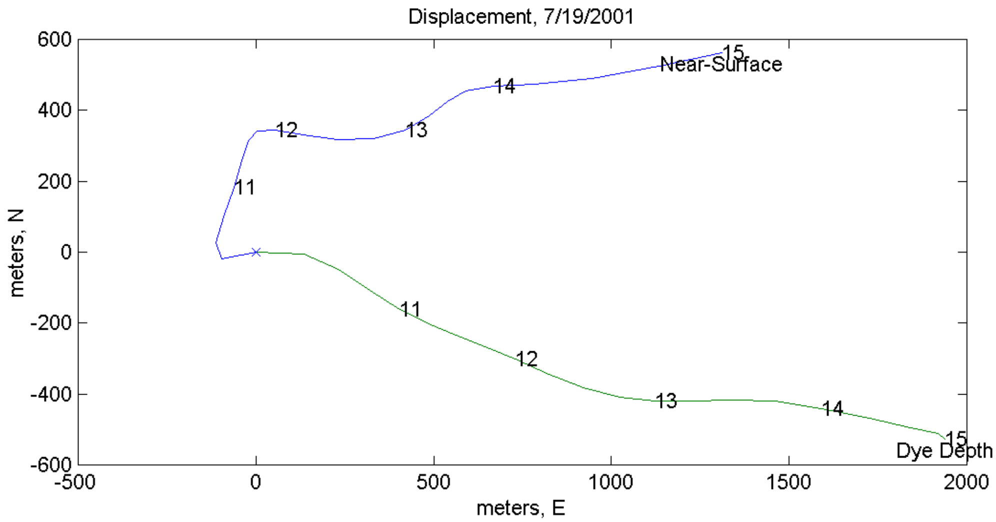
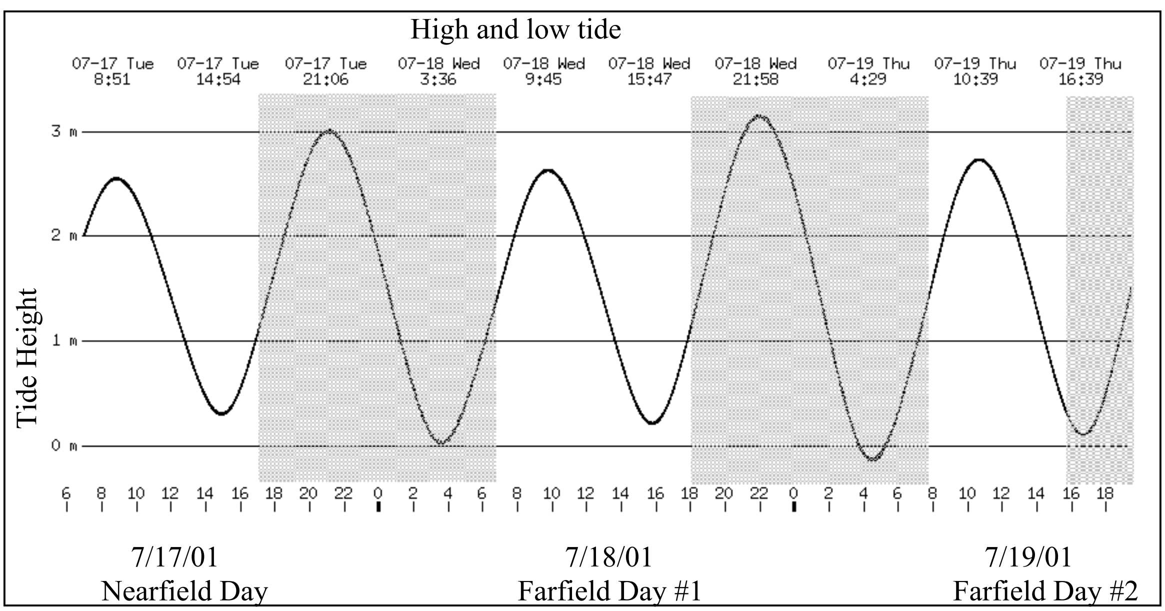
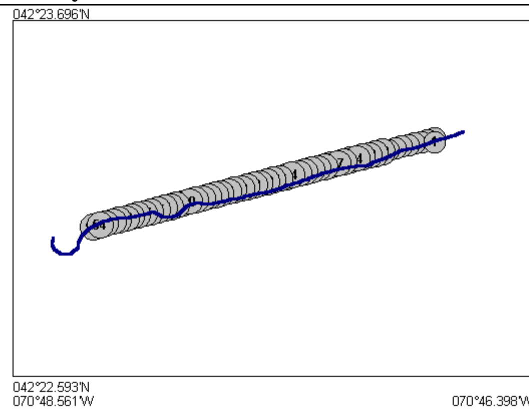
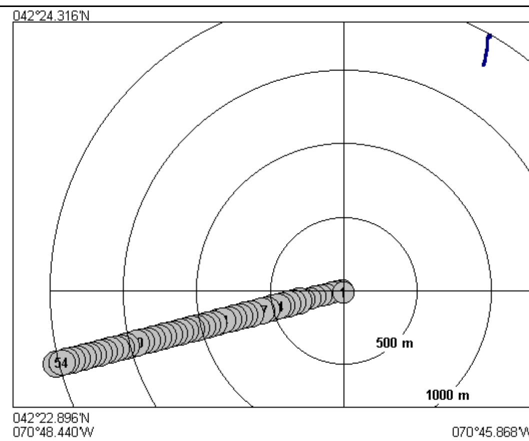


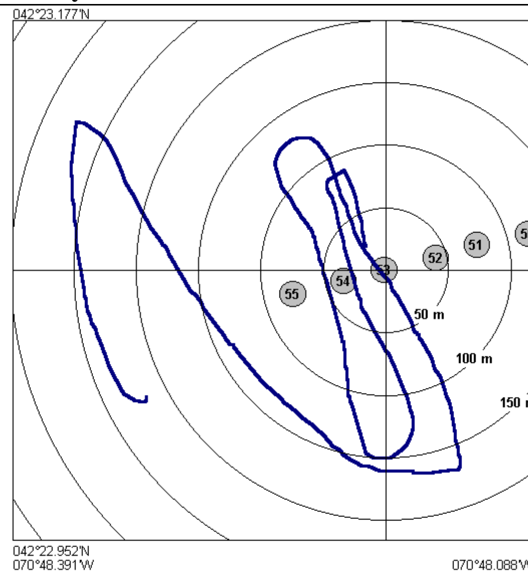
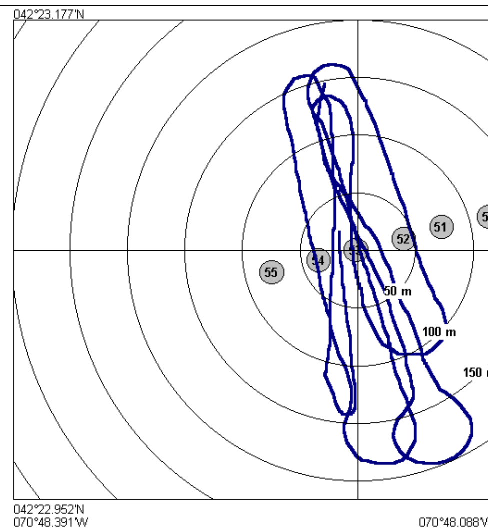
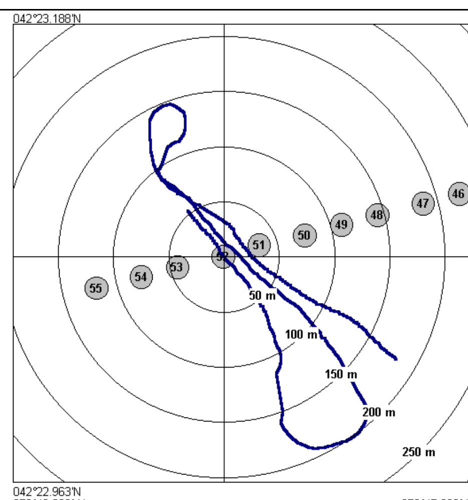
Figure 22. Tide Cycles During the Offshore Surveys

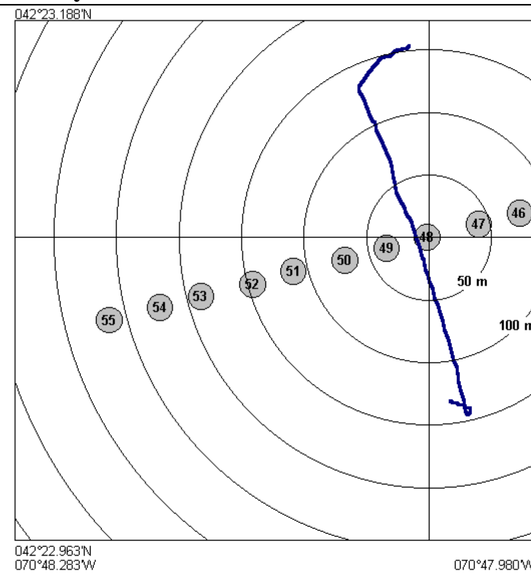
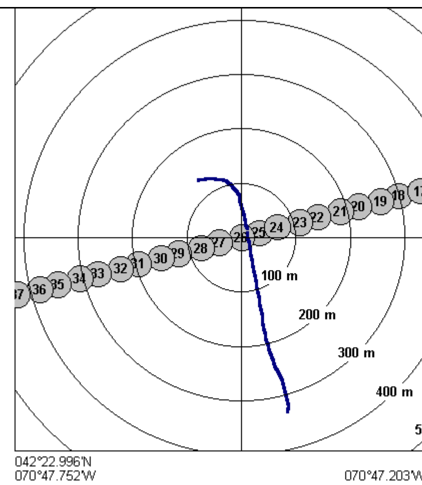


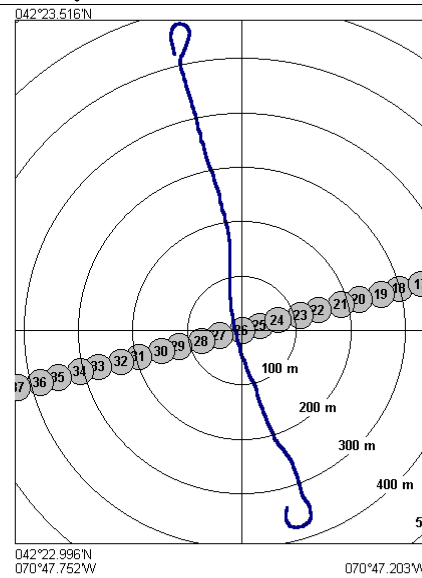
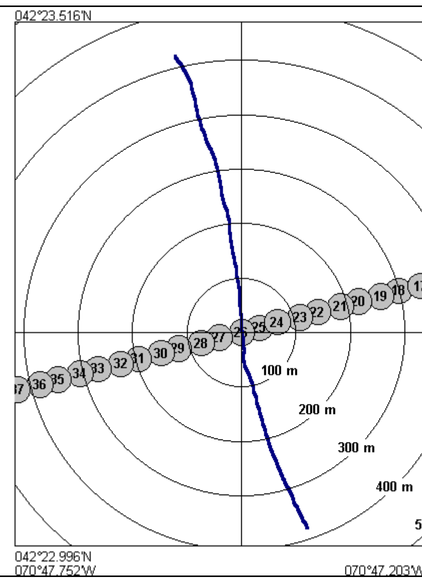
3.4 Offshore Survey Chronology

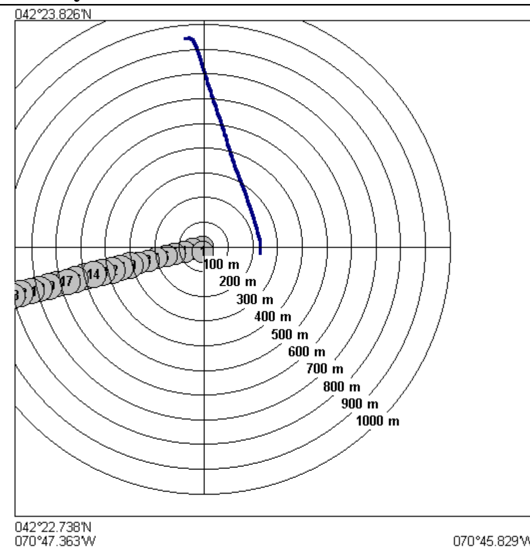
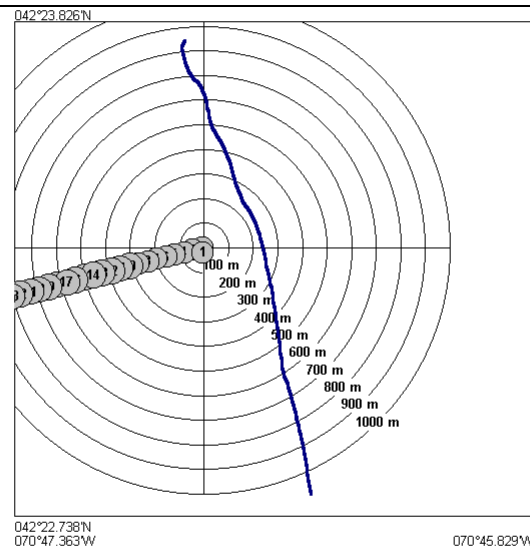
Note: All times in this report are Eastern Daylight Time (EDT) except for Appendix 1 which is in Eastern Standard Time (EST).

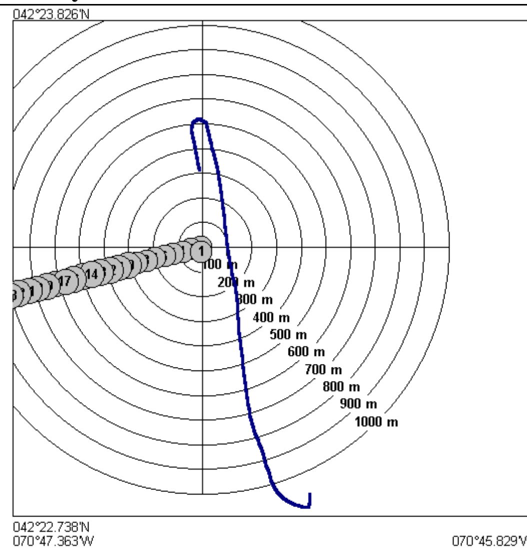
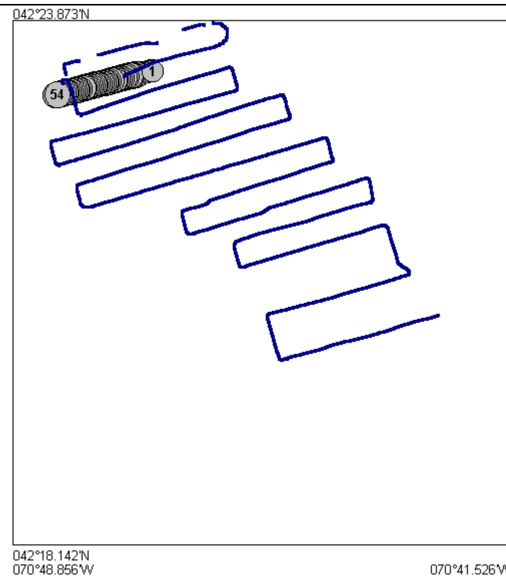
Purpose/Date-Time/Comments	Survey Vessel Path
1. Down the diffuser line to provide ambient background values for blank dye reading. 17 July 2001, 08:07 to 08:38	
2. Background station where 4 water sample sets were taken. 17 July 2001, 09:10 to 09:29	

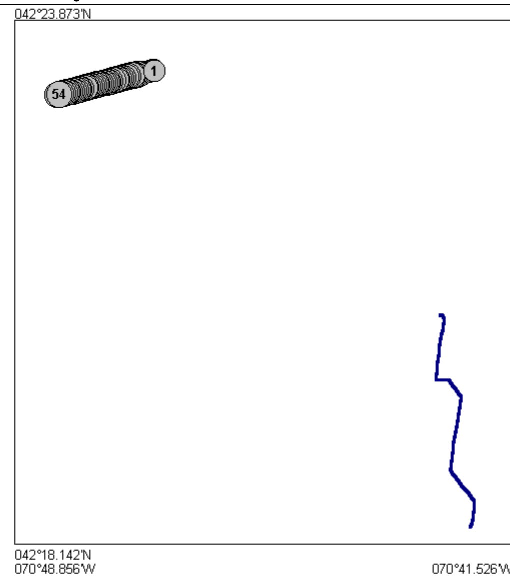
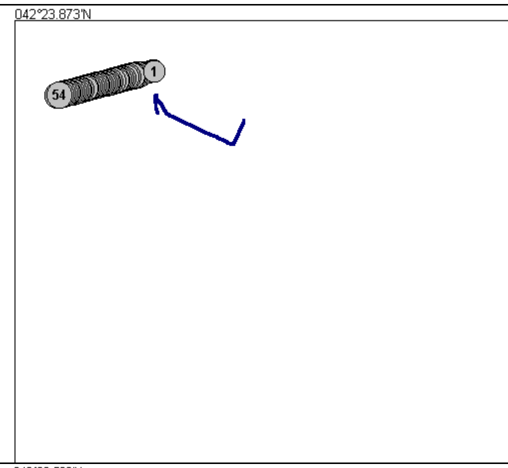
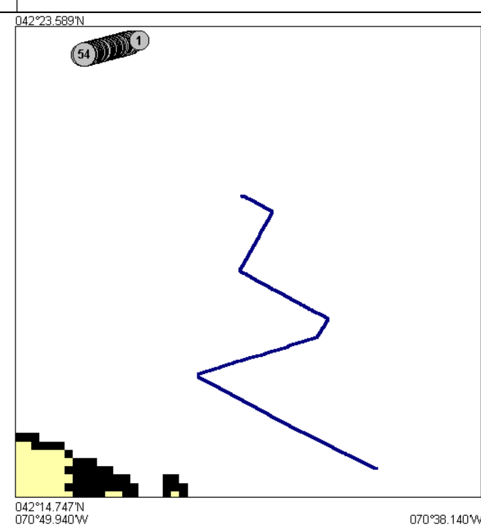
Purpose/Date-Time/Comments	Survey Vessel Path
3. Waiting for dye to exit at the most westward riser (#55). 17 July 2001, 09:50 to 10:32 Dye was detected at 10:27.	
4. Mapping the dye plume near Riser #53. 17 July 2001, 10:32 to 11:37	
5. Conducted first HMZ, perpendicular to the diffuser line at Riser #52. Took three sets of water samples. 17 July 2001, approximately 11:56 to 12:36	

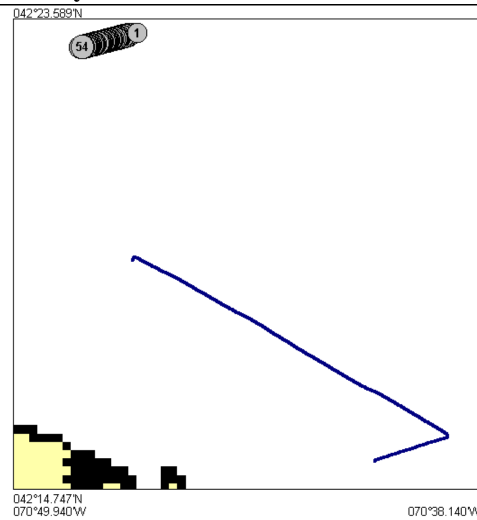
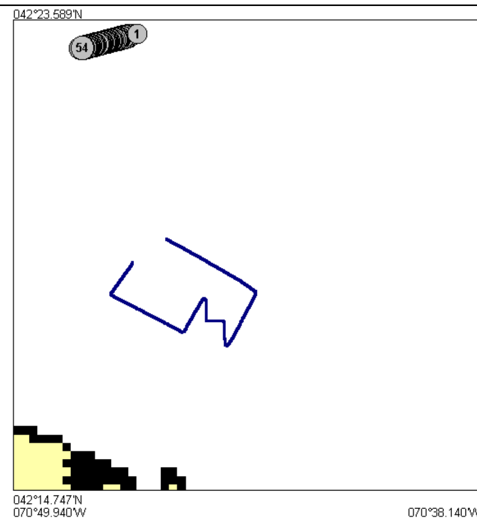
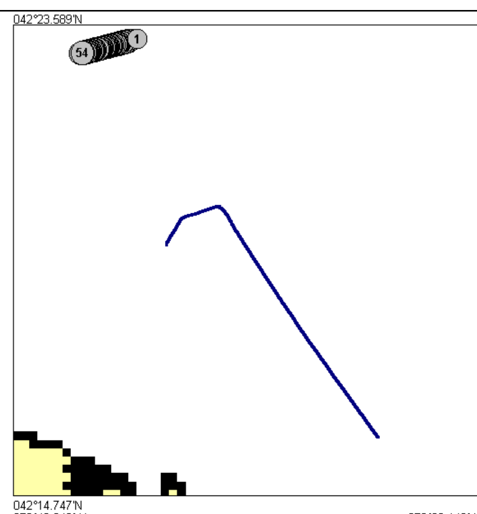
Purpose/Date-Time/Comments	Survey Vessel Path
6. Conducted perpendicular crossing at Riser #48. 17 July 2001, 12:41 to 12:52	
7. First crossing at Riser #26. 17 July 2001, 13:02 to 13:20	

Purpose/Date-Time/Comments	**Survey Vessel Path**
8. Second crossing at Riser #26 17 July 2001, 13:20 to 13:46	
9. Conducted second HMZ, perpendicular to the diffuser line at Riser #26. Took nine sets of water samples. 17 July 2001, 13:46 to 14:27 At approximately 14:46 a side-by-side comparison of the *in situ* sensors was performed with the *OSV Anderson.* The vessels were brought as close together as possible and a vertical profile was performed simultaneously with both sets of instruments.	

Purpose/Date-Time/Comments	**Survey Vessel Path**
10. Conducted south to north crossing about 200 meters to east of Diffuser Line. 17 July 2001, 15:06 to 15:30	
11. Conducted north to south crossing about 200 meters to east of Diffuser Line. 17 July 2001, 15:30 to 16:13	

Purpose/Date-Time/Comments	**Survey Vessel Path**
12. Conducted third HMZ, perpendicular to the diffuser line about 100 meters east of Riser #2. Took nine sets of water samples. 17 July 2001, 16:13 to 16:57	
13. Began Farfield Survey. Conduct grid pattern tow-yo operations parallel to Diffuser Line. At end of first line turned north. The second line showed little dye to north of Diffuser continued operations to south. 18 July 2001, 08:17 to 08:40, and 09:41 to 16:19 Except for equipment problems in the second line (08:40 to 09:41), sensor data was collected all the time.	

Purpose/Date-Time/Comments	**Survey Vessel Path**
14. Changed to Zigzag pattern to find southern end of plume. 18 July 2001, 16:19 to 16:55	
15. Looked for northern end of plume to determine drift. 18 July 2001, 17:25 to 17:51	
16. Conducted a southward zigzag search pattern, starting at a point about 6.5 km south of Diffuser, which was near where the plume was noted the previous day. 19 July 2001, 08:08 to 10:19 Continued south until beyond previous day position, elected to turn north with values less than 0.1ppb at a position 6.4 km to south of previous day position.	

Purpose/Date-Time/Comments	Survey Vessel Path
17. Conducted a northward zigzag search pattern with the second zigzag being roughly parallel to the shoreline. 19 July 2001, 10:19 to 12:05 The second trackline had the highest values for the day (0.42 ppb range), elected to turn south to determine boundary nearest to shore.	
18. Conducted a zigzag search pattern around the previous run maximum dye value. 19 July 2001, 12:05 to 13:39	
19.Conducted a long southeast run to find southern edge of plume. 19 July 2001, 13:39 to 15:05	

3.5 Whale Observations

There was no whale observer on board during these surveys. No marine mammals were observed by the regular scientific crew.

4.0 Overall Survey Results

4.1 Overview

Dye injection rate was paced proportionally to DITP flow rates throughout the addition period. Concentrations in the west basin stabilized after about 1 hour and remained stable throughout the dye addition period. Discrete samples collected in the east disinfection basin had slightly higher (2.22 μg/L) concentrations than those in the west basin. The overall average dye concentration in the effluent was 83.3 μg/L.

The dye began to emerge from riser #55 at approximately 10:27 on the nearfield day. Discrete samples were collected during one background and three HMZ surveys. The plume was successfully tracked for three days.

The general transport of this dye plume during the survey period was to the south-southeast. ADCP readings taken during the offshore survey days show a strong tidal influence on the direction of the plume movement. Outgoing (ebb) tides resulted in a predominately easterly movement of the water column and thus plume. Due to the timing of the surveys in relation to the tidal cycle, very little incoming (flood) tide data were recorded by the MWRA survey. The data that were recorded during flooding tides suggests this tidal phase resulted in a westward transport of the water column as is expected. The data did indicate that during the turning of tide from a low slack condition to flooding tide, a southerly translation of the water column occurred. This translation pushed the plume towards the south. Since ADCP data was not obtained during the tide's turn from high slack to ebbing conditions, there is no direct evidence of the influence of the turning tide on the observed position of the plume. However, the position of the plume in on the sequential survey days suggests the plume may have been pushed further south at this time. Further analysis of the currents in the area using data from the USGS mooring should help resolve this.

4.2 Nearfield Initial Dilution Estimates

Three HMZ surveys were conducted along the diffuser line to collect data for modeling the effluent plume and to measure initial dilution outside of the hydraulic mixing zone. The surveys were spaced along the diffuser line (west, center, and east) to characterize the dilution along the entire length of the diffuser. The discrete sample dataset provide a convenient data source for a rough initial estimate of outfall dilution, since many of the samples were intentionally taken from the plume at the depth of highest concentration, and at a distance from the diffuser beyond the region of turbulent mixing. Subsequent reports will examine other data. Table 6 lists the dye concentrations measured in the discrete HMZ samples. The initial concentration in the effluent was 83.3 μg/L.

The first HMZ survey was conducted at the west end of the diffuser between risers 51 and 52. Three discrete samples were collected from the plume observed at this location. Concentrations in the three samples ranged from 0.415 to 0.796 with a mean of 0.61 (stdev. = 0.191). This translates to a dilution of 1:137. Figure 10 suggests that the HMZ #1 samples were not collected in an area of relatively high, constant concentration, one of the criteria used to establish were samples should be collected. The dilution calculation was based on all three samples. However, based on the one sample collected at the higher concentration (which is more consistent with the data from the other HMZ surveys) the initial dilution estimate is 105. This represents a "worst-case" estimation of dilution from these three samples.

The second HMZ survey was located at the center of the diffuser at riser 26. Nine discrete sample locations were collected during HMZ #2. Only 8 of the 9 samples are used in the dilution estimate as the ninth location appears to be outside of high, stable dye concentration believed to indicate that initial hydraulic mixing was complete. The mean concentration of the 8 samples is 0.92 µg/L (stdev = 0.096). This is a dilution of 1:91.

Table 6. Rhodamine Concentrations in Discrete HMZ Samples.

SURVEY		Sample Rhodamine concentration (µg/L)
		0.796
		0.415
HMZ1		0.611
	Mean	**0.61**
	STDEV	**0.191**
	CV%	**31.4**
		0.829
		0.956
		0.963
		0.919
		1.015
HMZ2		1.023
		0.866
		0.785
		0.537
	Mean (8 of 9)	**0.92**
	STDEV	**0.09**
	CV%	**9.4**
		0.947
		0.817
		0.583
		0.891
		0.901
		0.953
HMZ3		0.843
		0.620
		1.044
	Mean (7 of 9)	**0.91**
	STDEV	**0.08**
	CV%	**8.3**

Note: Highlighted samples are believed to be outside of the HMZ sampling area.

The third HMZ survey was conducted off the east end of the diffuser array. Nine samples were collected during this survey. Again, samples outside of the target zone were discounted for the dilution calculation and only 7 of the 9 samples are included. The mean rhodamine concentration was 0.91 µg/L (stdev = 0.08). This is a dilution of 1:91.

4.3 Preliminary Sensor Data Synopsis

Discrete dye values for DITP and the HMZ surveys are listed in Tables 3 and 6, and discussed in sections 2.3 and 3.2 through 3.3. The station data table is presented in Appendix I. Further evaluation using the *in situ* data and plume modeling will refine these values. These will be reported in the synthesis report prepared for this survey.

5.0 Problems Experienced, Actions Taken, and Recommendations

5.1 Schedule

No problems were experienced due to schedule during the 3 days of this survey.

5.2 Technical

-Deer Island

Dye injection systems were set up at DITP prior to the survey. Included in this set up was a PVC tube installed at the dye injection point. This tube was intended to carry the dye down to a point just above the flowing effluent. This design was intended to eliminate possible confounding factors encountered during the winter shakedown survey, which may have caused unreliable dye flow rates to be administered. Upon arriving at DITP on July 16, 2001 the dye injection team observed that the PVC tube had used for other purposes and was now unusable. Instead, dye injection was rerouted around this tube and the dye was allowed to fall approximately 10 feet directly from the pump tubing to the effluent. The data show that this system worked adequately for the survey, as dye concentrations were stable and near the target concentration.

During the equipment setup and testing at the start of the DITP survey, it was observed that the CTD (serial # 521) was producing unexpected results. This instrument was replaced with a backup CTD (serial # 464). This instrument was past due for calibration and was sent to the manufacturer for recalibration immediately following the survey. Data values in this report are based on discrete sample analysis and are not affected by this issue. All *in situ* data from DITP will be post-processed using the recalibrated coefficients.

-**Offshore**

Based on the “spikey” appearance of Figures 10, 12, and 14 it appears that water may become entrained inside the towed body and slowly flushes out. This would cause a delay in detecting the edge of the dye plume or change in concentration either while entering it or exiting it. It should not, however, have a significant effect on concentration values detected.

6.0 References

Bruce EJ, Albro CS, Hunt CD, Trulli HK, Cheng SA, Pichiarallo D, Mickelson MJ, Geyer, RW. 2000. Combined work/quality assurance plan for plume tracking: 2001. Boston: Massachusetts Water Resources Authority. Report ENQUAD ms-058 (revision 1). 63 p.

APPENDIX I
STATION DATA TABLE FROM WP012

STUDY_ID	EVENT_ID	STAT_ID	LOC_DESC	STAT_ARRIV (EST)	BEG_LATITUDE	BEG_LONGITUDE	DEPTH_TO_BOTTOM	DEPTH_UNIT_CODE	NAVIGATION_CODE	NAV_QUAL	MATRIX_CODE	GEAR_CODE	DEPTH	DEPTH_TOP	DEPTH_UNIT_CODE	SAMPLE_ID	SAMP_VOL	SAMP_VOL_UNIT_CODE	DEPTH_CLASS_CODE
PLUME	WP012	2K1	Hydraulic mixing zone (HMZ) sampling #3	7/17/01 15:13	42.387184	-70.778397	34	m	DGPS	+/- 15m	WAT	BOSS	14.28	13.28	m	P012B085	9	L	PT
PLUME	WP012	2K2	Hydraulic mixing zone (HMZ) sampling #3	7/17/01 15:17	42.388001	-70.778618	35	m	DGPS	+/- 15m	WAT	BOSS	14.77	13.77	m	P012B088	9	L	PT
PLUME	WP012	2K3	Hydraulic mixing zone (HMZ) sampling #3	7/17/01 15:20	42.388733	-70.778801	35	m	DGPS	+/- 15m	WAT	BOSS	14.75	13.75	m	P012B08B	9	L	PT
PLUME	WP012	2K4	Hydraulic mixing zone (HMZ) sampling #3	7/17/01 15:24	42.389717	-70.778954	34	m	DGPS	+/- 15m	WAT	BOSS	12.22	11.22	m	P012B08E	9	L	PT
PLUME	WP012	2K5	Hydraulic mixing zone (HMZ) sampling #3	7/17/01 15:28	42.3904	-70.779068	31	m	DGPS	+/- 15m	WAT	BOSS	12.97	11.97	m	P012B091	9	L	PT
PLUME	WP012	2K6	Hydraulic mixing zone (HMZ) sampling #3	7/17/01 15:31	42.391132	-70.779198	31	m	DGPS	+/- 15m	WAT	BOSS	14.75	13.75	m	P012B094	9	L	PT
PLUME	WP012	2K7	Hydraulic mixing zone (HMZ) sampling #3	7/17/01 15:34	42.391682	-70.77932	29	m	DGPS	+/- 15m	WAT	BOSS	13.70	12.70	m	P012B097	9	L	PT
PLUME	WP012	2K8	Hydraulic mixing zone (HMZ) sampling #3	7/17/01 15:37	42.392384	-70.779564	28	m	DGPS	+/- 15m	WAT	BOSS	14.00	13.00	m	P012B09A	9	L	PT
PLUME	WP012	2K9	Hydraulic mixing zone (HMZ) sampling #3	7/17/01 15:45	42.391766	-70.780251	30	m	DGPS	+/- 15m	WAT	BOSS	14.13	13.13	m	P012B0A1	9	L	PT
PLUME	WP012	B1	Background station	7/17/01 8:04	42.404266	-70.768166	42	m	DGPS	+/- 15m	WAT	BOSS	39.44	38.44	m	P012B014	9	L	PT
PLUME	WP012	B2	Background station	7/17/01 8:06	42.403984	-70.768219	42	m	DGPS	+/- 15m	WAT	BOSS	30.86	29.86	m	P012B017	9	L	PT
PLUME	WP012	B3	Background station	7/17/01 8:09	42.403732	-70.768234	42	m	DGPS	+/- 15m	WAT	BOSS	23.81	22.81	m	P012B01A	9	L	PT
PLUME	WP012	B4	Background station	7/17/01 8:12	42.403351	-70.76828	42	m	DGPS	+/- 15m	WAT	BOSS	16.25	15.25	m	P012B01D	9	L	PT
PLUME	WP012	DAEE	DITP Disinfection basin, East channel (Effluent)	7/16/01 20:25	42.351451	-70.96015			DGPS	+/- 15m	WAT	BOSS	1.28	0.28	m	P012A033	9	L	PT
PLUME	WP012	DAEE	DITP Disinfection basin, East channel (Effluent)	7/16/01 21:37	42.351451	-70.96015			DGPS	+/- 15m	WAT	BOSS	1.33	0.33	m	P012A03C	9	L	PT
PLUME	WP012	DAEE	DITP Disinfection basin, East channel (Effluent)	7/16/01 21:49	42.351451	-70.96015			DGPS	+/- 15m	WAT	BOSS	2.59	1.59	m	P012A043	9	L	PT
PLUME	WP012	DAEE	DITP Disinfection basin, East channel (Effluent)	7/16/01 22:19	42.351451	-70.96015			DGPS	+/- 15m	WAT	BOSS	2.62	1.62	m	P012A049	9	L	PT
PLUME	WP012	DAEE	DITP Disinfection basin, East channel (Effluent)	7/16/01 22:48	42.351451	-70.96015			DGPS	+/- 15m	WAT	BOSS	2.61	1.61	m	P012A04D	9	L	PT
PLUME	WP012	DAEE	DITP Disinfection basin, East channel (Effluent)	7/16/01 23:19	42.351451	-70.96015			DGPS	+/- 15m	WAT	BOSS	2.61	1.61	m	P012A051	9	L	PT
PLUME	WP012	DAEE	DITP Disinfection basin, East channel (Effluent)	7/16/01 23:52	42.351451	-70.96015			DGPS	+/- 15m	WAT	BOSS	2.58	1.58	m	P012A058	9	L	PT
PLUME	WP012	DAEE	DITP Disinfection basin, East channel	7/17/01 0:20	42.351451	-70.96015			DGPS	+/- 15m	WAT	BOSS	2.64	1.64	m	P012A05C	9	L	PT

			(Effluent)																
PLUME	WP012	DAEE	DITP Disinfection basin, East channel (Effluent)	7/17/01 0:20	42.351451	-70.96015			DGPS	+/- 15m	WAT	BOSS	2.54	1.54	m	P012A05F	9	L	PT
PLUME	WP012	DAEE	DITP Disinfection basin, East channel (Effluent)	7/17/01 1:16	42.351451	-70.96015			DGPS	+/- 15m	WAT	BOSS	2.60	1.60	m	P012A064	9	L	PT
PLUME	WP012	DAEE	DITP Disinfection basin, East channel (Effluent)	7/17/01 1:48	42.351451	-70.96015			DGPS	+/- 15m	WAT	BOSS	2.60	1.60	m	P012A068	9	L	PT
PLUME	WP012	DAEE	DITP Disinfection basin, East channel (Effluent)	7/17/01 2:18	42.351451	-70.96015			DGPS	+/- 15m	WAT	BOSS	2.64	1.64	m	P012A06C	9	L	PT
PLUME	WP012	DAEE	DITP Disinfection basin, East channel (Effluent)	7/17/01 4:27	42.351451	-70.96015			DGPS	+/- 15m	WAT	BOSS	2.61	1.61	m	P012A076	9	L	PT
PLUME	WP012	DAWE	Disinfection basin, West Channel (Effluent)	7/16/01 20:25	42.351451	-70.96015			DGPS	+/- 15m	WAT	BOSS	1.29	0.29	m	P012A032	9	L	PT
PLUME	WP012	DAWE	Disinfection basin, West Channel (Effluent)	7/16/01 21:37	42.351451	-70.96015			DGPS	+/- 15m	WAT	BOSS	1.28	0.28	m	P012A03B	9	L	PT
PLUME	WP012	DAWE	Disinfection basin, West Channel (Effluent)	7/16/01 21:49	42.351451	-70.96015			DGPS	+/- 15m	WAT	BOSS	2.62	1.62	m	P012A042	9	L	PT
PLUME	WP012	DAWE	Disinfection basin, West Channel (Effluent)	7/16/01 22:19	42.351451	-70.96015			DGPS	+/- 15m	WAT	BOSS	2.59	1.59	m	P012A048	9	L	PT
PLUME	WP012	DAWE	Disinfection basin, West Channel (Effluent)	7/16/01 22:48	42.351451	-70.96015			DGPS	+/- 15m	WAT	BOSS	2.59	1.59	m	P012A04C	9	L	PT
PLUME	WP012	DAWE	Disinfection basin, West Channel (Effluent)	7/16/01 23:19	42.351451	-70.96015			DGPS	+/- 15m	WAT	BOSS	2.58	1.58	m	P012A050	9	L	PT
PLUME	WP012	DAWE	Disinfection basin, West Channel (Effluent)	7/16/01 23:52	42.351451	-70.96015			DGPS	+/- 15m	WAT	BOSS	2.62	1.62	m	P012A057	9	L	PT
PLUME	WP012	DAWE	Disinfection basin, West Channel (Effluent)	7/17/01 0:20	42.351451	-70.96015			DGPS	+/- 15m	WAT	BOSS	2.57	1.57	m	P012A05B	9	L	PT
PLUME	WP012	DAWE	Disinfection basin, West Channel (Effluent)	7/17/01 0:48	42.351451	-70.96015			DGPS	+/- 15m	WAT	BOSS	2.55	1.55	m	P012A060	9	L	PT
PLUME	WP012	DAWE	Disinfection basin, West Channel (Effluent)	7/17/01 1:16	42.351451	-70.96015			DGPS	+/- 15m	WAT	BOSS	2.54	1.54	m	P012A067	9	L	PT
PLUME	WP012	DAWE	Disinfection basin, West Channel (Effluent)	7/17/01 1:16	42.351451	-70.96015			DGPS	+/- 15m	WAT	BOSS	2.52	1.52	m	P012A063	9	L	PT
PLUME	WP012	DAWE	Disinfection basin, West Channel (Effluent)	7/17/01 2:18	42.351451	-70.96015			DGPS	+/- 15m	WAT	BOSS	2.55	1.55	m	P012A06B	9	L	PT
PLUME	WP012	DAWE	Disinfection basin, West Channel (Effluent)	7/17/01 4:27	42.351451	-70.96015			DGPS	+/- 15m	WAT	BOSS	2.51	1.51	m	P012A075	9	L	PT
PLUME	WP012	H1	Hydraulic mixing zone (HMZ) sampling #1	7/17/01 11:18	42.384384	-70.80175	33	m	DGPS	+/- 15m	WAT	BOSS	16.27	15.27	m	P012B037	9	L	PT
PLUME	WP012	H2	Hydraulic mixing zone (HMZ) sampling #1	7/17/01 11:20	42.384251	-70.801498	34	m	DGPS	+/- 15m	WAT	BOSS	13.22	12.22	m	P012B03A	9	L	PT
PLUME	WP012	H3	Hydraulic mixing zone (HMZ) sampling #1	7/17/01 11:23	42.384117	-70.801148	34	m	DGPS	+/- 15m	WAT	BOSS	20.55	19.55	m	P012B03D	9	L	PT
PLUME	WP012	K1	Hydraulic mixing zone (HMZ) sampling #2	7/17/01 12:42	42.389416	-70.791336	34	m	DGPS	+/- 15m	WAT	BOSS	18.11	17.11	m	P012B055	9	L	PT

PLUME	WP012	K2	Hydraulic mixing zone (HMZ) sampling #2	7/17/01 12:45	42.388817	-70.79113	34	m	DGPS	+/- 15m	WAT	BOSS	17.58	16.58	m	P012B058	9	L	PT
PLUME	WP012	K3	Hydraulic mixing zone (HMZ) sampling #2	7/17/01 12:48	42.388401	-70.791054	34	m	DGPS	+/- 15m	WAT	BOSS	18.77	17.77	m	P012B05B	9	L	PT
PLUME	WP012	K4	Hydraulic mixing zone (HMZ) sampling #2	7/17/01 12:51	42.387966	-70.790947	33	m	DGPS	+/- 15m	WAT	BOSS	19.11	18.11	m	P012B05E	9	L	PT
PLUME	WP012	K5	Hydraulic mixing zone (HMZ) sampling #2	7/17/01 12:54	42.387249	-70.790833	31	m	DGPS	+/- 15m	WAT	BOSS	19.86	18.86	m	P012B061	9	L	PT
PLUME	WP012	K6	Hydraulic mixing zone (HMZ) sampling #2	7/17/01 12:58	42.386635	-70.790764	32	m	DGPS	+/- 15m	WAT	BOSS	16.23	15.23	m	P012B064	9	L	PT
PLUME	WP012	K7	Hydraulic mixing zone (HMZ) sampling #2	7/17/01 13:03	42.386135	-70.790665	31	m	DGPS	+/- 15m	WAT	BOSS	19.12	18.12	m	P012B067	9	L	PT
PLUME	WP012	K8	Hydraulic mixing zone (HMZ) sampling #2	7/17/01 13:06	42.385567	-70.790436	30	m	DGPS	+/- 15m	WAT	BOSS	18.36	17.36	m	P012B06A	9	L	PT
PLUME	WP012	K9	Hydraulic mixing zone (HMZ) sampling #2	7/17/01 13:09	42.385101	-70.790253	29	m	DGPS	+/- 15m	WAT	BOSS	19.29	18.29	m	P012B06D	9	L	PT