WP011

WINTER 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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January, 2002

TABLE OF CONTENTS – WP011

LIST OF TABLES

LIST OF FIGURES

1. Introduction

On April 18, 19, and 20, 2001, the Winter Plume Tracking survey WP011 was conducted at Deer Island Treatment Plant (DITP) and Massachusetts Bay. This survey was designed to practice and evaluate field logistics and explore plume tracking options for the summer 2001 NPDES certification survey. This winter survey was also designed to provide information on the effluent plume characteristics under unstratified conditions. Rhodamine WT dye was added at MWRA's Deer Island Treatment Plant (DITP) and traced offshore for two 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. Mr. Bob Carr captained the vessel. The scientific crew was composed of Battelle employees and subcontractors (Table 1). Dr. Phil Roberts observed the offshore operations. Dr. Michael Mickelson of MWRA observed the dye addition operations.

Table 1. Survey Personnel for Winter Plume Tracking/ Survey WP011.

Activity: **Date:** **Port:**	Mobilization Wed 4/18 Hingham & DITP	Dye Addition Wed 4/18 DI Plant	Dye Addition cont. Thurs 4/19 DI Plant	Nearfield Day Thurs 4/19 Boston	Farfield Day Fri 4/20	Demobilization Mon 4/23 Hingham
Battelle Staff						
Chief Scientist	A. Mansfield	NA	NA	A. Mansfield	A. Mansfield	A. Mansfield
NAVSAM Operator	B. Mandeville	B. Mandeville	B. Mandeville	L. Short	C. Albro	B. Mandeville
Technician	B. Curtis	C. Gagnon	C. Gagnon	B. Curtis	B. Curtis	B. Curtis
Technician	T. Kaufman	T. Kaufman	T. Kaufman	--	--	T. Kaufman
Technician	--	--	--	C. Albro	--	L. Short
Contractors						
Captain	NA	NA	NA	B. Carr	B. Carr	NA
Observer	--	--	--	P. Roberts	P. Roberts	--
MWRA Observer	--	M. Mickelson	M. Mickelson	--	--	--
Drifter Tracker	--	--	--	--	J. Churchill	--
At-sea Totals	NA	NA	NA	6	6	NA

Mobilization for the survey was conducted on Wednesday, April 18th. On April 19th the Dye Addition portion of the Winter Plume Tracking was successfully conducted, sampled, and completed. The Nearfield portion of the Winter Plume Tracking survey was conducted on April 19th. The Farfield portion was conducted on the 20th

This survey report describes the daily activities of cruise WP011, and provides a synopsis of preliminary observations from the survey. A description of the survey methods is provided in Section 2. A chronological summary of survey activities and observations is provided in Section

3. Preliminary survey results are provided in Section 4. A description of survey problems and corrective actions, and recommendations for the certification survey can be found in Section 5.

Section 4.2.2 includes a discussion the comparison of discrete sample dye data related to the companion *in situ* data.

2. Methods

The next three subsections briefly describe the methods used during this survey. The water quality monitoring CW/QAPP (Bruce *et. al.,* 2000) contains additional details on survey/sampling methods.

The 2001 Winter Plume Tracking survey was broken into two major survey components: 1) Deer Island Treatment Plant and 2) the offshore field program. Activities conducted at DITP included 1) dye addition, 2) *in situ* effluent monitoring, and 3) discrete effluent sampling. The offshore component was comprised of four distinct surveys types 1) a background survey, 2) two hydraulic mixing zone (HMZ)[1] surveys, 3) a nearfield/segment survey, and 4) a farfield tracking survey. The first three activities occurred on day 1. The farfield survey took place on the day after the dye addition. Over the course of the offshore surveys, both *in situ* and discrete samples were collected. The details of each of these components are given below.

2.1. Data

The fluorescence of rhodamine WT dye has been shown to have an inverse response to temperature (i.e. decreasing temperature produces increasing fluorescence). In order to compensate for this response, a temperature compensation equation was applied to the raw data. This equation was developed through a series of experiments conducted in the Battelle laboratory in March, July and August of 2001. The methods and results of these experiments were reported in a letter report to MWRA on November 2, 2001. All dye fluorescence data reported here has been post-processed to include this temperature compensation.

2.2. Deer Island Treatment Plant Activities

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 the two streams that lead 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-

[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.

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 100 µg/L (100 ppb).

Rhodamine WT dye was purchased from Keystone Aniline Corporation at a concentration of 20% wt/vol active ingredient. The dye was injected straight from the 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 pump speed was controlled by a 4-20 mA signal provided directly to the peristaltic pump 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 addition team monitored the dye injection rate at the point of dye addition. The pump speed was recorded periodically throughout the dye addition. On six occasions during the pump monitoring, the dye addition team verified the plant flow rate with DITP operators.

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. Fluorescence, temperature, conductivity, density, pH and turbidity were continuously measured at this point. 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). Effluent was monitored at a single depth (~1 meter below the surface) along the west wall of the west disinfection basin. Approximately 1 hour after the start of dye addition, vertical profiles were conducted within the west disinfection basin. Three profiles were conducted: 1) at 4 m from the west wall, 2) in the center of the basin and 3) at the east wall of the basin. The dye concentration was uniform across all locations and depths sampled. As a result, *in situ* monitoring was conducted near the west wall for the remainder of the survey. See section 4.2.1 for dye concentrations and section 5.2 for a discussion of difficulties encountered with the *in situ* sampling method.

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 *in situ* monitoring point and discrete samples were collected as grabs from the pump flow. 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. Four extra samples were collected for rhodamine analysis from the east disinfection basin. The final "hourly" sampling event was unintentionally skipped by the dye addition team.

[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.

Table 2. Samples Collected For Analysis 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/ hour (7 total)	None	11 (4 from E. basin)
Chloride	2 samples/hour (13 total)	None	12	None
TSS	2 samples/ hour (13 total)	1 sample/ hour (7 total)	12	6
NH_4/PO_4	2 samples/for each type of sample/hour (13 each total)	1 sample/hour (7 total)	12	6
Ag/Cu	None	1 sample/ hour (7 total)	None	6
Fecal Coliform/ *Enterococcus*	1 sample/ hour (7) total)	None	6	None

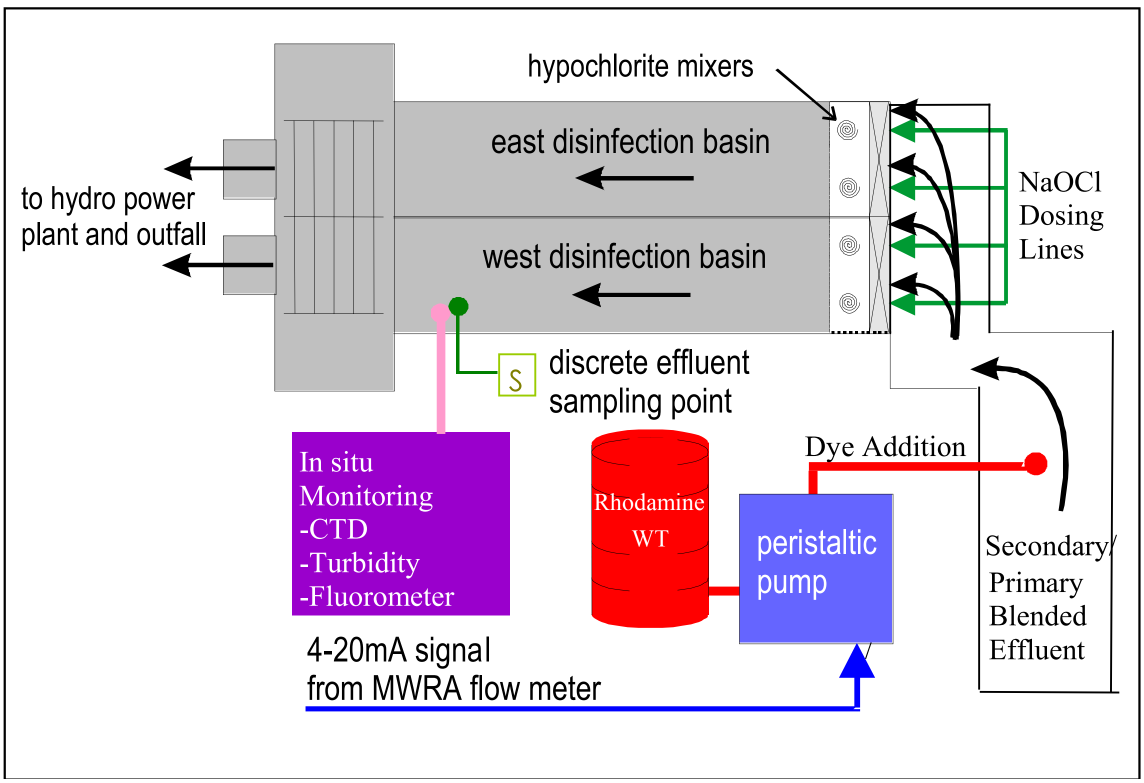

Figure 1. Schematic of Deer Island Treatment Plant dye addition and sampling locations.

2.3. Offshore Activities

Plume tracking was conducted using a second BOSS deployed from the *R/V Aquamonitor*. The BOSS *in situ* sensor package included: a Rhodamine fluorometer (Seapoint), a chlorophyll fluorometer (WET Labs WETStar), a CTD (which measures temperature, conductivity, and pressure (for depth)), and light transmission (Sea Tech transmissometer). A winch and the vessel's speed was used to control the depth of the towed sensor package. 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.

Two different types of BOSS cables were used during this experiment. During the nearfield operations an electrical-mechanical cable (200 ft long) with a Teflon tube down the middle of the cable was used. This system allowed collection of discrete water samples during the background and HMZ surveys. For the farfield day, a standard electrical mechanical cable (500 ft long) was used.

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).

Background Survey- *The objective 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 initiated during transit to the nearfield area. Figure 2 shows the Background survey trackline. Starting approximately 1800 meters west of the diffuser array [1] the sensor package was towed towards the diffusers [2] in towyo mode. The track continued straight down the diffuser line from riser 55 to riser 30 [3]. At riser 30 the sensors were towed north (perpendicular to the diffuser line) for ~300 m [4]. The vessel turned and headed south [5] then west [6] to approximately 1000 meters due south of riser 55 [7]. At this site the discrete background samples were collected at 4 depths (2.4, 10.4, 21.9, and 31.4 meters). See Table 3 for collected samples. After background samples were collected the sensors were towed back to the diffuser line [8] where short perpendicular [9] and parallel [10] tracks were conducted in the segment between risers 55 and 30 until dye began to emerge from riser #55 at 12:06.

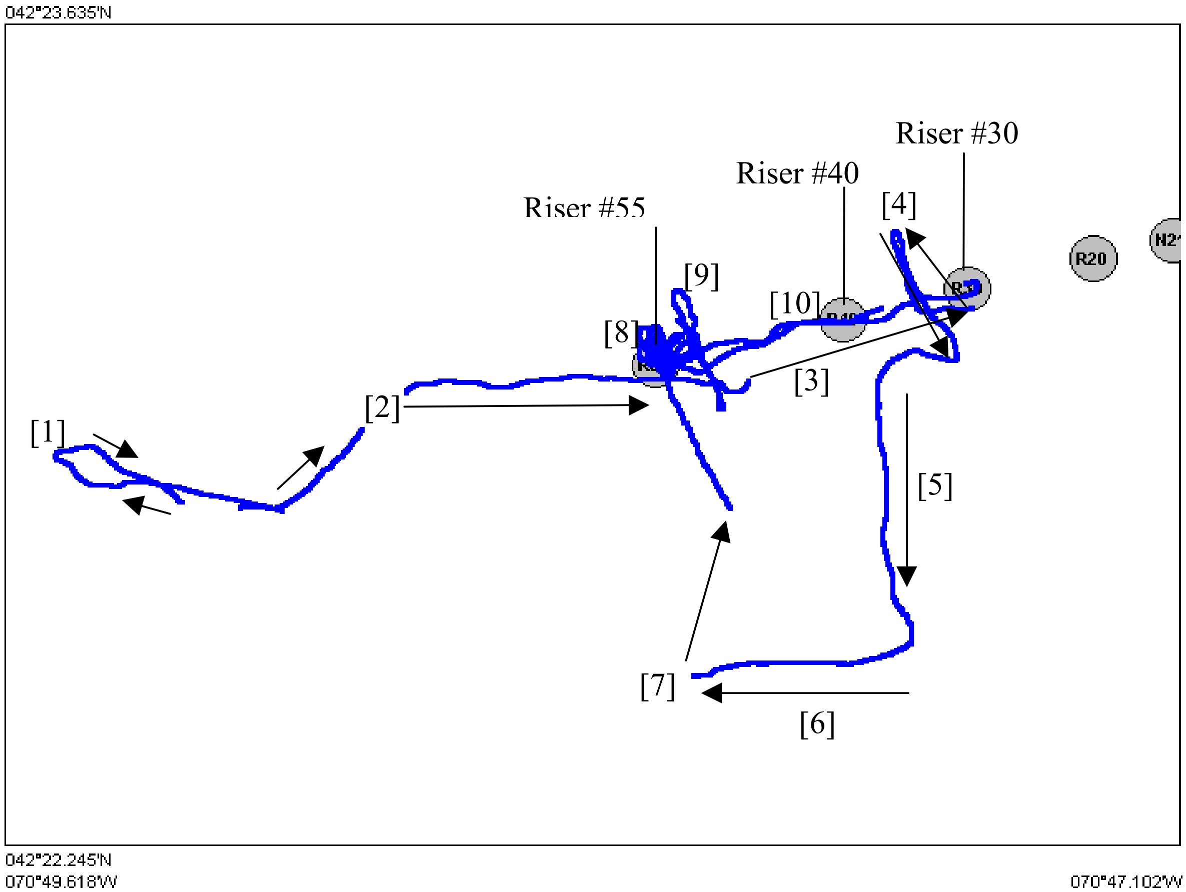

Figure 2. Background Survey Transect.

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

Prior to the segment survey, exploratory transects were conducted to define the gradients in the dye (thus effluent) field. These transects were conducted from north or south of the diffuser line (perpendicular the diffuser) at fixed depths and under towyo operations. Figure 3 shows these transects. The top panels depict the depth of the towed sensors during the exploratory transects. The second row of panels shows dye concentration during those same transects. The bottom row of panels depicts dye concentration (black) and depth (green) plotted against time over the course of all of the exploratory transects. The data in the bottom panel has been averaged for simplicity of presentation. Due to the variable time lengths of the tracklines, no time scale is provided for the bottom panel. The track line shown in panel 1 was conducted at multiple depths just as the dye began to emerge from riser # 55. In panel 2 the dye had been steadily emerging from riser #55 for ~45 minutes, towyos were conducted to establish appropriate depths for the fixed depth towing. Panels 3-6 show the fixed depth tows to define the plume field. Panel 7 shows a deep-water towyo below the plume.

From the exploratory transects it appeared that the plume field was centered along the diffuser line with little net movement to the north or south. As a result the segment survey was conducted along the diffuser line as planned. The segment survey (Figure 4) included a set of oval transects conducted near a subset of the diffusers (between diffusers 55 and 47). During this segment survey, the *in situ* sampling system was operated at a set of fixed depths sampled in rapid succession. Figure 4 shows the segment survey trackline at multiple depths. The two upper panels of the figure show depth and dye concentration along the trackline. The lower panel of Figure 4 shows the dye data as a function of time during the segment survey.

The Survey Plan called for 5 segment surveys to be conducted. The timing and location of these surveys was left to the discretion of the Chief Scientist and offshore team based on the observations in the field. Based on the findings of the exploratory transects, only one segment survey was actually conducted by the methods described in the Survey Plan. Instead, tracklines perpendicular to the diffuser array and down the center of the diffuser line were added in an attempt to define the dye gradient away for the diffusers.

Following the completion of the segment survey, the sensors were towed straight down the diffuser line at a depth of approximately 16 meters. The track continued past the eastern end of the diffuser (risers #1 and 2) until the dye was no longer detected (approximately 200 m east of the diffuser line). This track was conducted to check for the emergence of dye along the entire length of the diffuser. During this transect the highest dye concentrations of the survey were recorded. Dye was detected above 0.5 µg/L the entire length of the diffuser line with peak values between 0.9 and 1.0 µg/L found intermittently along the trackline. Figure 5 shows dye concentration, temperature, beam attenuation, and depth during this trackline. It appears that this trackline ran through the upper portion of the initial mixing zone. The tops of the diffuser risers are approximately 29 to 32 meters deep. It may be assumed that higher concentrations would have been observed on a deeper tow.

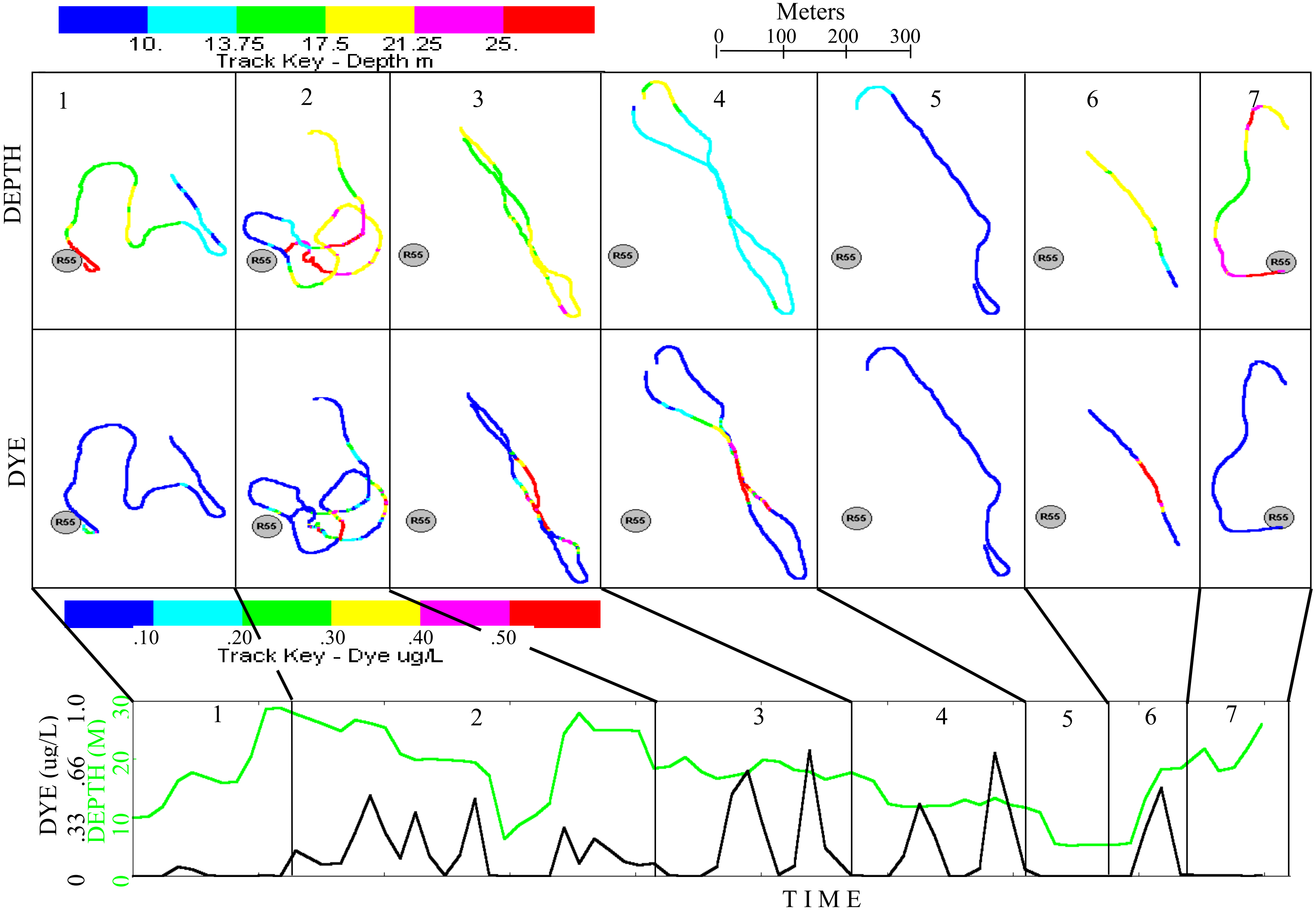

Figure 3. Exploratory Survey Transects.

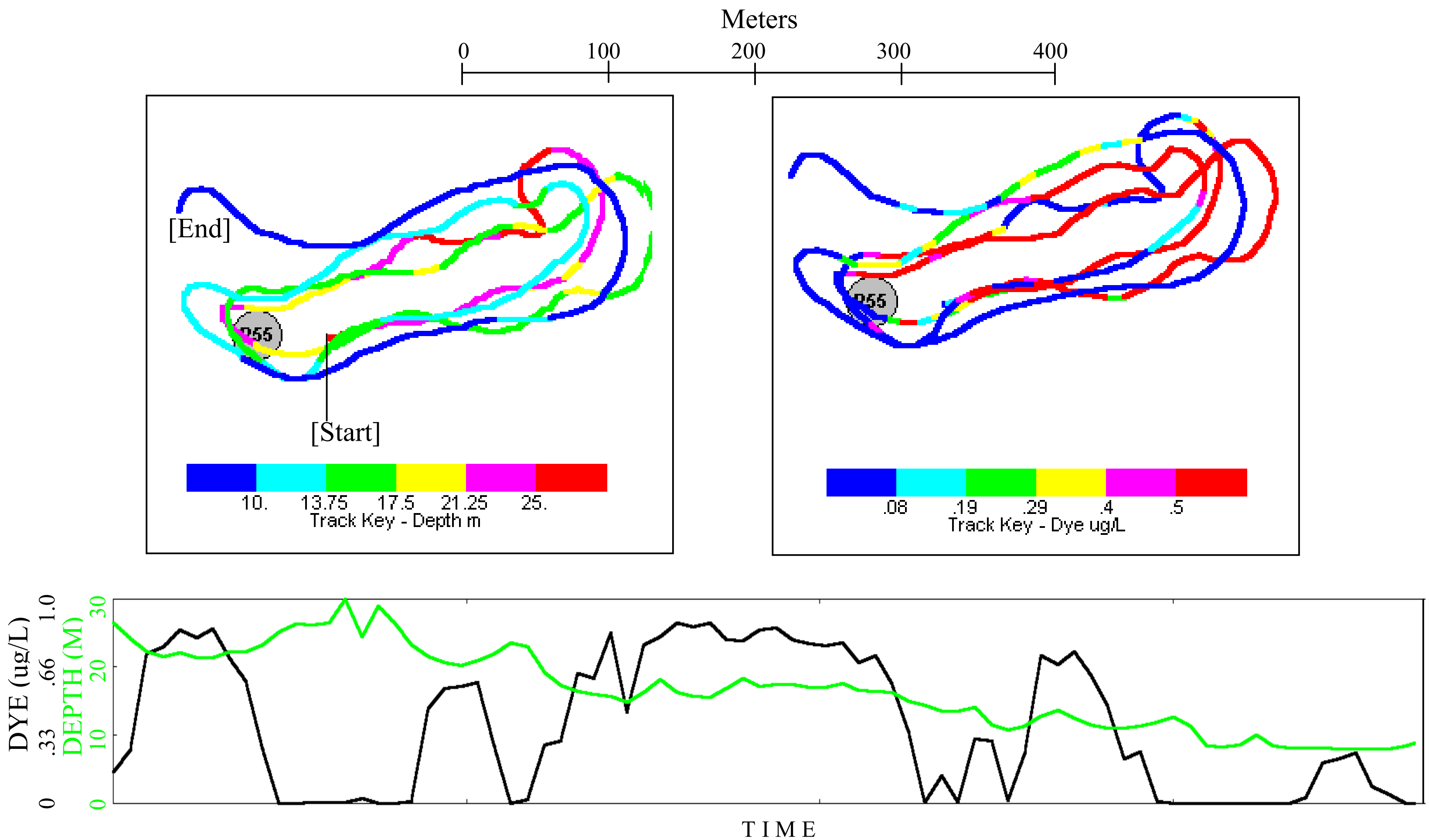

Figure 4. Segment Survey Transects.

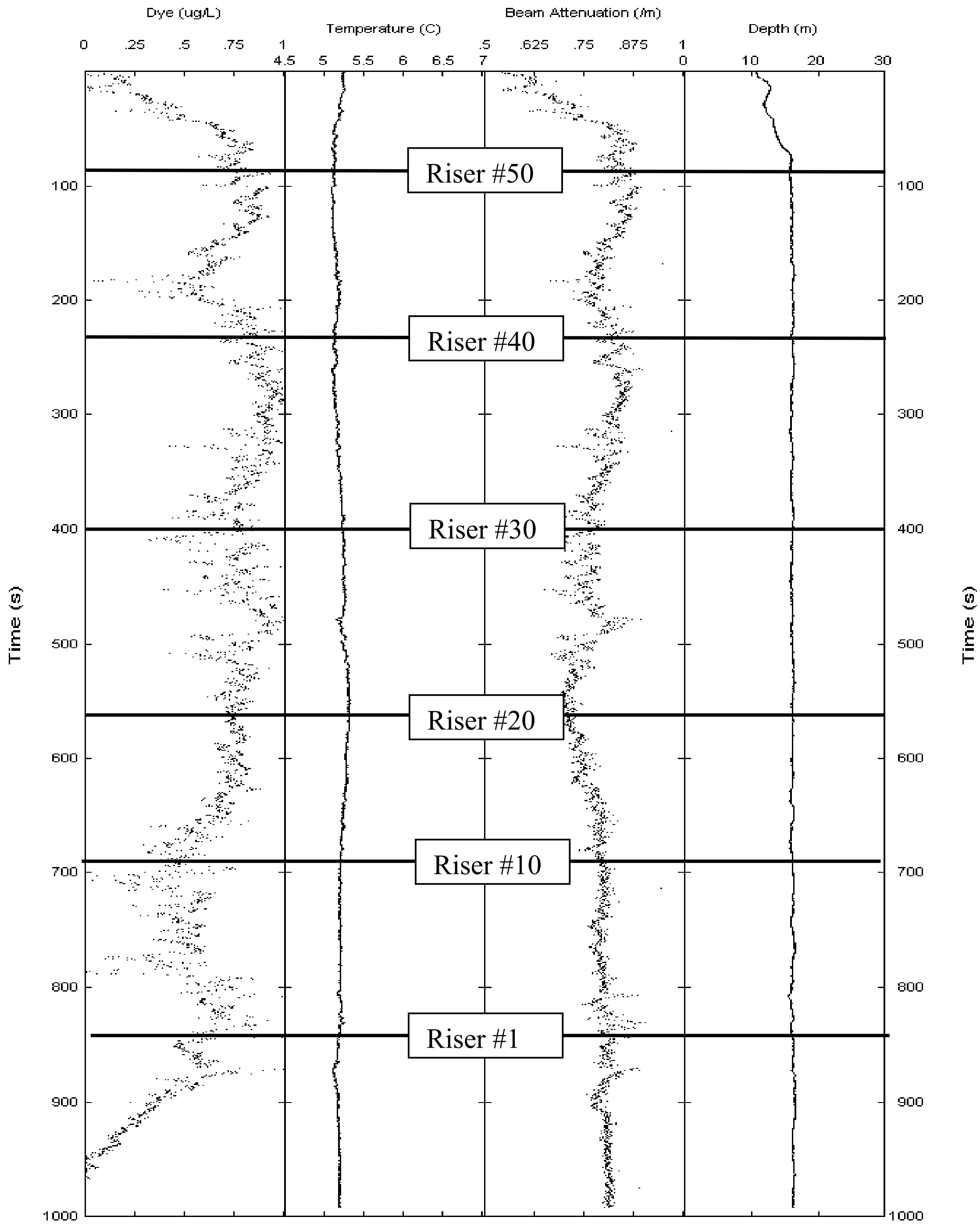

Figure 5. Diffuser Centerline Track.

Hydraulic Mixing Zone (HMZ) Surveys - *The objective of these surveys was to measure dilution at the edge of the hydraulic mixing zone to determine compliance with the requirements of the NPDES permit.*

Based on the information from the segment survey and centerline track, a Hydraulic Mixing Zone transect was initiated from east to west as planned. The sensors were towyoed to riser #40 along a line 90 meters to the north and parallel to the diffuser line. This location was selected based on the results of the previous transects. The towyo depths were between 4 and 25 meters deep. At depths between 10 and 25 meters dye concentration was consistently above 0.5 µg/L along this towyo line. Figure 6 shows this lengthwise trackline.

Defining the HMZ in the field proved difficult. During the segment survey, centerline transect, and the east-west towyo no distinct dye gradient indicative of an HMZ was observed. Dye concentration was still around 0.5 µg/L as much as 100 meters to the north of the diffuser line. It was therefore decided to deviate from the sampling plan and redefine the HMZ survey as towyo transects run perpendicular to the diffuser line rather than parallel to the line (Figure 7). This modification was intended to follow the plume away from the diffuser and find the point where rapid mixing gave way to oceanic dispersion. During these transects dye concentration was fairly stable (above 0.5 µg/L) from the diffuser area to as far as 400 m to the north and 75 m to the south. As a result it was difficult to discern where rapid dilution gave way to dispersion. Based on these transects, vertical profiles with five discrete sampling depths were conducted ~125 meters north of riser #40 (Figure 7). Because a distinct dye gradient was not found, this location was selected to ensure that the samples were taken outside the initial mixing zone.

The second HMZ sampling was conducted ~80 meters north of riser #10. This location was selected to capture the properties of the plume and HMZ at the eastern end of the diffuser line.

Figures 8 and 9 display the sampling depths and profile data for dye concentration, beam attenuation, and temperature during each of the vertical HMZ casts. From the profiles in Figures 8 and 9, it appears that changes in beam attenuation (turbidity) may be a useful indicator of plume structure.

During each of these vertical profiles discrete samples were collected for analysis of TSS, NH_4, PO_4, rhodamine and chlorophyll at 5 depths (maximum dye concentration, minimum dye concentration, and 3 other depths) and for silver and copper at maximum dye concentration and one other depth of high dye concentration. On the second HMZ profile samples were also collected for bacterial indicators at the 5 depths plus three additional samples taken from the area of maximum dye concentration.

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) are 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 transit time of water in the hose, 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 reaches zero the sampling technician was instructed to collect the sample, 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* were delivered to the DITP lab at the end of the survey day.

Table 3. Samples Collected For Analysis During the Nearfield Survey WP011.

	Planned Samples		Actual Samples	
Parameter	**From Background Survey**	**From HMZ Surveys**	**From Background Survey**	**From HMZ Surveys**
Rhodamine WT	4	10 (5 samples / HMZ survey)	4	10 (5 samples/HMZ Survey)
TSS	4	10 (5 samples/ HMZ survey)	4	10 (5 samples/HMZ Survey)
NH_4/PO_4	4	10 (5 samples/ HMZ survey)	4	10(5 samples/HMZ Survey)
Ag/Cu Total	2	4 (2 samples/ HMZ survey)	2	4 (2 samples/HMZ Survey)
Fecal Coliform/ *Enterococcus*	0	8 samples (all in one HMZ survey)	0	8 (all in one HMZ survey)
Chlorophyll	4	10 (5 samples/HMZ survey)	4	10 (5 samples/HMZ Survey)

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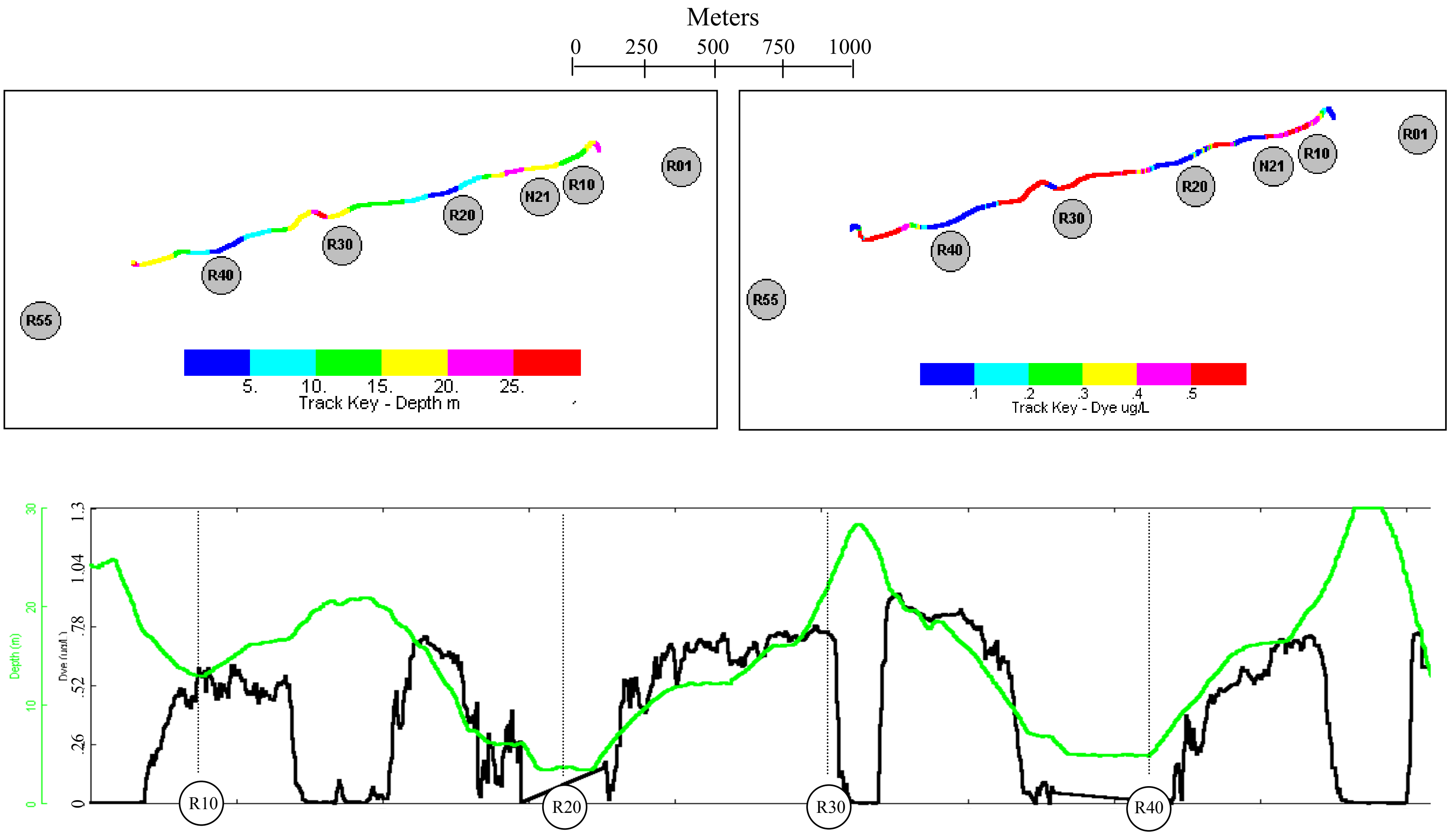

Figure 6. Hmz East-West Trackline.

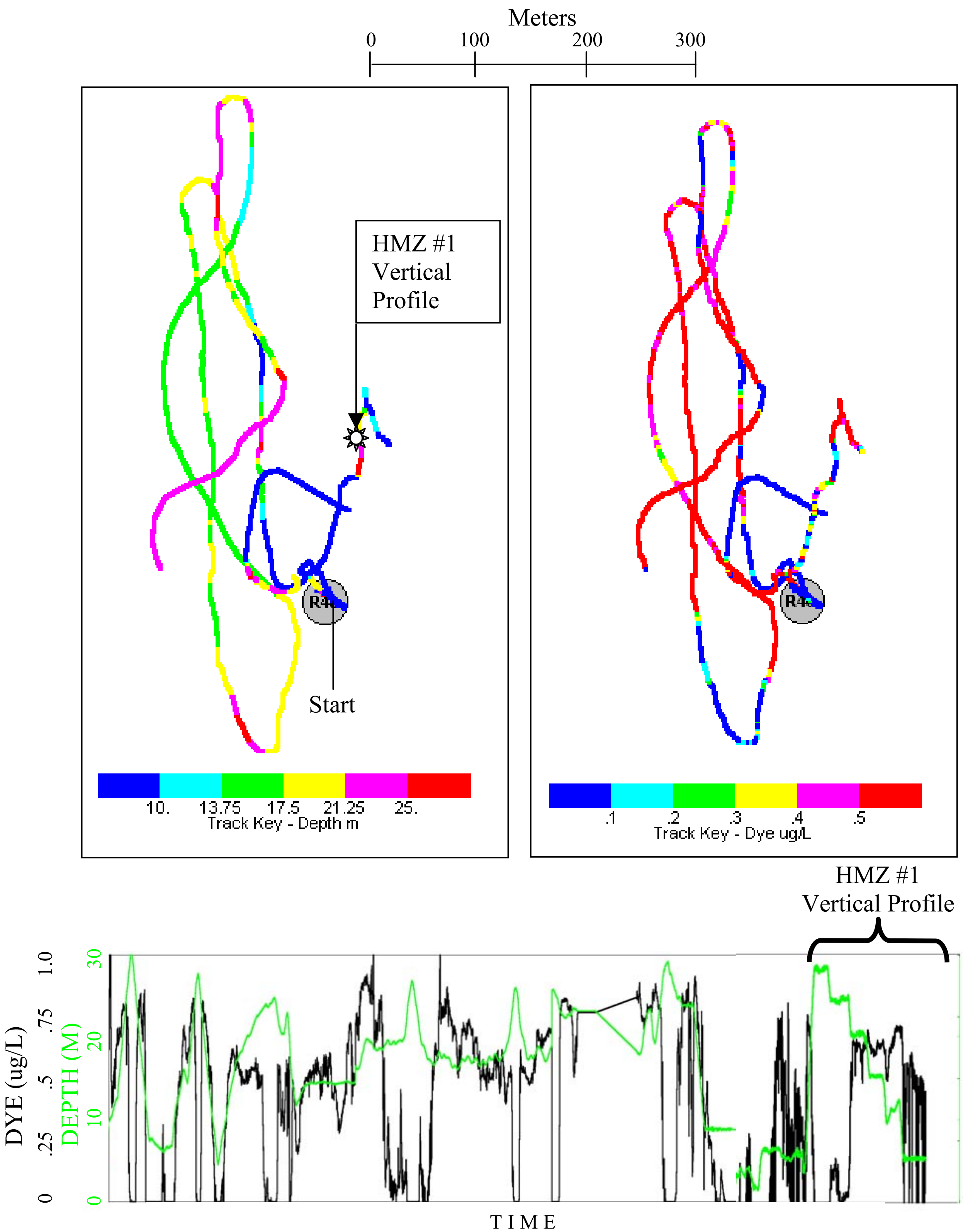

Figure 7. HMZ Transects.

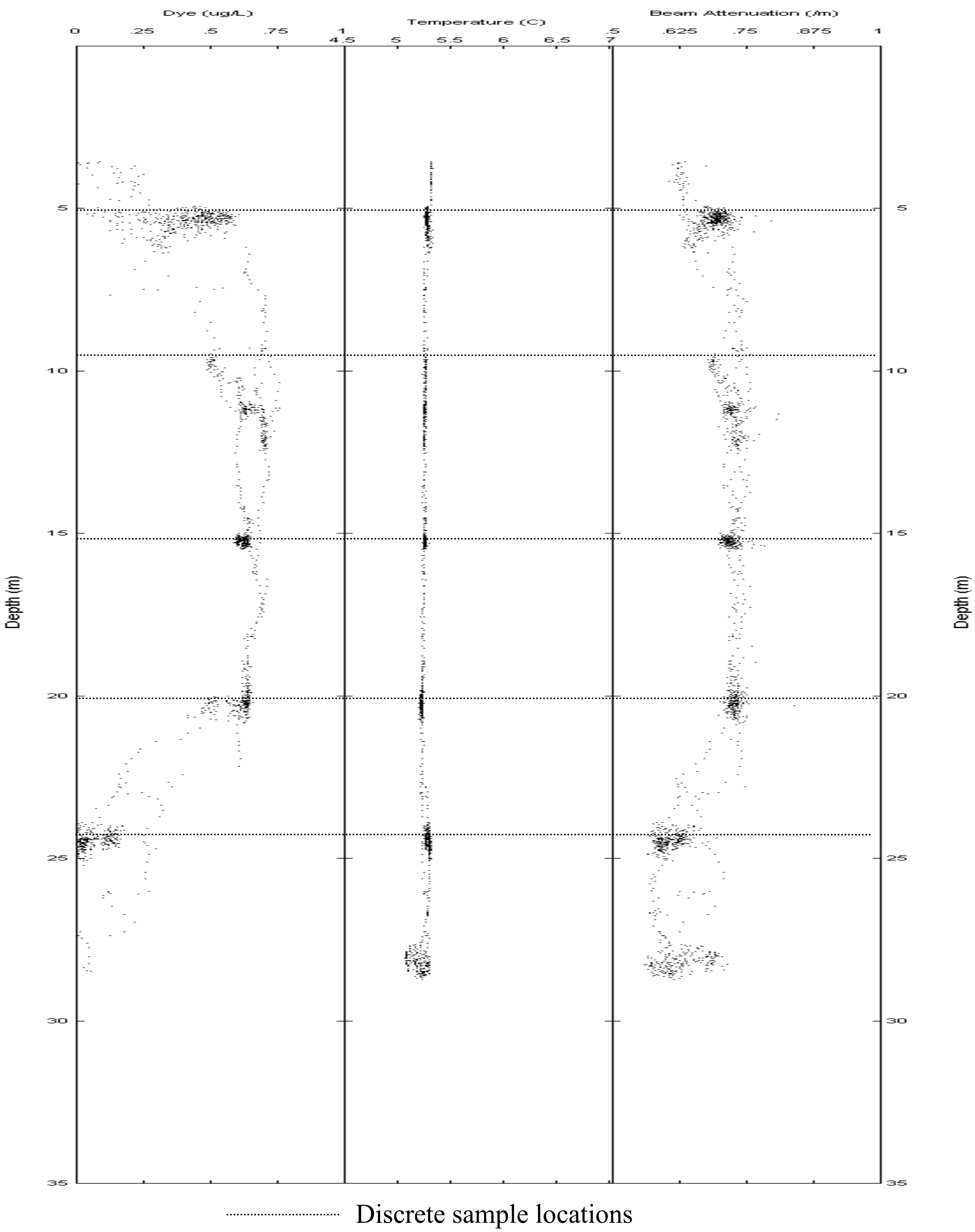

Figure 8. HMZ #1 Vertical Profile.

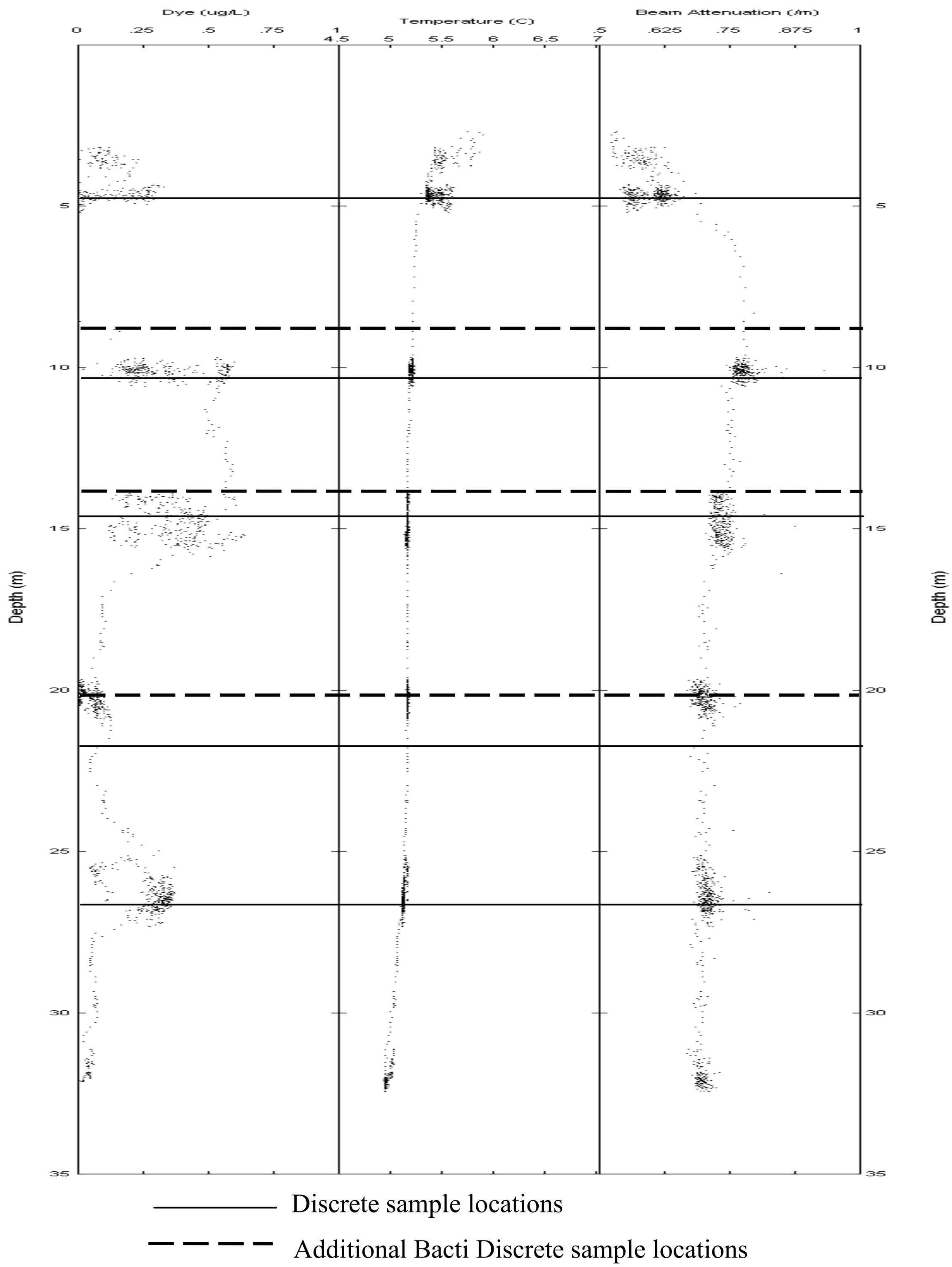

Figure 9. HMZ #2 Vertical Profile.

Farfield Survey - *The objective was to determine plume structure and behavior in the Farfield by tracking the spread of the dye to dilutions of at least 1:1000 (down to 0.10 µg/L active dye ingredient).*

At the end of the nearfield day a satellite-tracked drifter was deployed at approximately 60 m due north of riser #14 (42° 23.301'N 70° 47.121W). The drogue was set at a depth of 15 meters (the approximate center of the plume). At the start of the farfield day the vessel followed the drifter signal and easily located the unit 1.25 nautical miles due north of the diffuser array. The drifter was left in the water throughout the farfield day. The towed sensors were deployed at the drifter location. Dye concentrations were as high as 0.5 µg/L at approximately 20 meters depth. The vessel then transited away from the drifter on a trackline perpendicular to the diffuser line (towards the northwest). The sensors were operated in towyo mode. This trackline was continued until the dye was no longer detected (~3 nautical miles to the northwest of the diffuser array). At this point the vessel turned back towards the drifter and the diffusers and ran a series of perpendicular and parallel tracklines in and out of the plume field. Figure 10 shows these track lines with tow depth and dye concentration.

The overall plume field was approximately 3.8 nautical miles across in an east-west direction and 3.1 nm in a north-south direction. The farfield tracking operations comprised over 8 hours of towing. During this time there appeared to be some dispersion of the plume as well as a net movement of the plume field towards the north. These two factors make it difficult to define the exact location of plume boundaries at any given time.

The plume was reliably tracked to rhodamine concentrations as low as 0.05 µg/L. With an initial dye concentration in the effluent of ~55 µg/L, this represents a dilution of approximately 1:500. The highest dye concentrations observed on the farfield day were approximately 0.46 µg/L. This represents a dilution of 1:119 relative to the DITP effluent dye concentration. A line of high concentrations was located 2 nautical miles northwest and parallel to the diffuser line and extended for approximately 3.6 nautical miles. Maximum concentrations were found between 18 and 20 meters deep. The location of the plume in the farfield was consistent with ADCP data taken during the survey. Figure 11 shows current direction throughout the water column on April 19, 2001. The data suggest a set northwest movement of the water column.

Figure 12 shows the overall plume structure and temperature profile throughout the duration of the farfield day.

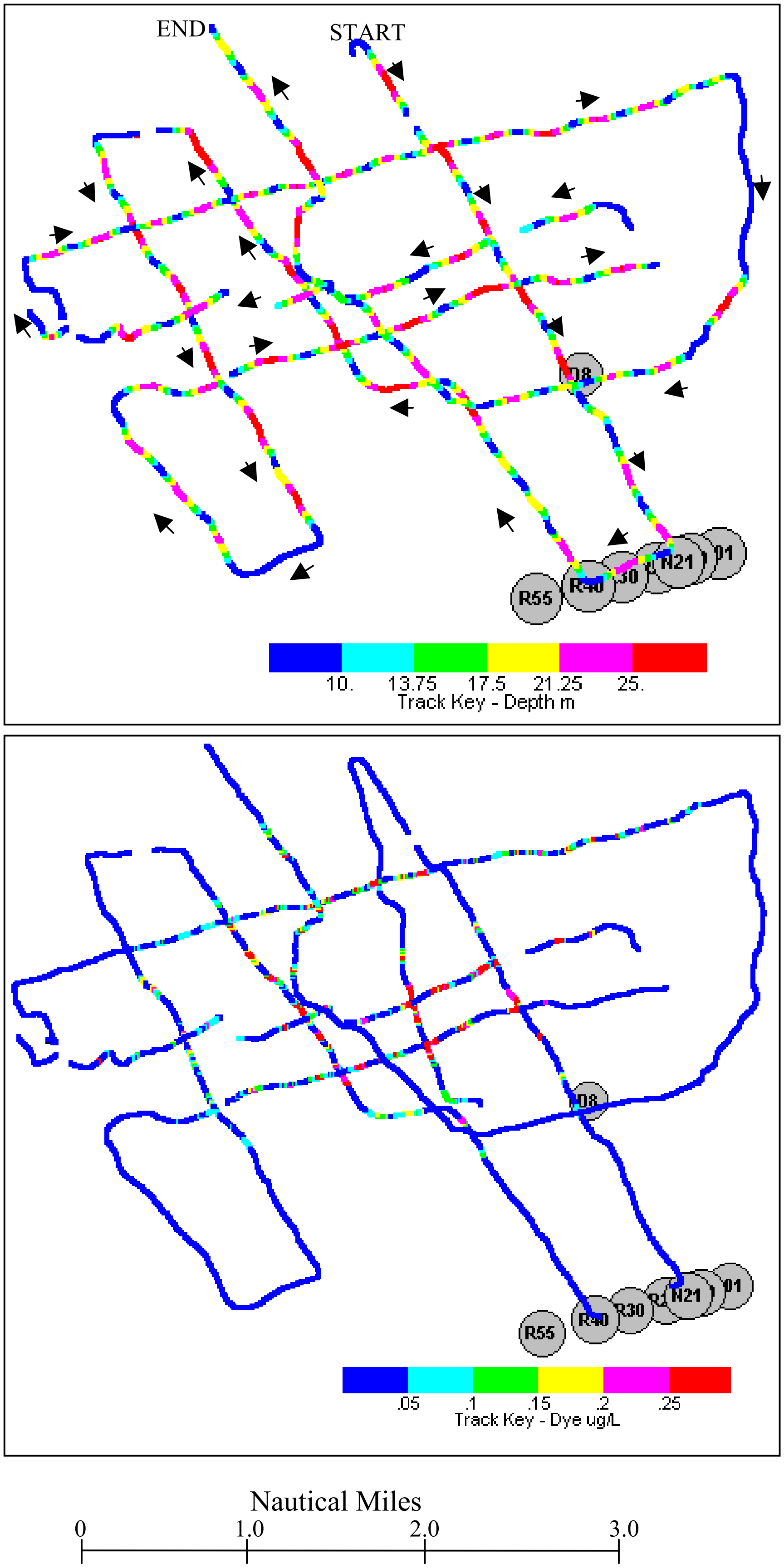

Figure 10. Farfield Tracklines.

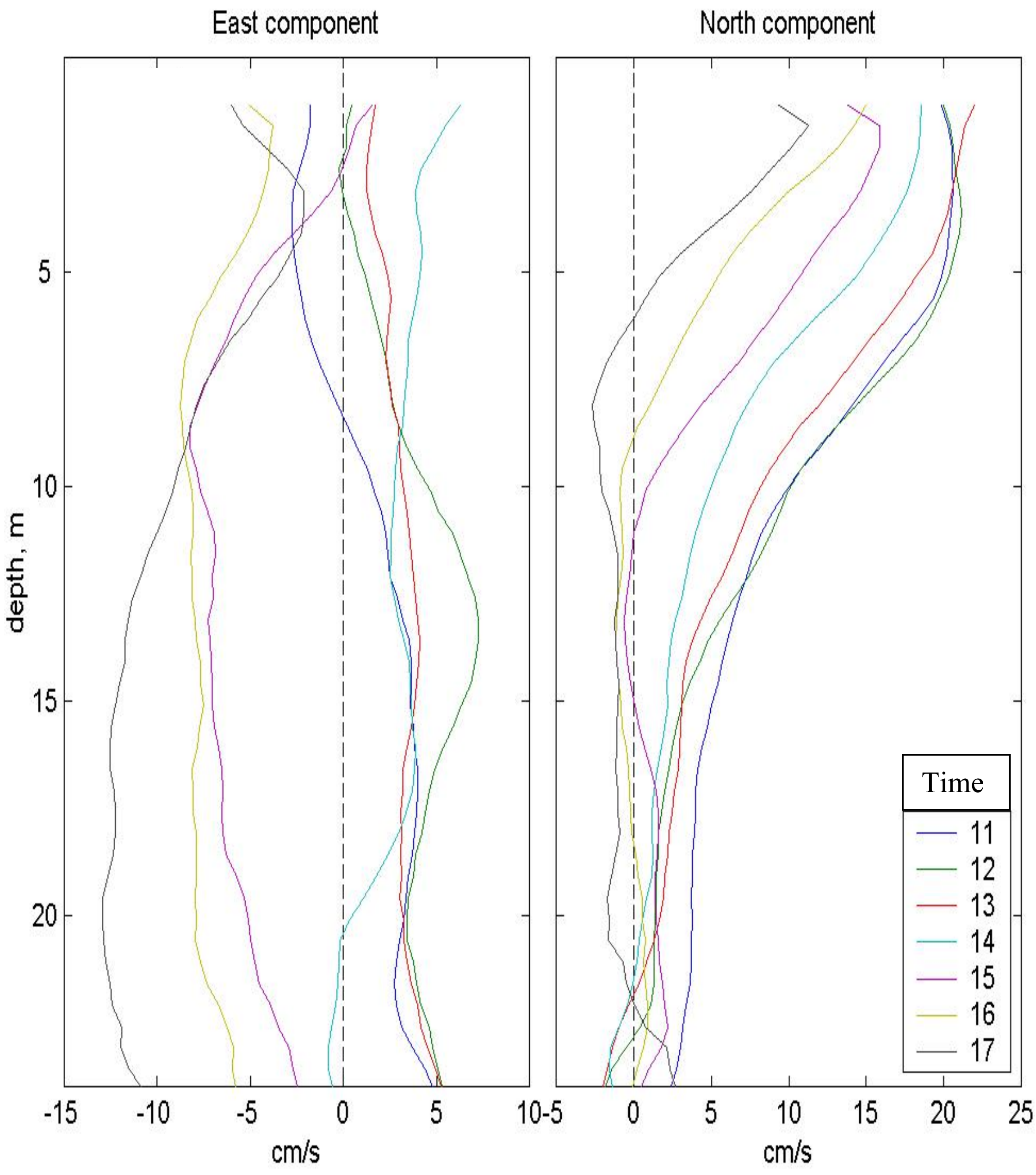

Figure 11. ADCP Current Velocity Data.

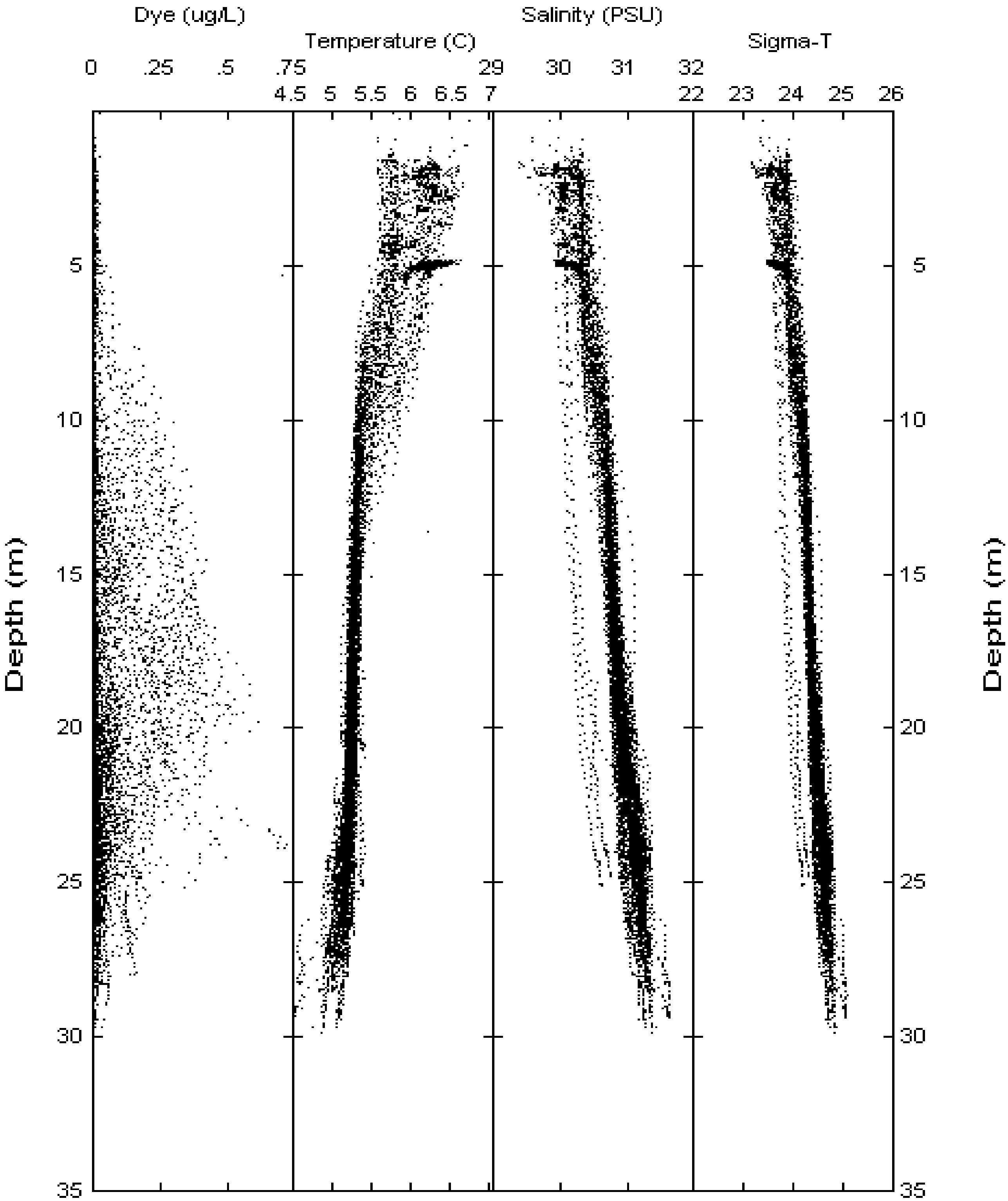

Figure 12. Dye, Temperature, Salinity and Density Profiles throughout the Farfield area.

2.4. Whale Observations

Incidental marine mammal observations were recorded by the survey Chief Scientist and reported in the survey logbook

3. Survey Chronology

Note: All times are recorded as Eastern Daylight Time

Wednesday, April 18th

0900	Began mobilization of R/V *Aquamonitor* in Hingham, MA and Deer Island Treatment Plant in Boston, MA.
1800	Mobilization completed.
2230	Crew meet at Battelle, travel to Deer Island Treatment Plant.
2340	Arrive at Deer Island Treatment Plant. Begin setting up for Dye Addition.

Thursday, April 19th– Dye Addition

0132	Station 0130. Collect baseline samples prior to turning on Dye.
0142	Begin pumping dye.
0224	Problems occur with deploying CTD. The sea cable was becoming jammed in the pulley on the float. The pulley was removed and a rope was used in the form of a "clothesline" to lower the CTD.
0240	Station 0230. Begin half hour sampling. Half hour samples collected included TSS, NH_4, PO_4, and Chloride samples.
0310	Station 0300. Begin hourly sampling. Hourly samples collected included Dye, TSS, NH_4/PO_4, and Ag/Cu samples. Half hour samples collected included Fecal Coliform, TSS, NH_4, PO_4, and Chloride samples.
0340	Station 0330. Begin half hour sampling. Half hour samples collected included TSS, NH_4, PO_4, and Chloride samples.
0410	Station 0400. Begin hourly sampling. Hourly samples collected included Dye, TSS, NH_4/PO_4, and Ag/Cu samples. Half hour samples collected included Fecal Coliform, TSS, NH_4, PO_4, and Chloride samples.
0440	Station 0430. Begin half hour sampling. Half hour samples collected included TSS, NH_4, PO_4, and Chloride samples.
0510	Station 0500. Begin hourly sampling. Hourly samples collected included Dye, TSS, NH_4/PO_4, and Ag/Cu samples. Half hour samples collected included Fecal Coliform, TSS, NH_4, PO_4, and Chloride samples.
0540	Station 0530. Begin half hour sampling. Half hour samples collected included TSS, NH_4, PO_4, and Chloride samples.
0610	Station 0600. Begin hourly sampling. Hourly samples collected included Dye, TSS, NH_4/PO_4, and Ag/Cu samples. Half hour samples collected included Fecal Coliform, TSS, NH_4, PO_4, and Chloride samples.
0640	Station 0630. Begin half hour sampling. Half hour samples collected included TSS, NH_4, PO_4, and Chloride samples.
0710	Station 0700. Begin last hourly sampling. Hourly samples collected included Dye, TSS, NH_4/PO_4, and Ag/Cu samples. Half hour samples collected included Fecal Coliform, TSS, NH_4, PO_4, and Chloride samples.

0740	Begin last half hour sampling. Half hour samples collected included TSS, NH_4, PO_4, and Chloride samples.
0750	Shut down Rhodamine Dye. Shut down CTD.
0800	Decide to track decline of dye concentration. Restart CTD.
0845	Dye concentration back down pre-addition levels. Shut down CTD.

Thursday, April 19th – Nearfield Plume Tracking Day

0639	Perform navigation calibration. Head for nearfield area to conduct Background survey.
0737	Arrive in the nearfield area.
0900	Begin Background survey, discrete water samples taken.
0930	Completed Background Survey. Stood by Riser #55 waited for sign of dye.
1206	Definite sign of Dye on NAVSAM.
1206-1340	Conduct segment survey operations
1500	On station HMZ1. Pump failed. Rewired to spare connection.
1635	Begin HMZ1 discrete water sampling.
1641	Completed HMZ1 sampling.
1653	Arrive on station HMZ2. Begin discrete water sampling.
1710	Take additional HMZ2 samples for Fecal Coliform (Station ID = HMZF).
1719	Complete HMZ2 / HMZF sampling.
0728	Deployed drifter Lat: 042°23.301'N Long: 070°47.121'W
1730	Head for Deer Island.
1814	Arrive DI, transfer Bacti samples and COC's to MWRA. Head for HCM.
1859	Arrive at Hewitt's Cove Marina and perform navigation calibration.

Friday, April 20th – Farfield Plume Tracking Day

0632	Arrive at Hewitt's Cove Marina and perform navigation calibration.
0700	Leave dock, head for Farfield area and drifter.
0803	Arrive at drifter.
0830	Out of plume area to the North, turn to the South.
1230	Light shielded the Seapoint fluorometer.
	Losing power to CTD at ~ 12m. Checked all connections, still had bad power. Changed out sea cable.
1435	Back in the water with new sea cable.
1708	Stopped towing operations.
1725	Retrieve drogue.
1830	Arrive at Hewitt's Cove Marina and perform navigation calibration.

4. Survey Results

4.1. Overview

Dye injection rate was paced proportionally to DITP flow rates (although not at the planned concentration) 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 higher concentrations than those in the west basin.

The dye began to emerge from riser #55 at approximately 12:06 on the nearfield day. The plume was successfully tracked for two days.

4.2. Preliminary Sensor Data Synopsis

The station data table is presented in Table 5.

4.2.1 Effluent

The DITP effluent flow rate varied from 412 MGD at the start of dye injection to 346 MGD at the end of dye injection. Figure 13 shows the DITP plant flows during the hours of the dye addition, nearfield survey, and farfield survey.

The discrete samples collected from the disinfection basins during dye addition were analyzed at Battelle on April 26th. Each sample was run on both the offshore and DITP fluorometers to ensure intercalibration. Table 4 shows the results of the discrete samples and the *in situ* data collected at the time of discrete sampling.

Table 4. Discrete and *in situ* Dye Concentrations from DITP.

Sample ID	Discrete 1 DITP Fluorometer	Discrete 2 Offshore fluorometer	In situ
P011A01B	-0.38	--	0.00
P011A03A	55.32	55.23	57.20
P011A049	55.27	55.39	57.62
P011A060	56.43	63.65	57.96
P011A06C	54.12	60.96	56.80
P011A078	54.88	--	56.82

Table 5. Station Data Table for WP011.

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	WP011	BK1	Background location for plume tracking survey	4/19/01 7:54	42.375717	-70.80167	34.6	m	DGPS	+/- 15m	WAT	BOSS	31.4	30	m	P011B025	9	L	PT
PLUME	WP011	BK1	Background location for plume tracking survey	4/19/01 7:54	42.375717	-70.80167	34.6	m	DGPS	+/- 15m	WAT	BOSS	21.9	21	m	P011B028	9	L	PT
PLUME	WP011	BK1	Background location for plume tracking survey	4/19/01 7:54	42.375717	-70.80167	34.6	m	DGPS	+/- 15m	WAT	BOSS	10.4	9.4	m	P011B02C	9	L	PT
PLUME	WP011	BK1	Background location for plume tracking survey	4/19/01 7:54	42.375717	-70.80167	34.6	m	DGPS	+/- 15m	WAT	BOSS	2.38	1.4	m	P011B02F	9	L	PT
PLUME	WP011	DAEE	DITP Disinfection basin, East channel (Effluent)	4/19/01 2:10	42.351451	-70.96015	7.6	m	FIXED	+/- 15m	WAT	BOSS	1.94	0.9	m	P011A03F	4	L	PT
PLUME	WP011	DAEE	DITP Disinfection basin, East channel (Effluent)	4/19/01 2:17	42.351451	-70.96015	7.6	m	DGPS	+/- 15m	WAT	BOSS	1.93	0.9	m	P011A046	4	L	PT
PLUME	WP011	DAEE	DITP Disinfection basin, East channel (Effluent)	4/19/01 4:07	42.351451	-70.96015	7.6	m	DGPS	+/- 15m	WAT	BOSS	1.94	0.9	m	P011A063	4	L	PT
PLUME	WP011	DAEE	DITP Disinfection basin, East channel (Effluent)	4/19/01 5:03	42.351451	-70.96015	7.6	m	DGPS	+/- 15m	WAT	BOSS	2.01	1	m	P011A06F	4	L	PT
PLUME	WP011	DAEE	DITP Disinfection basin, East channel (Effluent)	4/19/01 6:05	42.351451	-70.96015	7.6	m	DGPS	+/- 15m	WAT	BOSS	1.98	1	m	P011A07B	4	L	PT
PLUME	WP011	DAWE	Disinfection basin, West Channel (Effluent)	4/19/01 0:22	42.351451	-70.96015	7.6	m	DGPS	+/- 15m	WAT	BOSS	2.18	1.2	m	P011A01B	4	L	PT
PLUME	WP011	DAWE	Disinfection basin, West Channel (Effluent)	4/19/01 0:22	42.351451	-70.96015	7.6	m	DGPS	+/- 15m	SEW	BUCKET	2	1	m	01016437	250	mL	PT
PLUME	WP011	DAWE	Disinfection basin, West Channel (Effluent)	4/19/01 0:22	42.351451	-70.96015	7.6	m	DGPS	+/- 15m	SEW	BUCKET	2	1	m	01016448	1	L	PT
PLUME	WP011	DAWE	Disinfection basin, West Channel (Effluent)	4/19/01 1:40	42.351451	-70.96015	7.6	m	FIXED	+/- 15m	SEW	BUCKET	2	1	m	01016449	1	L	PT
PLUME	WP011	DAWE	Disinfection basin, West Channel (Effluent)	4/19/01 2:10	42.351451	-70.96015	7.6	m	FIXED	+/- 15m	WAT	BOSS	2.01	1	m	P011A03A	4	L	PT
PLUME	WP011	DAWE	Disinfection basin, West Channel (Effluent)	4/19/01 2:10	42.351451	-70.96015	7.6	m	FIXED	+/- 15m	SEW	BUCKET	2	1	m	01016438	250	mL	PT
PLUME	WP011	DAWE	Disinfection basin, West Channel (Effluent)	4/19/01 2:10	42.351451	-70.96015	7.6	m	FIXED	+/- 15m	SEW	BUCKET	2	1	m	01016450	1	L	PT

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	WP011	DAWE	Disinfection basin, West Channel (Effluent)	4/19/01 2:40	42.351451	-70.96015	7.6	m	FIXED	+/- 15m	SEW	BUCKET	2	1	m	01016451	1	L	PT
PLUME	WP011	DAWE	Disinfection basin, West Channel (Effluent)	4/19/01 2:40	42.351451	-70.96015	7.6	m	DGPS	+/- 15m	SEW	BUCKET	2	1	m	01016439	250	mL	PT
PLUME	WP011	DAWE	Disinfection basin, West Channel (Effluent)	4/19/01 2:40	42.351451	-70.96015	7.6	m	DGPS	+/- 15m	SEW	BUCKET	2	1	m	01016452	1	L	PT
PLUME	WP011	DAWE	Disinfection basin, West Channel (Effluent)	4/19/01 2:40	42.351451	-70.96015	7.6	m	DGPS	+/- 15m	WAT	BOSS	1.93	0.9	m	P011A049	4	L	PT
PLUME	WP011	DAWE	Disinfection basin, West Channel (Effluent)	4/19/01 3:40	42.351451	-70.96015	7.6	m	FIXED	+/- 15m	SEW	BUCKET	2	1	m	01016453	1	L	PT
PLUME	WP011	DAWE	Disinfection basin, West Channel (Effluent)	4/19/01 4:07	42.351451	-70.96015	7.6	m	FIXED	+/- 15m	WAT	BOSS	2.02	1	m	P011A060	4	L	PT
PLUME	WP011	DAWE	Disinfection basin, West Channel (Effluent)	4/19/01 4:07	42.351451	-70.96015	7.6	m	FIXED	+/- 15m	SEW	BUCKET	2	1	m	01016440	250	mL	PT
PLUME	WP011	DAWE	Disinfection basin, West Channel (Effluent)	4/19/01 4:07	42.351451	-70.96015	7.6	m	FIXED	+/- 15m	SEW	BUCKET	2	1	m	01016454	1	L	PT
PLUME	WP011	DAWE	Disinfection basin, West Channel (Effluent)	4/19/01 4:40	42.351451	-70.96015	7.6	m	FIXED	+/- 15m	SEW	BUCKET	2	1	m	01016455	1	L	PT
PLUME	WP011	DAWE	Disinfection basin, West Channel (Effluent)	4/19/01 5:03	42.351451	-70.96015	7.6	m	FIXED	+/- 15m	WAT	BOSS	2.02	1	m	P011A06C	4	L	PT
PLUME	WP011	DAWE	Disinfection basin, West Channel (Effluent)	4/19/01 5:03	42.351451	-70.96015	7.6	m	FIXED	+/- 15m	SEW	BUCKET	2	1	m	01016441	250	mL	PT
PLUME	WP011	DAWE	Disinfection basin, West Channel (Effluent)	4/19/01 5:03	42.351451	-70.96015	7.6	m	FIXED	+/- 15m	SEW	BUCKET	2	1	m	01016456	1	L	PT
PLUME	WP011	DAWE	Disinfection basin, West Channel (Effluent)	4/19/01 5:40	42.351451	-70.96015	7.6	m	FIXED	+/- 15m	SEW	BUCKET	2	1	m	01016457	1	L	PT
PLUME	WP011	DAWE	Disinfection basin, West Channel (Effluent)	4/19/01 6:05	42.351451	-70.96015	7.6	m	FIXED	+/- 15m	WAT	BOSS	2.05	1.1	m	P011A078	4	L	PT
PLUME	WP011	DAWE	Disinfection basin, West Channel (Effluent)	4/19/01 6:05	42.351451	-70.96015	7.6	m	FIXED	+/- 15m	SEW	BUCKET	2	1	m	01016442	250	mL	PT
PLUME	WP011	DAWE	Disinfection basin, West Channel (Effluent)	4/19/01 6:05	42.351451	-70.96015	7.6	m	FIXED	+/- 15m	SEW	BUCKET	2	1	m	01016458	1	L	PT
PLUME	WP011	DAWE	Disinfection basin, West Channel	4/19/01	42.351451	-70.96015	7.6	m	FIXED	+/-	SEW	BUCKET	2	1	m	01016459	1	L	PT

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
			(Effluent)	6:40						15m									
PLUME	WP011	HMZ1	Hydraulic mixing zone towyo around outfall diffusers.	4/19/01 15:25	42.386665	-70.79675	31	m	DGPS	+/- 15m	WAT	BOSS	24.9	24	m	P011B070	9	L	PT
PLUME	WP011	HMZ1	Hydraulic mixing zone towyo around outfall diffusers.	4/19/01 15:25	42.386665	-70.79675	31	m	DGPS	+/- 15m	WAT	BOSS	21	20	m	P011B073	9	L	PT
PLUME	WP011	HMZ1	Hydraulic mixing zone towyo around outfall diffusers.	4/19/01 15:25	42.386665	-70.79675	31	m	DGPS	+/- 15m	WAT	BOSS	15.7	15	m	P011B076	9	L	PT
PLUME	WP011	HMZ1	Hydraulic mixing zone towyo around outfall diffusers.	4/19/01 15:25	42.386665	-70.79675	31	m	DGPS	+/- 15m	WAT	BOSS	10.2	9.2	m	P011B079	9	L	PT
PLUME	WP011	HMZ1	Hydraulic mixing zone towyo around outfall diffusers.	4/19/01 15:25	42.386665	-70.79675	31	m	DGPS	+/- 15m	WAT	BOSS	5.58	4.6	m	P011B07C	9	L	PT
PLUME	WP011	HMZ2	Hydraulic mixing zone profile at point of maximum bottom dye concentration.	4/19/01 15:53	42.388866	-70.78362	34.4	m	DGPS	+/- 15m	WAT	BOSS	27.3	26	m	P011B085	9	L	PT
PLUME	WP011	HMZ2	Hydraulic mixing zone profile at point of maximum bottom dye concentration.	4/19/01 15:53	42.388866	-70.78362	34.4	m	DGPS	+/- 15m	WAT	BOSS	21.1	20	m	P011B088	9	L	PT
PLUME	WP011	HMZ2	Hydraulic mixing zone profile at point of maximum bottom dye concentration.	4/19/01 15:53	42.388866	-70.78362	34.4	m	DGPS	+/- 15m	WAT	BOSS	20.7	20	m	P011B09A	9	L	PT
PLUME	WP011	HMZ2	Hydraulic mixing zone profile at point of maximum bottom dye concentration.	4/19/01 15:53	42.388866	-70.78362	34.4	m	DGPS	+/- 15m	WAT	BOSS	14.9	14	m	P011B08B	9	L	PT
PLUME	WP011	HMZ2	Hydraulic mixing zone profile at point of maximum bottom dye concentration.	4/19/01 15:53	42.388866	-70.78362	34.4	m	DGPS	+/- 15m	WAT	BOSS	14.6	14	m	P011B09D	9	L	PT
PLUME	WP011	HMZ2	Hydraulic mixing zone profile at point of maximum bottom dye concentration.	4/19/01 15:53	42.388866	-70.78362	34.4	m	DGPS	+/- 15m	WAT	BOSS	10.7	9.7	m	P011B08E	9	L	PT
PLUME	WP011	HMZ2	Hydraulic mixing zone profile at point of maximum bottom dye concentration.	4/19/01 15:53	42.388866	-70.78362	34.4	m	DGPS	+/- 15m	WAT	BOSS	10.2	9.2	m	P011B0A0	9	L	PT
PLUME	WP011	HMZ2	Hydraulic mixing zone profile at point of maximum bottom dye concentration.	4/19/01 15:53	42.388866	-70.78362	34.4	m	DGPS	+/- 15m	WAT	BOSS	5.27	4.3	m	P011B091	9	L	PT

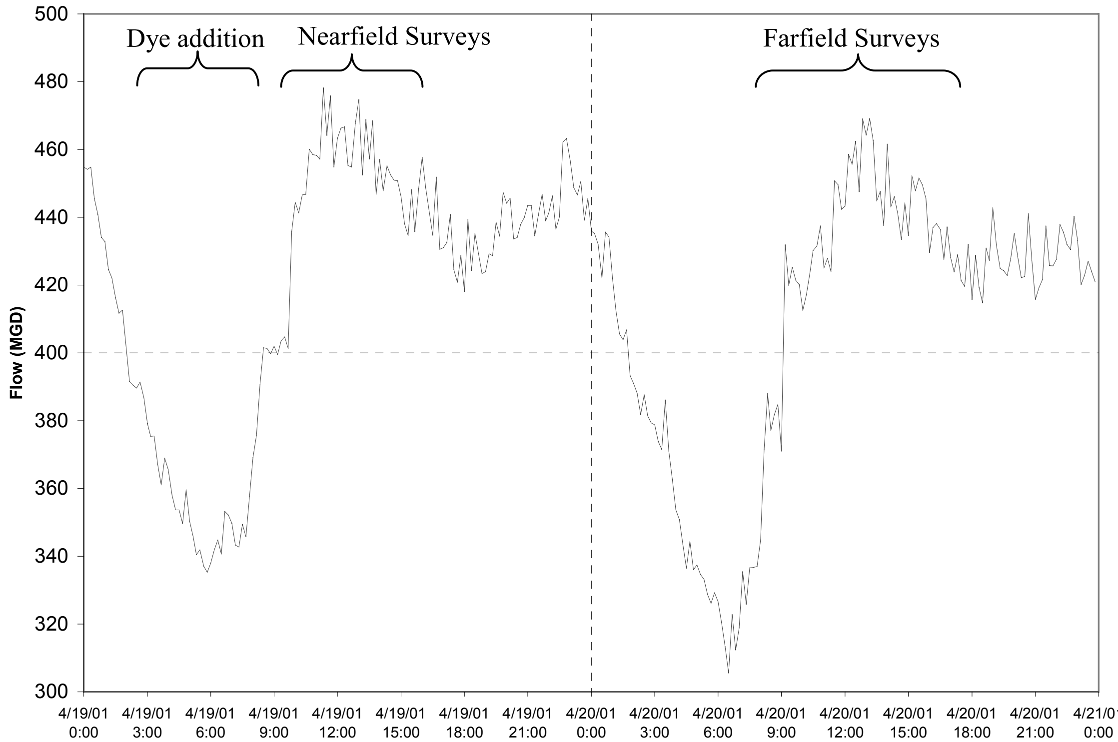

Figure 13. DITP Flow Rate.

Figure 14 shows dye concentration, temperature and depth of sample in the disinfection basin. Once the dye concentration stabilized in the disinfection basin (~45 minutes after start of dye addition), it was extremely stable at (~55 µg/L) until injection was discontinued. Dye concentration was also uniform with depth. Note that the spikes in the sensor data are a product of the difficulties conducting the vertical profiles and not an indication of problems with the sensors.. The sensors were removed from the water several times during the profiling.

Samples collected in the east disinfection basin were ~12% higher than the concurrent *in situ* readings from the west basin. A discussion of this is provided in section 5.2.

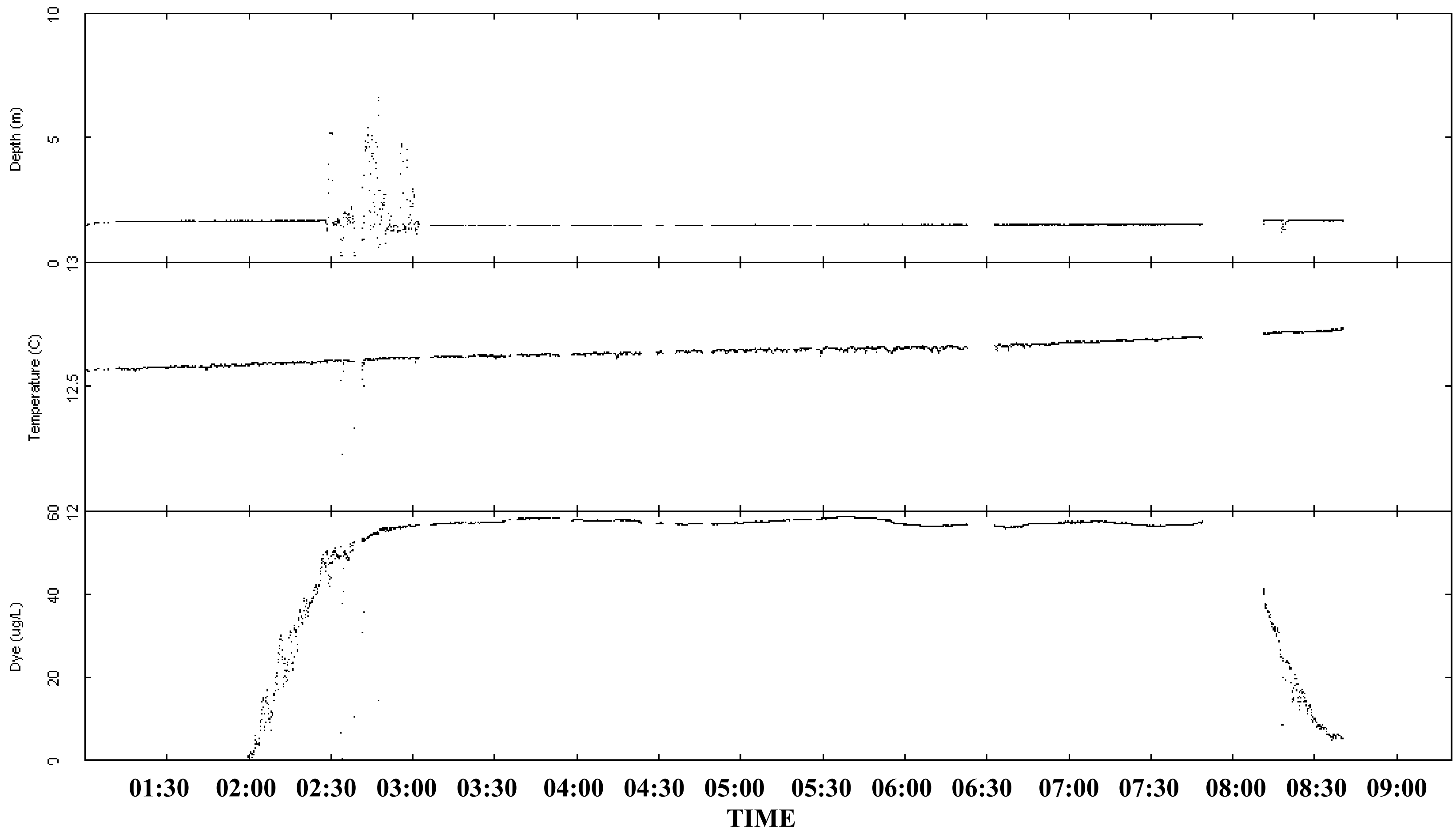

Figure 14. Dye concentration, Temperature and Depth of sample in West Disinfection Basin

4.2.2 Offshore

The background surveys conducted prior to dye release were designed to address the background fluorescent signal at the rhodamine wavelength. Figure 15 shows fluorescence, water temperature and beam attenuation plotted against depth for the background surveys. Based on background fluorescence, a background value of .0035 was subtracted from the raw dye fluorescence values recorded in the BOSS. The large grouping of negative dye values above 12 meters is the result of insufficient light shielding of the sensors in shallow waters. These values were not used for the calculation of background values.

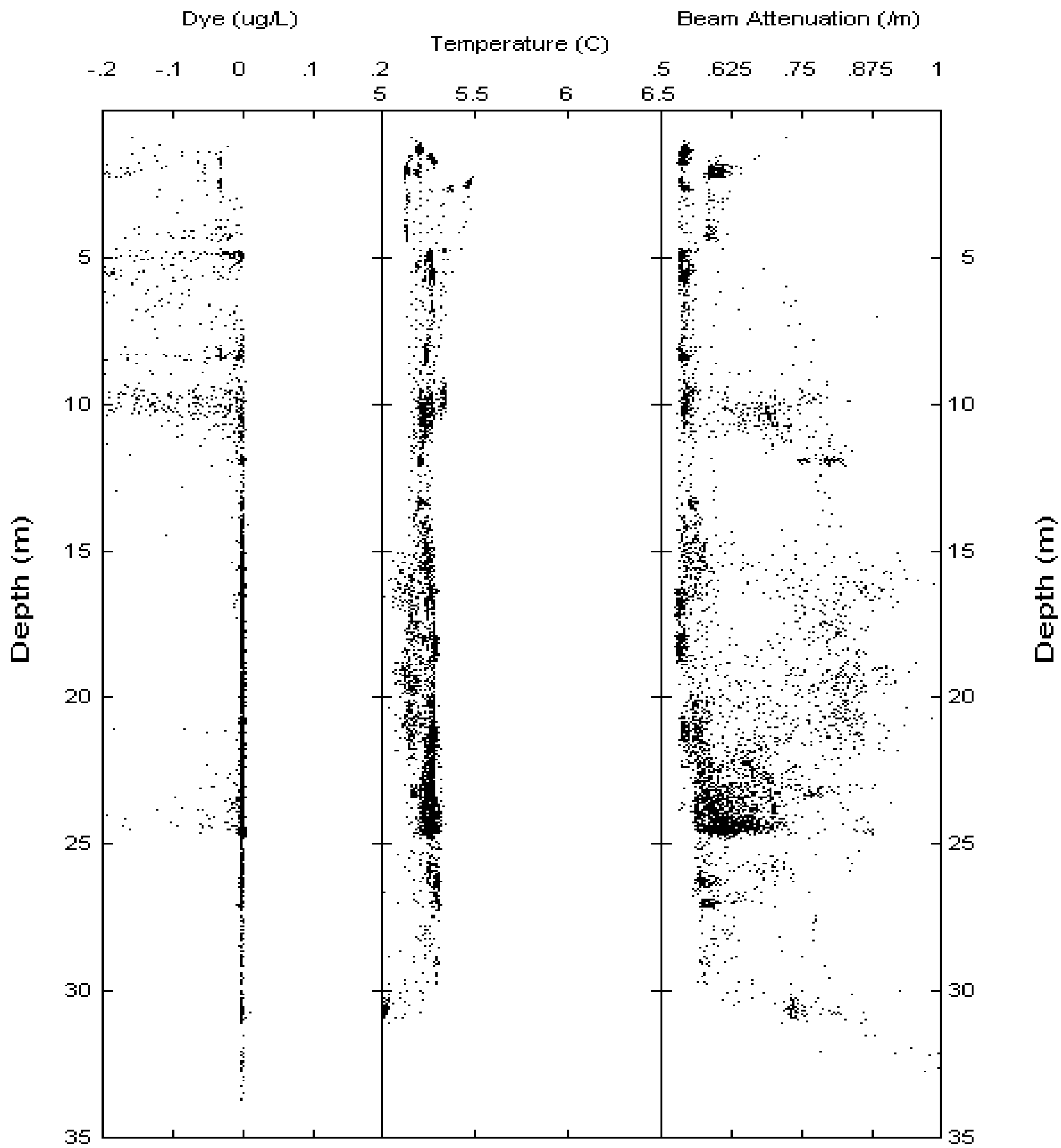

Figure 15. Background Survey Dye Concentration, Temperature and Beam Attenuation.

Figure 16 shows fluorescence versus beam attenuation. There was no relationship between beam attenuation and background fluorescence. Thus no corrections for turbidity interactions on the dye were required for this survey. As in Figure 16 the large negative values reflect the light shielding issue.

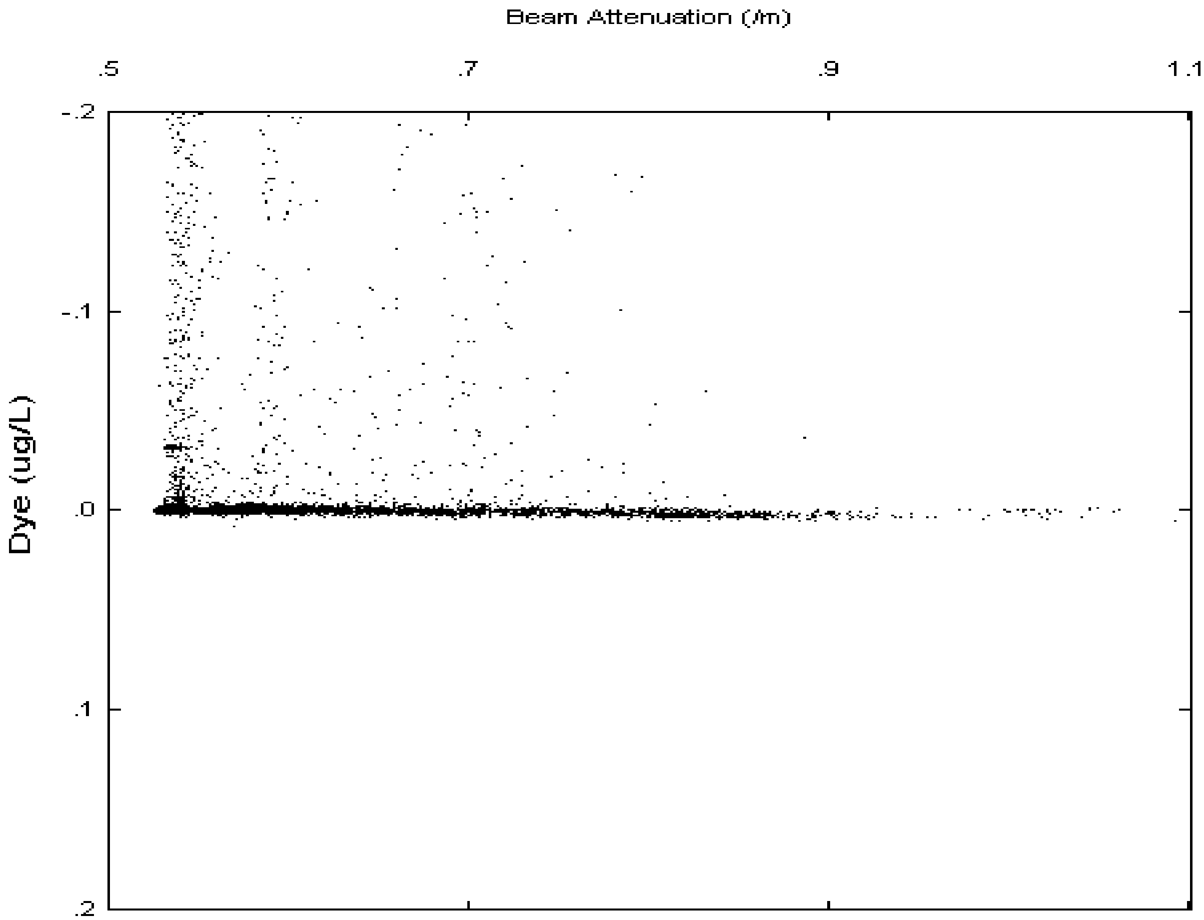

Figure 16. Background Dye Concentration Versus Beam Attenuation.

The discrete samples collected during the background and HMZ offshore surveys were analyzed at Battelle on April 26th. Discrete samples were analyzed by the DITP and offshore Rhodamine fluorometers. Table 6 shows the results of the discrete samples and the *in situ* data collected at the time of discrete sampling. Rhodamine concentrations in the discrete samples were found to be slightly higher from each sensor than the comparable *in situ.* Figure 17 shows the Discrete 1 (offshore sensor) data plotted against the *in situ* data with the regression and correction equation. The slope of the compared data was close to 1 (1.013) with a high R^2 value (0.9655). The data show that no additional correction was required and the temperature equation was used directly to calculate final *in situ* dye concentrations.

Table 6. Discrete and *in situ* Dye Concentrations (ppb) from Background and HMZ Surveys.

Survey	Sample ID	Discrete 1 Offshore Sensor	Discrete 2 DITP Sensor	in situ
Background	p011b025	0.047	0.036	0.000
	p011b028	0.048	0.039	0.000
	p011b02c	0.048	0.042	-0.116
	p011b02f	0.052	0.027	-0.032
HMZ #1	p011b070	0.211	0.185	0.130
	p011b073	0.717	0.669	0.634
	p011b076	0.689	0.663	0.635
	p011b079	0.711	0.659	0.647
	p011b07c	0.646	0.628	0.572
HMZ #2	p011b085	0.430	0.409	0.331
	p011b088	0.150	0.131	0.108
	p011b08b	0.355	0.336	0.336
	p011b08e	0.375	0.358	0.390
	p011b091	0.394	0.377	0.218

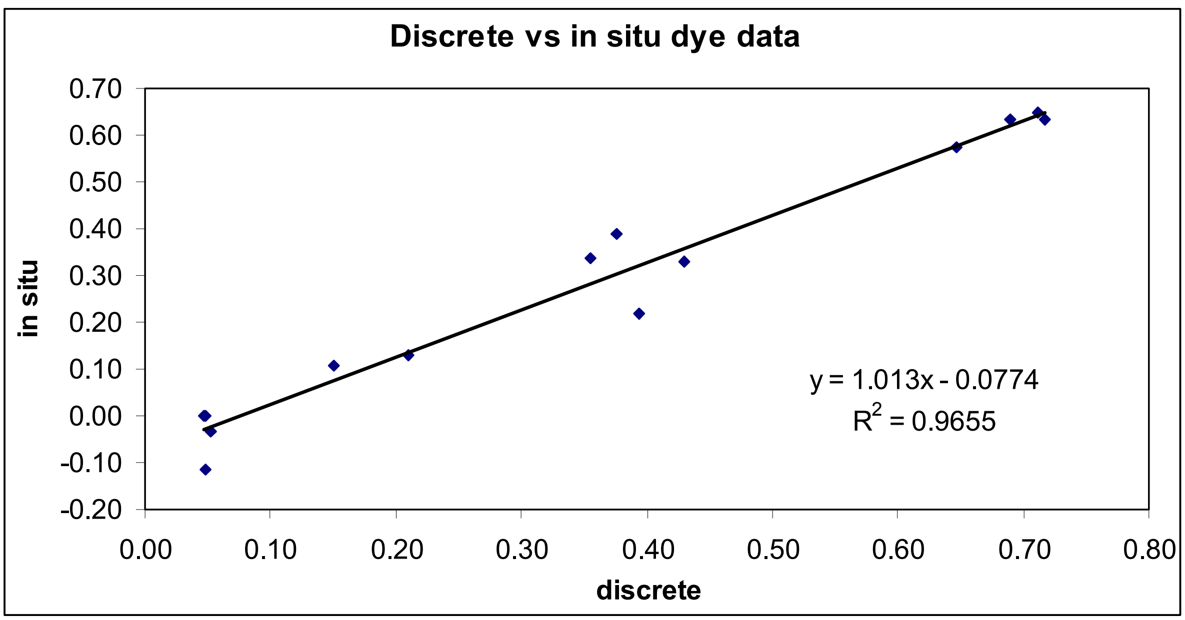

Figure 17. Comparison of Discrete and *In Situ* Data From Offshore Surveys. (Only data for offshore sensor units shown)

4.2.3 Initial Dilution

During the first HMZ survey, the dye plume was located between 7 and 20 meters deep. The plume was fairly uniform in concentration throughout. Dye concentration in four samples collected at a range of depths (5.6, 10.2, 15.7 and 21.0 m) within the plume were between 0.646 and 0.717 µg/L. A fifth sample, collected just on the upper edge of the dye plume at 5.1 meters, had a concentration of 0.211 µg/L.

During the second HMZ survey the plume was observed at two distinct depths. There was a small deep plume at approximately 27 meters. The main plume was located between 10 and 20 meters deep. The dye concentration in three samples collected from the main plume (10.7, 14.9, and 21.1 m) ranged from 0.355 to 0.394 µg/L. A fourth sample collected from the deep plume had a concentration of 0.430 µg/L. A fifth sample collected at 5.3 meters depth was just above the main body of the plume and had a dye concentration of 0.150 µg/L.

An estimate of the initial dilution of the effluent plume is based on the stable west basin dye concentration 55 µg/L and the highest value collected in during the HMZ surveys (0.717 µg/L). Using these values the estimated initial dilution of the effluent plume was 1:77. This value is conservative in that the overall initial concentration may have been higher than 55 µg/L. Based on a set of discrete samples collected from the east disinfection basin, concentrations from these samples were approximately 62 µg/L. If the east basin concentrations were as stable as the west basin and accounted for half of the total effluent flow, then the overall effluent concentration would be close to 58.5 µg/L and the initial dilution would be 1:82.

The highest dye concentrations recorded during the nearfield surveys were approximately 0.95 µg/L. This represents a dilution of 1:58. These values were recorded at 16 meters depth directly over the diffuser line (*i.e*. approximately 15 meters above the risers). Based on the HMZ survey tracklines conducted parallel to the diffuser axis, it appears that these values were located within the hydraulic mixing zone. Although no data was collected closer than 15 meters from the risers, it appears that rapid mixing takes place close to the diffusers. Because of this, it proved difficult to pinpoint the location where rapid mixing gave way to oceanic dispersion. If the values in the main body of the plume are used to estimate initial dilution, values of 80 and 146 are obtained for HMZ #1 and HMZ #2 respectively.

4.3. Marine Mammal Observations

04/20/2001 Time: 11:06:43 Lat: 042°23.352'N Long: 070°50.682'W Finbacks 1000 m to west

5. Problems Experienced, Actions Taken, and Recommendations

5.1. Schedule

The winter plume tracking survey was initially scheduled for March 2001. In the weeks leading up to the plume tracking survey, historically high rainfalls occurred in the New England area. As a result plant flows at DITP were at or above capacity. High plant flow rates and river runoffs into Massachusetts Bay created an atypical environment in the bay. In addition to the unusually high fresh water input, maximum DITP flows would have required substantially more Rhodamine WT dye to be added than was previously calculated. For these reasons the survey was postponed until April 19th. As a result of the delay, the survey was conducted under weakly stratified conditions. Although the intention of the winter survey was to assess an unstratified water column, the weak stratification provided substantial insight for the summer survey.

5.2. Technical

-Deer Island

The setup for transecting the disinfection basin with the sensor package did not work well. Horizontal transects were performed without major difficulty but full vertical profiles were unattainable. A new method for profiling the basin is planned for the summer survey.

The decision was made prior to the survey to sample only one basin and assume that concentrations were homogeneous across both basins. However, the grab samples taken from the east basin had higher concentrations than those in the west basin. For the summer survey, *in situ* transects of each basin are recommended or a large number of discrete samples collected. This will ensure the initial dye concentrations are well established.

It was observed both at DITP and offshore that strong ambient light caused the rhodamine fluorometers to zero out. This was not an issue for the majority of the DITP data as sampling was conducted at night. For the summer survey both DITP and offshore fluorometers will need to be light shielded. Shielding will be similar to that developed for the sensors during the farfield plume tracking.

During the dye addition, it was observed that the two dye barrels were not feeding dye evenly from the peristaltic pump. Concern for a stable dye concentration kept the dye addition team from trying to address the problem on the spot. Possible causes for this discrepancy in pump rate include 1) stretched tubing, 2) improper tubing loading, 3) suction from the effluent stream on the pump tubing, and 4) different input and output lengths on the tubing from one barrel to the other. As a result of the uneven pumping dye concentrations in the disinfection basin were approximately half those targeted. The dye addition method will be reviewed and corrected for the summer survey

After completion of the survey the dye drums were checked for final weight. During the weighing, “sludge” was found in the bottom of the drums. After several communications with the manufacturer, it was determined that the material was undissolved dye and a manufacturing defect. The drums were returned to the manufacturer and replaced with new product. No attempt was made to quantify the affect of this defect as the *in situ* data from the disinfection basin provides a reliable value for initial dye concentration.

The discrete sampling schedule was designed with hourly and half-hourly sampling events. The dye addition and sampling team at DITP ended the sampling on a half-hourly event. The schedule called for the final sampling event to be an hourly sampling. As a result one sample each for TSS, NH_4/PO_4, metals, and dye were not collected. A final sample, regardless of ending time, will be collected in the summer.

-Offshore
On April 19th, before conducting the first HMZ survey, the towyo pump failed. The problem was investigated and the pump was rewired to a spare connection.

On April 20th, the CTD started losing power around 12m depth. The connections were checked. Because power to the instruments continued to be unstable the sea cable was changed and the problem was corrected.

The survey plan called for 5 segment surveys to be conducted on the nearfield day. A field the decision was made to depart from the planned segment surveys and use perpendicular towyo transects to define the plume field. In addition to these transects, time was taken away from the segment surveys and devoted to defining the HMZ. Only one segment survey was conducted as planned. A second survey of tracklines perpendicular to the diffuser line was added to attempt to find a sharp gradient away from the plume source.

No salinity measurements were collected during the nearfield survey. A problem with the sensors caused variable and inaccurate results. Several attempts were made to identify the problem with no success. On the farfield day the sensors worked properly although the problem was still not identified. As a result salinity and density data are available for the farfield day only.

5.3 Recommendations:

-Deer Island
The dye addition team and MWRA participants made a number of suggestions to improve DITP operations for the summer survey. These suggestions include:

1) Add sample bottle rinsing requirements to the survey plan.
2) Create a table defining which bottles contain, which samples, including bottles with multiple samples.
3) Define stations names for the individual sampling points at DITP.
4) Organize the sample storage by recipient rather than by time of sampling.
5) Define an end point for monitoring of the disinfection basins.
6) Weigh dye drums prior to initiation of dye injection. This was in the QAPP but was not performed. Post addition weighing was completed by MWRA
7) Air temperature at the pump should be monitored and recorded.

-Offshore
Overall sampling during the offshore surveys was successful. Several observations were made to improve the sampling method. These include:

1) Defining the HMZ was difficult in the field. This may continue to be the case during the summer survey. A series of rapid towyos extending away from the diffuser array should be conducted. It will be beneficial to get closer to the risers to find high dye

concentrations and high variability. Locating the hydraulic mixing zone will help define the point at which hydraulic mixing gives way to oceanic dispersion effects. A series of vertical profiles with discrete sampling should be conducted based on the plume location and concentrations from the towyo lines. In addition, the sensor package should be held at given depths from at least 1-2 minutes to define stable dye levels. Instability in the dye concentrations at a given point over time could be considered indicative of hydrodynamic mixing. An increased number of discrete samples would provide a greater range of concentrations, allowing for better verification of the *in situ* data from the discrete values.

2) Background operations were completed before dye began to emerge from riser #55. This provided substantial insight about dye transit times and dispersion from the diffuser array. The summer survey schedule should include time to arrive at riser #55 and await emergence of the dye.

3) The rhodamine fluorometer needs to be light shielded.

-Overall

The six-hour ~50 µg/L dye addition produced an easily defined plume field. This was true on both the nearfield and farfield days. The summer survey plan calls for a dye addition of 28 hours at 50 µg/L. A potential problem of this long-term addition is “old” plume dye from early in the addition moving back into the “new” plume field where the HMZ is being defined. Based on the winter survey results, a six-hour addition is sufficient to reliably track the effluent plume. At 50 µg/L it is likely that the plume could be tracked for at least 3 days. Higher concentrations would enable longer tracking.

6. 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.

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