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Technical Memorandum

Date:	December 15, 2009
To:	Robert Leitch, PE, USACE North Atlantic Division New England District (NAE)
From:	Paul Dragos, Battelle
Subject:	Turbidity Monitoring and Plume Sampling Results for City Dredge Disposal at the New Bedford Harbor CAD Cell # 2

This Technical Memorandum presents a summary of the turbidity monitoring results for the surveys conducted at the navigational dredging Confined Aquatic Disposal (CAD) cell # 2 in New Bedford, Massachusetts (Figure 1). The turbidity sampling was conducted during disposal of navigational dredged material by the City of New Bedford into the CAD cell on April 14, May 20, 21, & 27, and July 8 of 2009. Dredged material released into the CAD cell during monitoring operations was dredged from the channel north of the Coggeshall Street Bridge, the Niemiec Boat Yard, the Packer Pier, and the Gifford Street Boat Ramp.

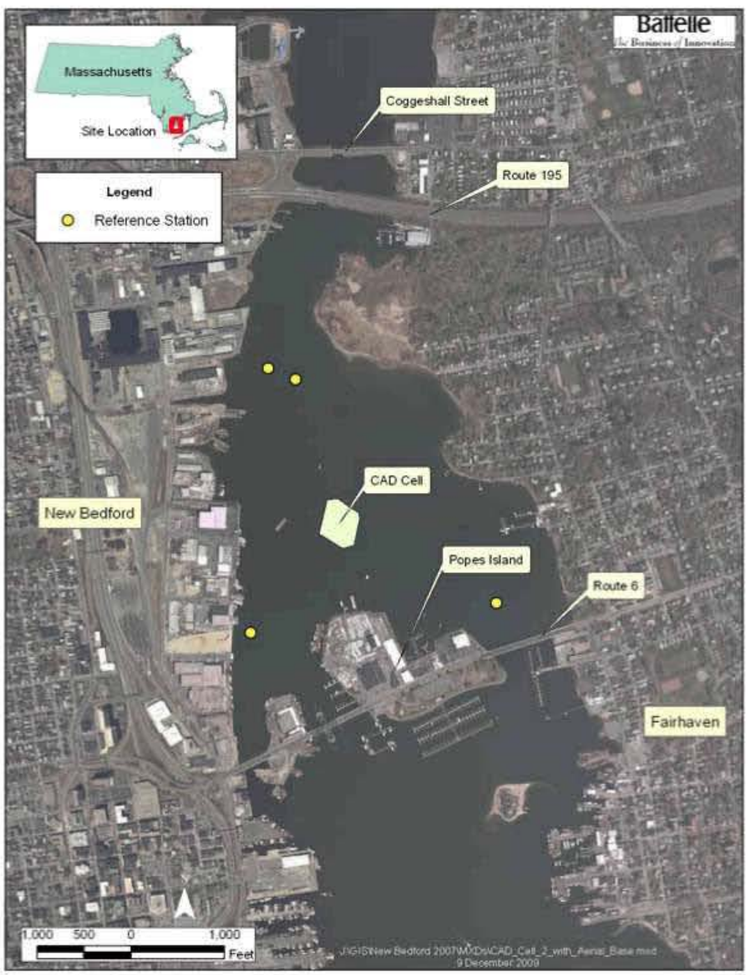

Figure 1. Portion of New Bedford Harbor Showing the Location of the City CAD Cell.

Background

The City of New Bedford was engaged in Phase III of the Harbor Maintenance Dredge Program performing maintenance dredging at various locations in New Bedford Harbor during the spring and summer of 2009. The City dredging was not part of the on-going EPA Superfund remedial dredging project. A number of dredge areas were included in Phase III infrastructure improvements at numerous piers and wharves that serve the fishing, ferry, tourism, and shipping industries. The dredged material was disposed into CAD cell # 2 located north of Popes Island. During the months of disposal operations, the CAD cell was surrounded by a silt curtain made of a porous fabric which was suspended from the water surface and hung to the harbor bottom. The curtain was intended to contain any suspended sediment plumes resulting from disposal of dredged material into the CAD cell. The curtain consisted of 6 or 8 separate sections of fabric. One section acted as a gate which was opened and closed to allow the barge and tug to enter and exit the cell.

Objective

The objective of this effort was to conduct shipboard, real-time tracking of suspended sediment plumes resulting from disposal operations in and around the CAD cell. The presence, extent, and concentration of suspended sediments were determined for plumes both inside and outside the silt curtain. The data obtained during this effort consisted of the following:

- water current velocity from continuous Acoustic Doppler Current Profiler (ADCP) measurements;
- turbidity and suspended sediment concentration derived from continuous ADCP measurements of acoustic backscatter;
- turbidity and total suspended solids (TSS) from whole water samples at plume and reference stations; and
- toxicity from whole water samples collected at plume and reference stations.

Methods

Details on the survey/sampling methods can be found in the project Field Sampling Plan (Battelle, 2009).

The study design incorporated broad scale monitoring of sediment plumes using a ship-mounted ADCP to collect continuous turbidity measurements combined with discrete location water column sampling for post-survey analysis of turbidity, TSS, and toxicity. The ADCP measurements were made as the survey vessels ran a series of transects within and outside (primarily down-current) of the CAD cell from immediately after the time of release until any plume had dissipated (approximately 1 to 1½ hours). The *in situ* ADCP backscatter data was compared to laboratory derived TSS and turbidity data from whole water samples to post-calibrate the instrument and to provide an independent measure of particulate concentration.

Velocity Survey

During the first day of the study and prior to dredged material disposal, a velocity survey was performed to delineate the current structures in the survey area over a tidal cycle. The velocity survey was conducted using one RD Instruments 1200kHz Workhorse Mariner ADCP mounted over the side of the 24 ft vessel *Sea Quest* (Figure 2). The ADCP measured current velocity every 1-2 seconds at 0.5 m vertical intervals throughout the water column while the vessel was underway. A series of harbor transects were occupied once every hour over a complete tidal cycle to determine the three-dimensional current structure throughout the survey area between Popes Island and the Route 195 bridge. The position and real-time current data were collected and displayed on the data collection laptop in real-time

(Figure 3). The tracklines were run 13 times over a period of approximately 13 hours. Current velocity data were processed on shore immediately after the survey and graphical outputs of each hourly run were developed for use by the survey crews during the plume tracking surveys.

Figure 2. ADCP Mounted in Operational Position Over the Side of the *Sea Quest* with the Acoustic Transducers Just Below the Water Surface.

Plume Tracking Surveys

Plume tracking was conducted using two RD Instruments 1200kHz Workhorse Mariner ADCPs mounted on two separate vessels, the *Gale Force* and the *Sea Quest*. The ADCP was used to measure current velocity and acoustic backscatter intensity in decibels (db) every 1-2 seconds at 0.33 m vertical intervals throughout the water column while the vessels were underway. The acoustic backscatter intensity is a function of the suspended sediment concentration in the water column. As the vessels ran transects across the survey area, the ADCP mapped out vertical slices of suspended sediment concentration along those transects. The ADCP concurrently measured velocity of the tidal currents (speed and direction) which was used to aid plume tracking. The ADCP measurements were recorded and displayed in real-time (Figure 3).

Transect locations were determined on-the-fly to maximize the plume coverage in response to plume dynamics. The general procedure during each disposal event was as follows:

1. Prior to beginning of sampling, each boat used the ADCP to monitor current direction and speed and confirm currents determined during the velocity survey. The boat locations were adjusted thereafter to be down-current of the dredged material release point.

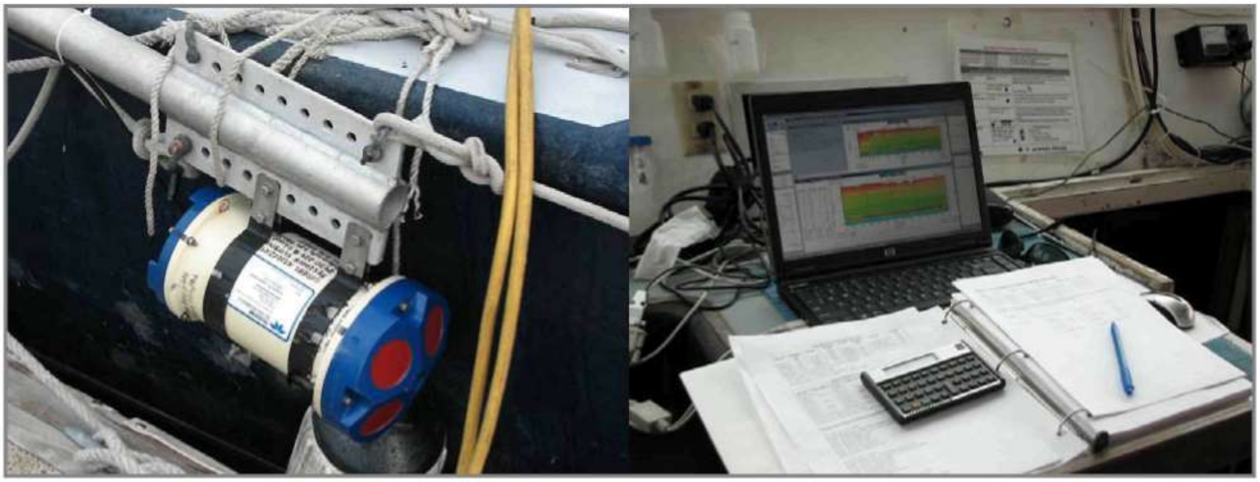

Figure 3. RD Instruments 1200khz Workhorse Mariner ADCP Mounted Over the Side of the Vessel and ADCP Real-Time Display / Data Collection Laptop.

2. Prior to release of the dredged material into the CAD cell, each boat collected whole water samples at mid-depth and near-bottom reference stations along with ADCP backscatter data. During the May 20 disposal event, an additional whole water sample was collected at mid-depth at the up-current reference station for toxicity analysis.
3. Immediately after the release (Figure 4), and for the next 1-1½ hours the *Sea Quest* ran east-west and north-south transects, at the discretion of the Chief Scientist, throughout the CAD cell until the plume was no longer significantly above background.
4. Immediately after the release, and for the next 1-1½ hours the *Gale Force* ran transects outside the CAD cell running east-west, north-south, and along the outside of the curtain, at the discretion of the Chief Scientist.
5. In the CAD cell, whole water samples were collected in the plume centroid and at two other locations within the plume (lateral stations). It was up to the discretion of the Chief Scientist to determine during which transect(s) and how long after release the samples were taken but samples were generally taken while the plume signal was still strong, in most cases during the second transect and again when the plume concentration was more moderate. During the May 20 disposal event, an additional whole water sample was collected at mid-depth in the plume centroid for toxicity analysis.
6. Outside the CAD cell, an attempt was made to collect whole water samples in any plume observed (three stations at two depths) at the discretion of the Chief Scientist. During the May 20 disposal event, an additional whole water sample was collected for toxicity analysis.

Real-time demarcation of the plume with ADCP provided the information needed to select sampling locations and depths. Each vessel collected TSS and turbidity samples from near-bottom (approximately 1 m above the bottom) and mid-depth at three plume stations and two reference stations (summarized in Table 1). Whole water samples were collected with Niskin bottles on hand lines. Three toxicity samples were also collected during the first of the disposal monitoring surveys: one from the plume centroid; one outside the silt curtain; and one at an up-current reference station unimpacted by dredging activities.

Laboratory TSS and Turbidity Testing Methods

The whole water samples collected during the survey were analyzed by Alpha Analytical Laboratory for TSS using U.S. EPA Method 2540 D. A well-mixed sample was filtered through a standard glass fiber filter (GF/F) and the residual retained on the filter was dried and weighed. For each batch of 20 or fewer samples, a laboratory method blank, duplicate, and laboratory control sample (LCS) was processed and analyzed with the field samples[1]. Results are reported on a dry-weight basis.

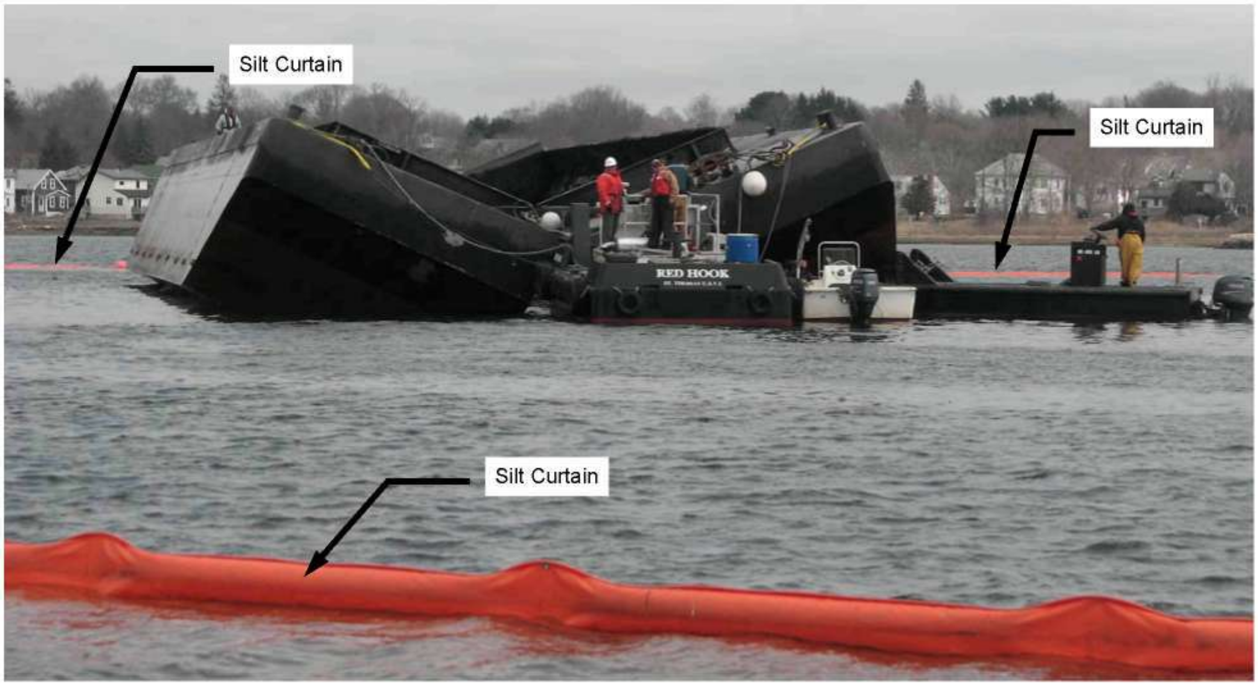

Figure 4. Split Hull Scow Immediately after Placement of Dredged Material into the CAD Cell.

Table 1. Sampling During Each Disposal Event by Each Survey Vessel.

Station	Parameters	Depth	Number of Water Samples	Comments
Turbidity and TSS Samples				
Plume Centroid Station	Turbidity, TSS	Near-bottom and mid-depth	2	Add 5% duplicate sample for QC
Plume Lateral Stations (2)	Turbidity, TSS	Near-bottom and mid-depth	4	
Reference Stations ≥1500 ft up- and down current (2)	Turbidity, TSS	Near-bottom and mid-depth	4	
Toxicity Samples (1 disposal event only)				
Plume Centroid Station	Toxicity	Mid-depth	1	
Plume Station outside Silt Curtain	Toxicity	Mid-depth	1	
Reference Station ≥1500 ft up or down current	Toxicity	Mid-depth	1	

[1] One exception to this QC procedure occurred during analysis of the April 14, 2009 samples when no laboratory duplicate was analyzed.

The whole water samples collected during the survey were also analyzed by Alpha Analytical Laboratory for turbidity using U.S. EPA Method 180.1. A well-mixed sample was analyzed for turbidity using a nephelometer to compare the intensity of light scattered by the sample under defined conditions with the intensity of light scattered by a standard reference suspension. Results are reported in nephelometric turbidity units (NTU).

Toxicity Testing Methods

Acute and chronic (sub-lethal) exposure screening assays were performed on discrete water samples to evaluate the potential toxicity of the water samples. Assay design included a laboratory control treatment, a site reference sample, and two site samples collected during disposal of dredged material. Samples were evaluated "As Received" without dilutions. Testing was based on programs and protocols developed by the U.S. EPA (2002) primarily designed to provide standard approaches for the evaluation of toxicological effects of discharges on aquatic organisms, and for the analysis of water samples. Testing included the following assays: modified 2 day acute and 7 day chronic assays conducted with the mysid shrimp, *Americamysis bahia*, and the red macro alga, *Champia parvula*, and 60 minute chronic fertilization assays conducted with the purple sea urchin, *Arbacia punctulata*. All mysid and urchin fertilization assays and the acute survival portion of the algal assays were conducted by EnviroSystems, Inc. (ESI) located in Hampton, New Hampshire. Additionally, the acute and chronic algal assays were also conducted by Aquatox Testing & Consulting, Inc. of Guelph, Ontario, Canada in order to provide data in the event that the assay conducted by ESI failed to meet the target endpoints.

Statistical analysis of acute and chronic exposure data was completed using CETIS (Comprehensive Environmental Toxicity Information System) software. The program computes acute and chronic exposure endpoints based on U.S. EPA decision tree guidelines specified in individual test methods. For chronic exposure endpoints statistical significance was accepted at $\propto < 0.05$.

As part of the toxicity testing laboratory quality control program, standard reference toxicant assays are conducted on a regular basis for each test species to provide relative health and response data while allowing for comparison with historic data sets.

ADCP Calibration

Data were collected to calibrate the acoustic ADCP instruments to TSS and turbidity correcting for site-specific factors including particle size distribution, particle type, and particle surface roughness. At whole water sampling stations, Niskin bottles were lowered over the side of the vessel to collect discrete water samples. Simultaneously, the ADCP collected acoustic backscatter data. Turbidity and TSS from water samples at a given depth and time were compared with acoustic backscatter from ADCP at the same depth and time. The sample volumes for turbidity/TSS and backscatter are not the same which, in a turbulent, heterogeneous suspended sediment plume introduces some bias to the calibration. However, the method has been commonly used with good results in many field studies with a range of current velocities, sediment types, and sediment grain size distributions (see the review paper by Poerbandono and Mayerle, 2004).

ADCPs were calibrated for turbidity and TSS against water samples analyzed in the laboratory. All samples available from both boats during all disposal monitoring surveys were used in the calibrations. The ADCP is primarily designed and used to quantify current velocity by measuring the Doppler frequency shift in the acoustic backscatter signal. The acoustic backscatter intensity is measured and recorded but processed no further by the ADCP because only the frequency shift is used to calculate velocity and the frequency shift is independent of the backscatter intensity. The backscatter intensity, however, is dependent on the suspended sediment concentration, but in order to calibrate backscatter to suspended sediment concentration, losses due to acoustic beam spreading and acoustic absorption by water must be accounted for in the backscatter signal. Based on the energy of acoustic intensity, Deines (1999) simplified the active sonar equation from underwater acoustic theory for the broadband ADCP:

$$10\log_{10}(SSC) = C_k + K_C E + 10\log_{10}(R^2) + 2\alpha_w R$$

where SSC is suspended sediment concentration, R is the range along the beam to the scatterer, α_w is the attenuation coefficient due to water absorption (primarily dependent on the frequency and provided by the instrument manufacturer), and E is the acoustic echo strength (in instrument counts). The last two terms in the equation represent the effects of acoustic beam spreading and acoustic absorption by water, respectively. C_k and K_C are constants that cannot be measured directly. Least squares regression analysis was used to estimate the best values for the constants C_k and K_C (Figure 5). The estimated values for C_k and K_C are -30.68 mg/L and 0.4371 mg/L/dB, respectively and are within the range suggested by Poerbandono and Mayerle (2004). The error on C_k with 95% confidence is ± 6.76 mg/L. Assuming a linear relationship between turbidity and suspended sediment concentration (Figure 6), an equation of the same form was used for calibration of the ADCP to turbidity (Figure 7). The estimated values for C_k and K_C for turbidity are -34.76 NTU and 0.4351 NTU/dB, and the error on C_k with 95% confidence is ± 6.68 NTU.

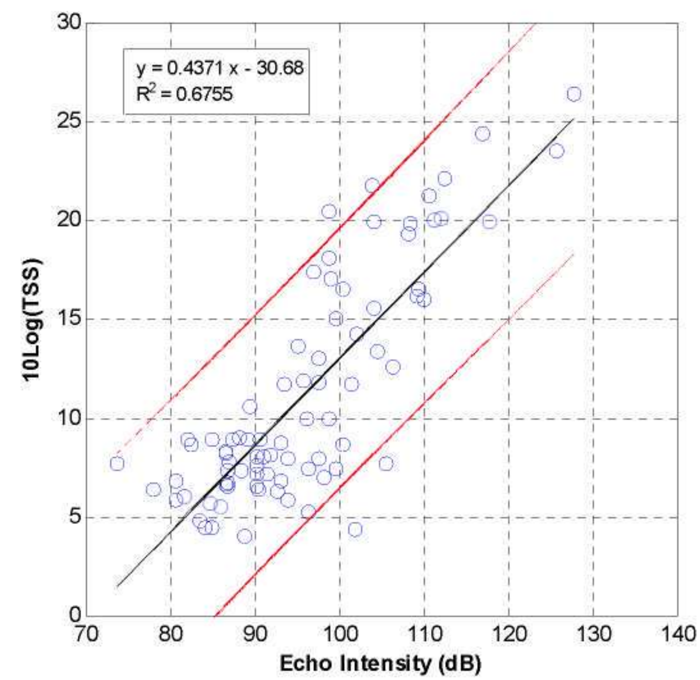

Figure 5. Least Squares Regression Analysis of Total Suspended Solids (TSS) from Whole Water Samples Analyzed in the Laboratory versus ADCP Echo Intensity in Decibels (dB).
Red Lines Indicate the Regression 95% Confidence Interval.

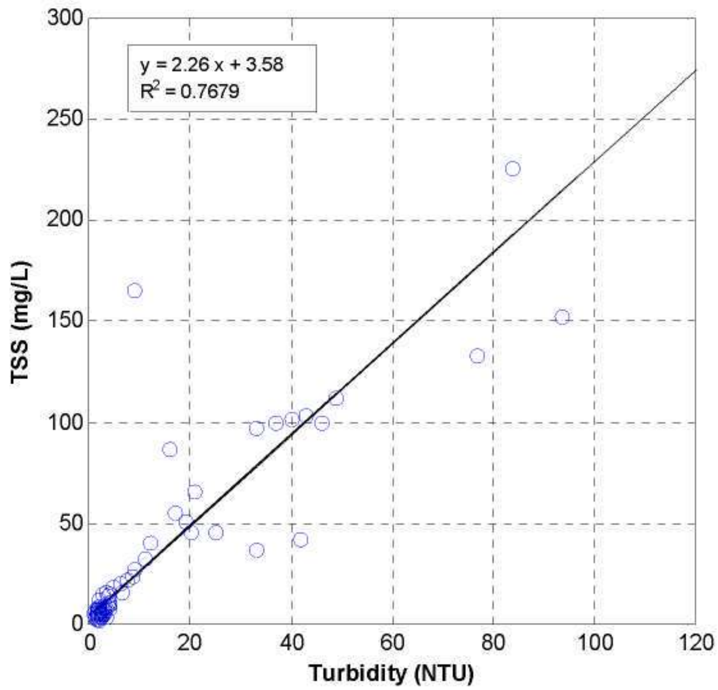

Figure 6. Least Squares Regression Analysis of TSS versus Turbidity from Whole Water Samples Analyzed in the Laboratory.

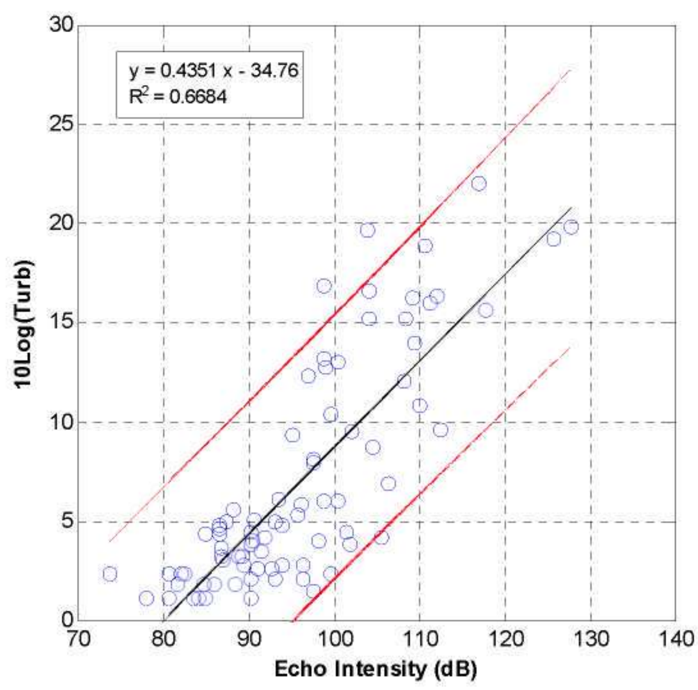

Figure 7. Least Squares Regression Analysis of Turbidity from Whole Water Samples Analyzed in the Laboratory versus ADCP Echo Intensity in Decibels (dB).
Red Lines Indicate the Regression 95% Confidence Interval.

Results

Velocity Survey

Tidal currents dominate the movement of water in New Bedford Harbor and thereby the movement of any suspended sediment in the water column. There exists, however, a generally weak inflow of fresh water from the Acushnet River at the north. This fresh water inflow results in a weak estuarine circulation which is superimposed on the stronger tidal flow. The estuarine circulation is the density driven movement of fresher surface water down the estuary simultaneous with the movement of saltier bottom water up the estuary. In New Bedford Harbor, the combined effect of the tides and the estuarine circulation is vertical shear in the water column velocity, in which the ebb currents are stronger near-surface and flood currents are stronger near-bottom. The Acushnet freshwater inflow varies seasonally and is significantly weaker than the tides except occasionally during large spring freshet events, which did not occur during this study.

A velocity survey was performed on March 27, 2009 using ADCP to delineate the current structure in detail in the survey area between Popes Island and the Route 195 bridge. The results of the velocity survey were used during the plume tracking surveys to provide *a priori* estimates of plume movement. Appendix A presents the results of that survey as a series of hourly velocity vectors along the harbor transects over a complete tidal cycle for the near-surface and mid-depth locations. Peak near-surface tidal flows were generally less that 35 cm/s (0.7 kts) in the immediate vicinity of the CAD cell and less than 55 cm/s (1.1 kts) in the navigation channel. The mid-depth tidal flows were slightly weaker that the near-surface flows with the strongest less that 30 cm/s (0.6 kts) near the CAD cell and less than 50 cm/s (1.0 kts) in the navigation channel. The configuration of the harbor results in a flow which diverges around Popes Island just below the CAD cell. During the ebb tide (southward flow) the currents diverge near Popes Island with most of the flow moving southwestward following the navigation channel and some moving southeastward around Popes Island to the east. During the flood tide (northward flow) the pattern reverses.

Current velocities inside the curtained CAD cell were too weak to measure accurately with ADCP at speeds less than 2 cm/s.

Turbidity and Suspended Sediment Results

Turbidity and TSS results from laboratory analysis of whole water samples collected at reference and plume stations during the plume tracking surveys are summarized in Appendix B. The data passed all laboratory quality control criteria. The relative percent differences (RPD) in field duplicate turbidity and TSS were acceptable; average RPD for turbidity was 22% and average RPD for TSS was 53%. This is typical given the small values being measured at reference stations (where small absolute differences can result in large RPDs) and the heterogeneous nature of the plume sampled at plume stations. The turbidity and TSS results presented in Appendix B are discussed throughout the rest of this technical memo.

Toxicity Testing Results

Toxicity results from the acute and chronic (sub-lethal) exposure assays performed on site water samples collected during disposal activities are summarized in Table 2. Results are presented for the test endpoints: survival, growth, development and reproduction. Results for test endpoints for each sample were statistically compared to those from both the event-specific site reference sample and the laboratory control sample. Assay results for the laboratory control sample met the minimum test acceptability criteria for the acute and chronic exposure assays, indicating the test was in control and that healthy test organisms were used. Assay results for the site water samples collected on May 20, 2009 during disposal activities at the City's CAD cell showed no significant reduction in endpoints for any of the test species between the reference and CAD sampling sites (Table 2). There were no measurable acute or sub-lethal impacts from exposure of the test species, *A. punctalata*, *A. bahia*, and *C. parvula*, to water collected during disposal activities.

Table 2. Summary of Toxicity Test Results, May 20, 2009 Water Samples

Sample	Time After Release (min)	Turbidity from ADCP (NTU)	Toxicity Results: Sea Urchin (*A. punctulata*)	Mysid (*A. bahia*)			Red alga (*C. parvula*)	
			mean fertilization (%)	48-hr mean survival (%)	7-day mean survival (%)	7-day mean biomass (mg/mysid)	48-hr mean survival (%)	7-day mean reproduction (cystocarp/ plant)
Lab Control	na	na	97.1	100	84.4	0.431	100	34.0
Site Reference	na	< 2	93.5[1]	100	82.5	0.462	100	34.0
Outside silt curtain	49	~12	95.0[1]	100	97.5	0.519	100	34.1
Inside silt curtain	20	~70	94.1[1]	97.5	87.5	0.435	100	34.7
Acceptance Criteria (for Lab Control)			> 70	≥ 90	≥ 80	>0.2	no necrosis	≥ 10

[1] Assay result significantly different compared to the laboratory control sample.

Disposal Plume Turbidity and Suspended Sediment

Background Turbidity

Prior to beginning each disposal sampling event, each boat collected reference samples at two stations (Figure 1) at two depths (mid-depth and near-bottom) at least 1500 ft from the CAD cell and away from any other dredge activity. The turbidity and TSS measured in the laboratory from whole water samples are presented in Appendix B. The reference levels were low and consistent across the study area. The mean background turbidity was 2.1 NTU and the mean background TSS was 5.7 mg/L. With the exception of one profile in the channel south of the CAD cell the background turbidity was approximately 1 – 3.2 NTU and the background TSS was approximately 2 – 12 mg/L.

Plume Measurements

Five disposal plumes were monitored in and around the CAD cell on five different days. In the series of figures presented in Appendix C, suspended sediment measurements collected during the plume surveys using ADCP are presented. For each disposal event, a series of 5 to 7 figures show water column observations made pre-release and at various times after releases. Included in each figure are three panels presenting the locations of measurements and vertical contours of observed turbidity inside and outside the CAD cell silt curtain. The location panel shows the CAD cell boundaries, the approximate location of the dredge barge at the time of release, and the locations of both the inner and outer boat transects at the time of the measurements as indicated. The two vertical contour panels present the calibrated turbidity in NTU and TSS in mg/L along each vessel transect. The contours are labeled and oriented west to east (or east to west) based on the end points of the transect. In the following sections, TSS values in mg/L are referenced alongside corresponding turbidity values.

Disposal Plume April 14, 2009

On April 14, 2009, a disposal plume was surveyed during a dredged material release from a split hull barge at the New Bedford Harbor CAD cell. The material placed into the CAD cell was from City dredging operations north of the Coggeshall Street Bridge. The release took place at 16:47 hours and monitoring was carried out during the approximately 1 hour period of weak northerly currents that followed (published low tide for the day was 16:59). The currents outside the cell were weak and variable (< 10 cm/s) with a slight northward component particularly on the west of the cell in the navigation channel. Currents inside the silt curtain were too weak to measure at speeds less than 2 cm/s. In the presence of little current to transport and disperse the suspended sediment, the disposal plume stayed close to the point of release, transported primarily by its own momentum.

Part 1 of Appendix C documents the suspended sediment plume observed in the water column after the release. In it, a series of five figures are presented showing the results from five sets of concurrent inner and outer transects selected at intervals over a period of approximately 45 minutes until the plume dissipated. Figure 1-1 presents background conditions before the release showing two transects run just inside and outside the silt curtain on the north side of the CAD cell. Water column turbidity was observed at background levels during both transects, although an offset bottom echo is visible in the inner transect which should not be confused with any water column turbidity[2]. By 8 to 11 minutes after release (Figure 1-2), the disposal plume was observed at approximately 25 NTU (62 mg/L) inside the silt curtain north of the point of release. Seen in the outer turbidity profile, there was a very weak turbidity signal, just above background (< 5 NTU; 12 mg/L), visible leaking from one of the seam slits in the silt curtain. By 19 to 22 and 27 to 39 minutes after release (Figures 1-3 and 1-4), the inner boat was measuring turbidity at approximately 15 NTU (38 mg/L) near bottom and the outer boat could find no trace of the plume. By 40 to 44 minutes after release (Figure 1-5), the plume had settled and water column turbidity had returned to background levels.

Disposal Plume May 20, 2009

On May 20, 2009, a disposal plume was surveyed during a dredged material release from a hopper barge. The material placed into the CAD cell was dredged during City dredging operations at the Niemiec Boat Yard just north of Popes Island. The barge hoppers were opened at 07:50 hours, however, some of the dredged material did not fall readily through the hopper doors. An excavator was used to shovel material out of some hopper bins and to dump water into the bins to wash away the material that was adhering to the sides.

The currents in the harbor were at ebb during the approximately 90 minute monitoring period (published high tide was 04:51). Outside the cell currents were as strong as 30 cm/s to the south on the west side of the cell and 15 cm/s to the south on the east side. Currents inside the silt curtain were too weak to measure at speeds less than 2 cm/s.

Part 2 of Appendix C documents the turbidity and TSS observations at the CAD cell on May 20th. In it, a series of seven figures are presented with the results of seven sets of concurrent inner and outer transects selected at intervals over a period of approximately 90 minutes until the plume dissipated. Figure 2-1 presents background conditions before the release. Inside and outside the silt curtain, turbidity was < 2 NTU and TSS was <5 mg/L. Figure 2-2 presents turbidity observed 3 to 6 minutes after release where a very strong plume signal can be seen inside the silt curtain, near-bottom, south of the barge with turbidity as high as 70 NTU (175 mg/L)[3]. Outside the silt curtain to the south, a filament of slightly elevated turbidity (< 5 NTU; <12 mg/L) was visible near the curtain gate. Between 10 and 24 minutes after release (Figures 2-3 and 2-4) the plume spread within the cell and the concentration remained high (70 NTU; 175 mg/L)[3]. The use of the excavator to liberate the dredged material stuck in the hopper bins probably contributed to the elevated turbidity in the cell. Outside the silt curtain there was no evidence of

[2] Bottom echoes occasionally appear reflected in the water column as a result of surface acoustic reflections or software inability to correctly identify sharp depth changes. However, these ‘bright lines’ are not easily confused with water column plumes because of their linear nature.

[3] A uniform color scale was used in all figures unless otherwise noted. These peak values are offscale on the figure.

the plume at that time, suggesting that the previously seen filament of the plume near the gate was short lived. By 39 minutes after release (Figure 2-5), turbidity within the CAD cell was reduced to approximately 30 NTU (75 mg/L) near bottom and by 55 minutes after release (Figure 2-6) it was further reduced to 20 NTU (50 mg/L). During both these intervals some evidence of elevated turbidity was seen just outside the CAD cell, probably emanating from seam slits in the silt curtain or possibly caused by some low-level turbidity seepage through the curtain itself. Even so, the highest turbidity observed outside was approximately 12 NTU (30 mg/L). Finally after 84 minutes (Figure 2-7), turbidity within the CAD cell was approaching background at 10 NTU (25 mg/L).

Disposal Plume May 21, 2009

On May 21, 2009, a disposal plume was surveyed during a dredged material release from a hopper barge. The material placed into the CAD cell was dredged during City dredging operations at the Gifford Street Boat Ramp, located just north of the hurricane barrier. The barge hoppers were opened at 08:18 hours and no excavator was necessary to help release the material. The currents in the harbor were at ebb during the approximately 1 hour monitoring period (published high tide was 05:48). Outside the cell, currents were as strong as 30 cm/s to the south on the west side of the cell and 15 cm/s to the south on the east side. Currents inside the silt curtain were too weak to measure at less than 2 cm/s.

Part 3 of Appendix C documents the turbidity and TSS observations at the CAD cell on May 21th. Figure 3-1 presents background conditions before the release. Inside and outside the silt curtain, turbidity was < 2 NTU and TSS was <5 mg/L. Figure 3-2 presents turbidity observed 1 to 6 minutes after release; a very strong plume signal was present near-bottom inside the silt curtain (65 NTU; 136 mg/L) [3]. Outside the silt curtain there was no evidence of the plume. Between 5 and 9 minutes after release (Figure 3-3), the plume concentration remained high at approximately 50 NTU (125 mg/L) near-bottom as well as higher in the water column near the center of the cell. During this time interval, elevated turbidity was seen outside the CAD cell at concentrations as high as 20 NTU (50 mg/L). These were the highest values observed outside the cell during any of the surveys. They are probably the result of some of the plume escaping when the gate was opened to allow the tug and barge to exit. By 18 minutes after release (Figure 3-4), turbidity inside the CAD cell had dissipated to approximately 25 NTU (62 mg/L), by 39 minutes after release (Figure 3-5) it had dissipated to 15 NTU (38 mg/L), and by 51 minutes after release (Figure 3-6) it had further dissipated in size if not in concentration (15 NTU; 38 mg/L). Outside the silt curtain there was no evidence of the plume at these times. Finally, after 57 minutes (Figure 3-7) turbidity within the CAD cell was observed just above background at approximately 8 NTU (20 mg/L).

Disposal Plume May 27, 2009

On May 27, 2009, a disposal plume was surveyed during release of dredged material from the City dredging project at the Niemiec Boat Yard. The dredged material was released from a hopper barge although an excavator was used to help push some of the material out of some of the hopper bins. The barge hoppers were opened at 08:16. The currents in the harbor were at flood during the approximately 70 minute monitoring period (published low tide was 04:37). Outside the cell currents were 20-25 cm/s to the north on the west side of the cell and weak and variable to 10 cm/s northward on the east side. Currents inside the silt curtain were less than 2 cm/s.

Part 4 of Appendix C documents the turbidity and TSS observations at the CAD cell on May 27th. Figure 4-1 presents background conditions before the barge entered the CAD cell. Inside and outside the silt curtain, turbidity was < 2 NTU and TSS was <5 mg/L. Figure 4-2 presents turbidity observed 3 to 6 minutes after release; a very strong plume signal was present near-bottom inside the silt curtain (110 NTU; 260 mg/L) [3]. Note the change in the turbidity scale used in this figure and the next. Outside the silt curtain there was no evidence of the plume. Between 5 and 9 minutes after release (Figure 4-3), the plume concentration remained high at approximately 100 NTU (247 mg/L) near-bottom. Again there was no evidence of the plume outside the silt curtain. By 31 minutes after release (Figure 4-4), turbidity inside the CAD cell had dissipated to approximately 25 NTU (62 mg/L) and by 50 and 54 minutes after release (Figure 4-5 and 4-6) it had further dissipated to 15 NTU (38 mg/L). Outside the silt curtain there was no evidence of the plume. Finally, after 63 minutes (Figure 4-7) turbidity within the CAD cell was nearing background at approximately 13 NTU (32 mg/L).

Disposal Plume July 8, 2009

On July 8, 2009, a disposal plume was surveyed during a dredged material release from a hopper barge. The material placed into the CAD cell was dredged during City dredging operations at the Packer Pier, located on the New Bedford Harbor shoreline between the Route 6 and Route 195 bridges. The silt curtain gate was left open during the dump and the survey; the silt curtain being no longer required at this time of year under the conditions of the dredging permit. The barge hoppers were opened at 12:04 and no excavator was necessary to help release the material. The barge had been on a mooring in the CAD cell since the previous afternoon and it was not moved out of the CAD cell after release. In addition, two other barges were moored in the cell alongside the dredged material barge. As a result, the inner survey boat did not have access to the center area of the CAD cell. The currents in the harbor were at ebb during the approximately 1 hour monitoring period (published high tide was 09:20). Outside the cell, currents were 20-25 cm/s to the south on the west side of the cell and 10-20 cm/s to the south on the east side. Currents inside the silt curtain were less than 2 cm/s.

Part 5 of Appendix C documents the turbidity and TSS observations at the CAD cell on July 8th. Figure 5-1 presents background conditions before the release. Inside and outside the silt curtain, turbidity was < 2 NTU and TSS was <5 mg/L. Figure 5-2 presents turbidity observed 1 to 4 minutes after release; a strong plume signal was present inside the silt curtain near-bottom at 45 NTU (112 mg/L) extending to near the surface at 18 NTU (45 mg/L). Outside the silt curtain there was no evidence of the plume. Between 9 and 16 minutes after release (Figure 5-3), the plume had nearly dissipated inside the cell except for a relatively high concentration (20 NTU; 50 mg/L) within 1 m of the bottom. No plume was observed outside the cell at this time. The transects performed 15, 26, and 46 minutes after release (Figures 5-4 through 5-6) all observed low turbidity concentrations (<20 NTU; <50 mg/L) inside the cell and no turbidity above background outside the cell. Finally, after 58 minutes (Figure 5-7), turbidity within the CAD cell was just above background at approximately 6 NTU (15 mg/L).

That no evidence of the plume was observed outside the open curtain gate seemed at first surprising, but there were factors that kept the plume contained despite the open gate. First, the plume dissipated quickly and after the first few minutes it was limited to the lower ¼ of the water column within the excavated part of the cell where it was confined by the shoulder slope; and second, the gate was located on the west side of the cell where the tidal current in large part simply passed by the gate without flowing into or out of the cell.

Summary

A number of general observations can be made and conclusions drawn based on an overview of the results from the five CAD cell disposal plume surveys performed during this study, including:

- Water column plumes created during disposal of dredged material into the CAD cell were nearly completely contained within the CAD cell silt curtain.
- Inside the silt curtain, turbidities were observed as high as 110 NTU with TSS concentrations as high as 260 mg/L.

- Outside the silt curtain, the highest turbidities observed were only 20 NTU with TSS concentration of 50 mg/L and then only within close proximity to the cell in small filaments of plume which appear to have escaped the silt curtain at one of its seams.
- The presence of the silt curtain nearly eliminated any tidal current within the CAD cell; currents inside the cell were less than 2 cm/s and too weak to measure.
- Within the CAD cell, the bulk of the turbidity plumes were limited to the lower half of the water column, down within the excavated cell, with the highest values usually within 1 or 2 meters of the bottom.
- All the plumes dissipated to near background levels within 1 to 1-1½ hours.
- During near slack tide conditions the disposal plumes largely pooled beneath the barge within the cell but during flood or ebb tides some of the plume collected against the inside of the silt curtain on the north or south side, respectively.
- There were no significant reductions in endpoints for any of the toxicity test species, indicating that there were no measurable acute or sub-lethal impacts to marine organisms from exposure to the plume samples collected.

Literature Cited

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APPENDIX A

New Bedford Harbor Tidal Velocity Structure
Measured with ADCP
March 27, 2009

Part 1: Near-Surface Tidal Velocity

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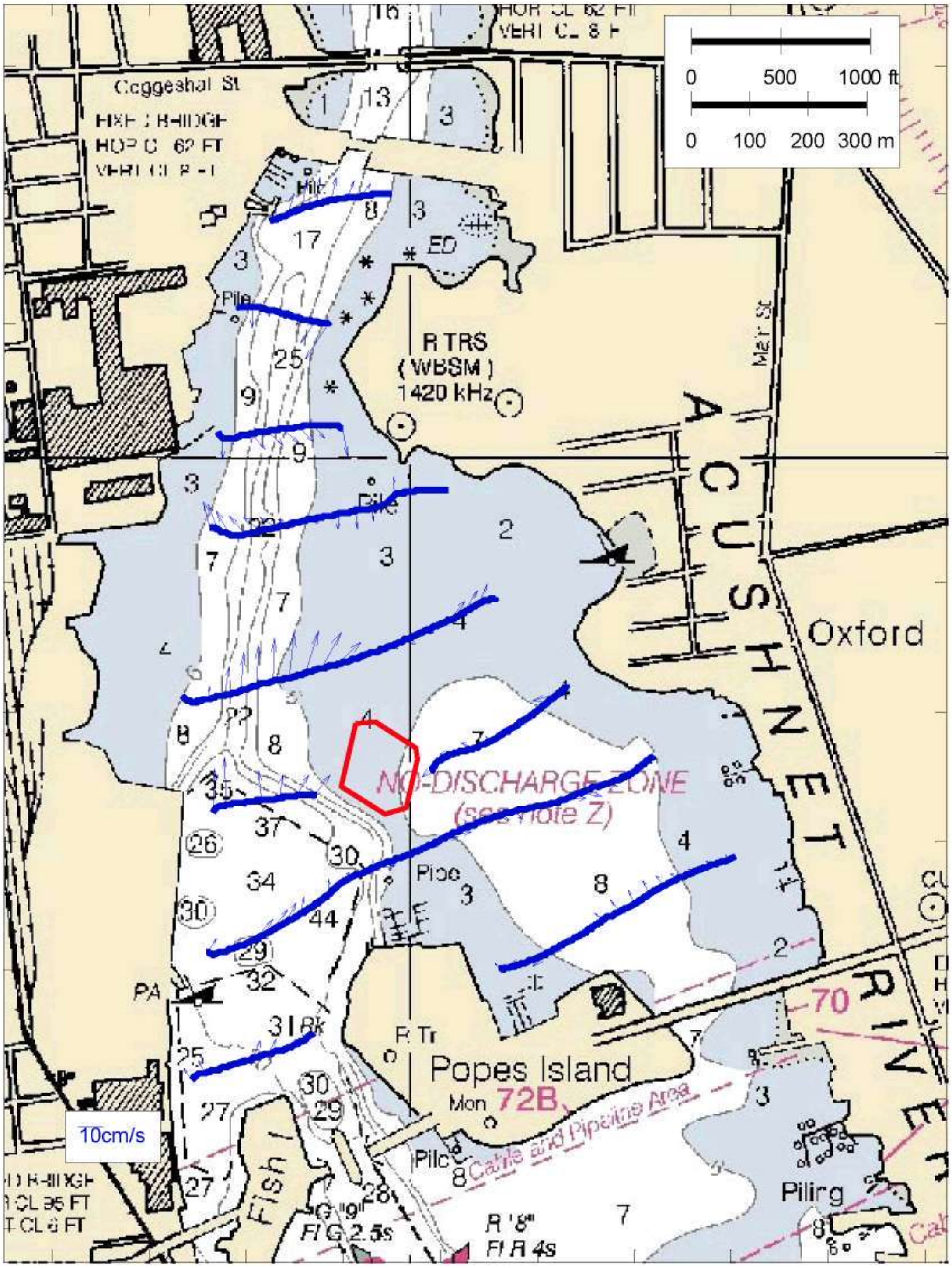
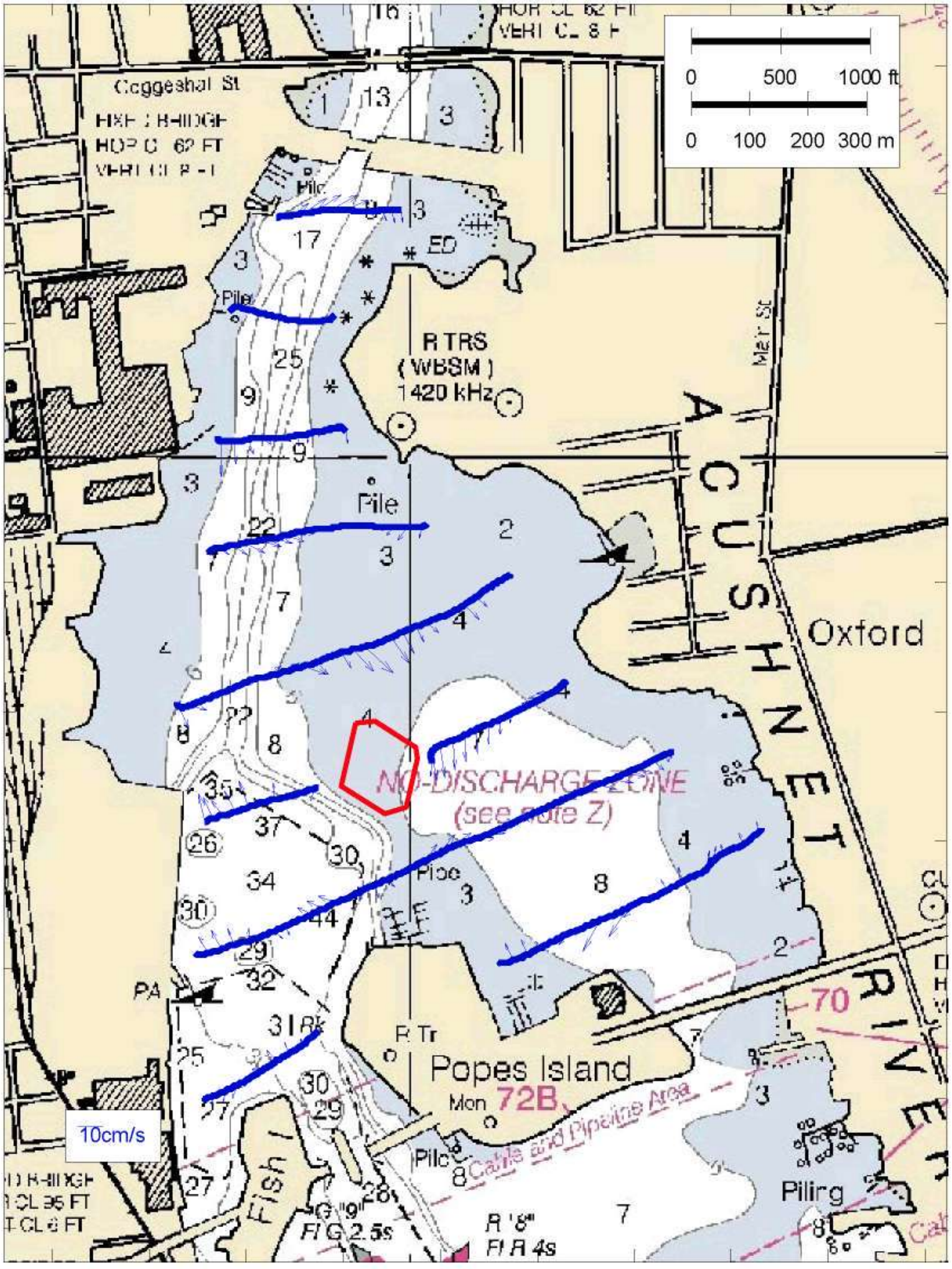
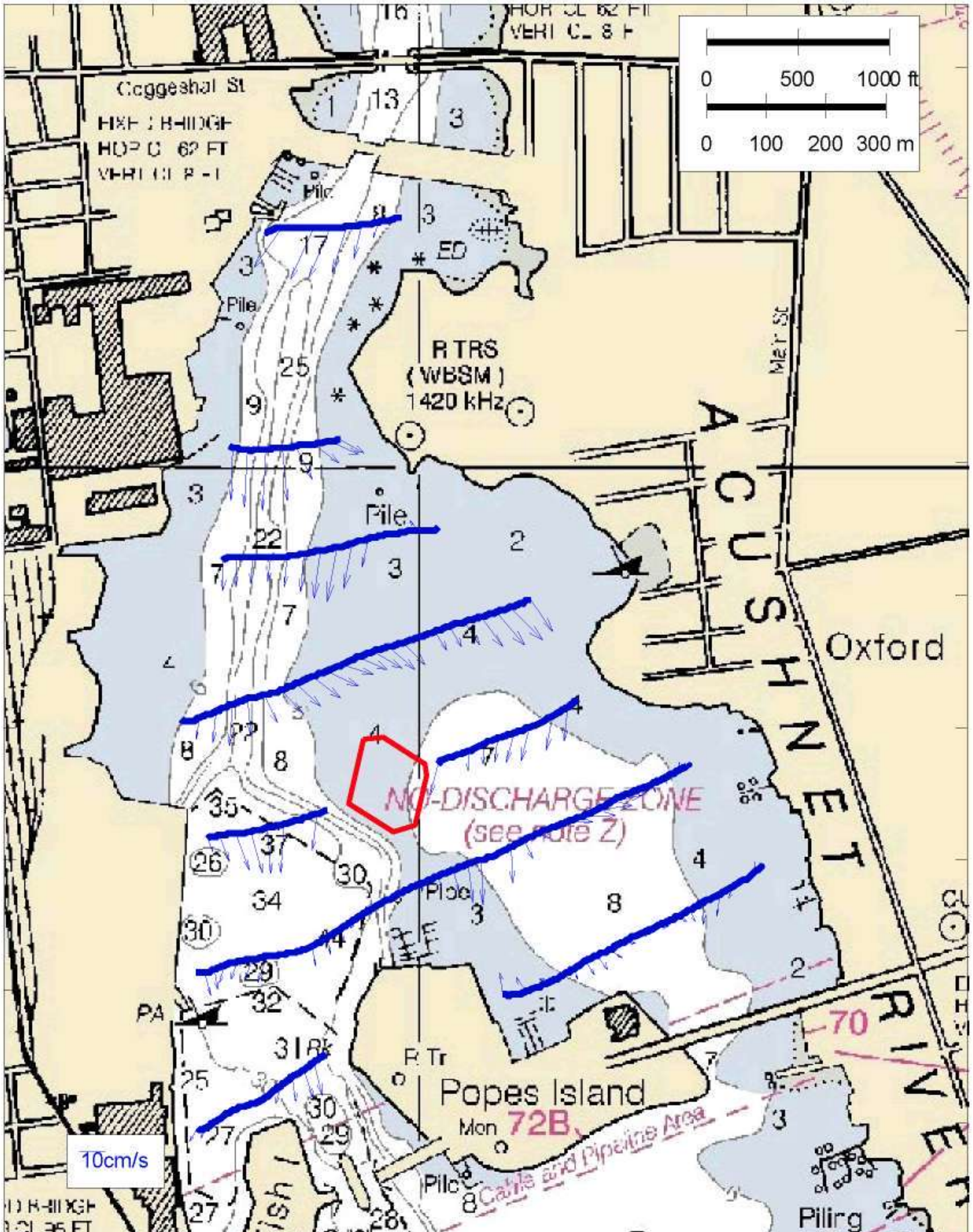
2 HOURS BEFORE HIGH SLACK - Depth 1.21m



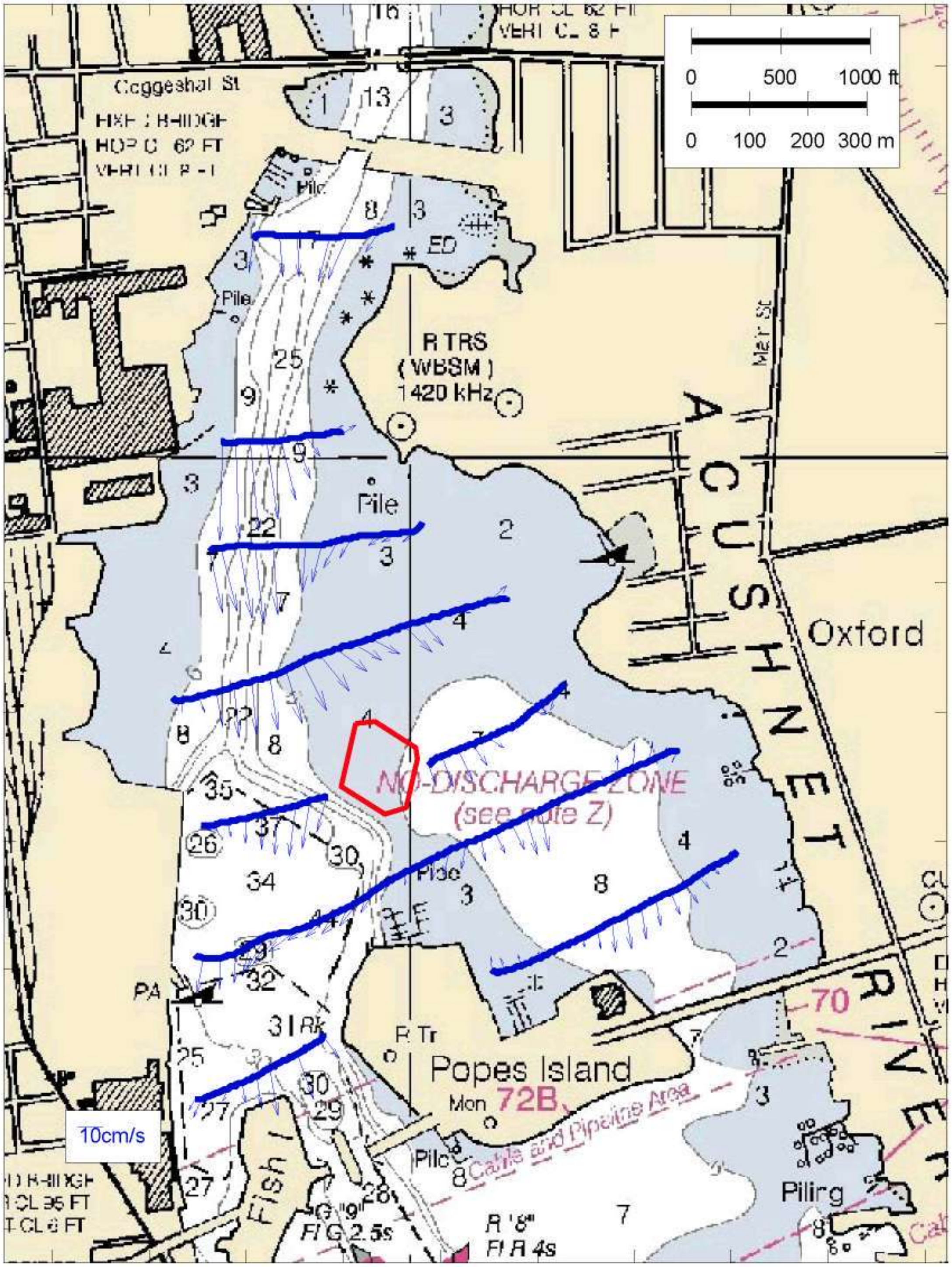
1 HOUR BEFORE HIGH SLACK - Depth 1.21m



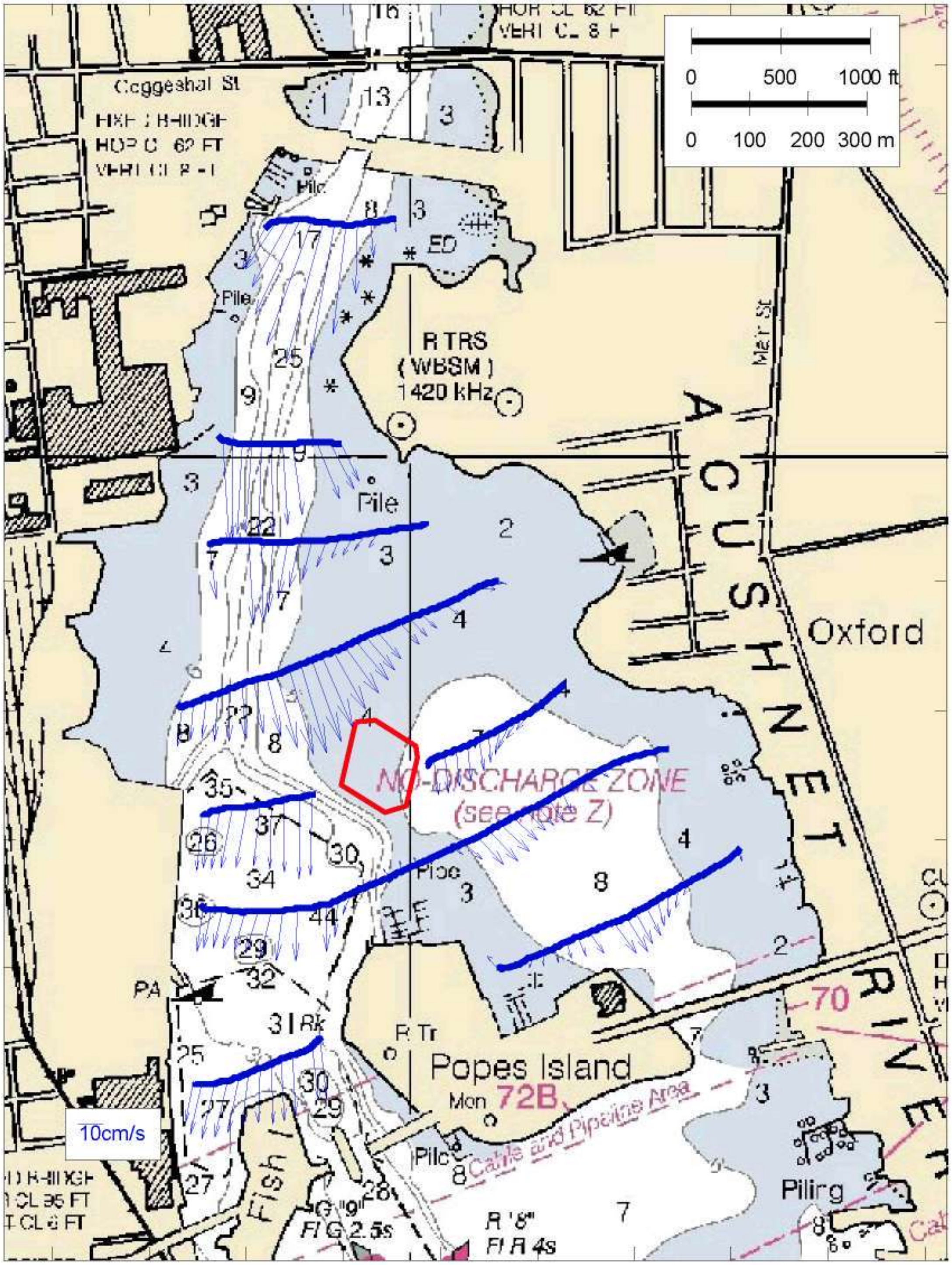
HIGH SLACK - Depth 1.21m



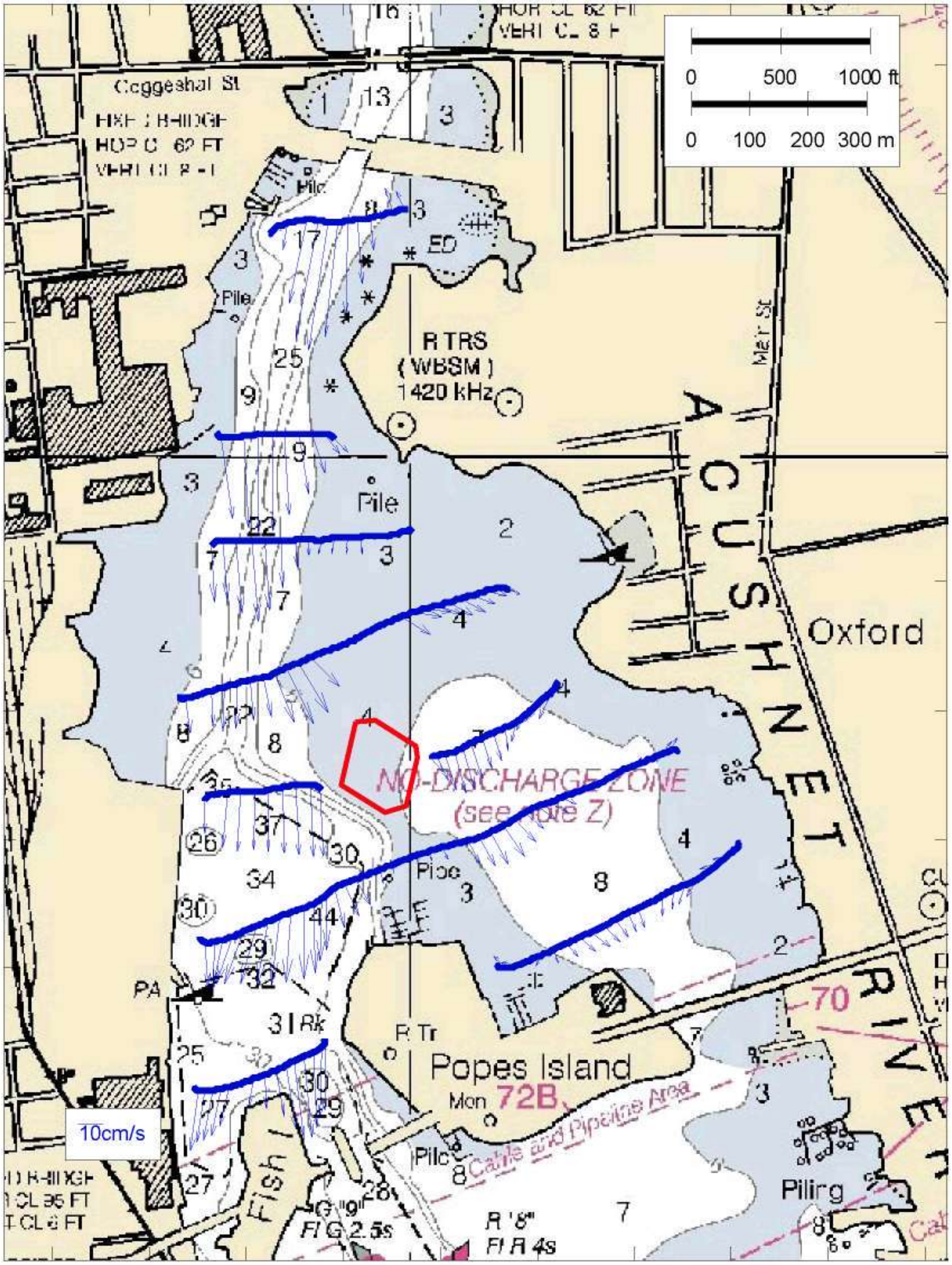
1 HOUR AFTER HIGH SLACK - Depth 1.21m



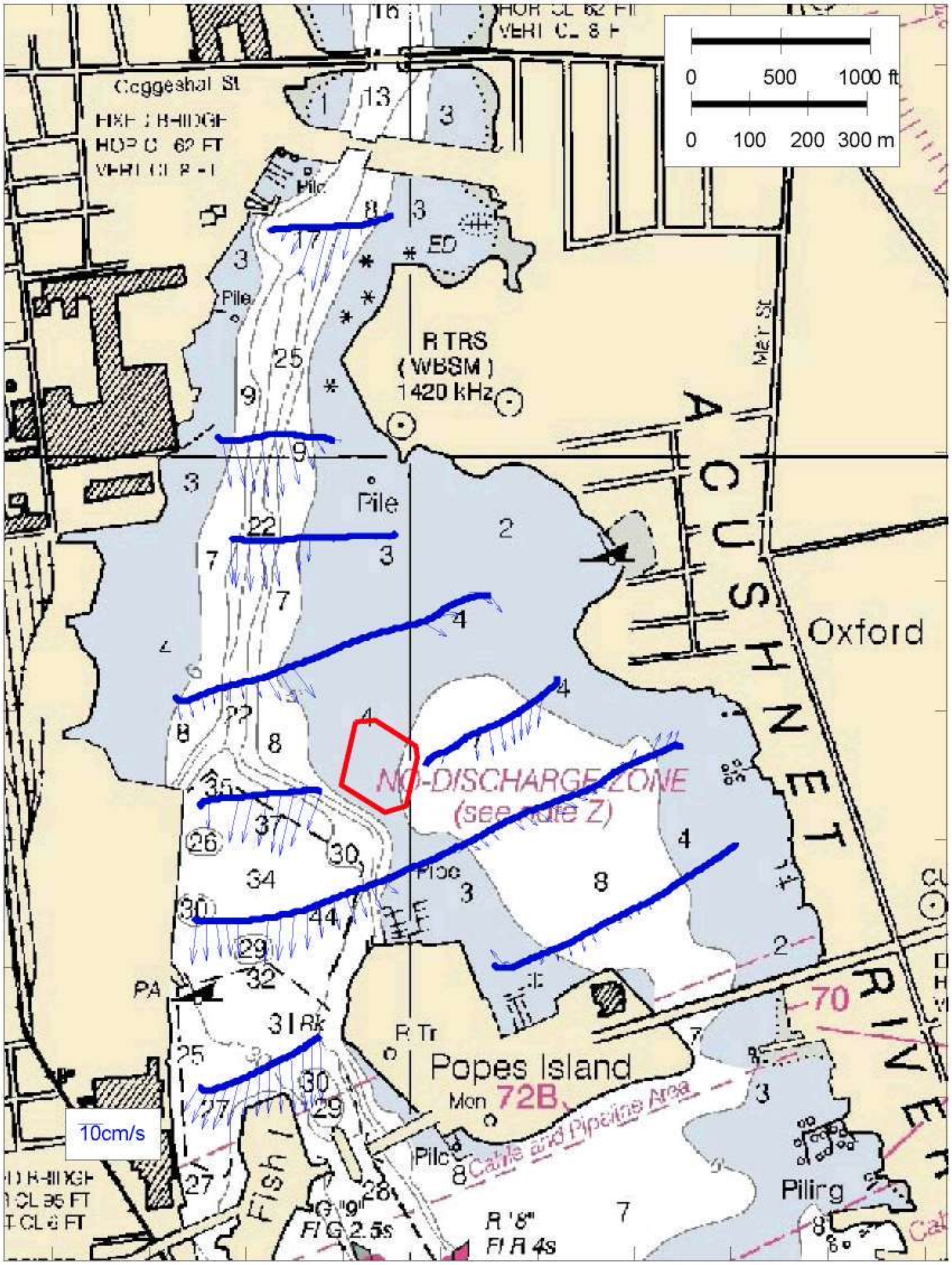
2 HOURS AFTER HIGH SLACK - Depth 1.23m



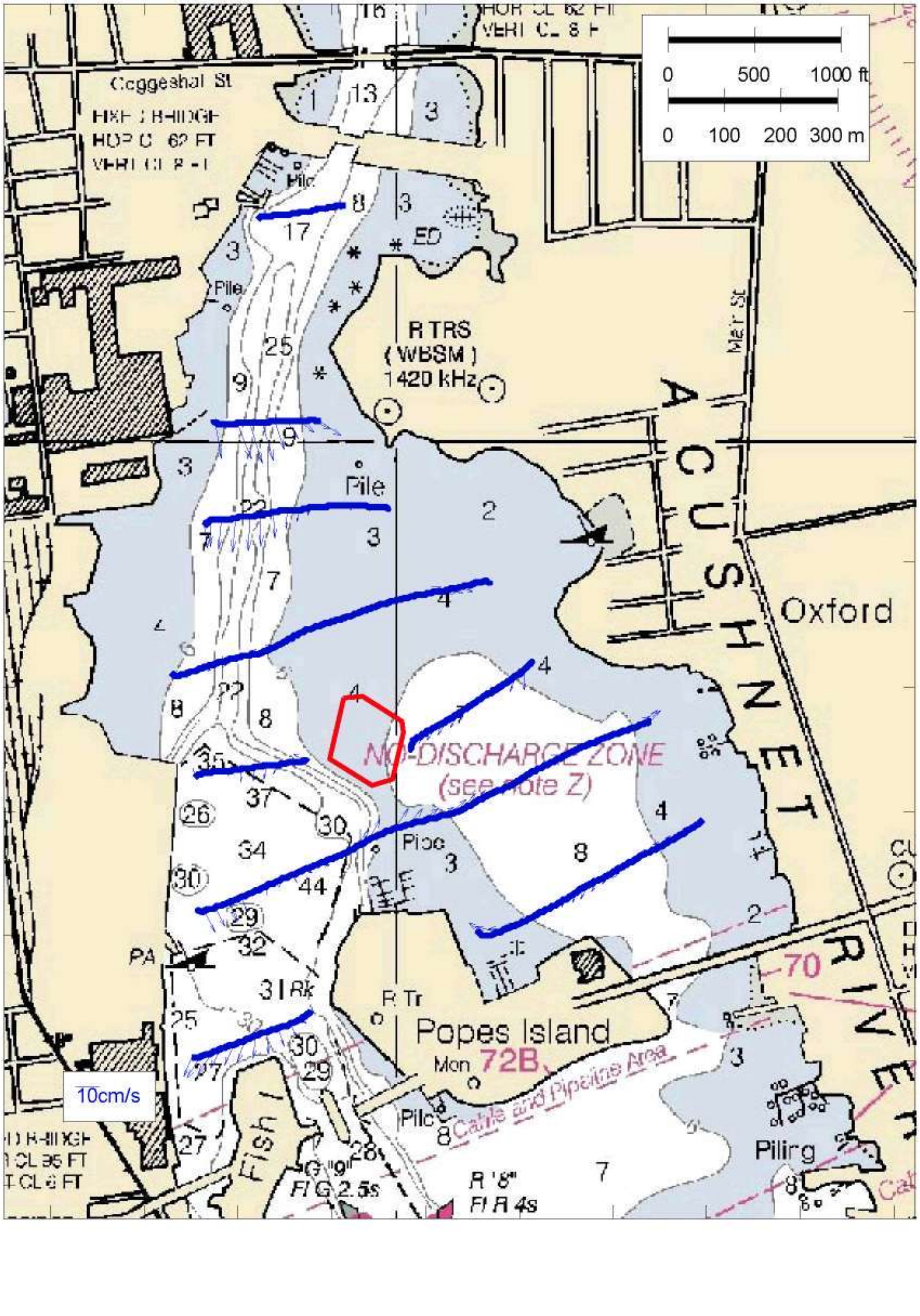
3 HOURS AFTER HIGH SLACK - Depth 1.24m



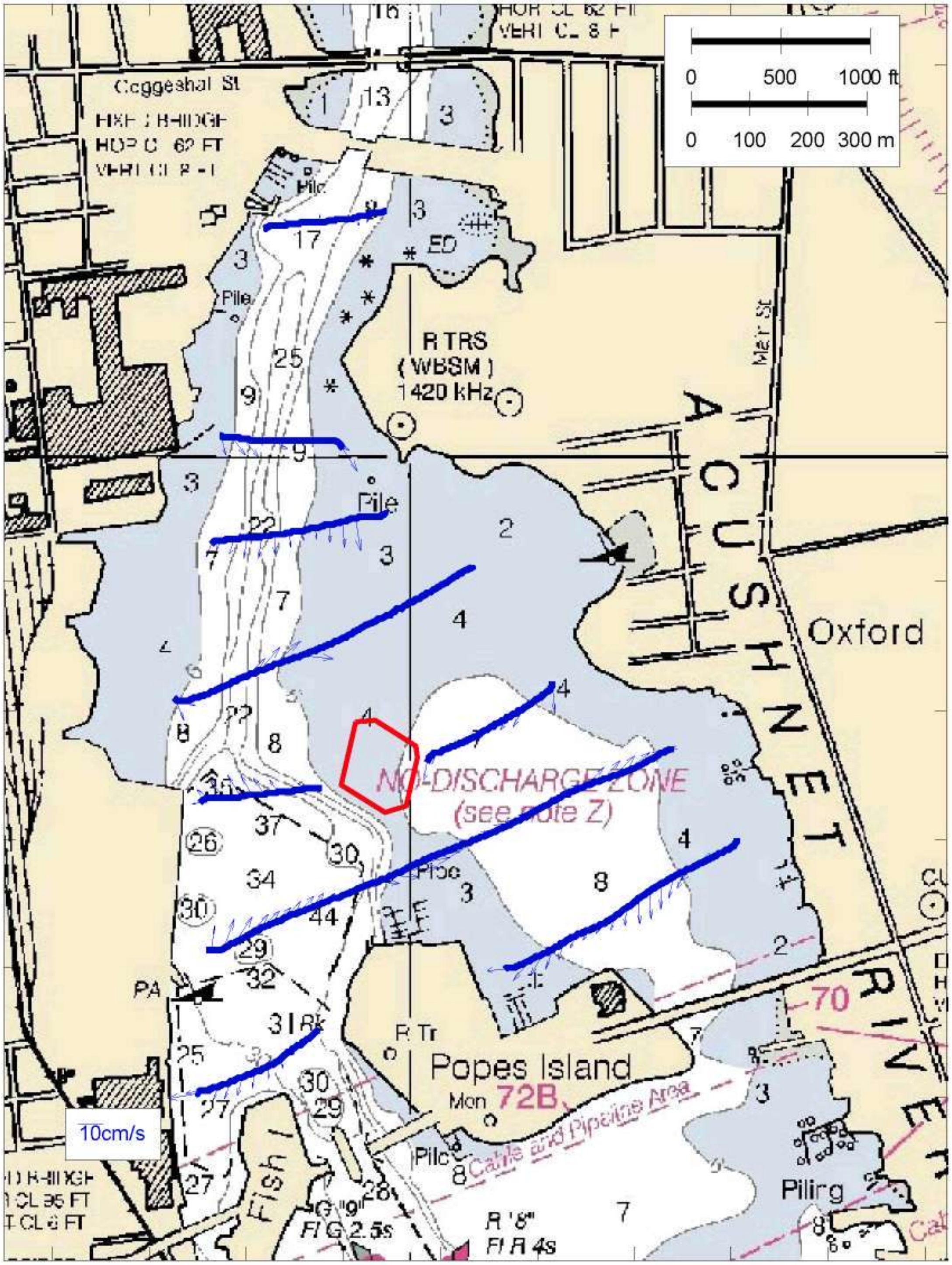
4 HOURS AFTER HIGH SLACK - Depth 1.24m



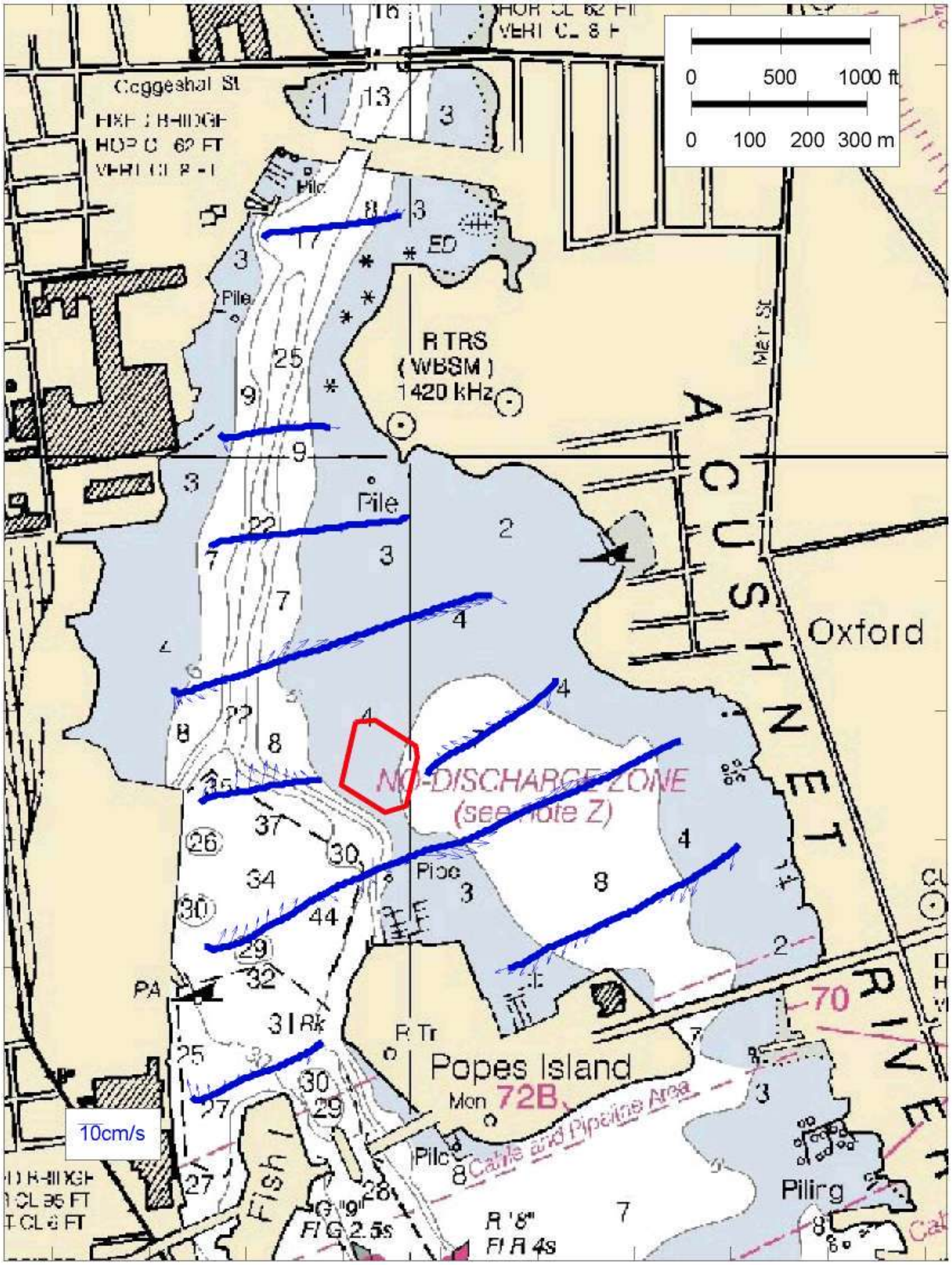
5 HOURS AFTER HIGH SLACK - Depth 1.24m



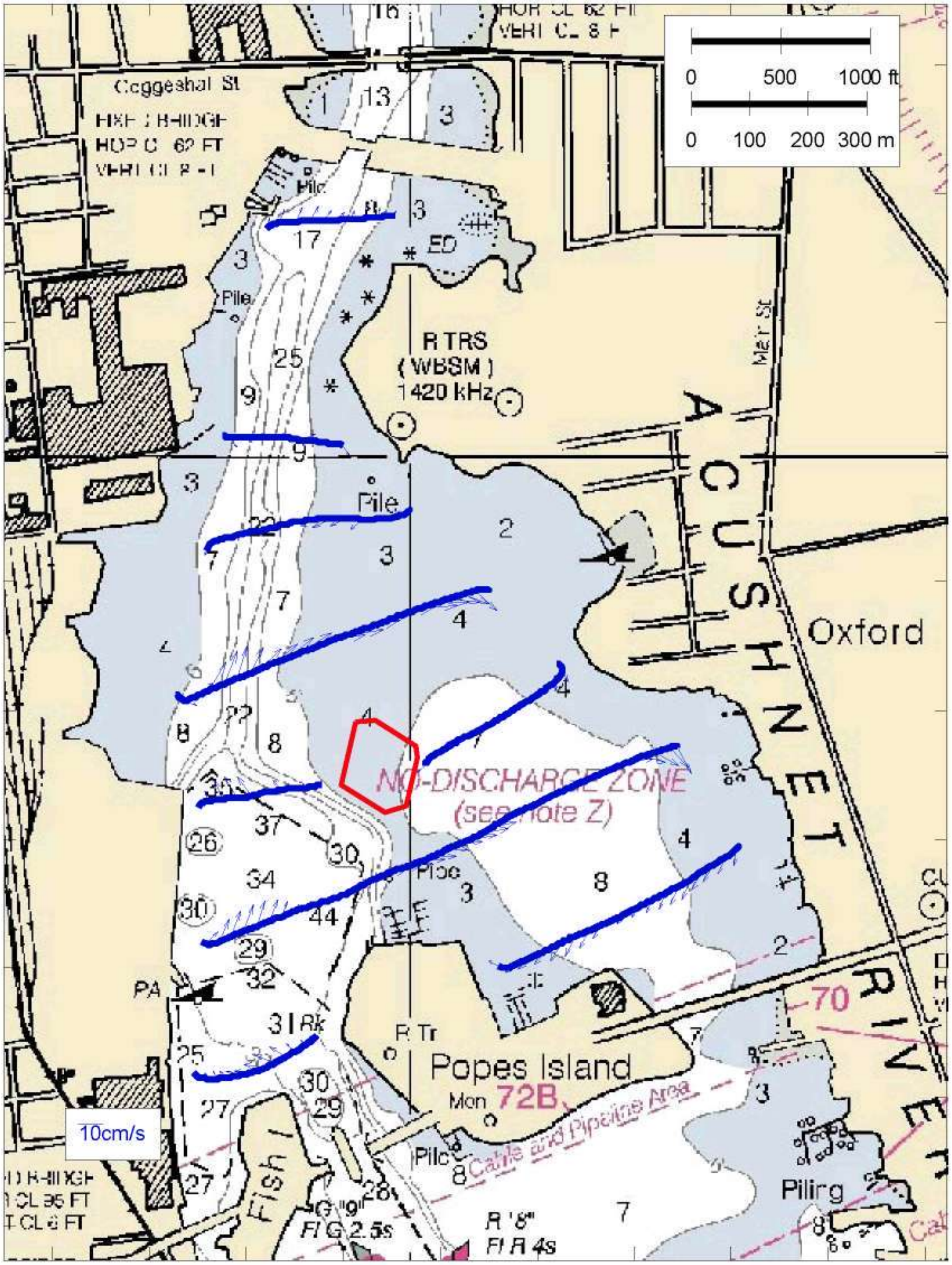
0.5 HOURS AFTER LOW SLACK - Depth 1.24m



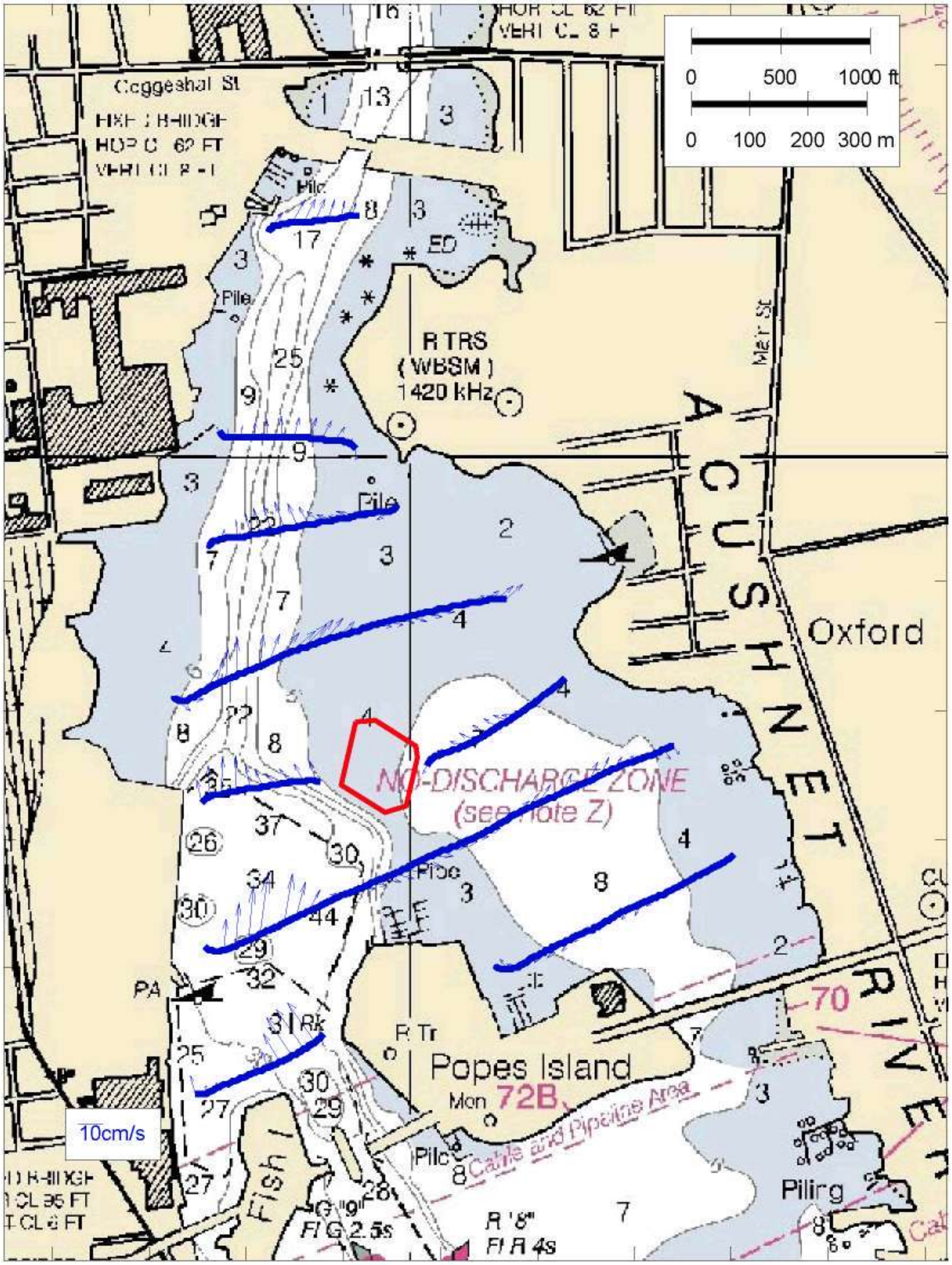
1.5 HOURS AFTER LOW SLACK - Depth 1.24m



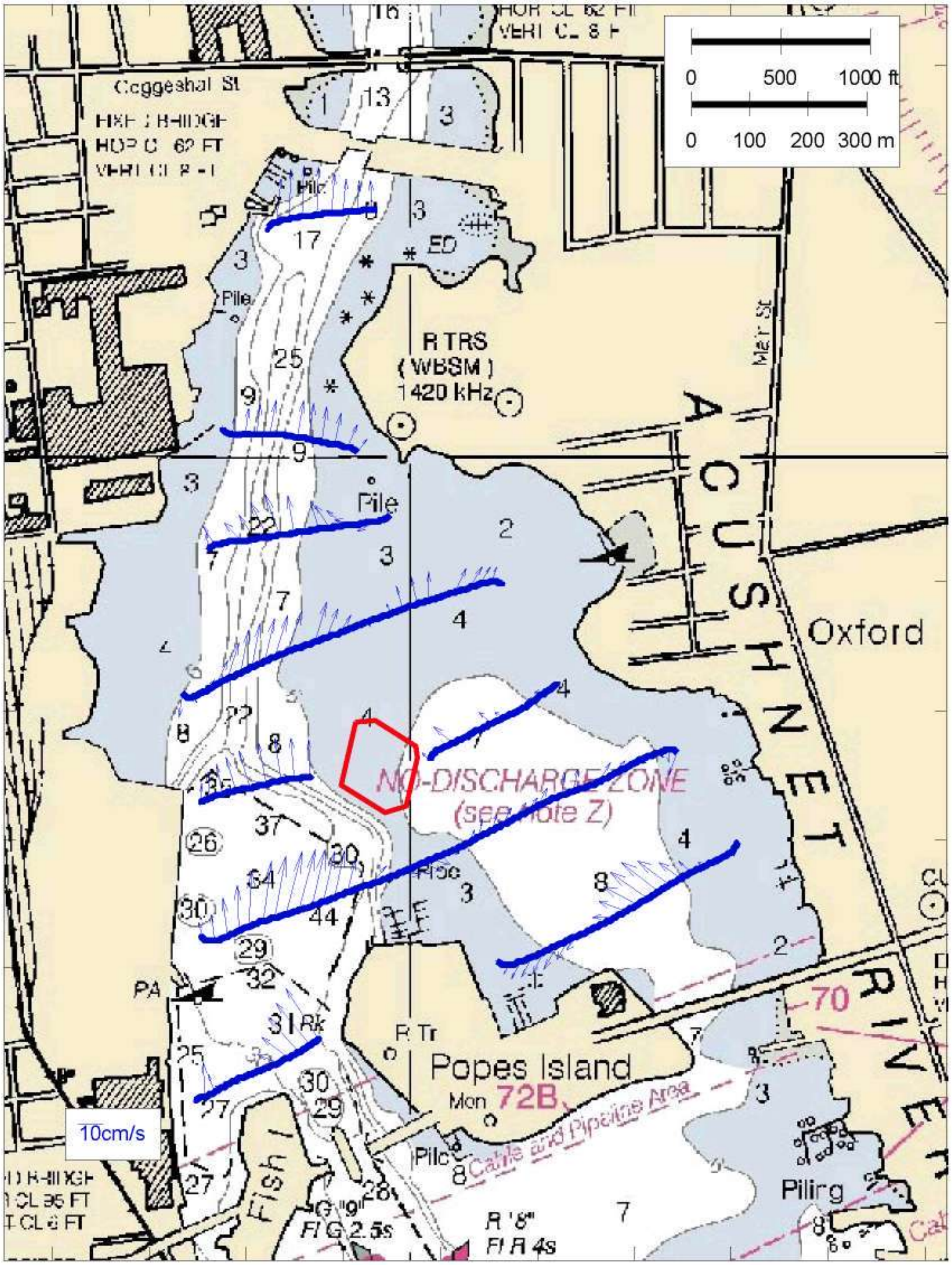
2.5 HOURS AFTER LOW SLACK - Depth 1.24m



3.5 HOURS AFTER LOW SLACK - Depth 1.24m



4.5 HOURS AFTER LOW SLACK - Depth 1.24m



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Part 2: Mid-Depth Tidal Velocity

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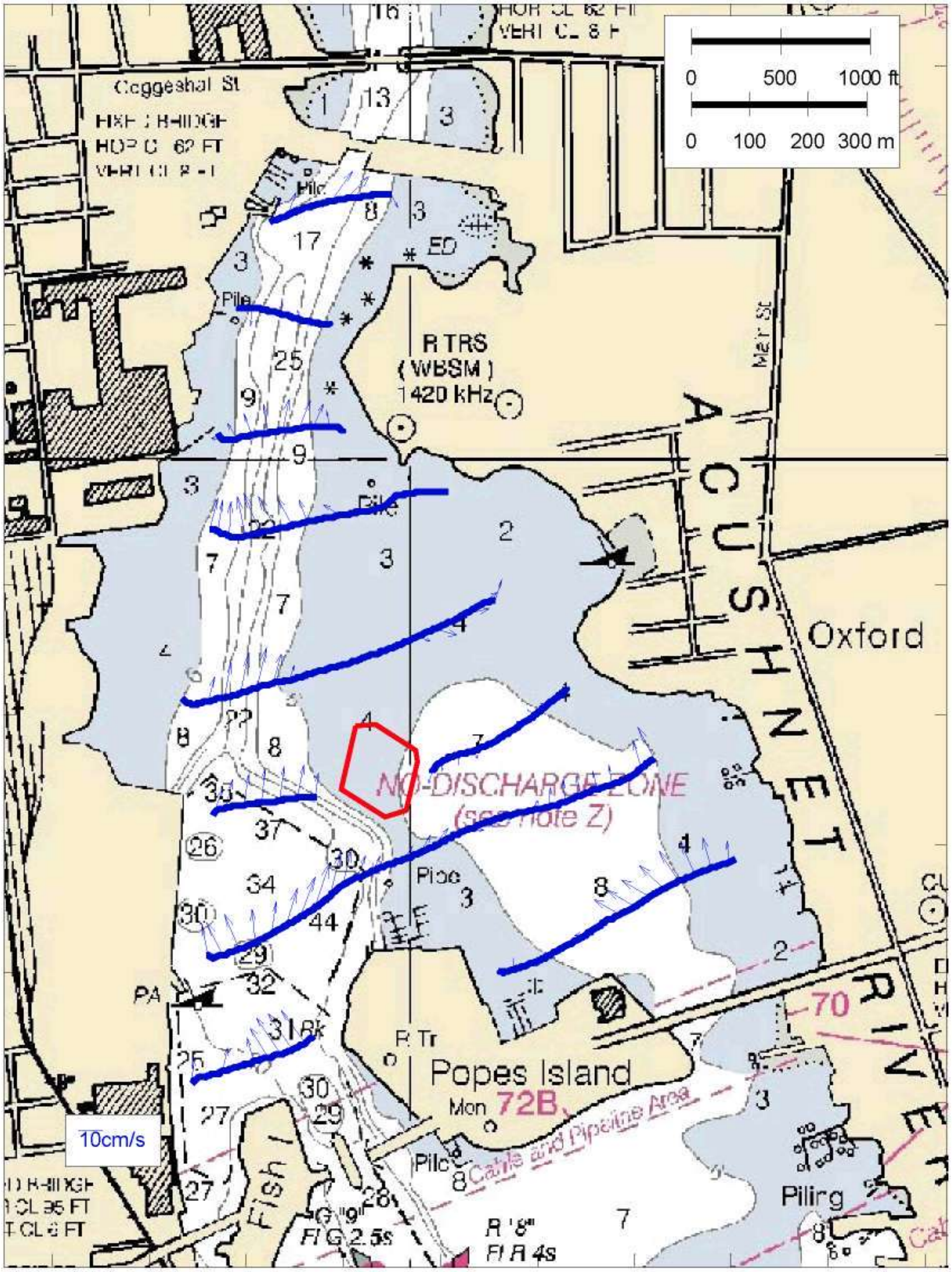
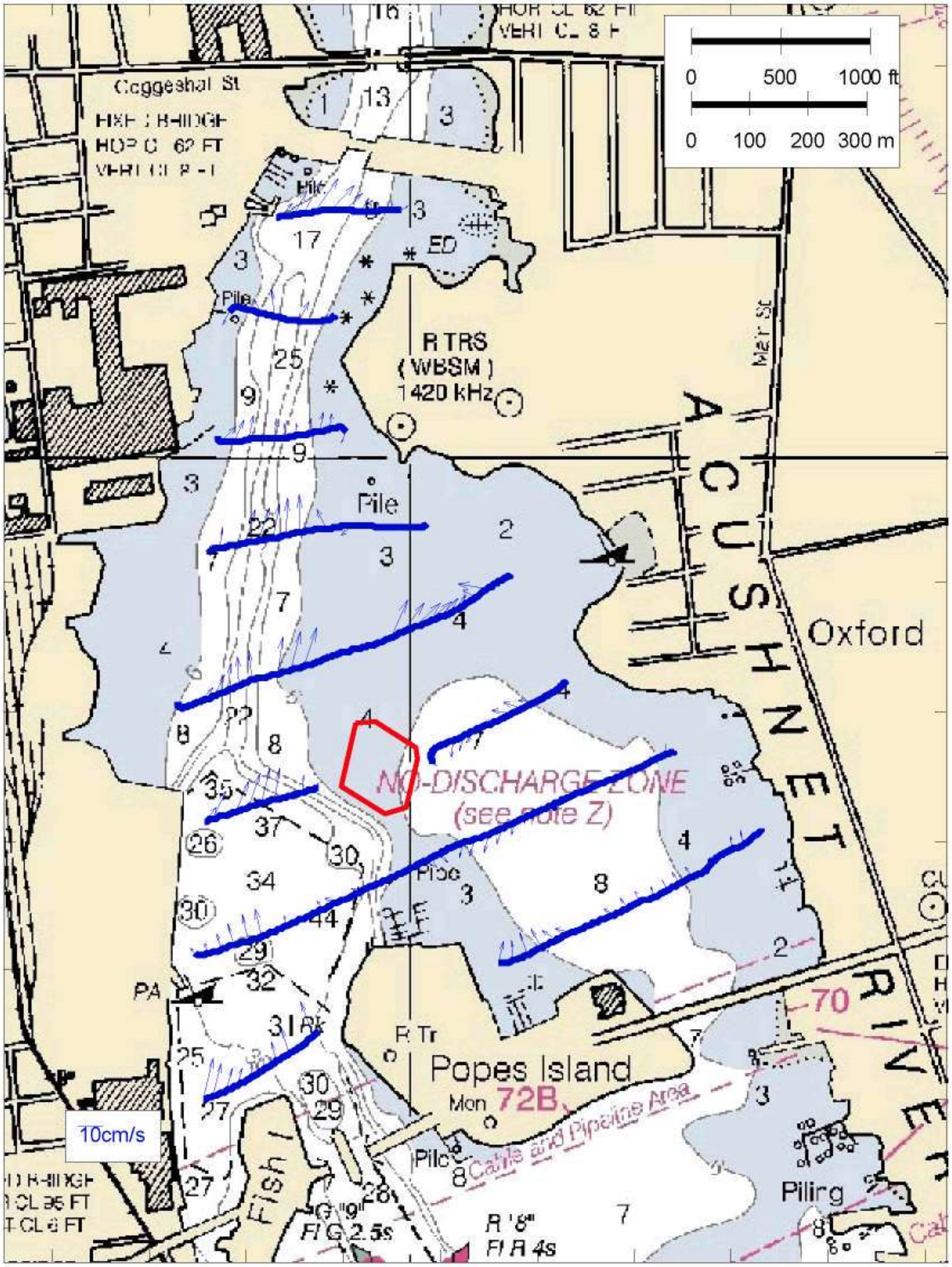
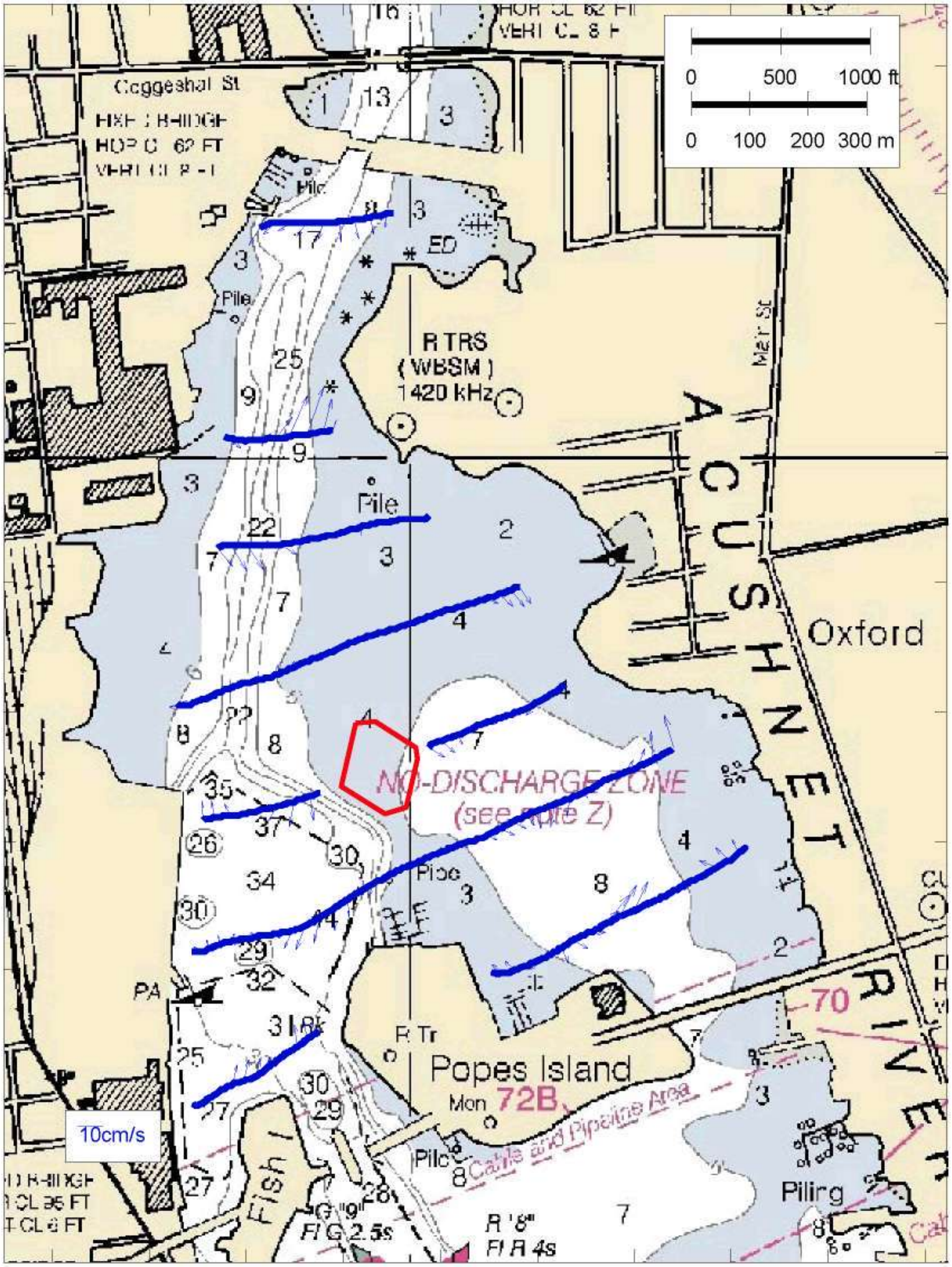
2 HOURS BEFORE HIGH SLACK - Depth 2.21m



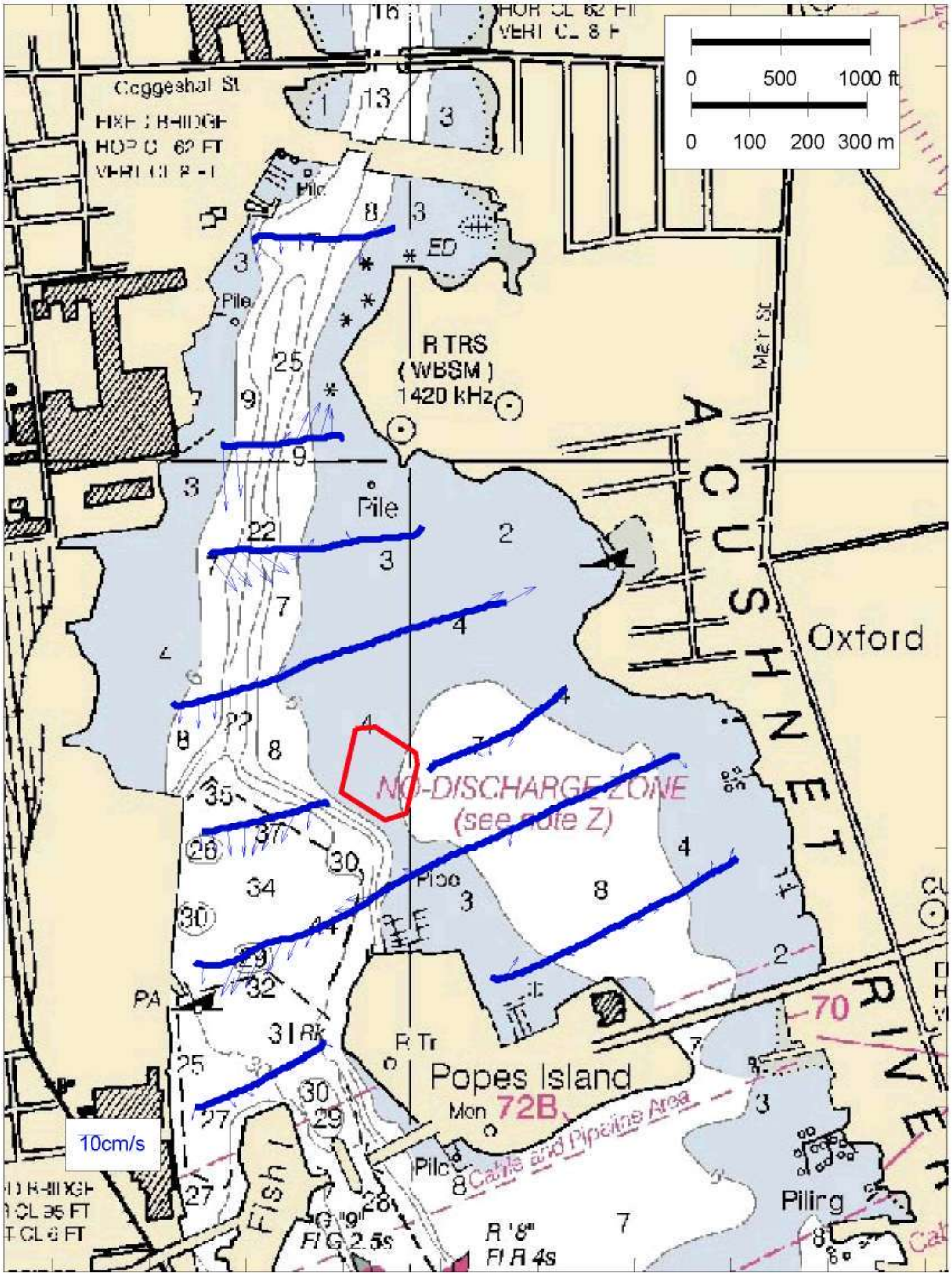
1 HOUR BEFORE HIGH SLACK - Depth 2.21m



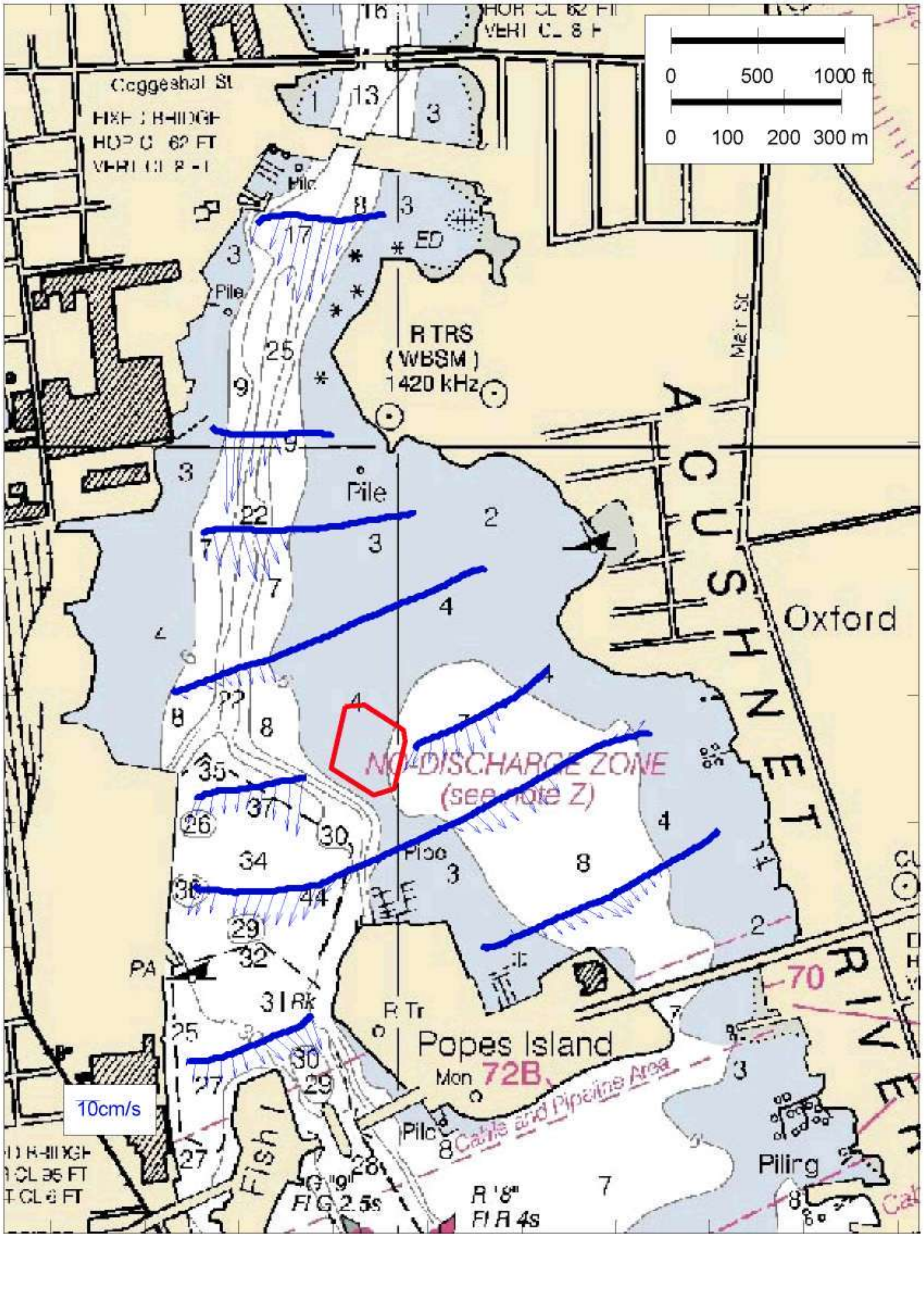
HIGH SLACK - Depth 2.21m



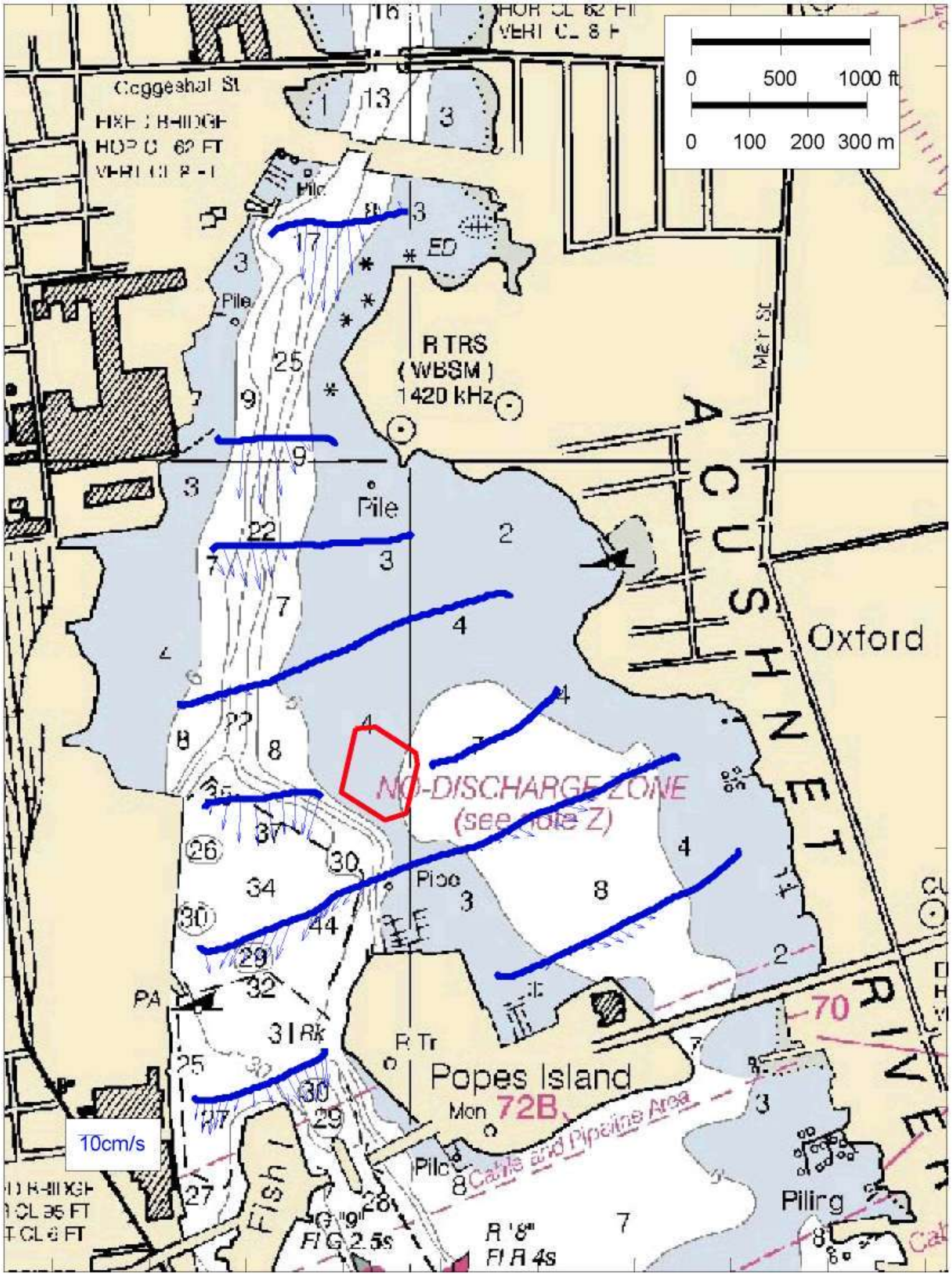
1 HOUR AFTER HIGH SLACK - Depth 2.21m



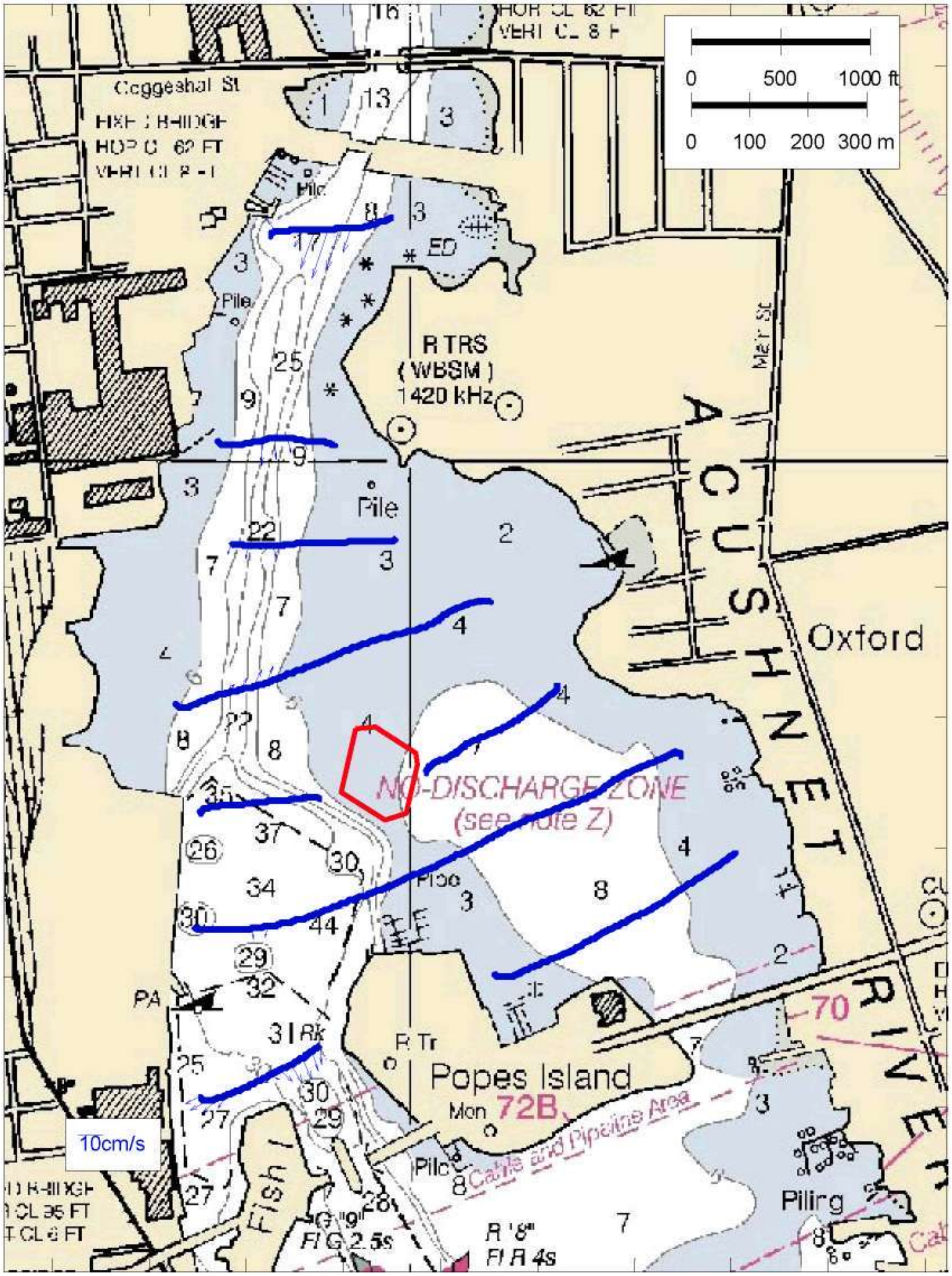
2 HOURS AFTER HIGH SLACK - Depth 2.23m



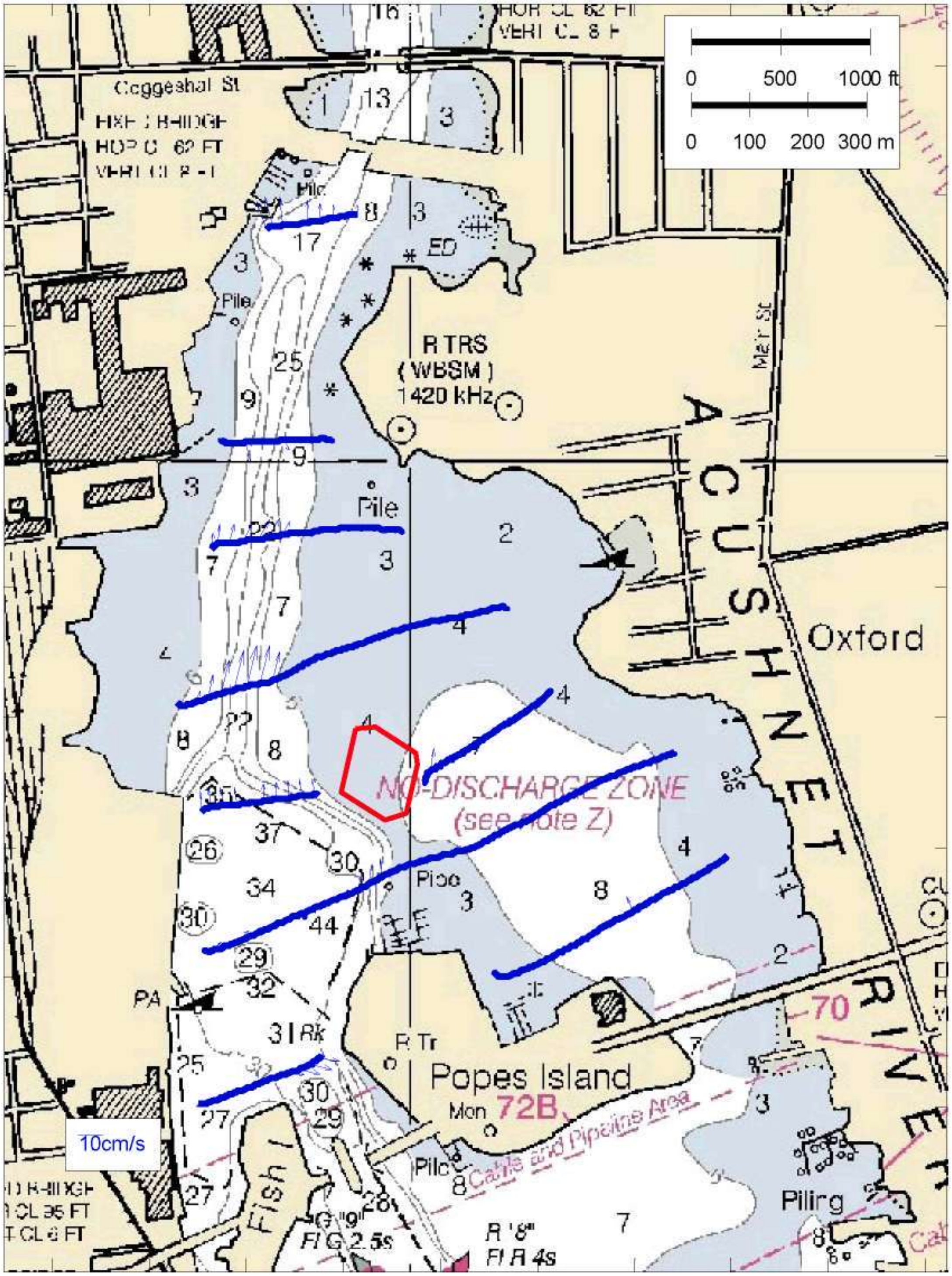
3 HOURS AFTER HIGH SLACK - Depth 2.24m



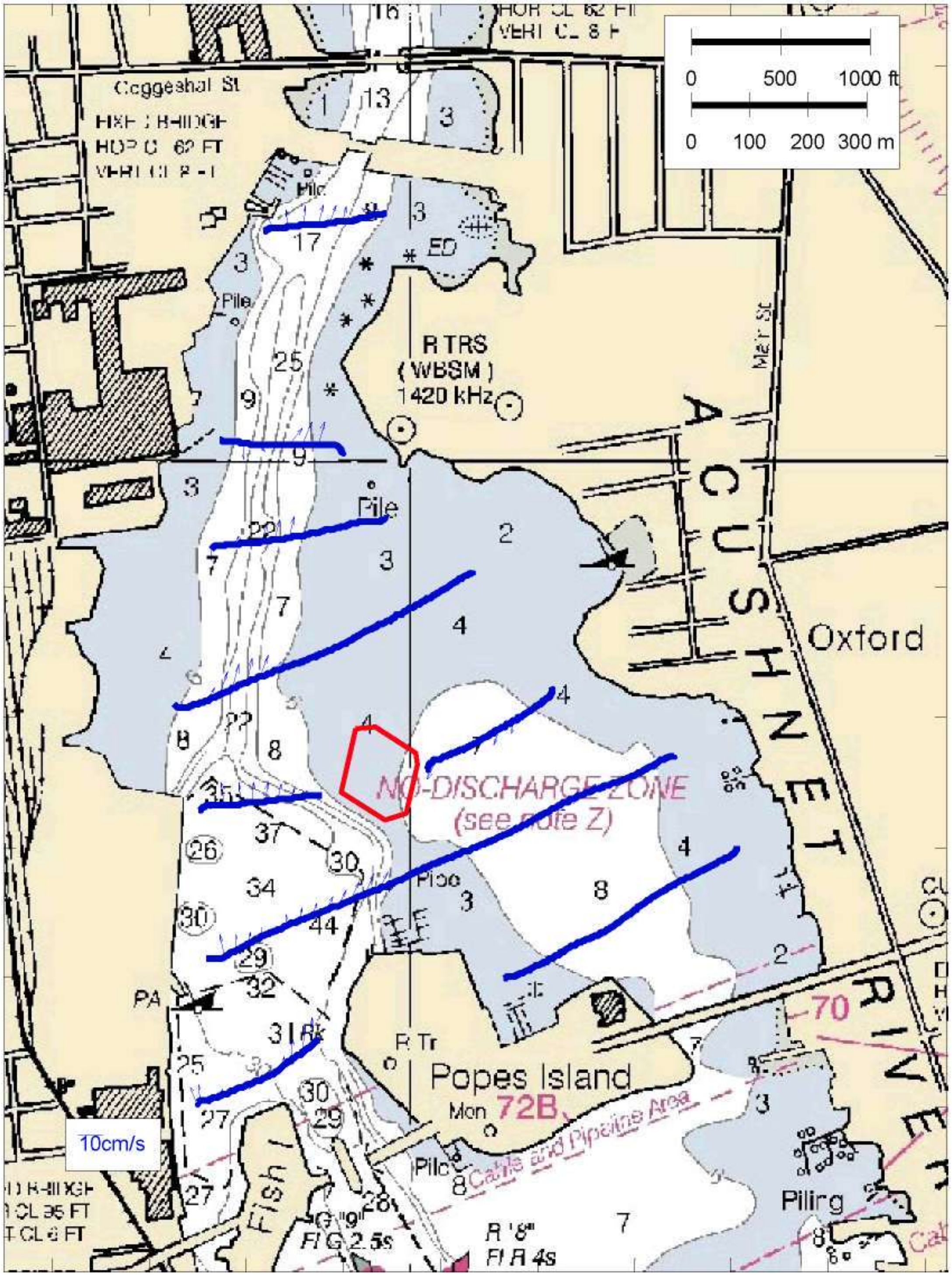
4 HOURS AFTER HIGH SLACK - Depth 2.24m



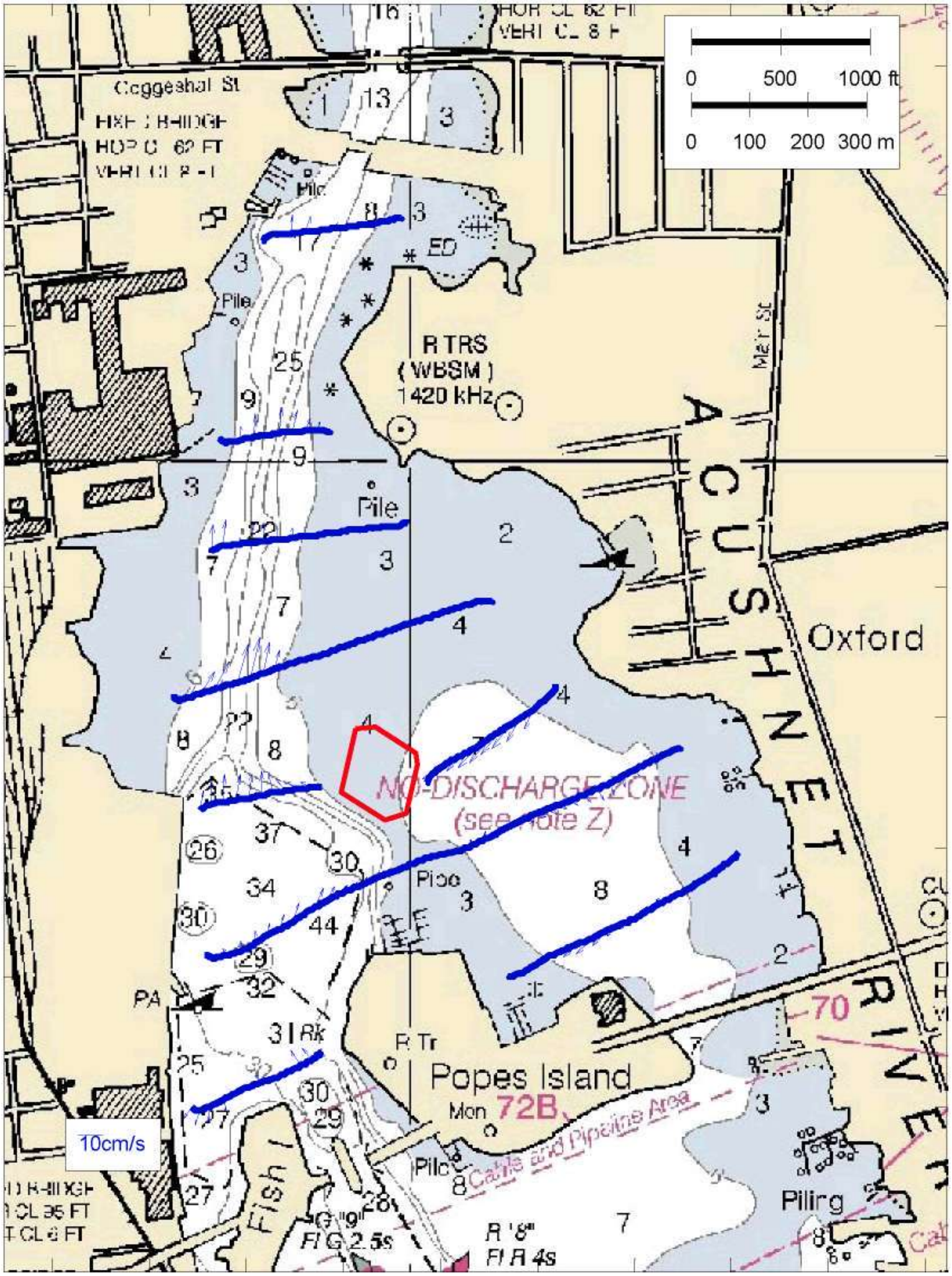
5 HOURS AFTER HIGH SLACK - Depth 2.24m



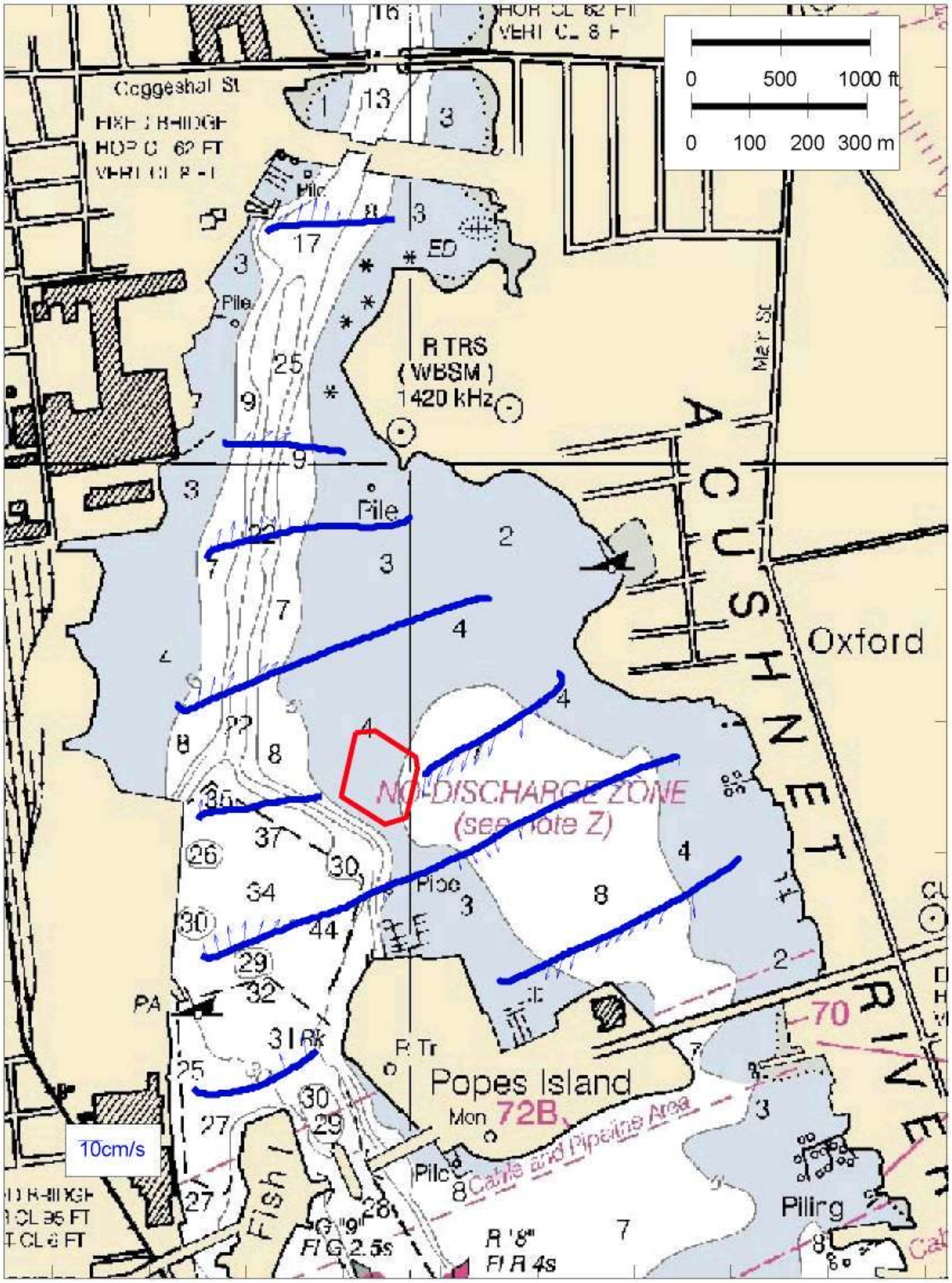
0.5 HOURS AFTER LOW SLACK - Depth 2.24m



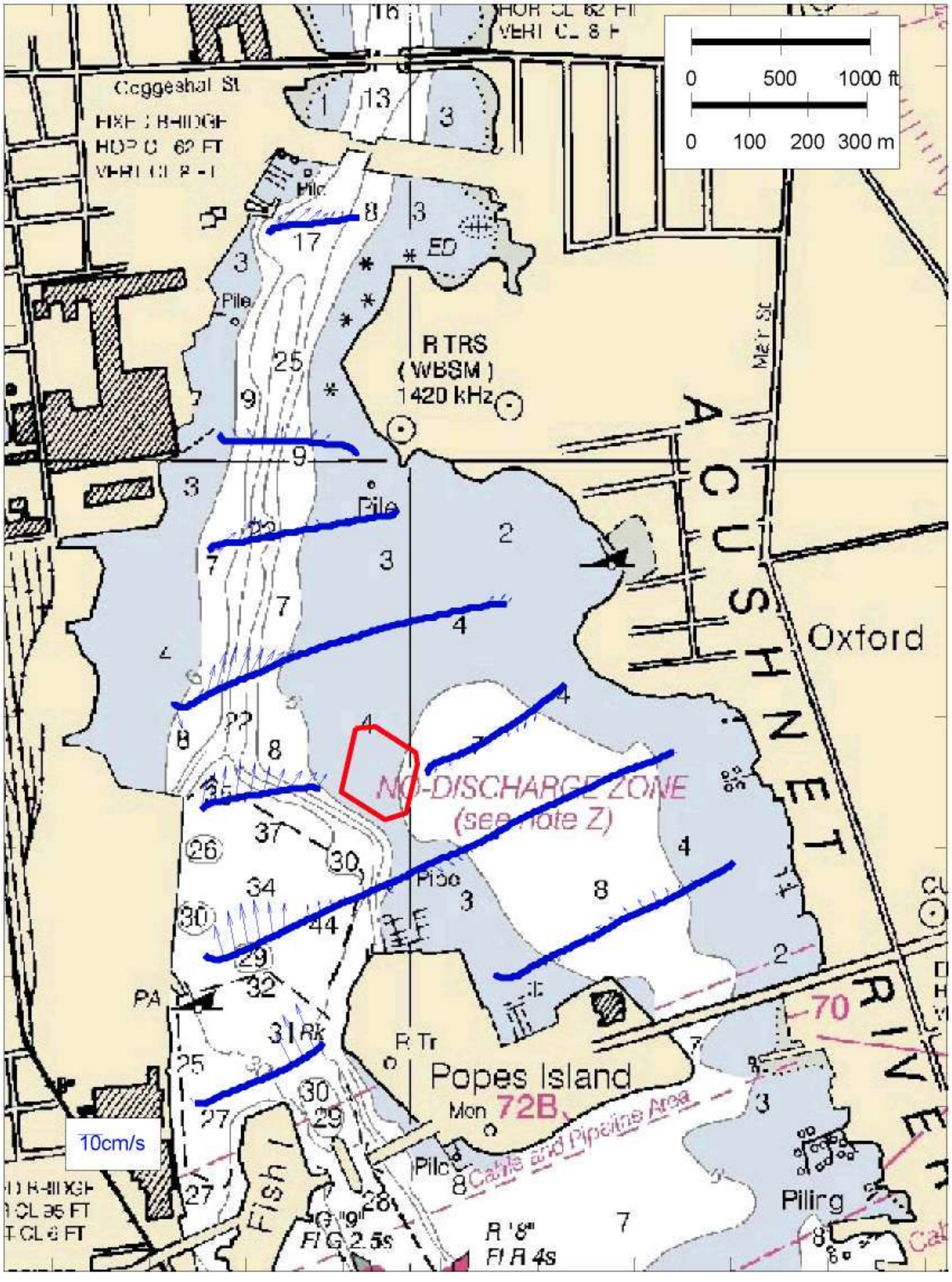
1.5 HOURS AFTER LOW SLACK - Depth 2.24m



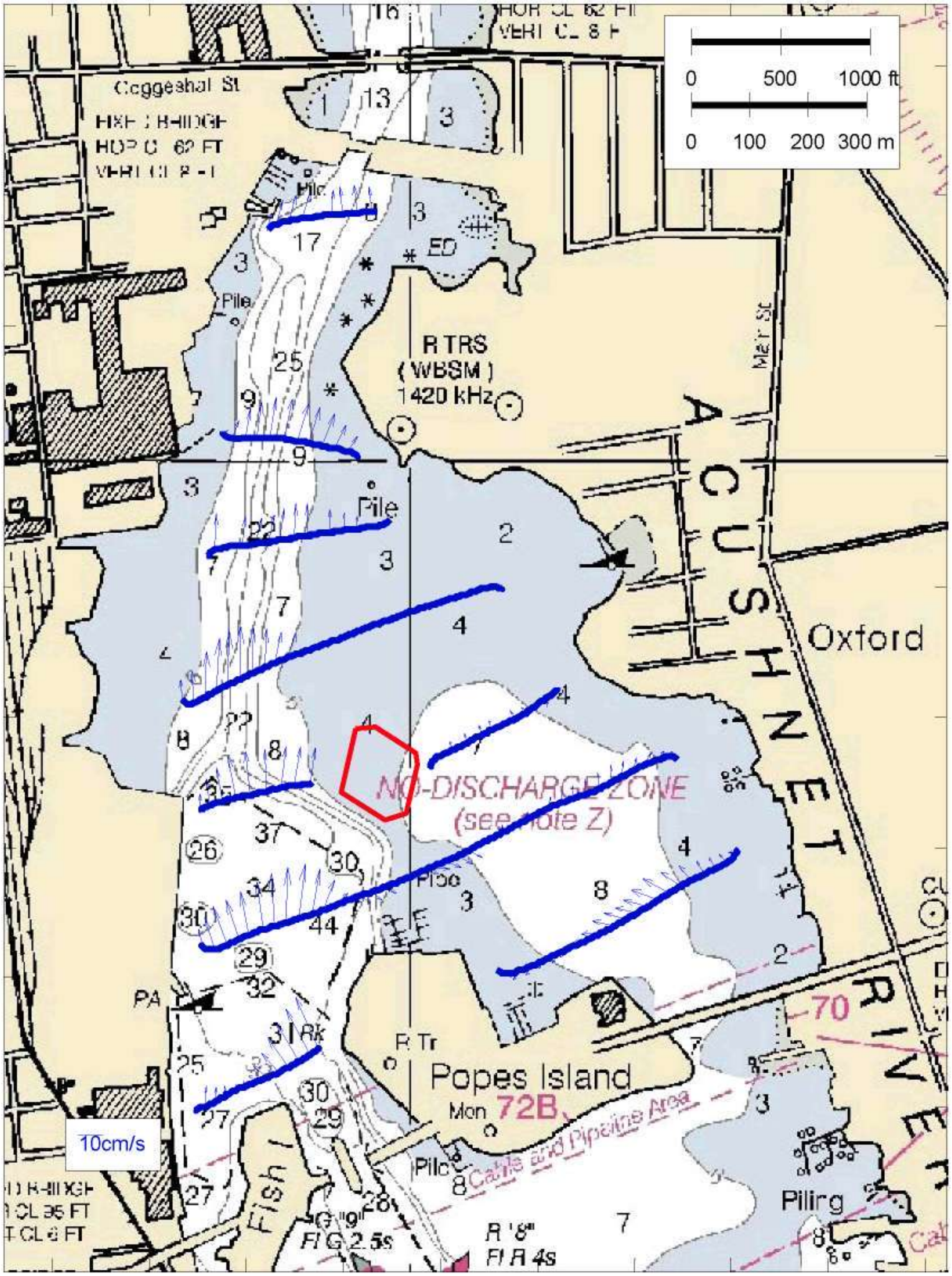
2.5 HOURS AFTER LOW SLACK - Depth 2.24m



3.5 HOURS AFTER LOW SLACK - Depth 2.24m



4.5 HOURS AFTER LOW SLACK - Depth 2.24m



APPENDIX B

New Bedford Harbor
Laboratory Turbidity and TSS Results
April 14, May 20, 21, 27, and July 8, 2009

New Bedford Harbor Laboratory Turbidity and TSS Results

Date	Time	Depth (ft)	Turbidity (NTU)	TSS (mg/L)	Station ID	Station Type	ADCP File Name
Event (NB1) Date: April 14, 2009							
Sea Quest – inside silt curtain							
4/14/2009	16:00	5	1.3	4.3	1460	North Reference	NB09A034.mat
4/14/2009	16:00	10	1.3	2.8	1460	North Reference	NB09A034.mat
4/14/2009	16:14	15	4.1	14.8	1461	South Reference	NB09A034.mat
4/14/2009	16:14	30	4.9	18.2	1461	South Reference	NB09A034.mat
4/14/2009	17:07	15	7.5	21.7	S019	Plume Lateral	NB09A035.mat
4/14/2009	17:07	30	25	44.9	S019	Plume Lateral	NB09A035.mat
4/14/2009	17:22	15	1.9	5.5	S020	Plume Lateral	NB09A036.mat
4/14/2009	17:22	30	94	152	S020	Plume Lateral	NB09A036.mat
4/14/2009	17:40	4	1.5	4	S021	Plume Centroid	NB09A036.mat
4/14/2009	17:40	8	1.5	3.5	S021	Plume Centroid	NB09A036.mat
Gale Force – outside silt curtain							
4/14/2009	15:55	9	3	4.6	17	North Reference	NB09B014.mat
4/14/2009	15:55	18	1.9	11.5	17	North Reference	NB09B014.mat
4/14/2009	16:17	4	1.7	5.8	18	South Reference	NB09B015.mat
4/14/2009	16:17	9	1.3	2.8	18	South Reference	NB09B015.mat
4/14/2009	17:01	4	1.3	3	19	Plume Centroid	NB09B018.mat
4/14/2009	17:01	8	1.5	3.7	19	Plume Centroid	NB09B018.mat
4/14/2009	17:05	4	1.3	3.8	20	Plume Lateral	NB09B018.mat
4/14/2009	17:05	2	1.6	2.5	20	Plume Lateral	NB09B019.mat
4/14/2009	17:10	4	1.2	3	21	Plume Lateral	NB09B019.mat
4/14/2009	17:10	2	0.95	4.8	21	Plume Lateral	NB09B019.mat
4/14/2009	17:12	2	1.3	2.2	22	Dup	NB09B019.mat
Event (NB2) Date: May 20, 2009							
Sea Quest – inside silt curtain							
5/20/2009	7:40	5	1.7	7.8	1460	North Reference	NB09A043.mat

New Bedford Harbor Laboratory Turbidity and TSS Results

Date	Time	Depth (ft)	Turbidity (NTU)	TSS (mg/L)	Station ID	Station Type	ADCP File Name
5/20/2009	7:40	9	2.1	7.7	1460	North Reference	NB09A043.mat
5/20/2009	8:10	15	17	54.8	S023	Plume Centroid	NB09A045.mat
5/20/2009	8:10	30	84	226	S023	Plume Centroid	NB09A045.mat
5/20/2009	8:25	10	3.4	15.3	S025	Plume Lateral	NB09A047.mat
5/20/2009	8:25	18	33	97.1	S025	Plume Lateral	NB09A047.mat
5/20/2009	8:38	15	20	45.1	S026	Plume Lateral	NB09A049.mat
5/20/2009	8:38	30	43	103	S026	Plume Lateral	NB09A049.mat
5/20/2009	9:45	12	1.8	6.3	S027	South Reference	NB09A054.mat
5/20/2009	9:45	25	1.3	6.3	S027	South Reference	NB09A054.mat
Gale Force – outside silt curtain							
5/20/2009	7:43	9	2.2	5.2	26	North Reference	NB09B023.mat
5/20/2009	7:43	17	2.1	2.5	26	North Reference	NB09B023.mat
5/20/2009	8:24	5	1.8	5.7	28	Plume Lateral	NB09B025.mat
5/20/2009	8:24	3	1.9	3.7	28	Plume Lateral	NB09B025.mat
5/20/2009	8:27	6	2	1.8	29	Plume Lateral	NB09B025.mat
5/20/2009	8:27	3	1.6	3.5	29	Plume Lateral	NB09B025.mat
5/20/2009	8:31	5	2.4	5.8	30	Plume Centroid	NB09B025.mat
5/20/2009	8:31	10	1.9	6.5	30	Plume Centroid	NB09B025.mat
5/20/2009	9:42	3	1.7	2.5	32	South Reference	NB09B025.mat
5/20/2009	9:42	3	1.6	1.8	32	South Reference	NB09B025.mat
5/20/2009	9:42	6	1.6	6.3	32	South Reference	NB09B025.mat
Event (NB3) Date: May 21, 2009							
Sea Quest – inside silt curtain							
5/21/2009	7:03	5	1.7	7.3	S028	North Reference	NB09A057.mat
5/21/2009	7:03	8	2	6	S028	North Reference	NB09A057.mat
5/21/2009	7:19	15	1.3	6.3	S029	South Reference	NB09A058.mat
5/21/2009	7:19	28	1.6	4.5	S029	South Reference	NB09A058.mat
5/21/2009	8:27	16	37	99.5	S031	Plume Centroid	NB09A062.mat

Date	Time	Depth (ft)	Turbidity (NTU)	TSS (mg/L)	Station ID	Station Type	ADCP File Name
5/21/2009	8:27	30	160	278	S031	Plume Centroid	NB09A062.mat
5/21/2009	8:40	15	8.9	26.8	S032	Plume Lateral	NB09A064.mat
5/21/2009	8:40	26	77	133	S032	Plume Lateral	NB09A064.mat
5/21/2009	8:52	13	4	10	S033	Plume Lateral	NB09A065.mat
5/21/2009	8:52	25	46	99.7	S033	Plume Lateral	NB09A065.mat
Gale Force – outside silt curtain							
5/21/2009	7:01	10	2	5.2	34	North Reference	NB09B029.mat
5/21/2009	7:01	20	2	8.7	34	North Reference	NB09B029.mat
5/21/2009	7:15	9	1.8	4.2	36	South Reference	NB09B029.mat
5/21/2009	7:15	5	1.5	5.4	36	South Reference	NB09B029.mat
5/21/2009	8:31	9	6.2	20	38	Plume Lateral	NB09B031.mat
5/21/2009	8:31	18	11	31.8	38	Plume Lateral	NB09B031.mat
5/21/2009	8:31	9	6.5	15.2	38	Plume Lateral-dup	NB09B031.mat
5/21/2009	8:36	15	1.6	4.8	39	Plume Lateral	NB09B031.mat
5/21/2009	8:36	30	1.4	6.5	39	Plume Lateral	NB09B031.mat
5/21/2009	8:45	15	4	7.3	40	Plume Centroid	NB09B031.mat
5/21/2009	8:45	30	1.7	5.5	40	Plume Centroid	NB09B031.mat
Event (NB4) Date: May 27, 2009							
Sea Quest – inside silt curtain							
5/27/2009	7:17	5	2.5	4.3	S034	North Reference	NB09A073.mat
5/27/2009	7:17	8	2.6	6.5	S034	North Reference	NB09A073.mat
5/27/2009	7:34	12	2.4	2.7	S035	South Reference	NB09A074.mat
5/27/2009	7:34	24	1.6	3.3	S035	South Reference	NB09A074.mat
5/27/2009	8:25	8	2.6	5.8	S036	Plume Centroid	NB09A078.mat
5/27/2009	8:25	18	97	442	S036	Plume Centroid	NB09A078.mat
5/27/2009	8:43	16	16	86.5	S038	Plume Lateral	NB09A080.mat
5/27/2009	8:43	30	9.1	165	S038	Plume Lateral	NB09A080.mat
5/27/2009	9:01	15	42	41.8	S039	Plume Lateral	NB09A082.mat

New Bedford Harbor Laboratory Turbidity and TSS Results

Date	Time	Depth (ft)	Turbidity (NTU)	TSS (mg/L)	Station ID	Station Type	ADCP File Name
5/27/2009	9:01	30	40	101	S039	Plume Lateral	NB09A082.mat
Gale Force – outside silt curtain							
5/27/2009	7:15	13	2.2	4.2	42	North Reference	NB09B037.mat
5/27/2009	7:15	7	3.2	3	42	North Reference	NB09B037.mat
5/27/2009	7:15	7	2.6	6.3	42	North Reference-dup	NB09B037.mat
5/27/2009	7:34	4	2.1	1.7	44	South Reference	NB09B037.mat
5/27/2009	7:34	8	1.8	1.6	44	South Reference	NB09B037.mat
5/27/2009	8:33	4	3.2	7.8	45	Plume Lateral	NB09B041.mat
5/27/2009	8:33	8	19	50.6	45	Plume Lateral	NB09B041.mat
5/27/2009	8:42	8	2.8	14.7	47	Plume Centroid	NB09B041.mat
5/27/2009	8:42	4	2.5	5	47	Plume Centroid	NB09B041.mat
5/27/2009	8:56	3	3.9	9	48	Plume Lateral	NB09B041.mat
5/27/2009	8:56	7	3.8	13.7	48	Plume Lateral	NB09B041.mat
Event (NB5) Date: July 8, 2009							
Sea Quest – inside silt curtain							
7/8/2009	11:35	5	2.7	7.7	S040	North Reference	NB09A096.mat
7/8/2009	11:35	10	2.8	5.2	S040	North Reference	NB09A096.mat
7/8/2009	11:44	12	1.9	3.8	S041	South Reference	NB09A097.mat
7/8/2009	11:44	25	1.4	6.2	S041	South Reference	NB09A097.mat
7/8/2009	12:12	10	49	112	S042	Plume Centroid	NB09A100.mat
7/8/2009	12:12	20	12	39.8	S042	Plume Centroid	NB09A100.mat
7/8/2009	12:25	12	3.8	10	S043	Plume Lateral	NB09A102.mat
7/8/2009	12:25	25	21	65.3	S043	Plume Lateral	NB09A102.mat
7/8/2009	12:38	11	8.6	23	S044	Plume Lateral	NB09A104.mat
7/8/2009	12:38	20	33	36	S044	Plume Lateral	NB09A104.mat
Gale Force – outside silt curtain							
7/8/2009	11:29	6	2.7	6.6	55	North Reference	NB09B051.mat
7/8/2009	11:29	12	3.1	7.5	55	North Reference	NB09B051.mat

New Bedford Harbor Laboratory Turbidity and TSS Results

Date	Time	Depth (ft)	Turbidity (NTU)	TSS (mg/L)	Station ID	Station Type	ADCP File Name
7/8/2009	11:41	5	1.7	4.8	56	South Reference	NB09B052.mat
7/8/2009	11:41	9	2.1	4.7	56	South Reference	NB09B052.mat
7/8/2009	12:39	8	3.6	8	57	Plume Centroid	NB09B055.mat
7/8/2009	12:39	16	3	6.2	57	Plume Centroid	NB09B055.mat
7/8/2009	12:42	4	3.1	7.7	58	Plume Lateral	NB09B055.mat
7/8/2009	12:42	7	2.9	6.8	58	Plume Lateral	NB09B055.mat
7/8/2009	12:47	6	2.4	5.7	59	Plume Lateral	NB09B055.mat
7/8/2009	12:47	11	2.3	4.5	59	Plume Lateral	NB09B055.mat
7/8/2009	12:47	11	2.3	5.4	59	Plume Lateral-dup	NB09B055.mat

APPENDIX C

New Bedford Harbor
Observations of Turbidity
Measured with ADCP
April 14, May 20, 21, 27, and July 8, 2009

Part 1: Turbidity Survey April 14, 2009

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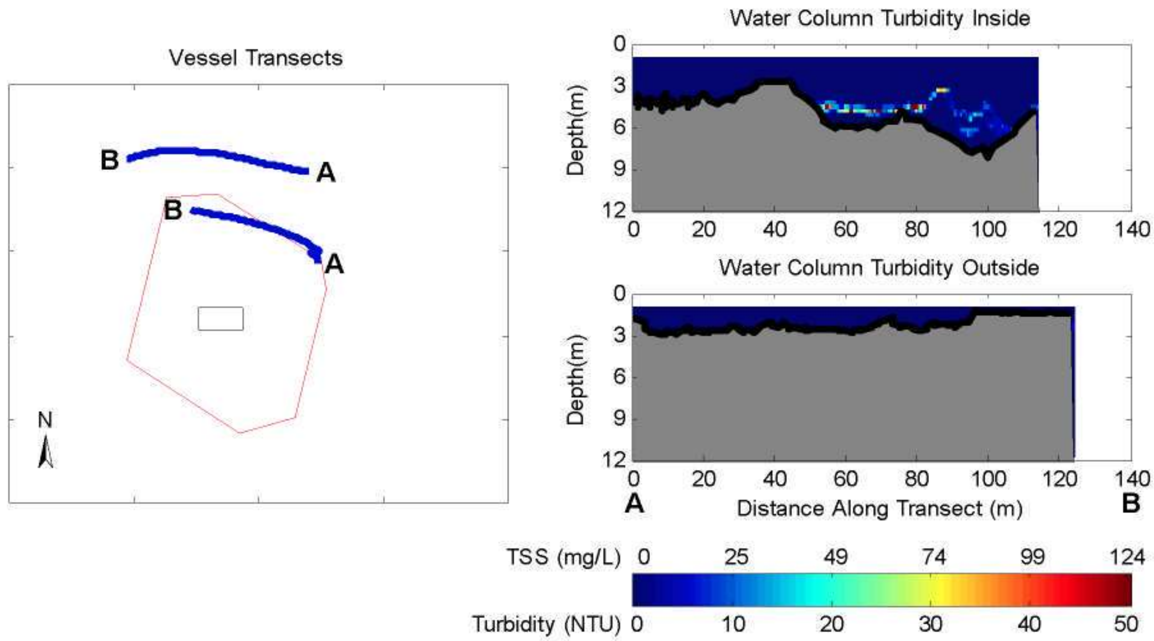

Figure 1-1. Observations Before Release During April 14, 2009 Disposal into the New Bedford Harbor CAD Cell. The left panel shows concurrent inner and outer vessel transects. The right panel shows vertical slices of calibrated turbidity and TSS measured with ADCP along each vessel transect.

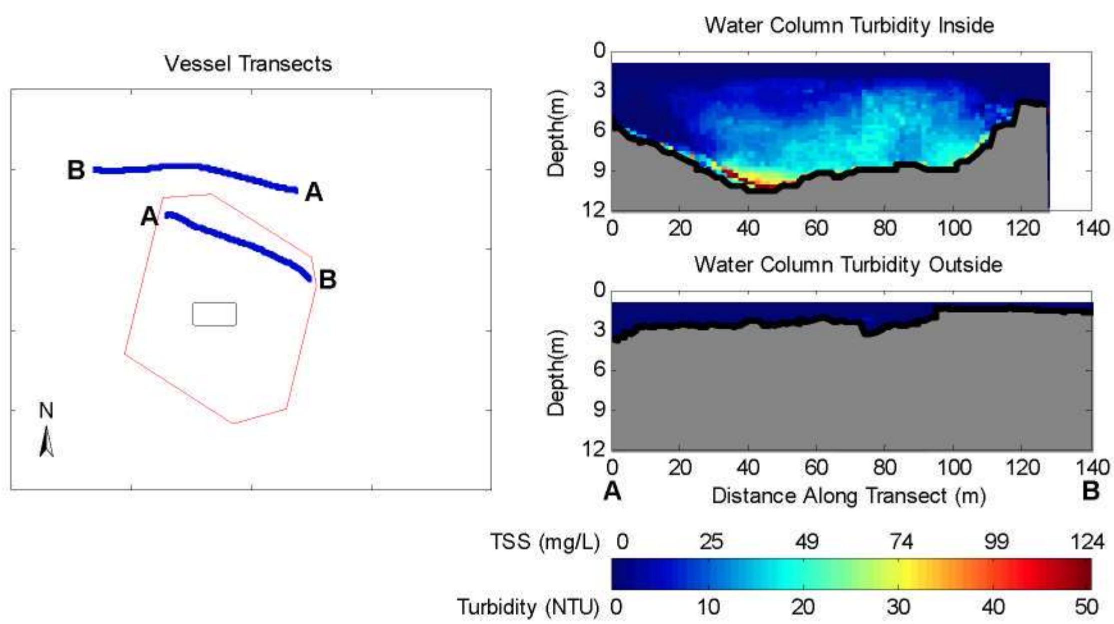

Figure 1-2. Observations from 8 to 11 Minutes after Release During April 14, 2009 Disposal into the New Bedford Harbor CAD Cell. The left panel shows concurrent inner and outer vessel transects. The right panel shows vertical slices of calibrated turbidity and TSS measured with ADCP along each vessel transect.

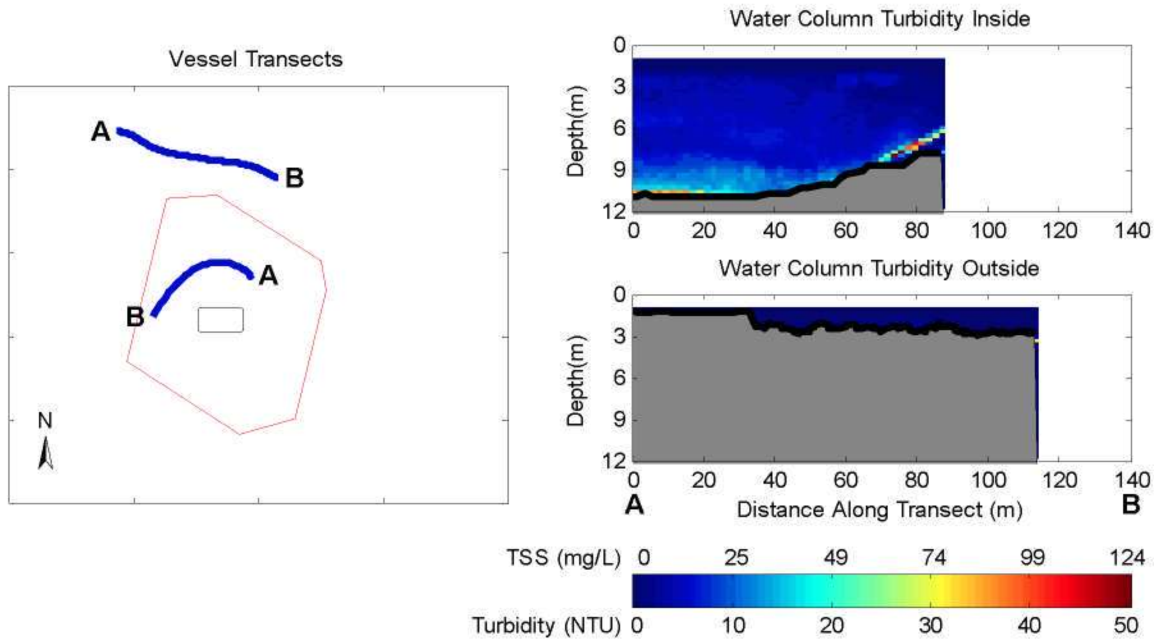

Figure 1-3. Observations from 19 to 22 Minutes after Release During April 14, 2009 Disposal into the New Bedford Harbor CAD Cell. The left panel shows concurrent inner and outer vessel transects. The right panel shows vertical slices of calibrated turbidity and TSS measured with ADCP along each vessel transect.

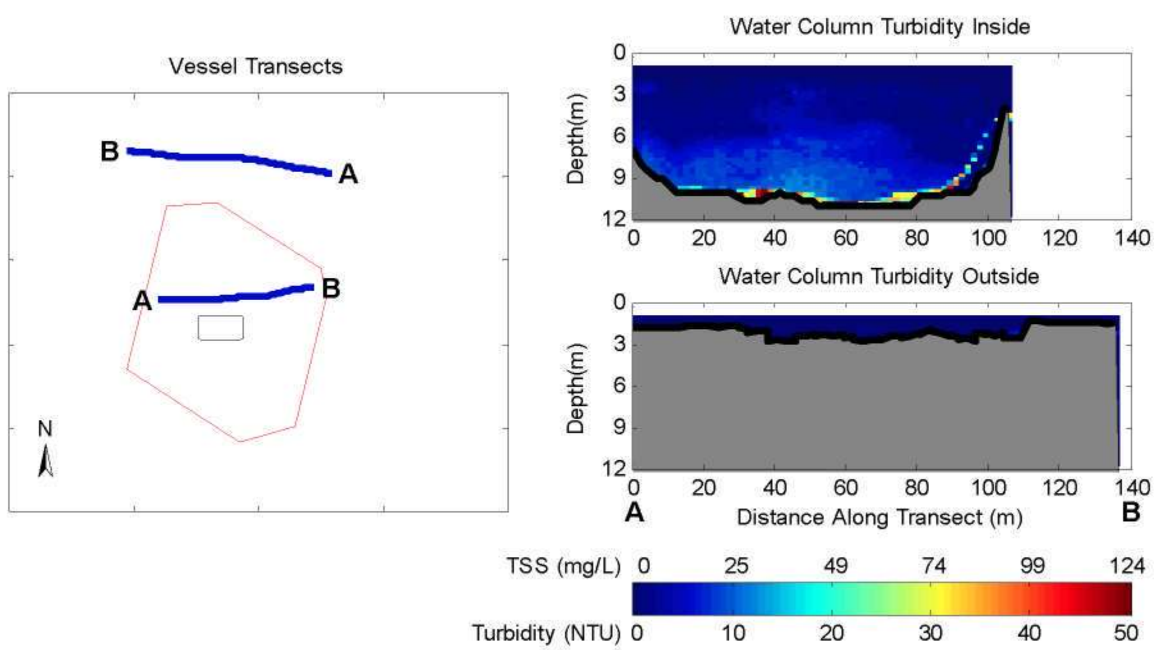

Figure 1-4. Observations from 27 to 39 Minutes after Release During April 14, 2009 Disposal into the New Bedford Harbor CAD Cell. The left panel shows concurrent inner and outer vessel transects. The right panel shows vertical slices of calibrated turbidity and TSS measured with ADCP along each vessel transect.

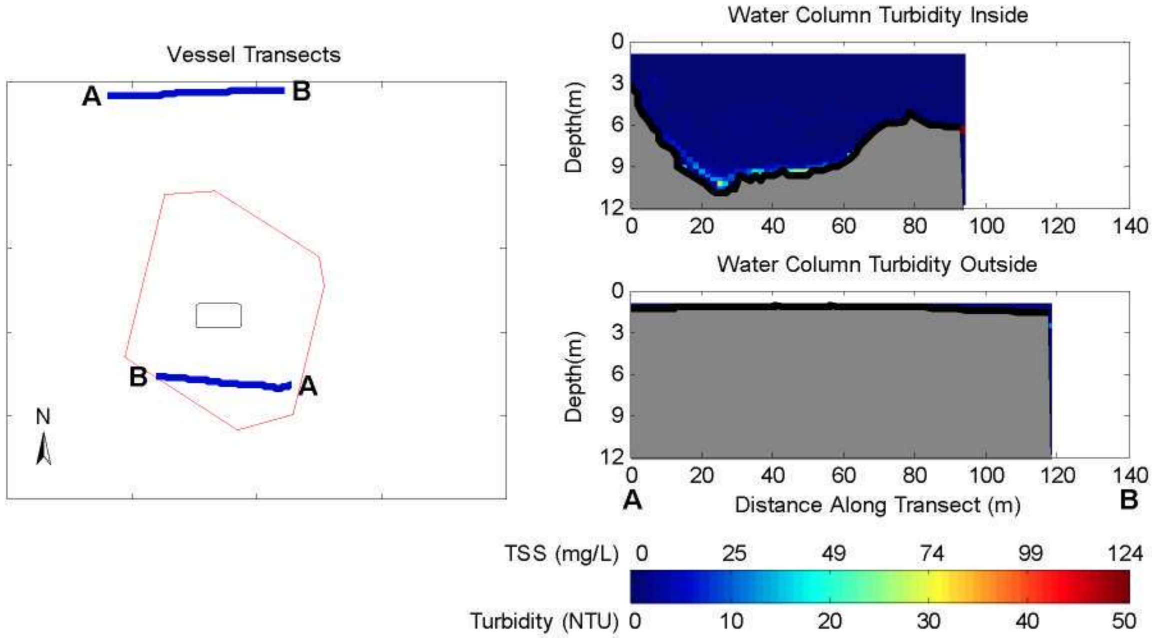

Figure 1-5. Observations from 40 to 44 Minutes after Release During April 14, 2009 Disposal into the New Bedford Harbor CAD Cell. The left panel shows concurrent inner and outer vessel transects. The right panel shows vertical slices of calibrated turbidity and TSS measured with ADCP along each vessel transect.

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Part 2: Turbidity Survey May 20, 2009

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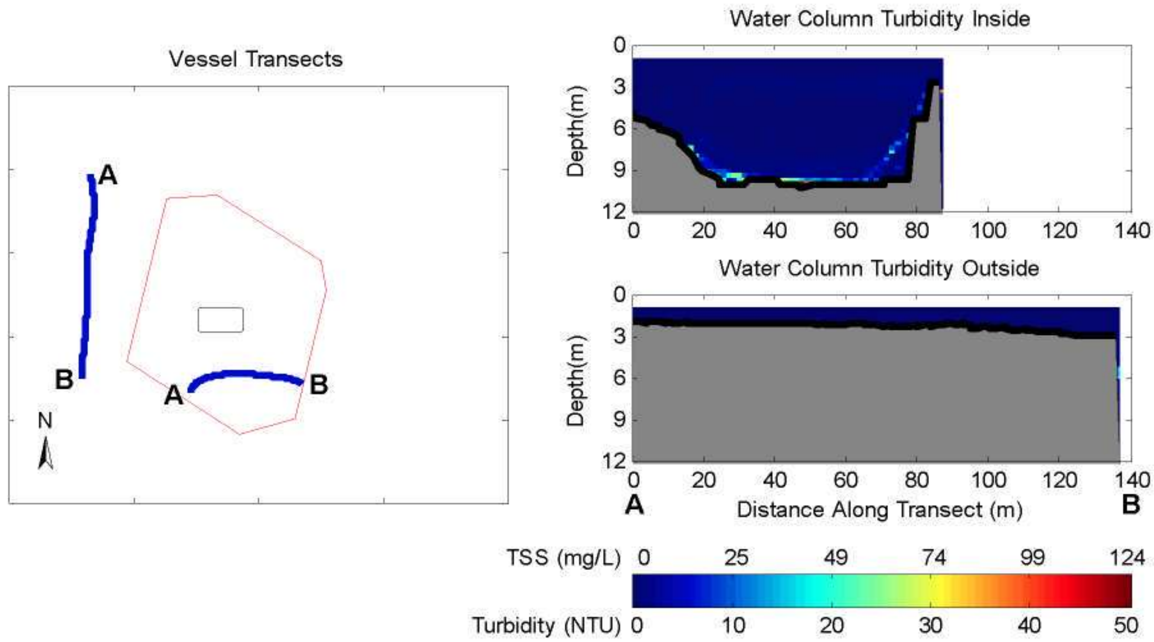

Figure 2-1. Observations Before Release During May 20, 2009 Disposal into the New Bedford Harbor CAD Cell. The left panel shows concurrent inner and outer vessel transects. The right panel shows vertical slices of calibrated turbidity and TSS measured with ADCP along each vessel transect.

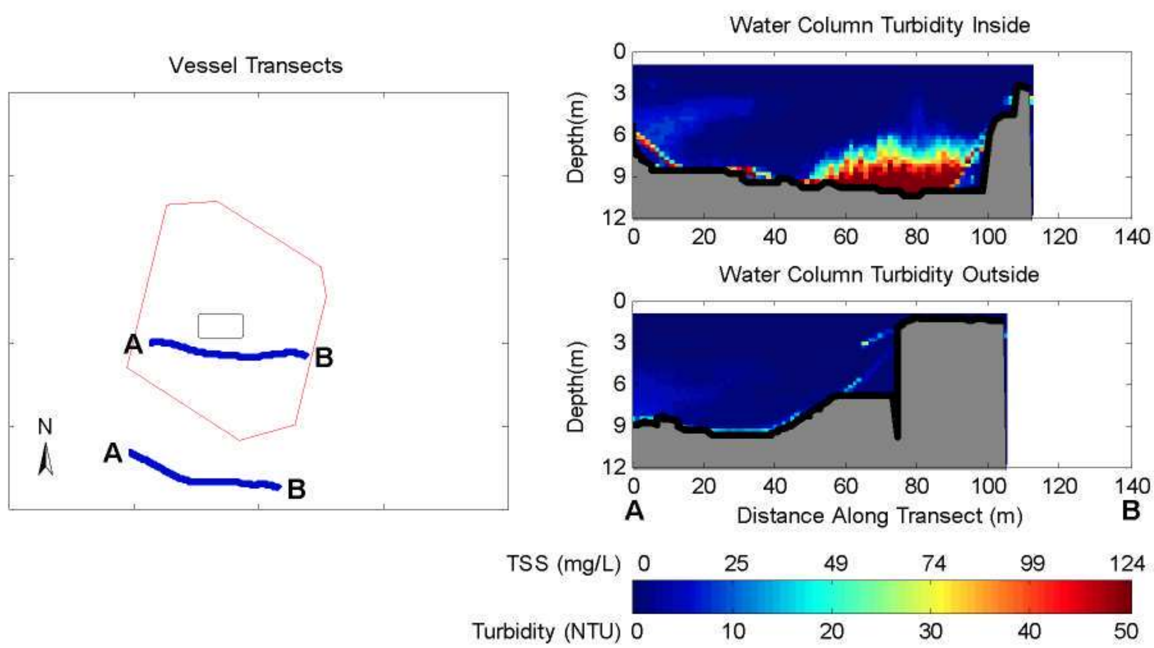

Figure 2-2. Observations from 3 to 6 Minutes after Release During May 20, 2009 Disposal into the New Bedford Harbor CAD Cell. The left panel shows concurrent inner and outer vessel transects. The right panel shows vertical slices of calibrated turbidity and TSS measured with ADCP along each vessel transect.

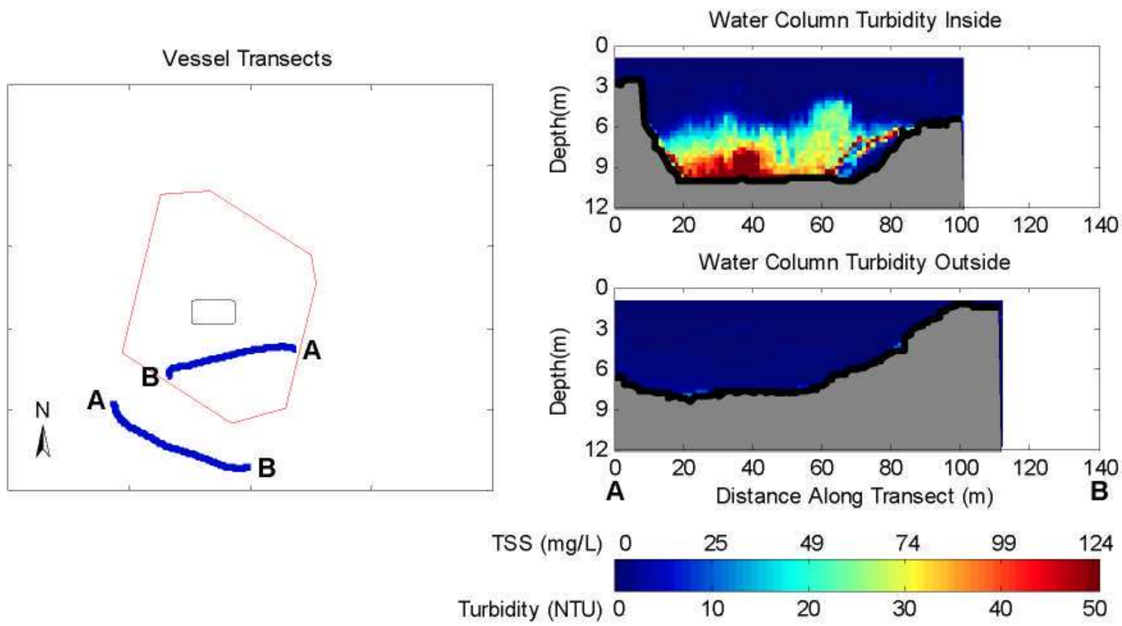

Figure 2-3. Observations from 10 to 12 Minutes after Release During May 20, 2009 Disposal into the New Bedford Harbor CAD Cell. The left panel shows concurrent inner and outer vessel transects. The right panel shows vertical slices of calibrated turbidity and TSS measured with ADCP along each vessel transect.

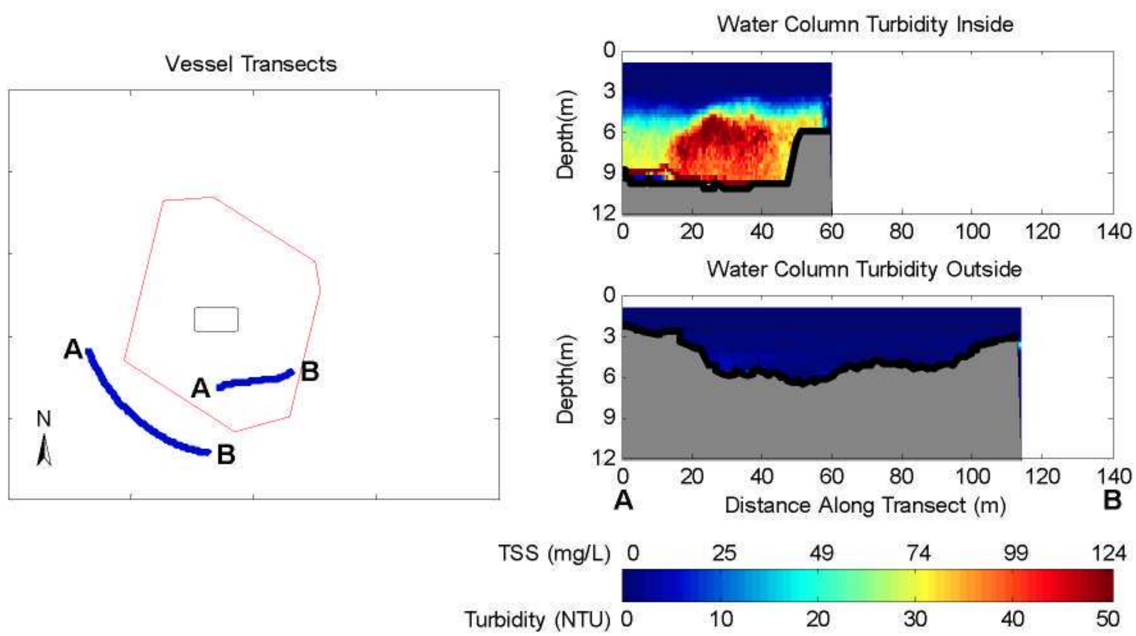

Figure 2-4. Observations from 18 to 24 Minutes after Release During May 20, 2009 Disposal into the New Bedford Harbor CAD Cell. The left panel shows concurrent inner and outer vessel transects. The right panel shows vertical slices of calibrated turbidity and TSS measured with ADCP along each vessel transect.

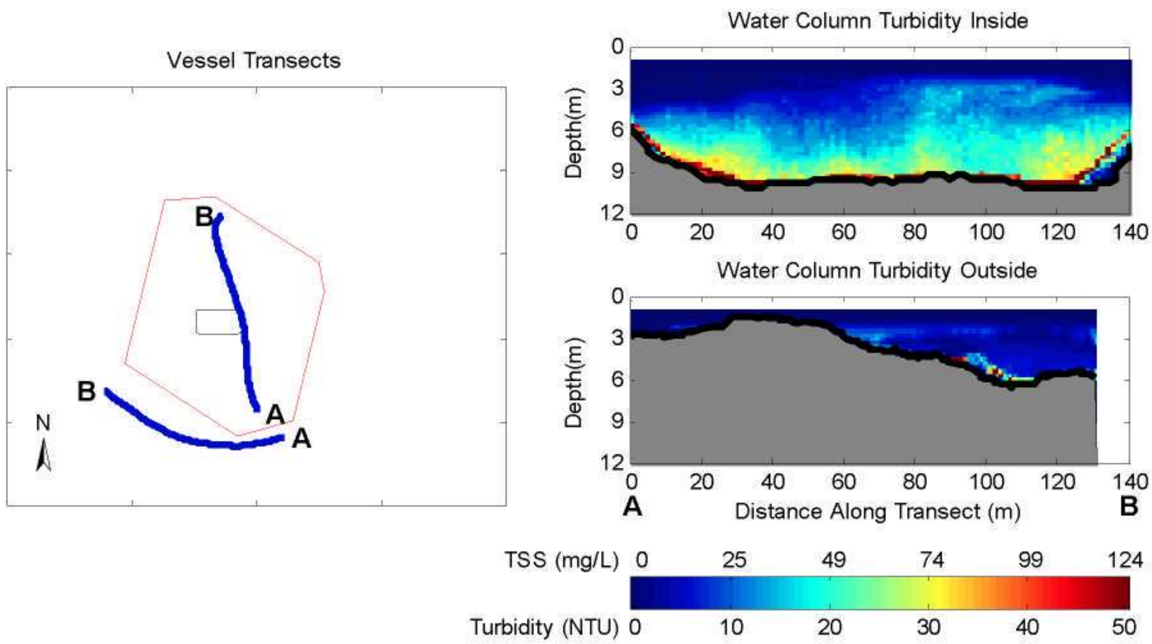

Figure 2-5. Observations from 39 to 43 Minutes after Release During May 20, 2009 Disposal into the New Bedford Harbor CAD Cell. The left panel shows concurrent inner and outer vessel transects. The right panel shows vertical slices of calibrated turbidity and TSS measured with ADCP along each vessel transect.

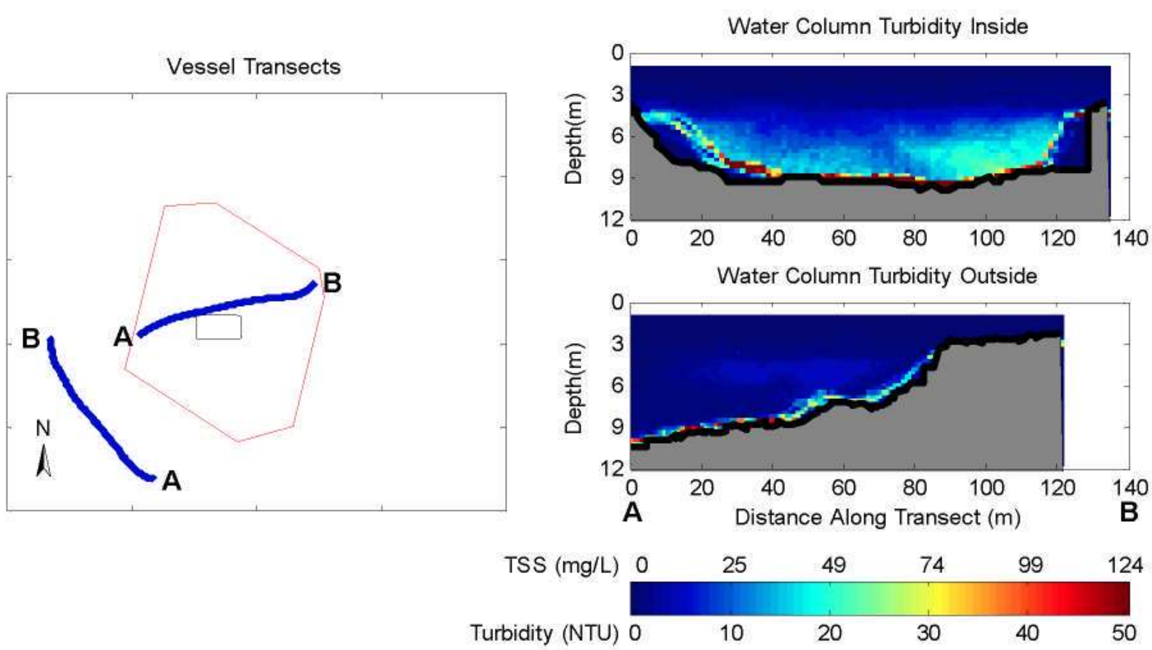

Figure 2-6. Observations from 55 to 57 Minutes after Release During May 20, 2009 Disposal into the New Bedford Harbor CAD Cell. The left panel shows concurrent inner and outer vessel transects. The right panel shows vertical slices of calibrated turbidity and TSS measured with ADCP along each vessel transect.

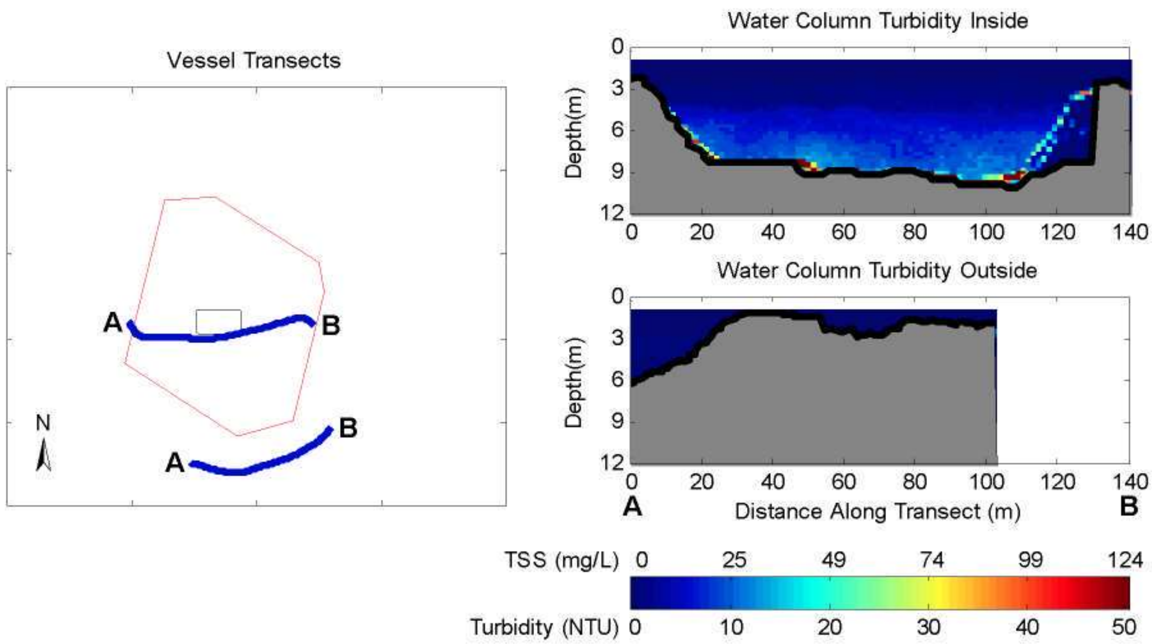

Figure 2-7. Observations from 84 to 87 Minutes after Release During May 20, 2009 Disposal into the New Bedford Harbor CAD Cell. The left panel shows concurrent inner and outer vessel transects. The right panel shows vertical slices of calibrated turbidity and TSS measured with ADCP along each vessel transect.

Part 3: Turbidity Survey May 21, 2009

Turbidity Survey May 21, 2009

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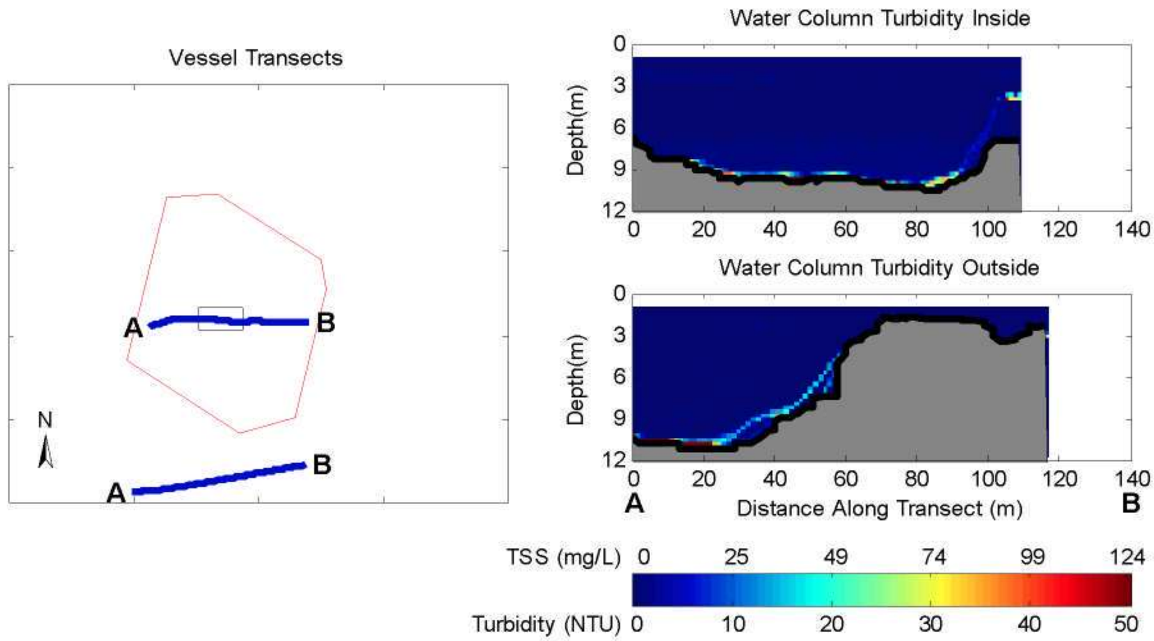

Figure 3-1. Observations Before Release During May 21, 2009 Disposal into the New Bedford Harbor CAD Cell. The left panel shows concurrent inner and outer vessel transects. The right panel shows vertical slices of calibrated turbidity and TSS measured with ADCP along each vessel transect.

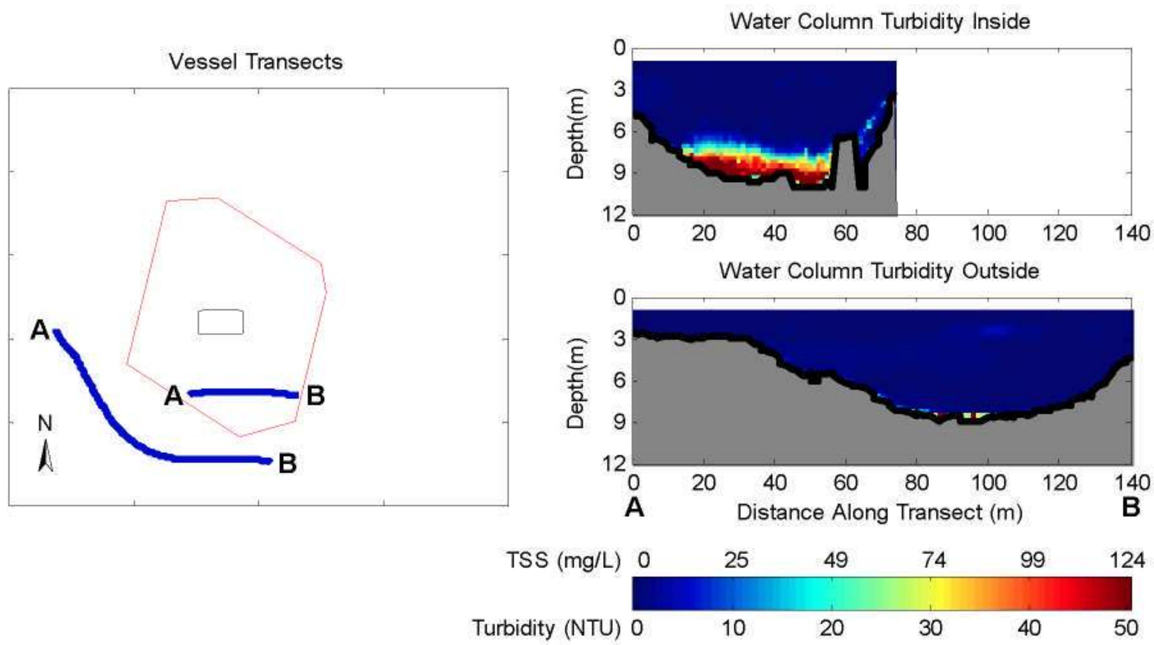

Figure 3-2. Observations from 1 to 6 Minutes after Release During May 21, 2009 Disposal into the New Bedford Harbor CAD Cell. The left panel shows concurrent inner and outer vessel transects. The right panel shows vertical slices of calibrated turbidity and TSS measured with ADCP along each vessel transect.

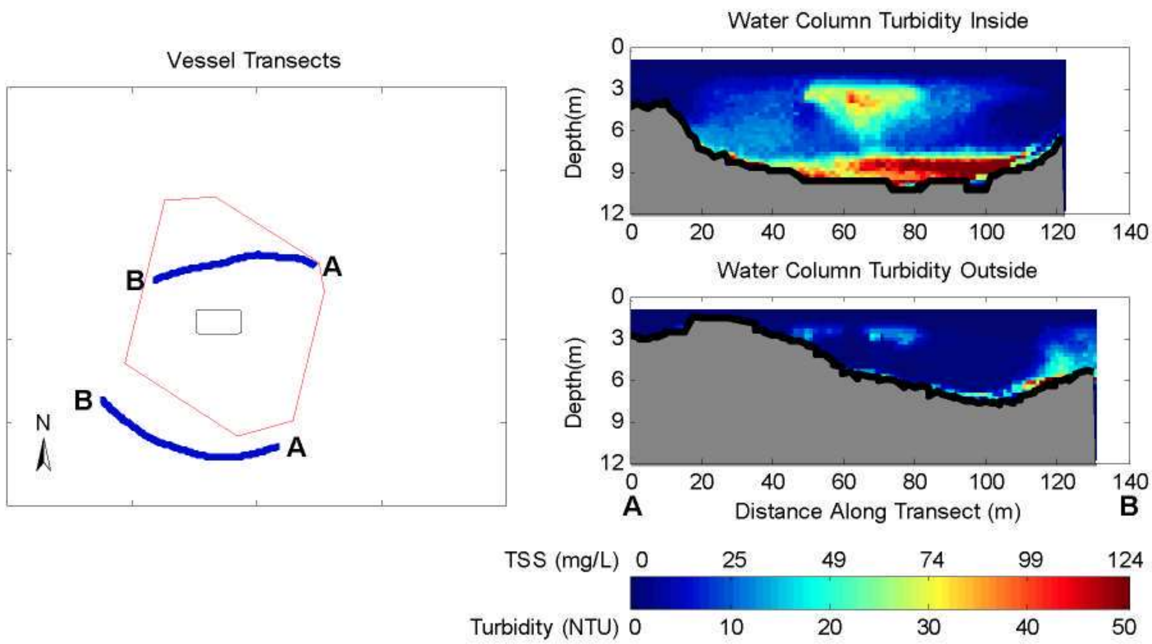

Figure 3-3. Observations from 5 to 9 Minutes after Release During May 21, 2009 Disposal into the New Bedford Harbor CAD Cell. The left panel shows concurrent inner and outer vessel transects. The right panel shows vertical slices of calibrated turbidity and TSS measured with ADCP along each vessel transect.

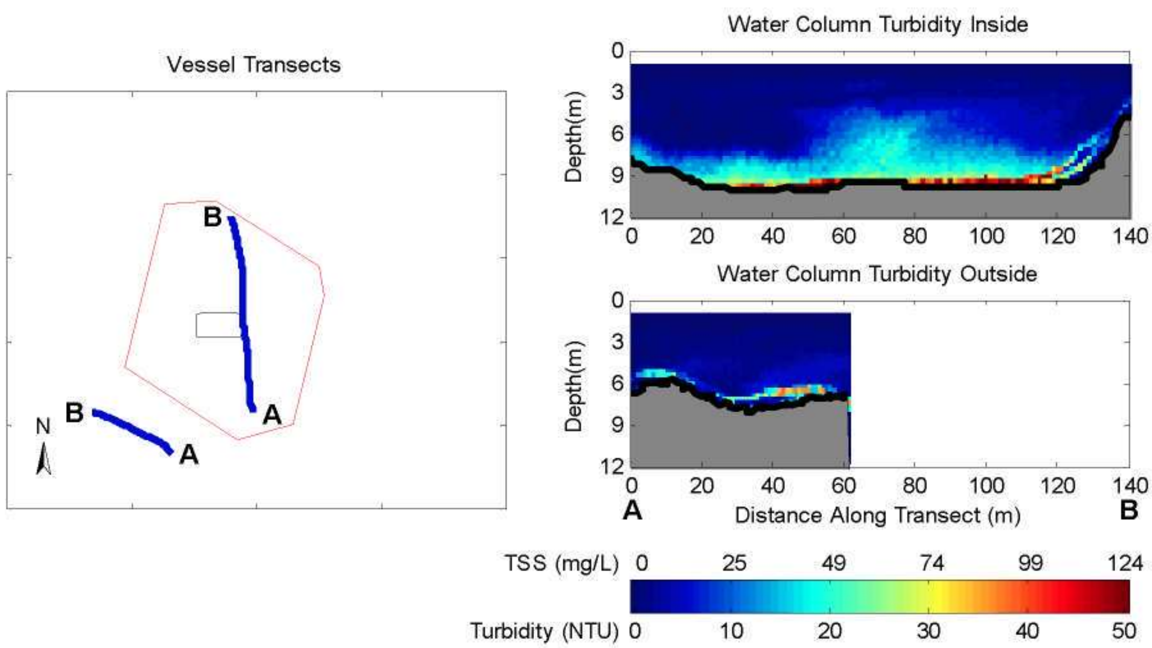

Figure 3-4. Observations from 18 to 21 Minutes after Release During May 21, 2009 Disposal into the New Bedford Harbor CAD Cell. The left panel shows concurrent inner and outer vessel transects. The right panel shows vertical slices of calibrated turbidity and TSS measured with ADCP along each vessel transect.

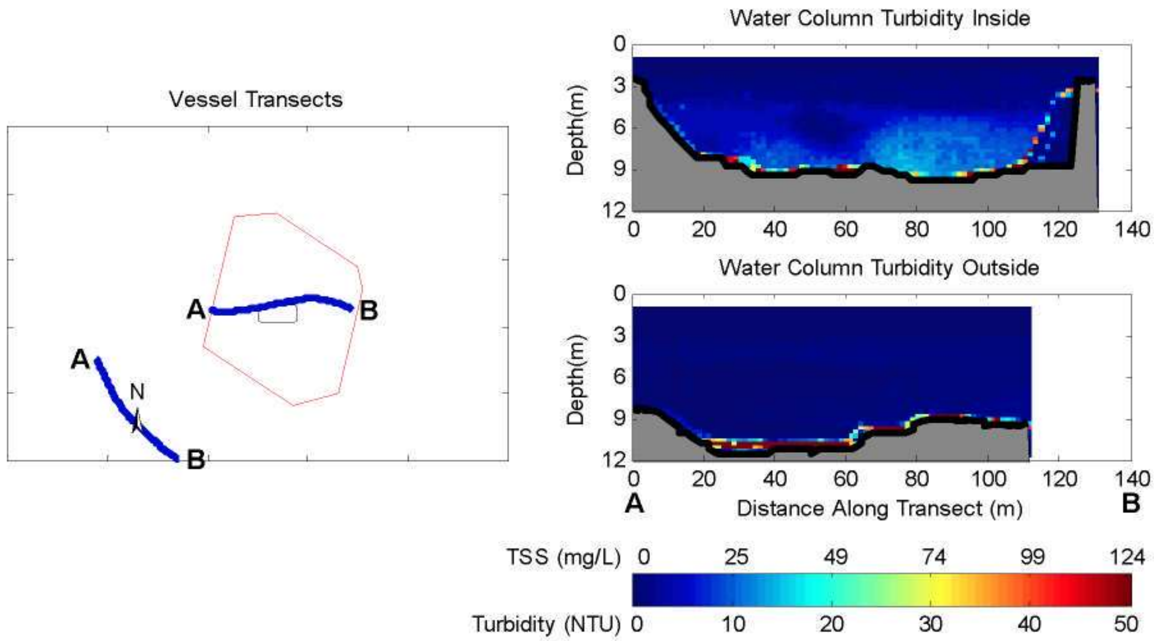

Figure 3-5. Observations from 39 to 42 Minutes after Release During May 21, 2009 Disposal into the New Bedford Harbor CAD Cell. The left panel shows concurrent inner and outer vessel transects. The right panel shows vertical slices of calibrated turbidity and TSS measured with ADCP along each vessel transect.

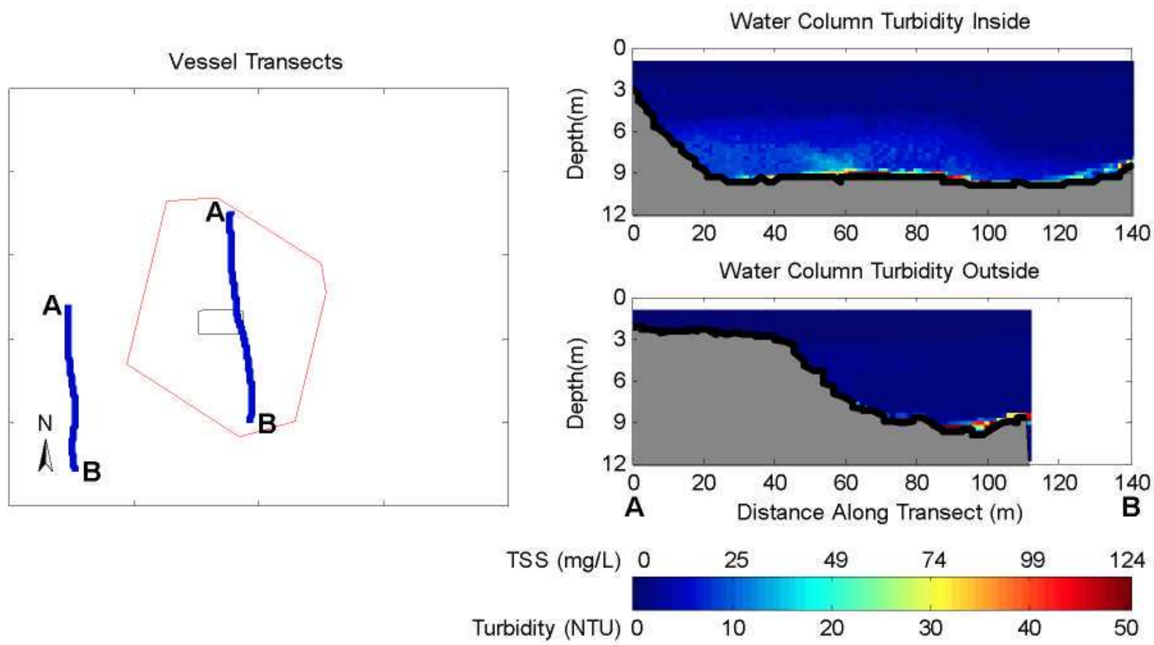

Figure 3-6. Observations from 51 to 54 Minutes after Release During May 21, 2009 Disposal into the New Bedford Harbor CAD Cell. The left panel shows concurrent inner and outer vessel transects. The right panel shows vertical slices of calibrated turbidity and TSS measured with ADCP along each vessel transect.

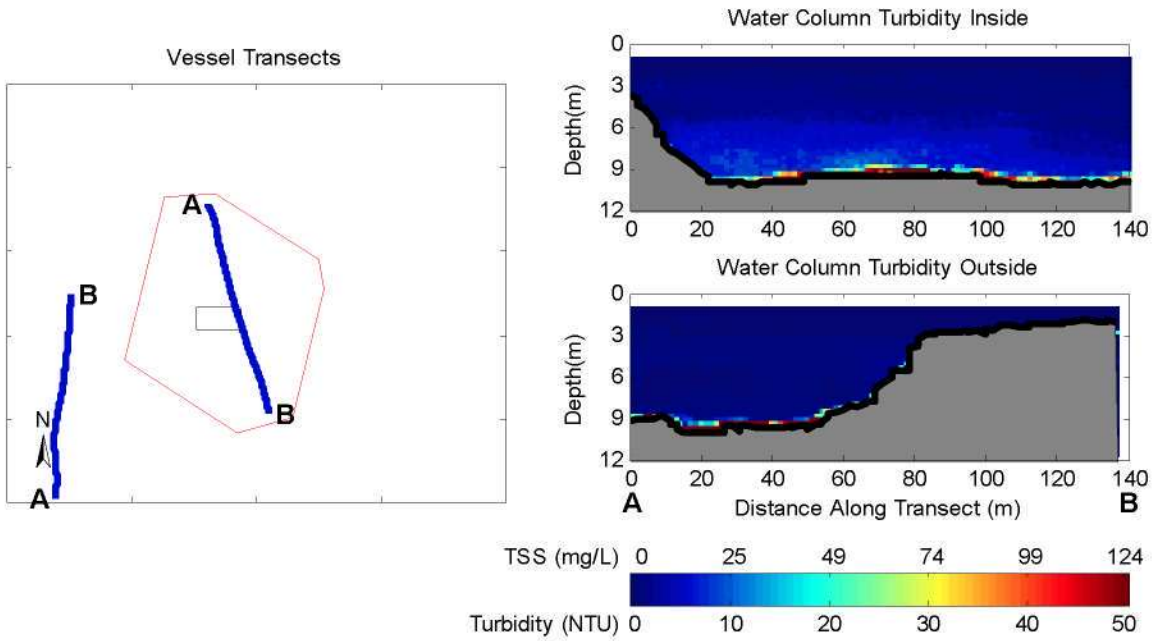

Figure 3-7. Observations from 57 to 59 Minutes after Release During May 21, 2009 Disposal into the New Bedford Harbor CAD Cell. The left panel shows concurrent inner and outer vessel transects. The right panel shows vertical slices of calibrated turbidity and TSS measured with ADCP along each vessel transect.

Part 4: Turbidity Survey May 27, 2009

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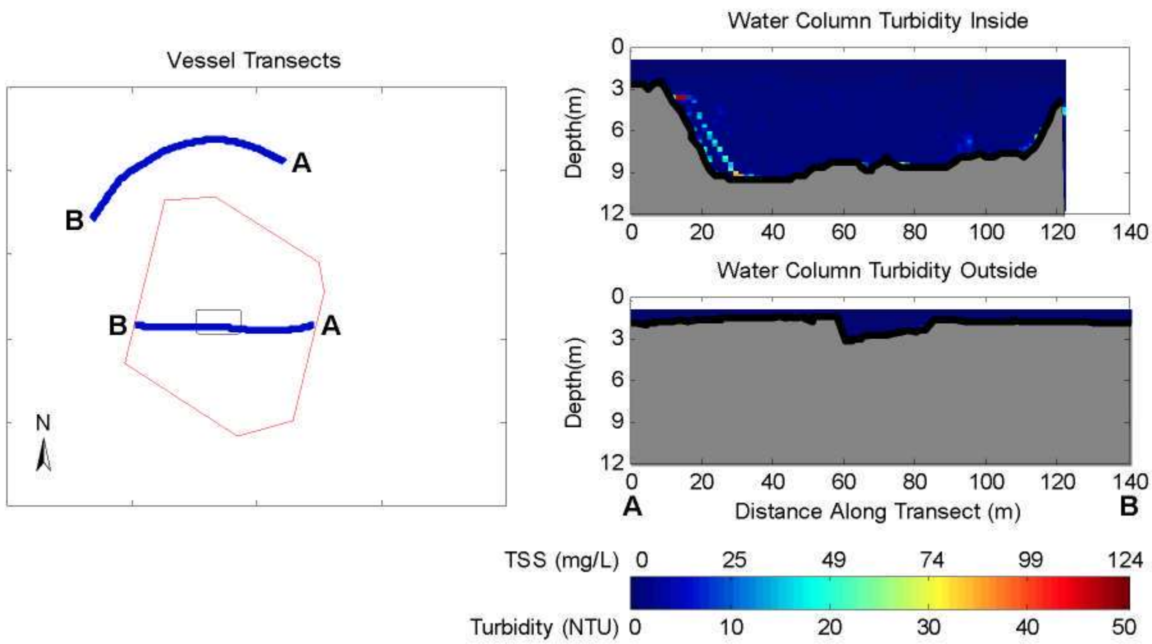

Figure 4-1. Observations Before Release During May 27, 2009 Disposal into the New Bedford Harbor CAD Cell. The left panel shows concurrent inner and outer vessel transects. The right panel shows vertical slices of calibrated turbidity and TSS measured with ADCP along each vessel transect.

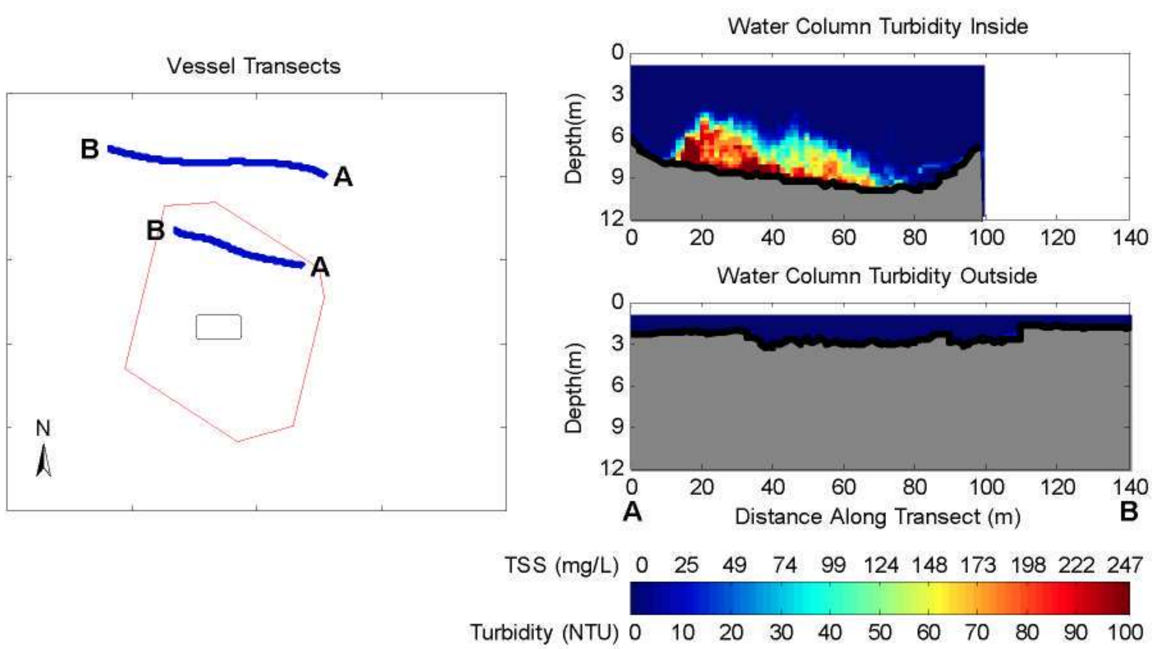

Figure 4-2. Observations from 3 to 6 Minutes after Release During May 27, 2009 Disposal into the New Bedford Harbor CAD Cell. The left panel shows concurrent inner and outer vessel transects. The right panel shows vertical slices of calibrated turbidity and TSS measured with ADCP along each vessel transect. Note change in turbidity scale.

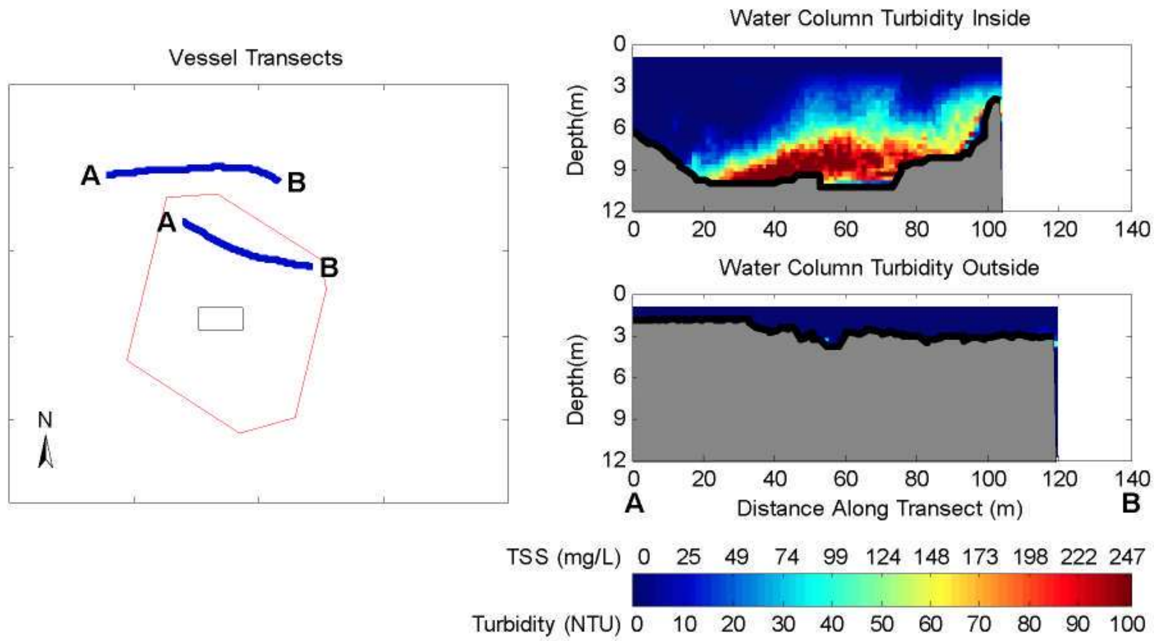

Figure 4-3. Observations from 5 to 9 Minutes after Release During May 27, 2009 Disposal into the New Bedford Harbor CAD Cell. The left panel shows concurrent inner and outer vessel transects. The right panel shows vertical slices of calibrated turbidity and TSS measured with ADCP along each vessel transect. Note change in turbidity scale.

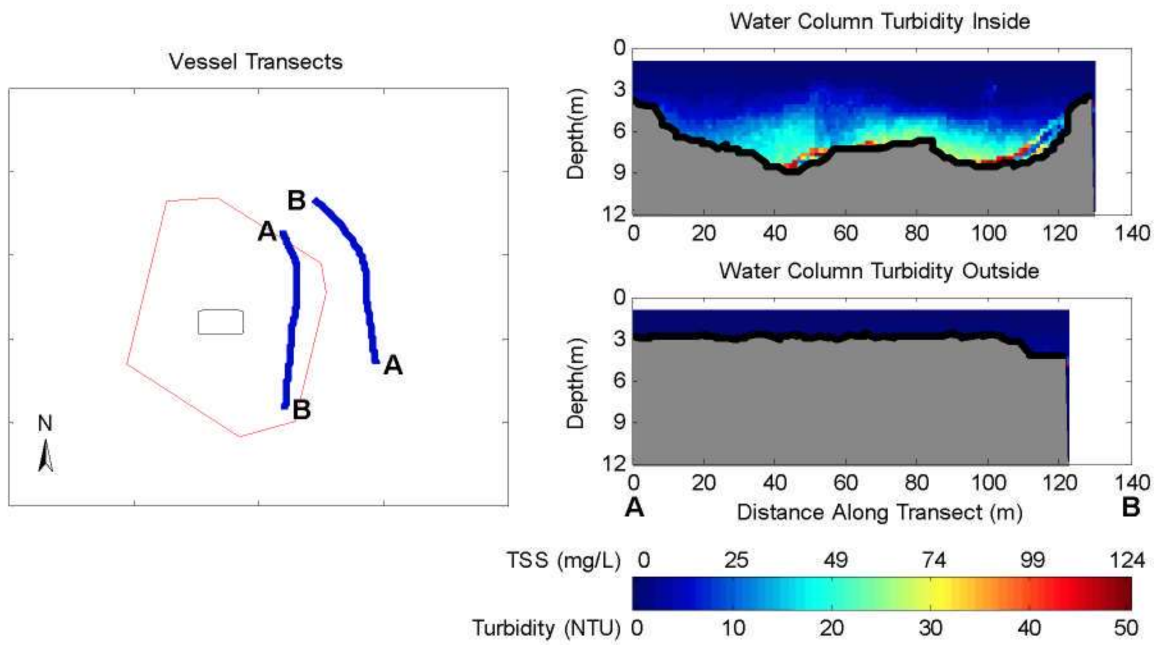

Figure 4-4. Observations from 31 to 34 Minutes after Release During May 27, 2009 Disposal into the New Bedford Harbor CAD Cell. The left panel shows concurrent inner and outer vessel transects. The right panel shows vertical slices of calibrated turbidity and TSS measured with ADCP along each vessel transect.

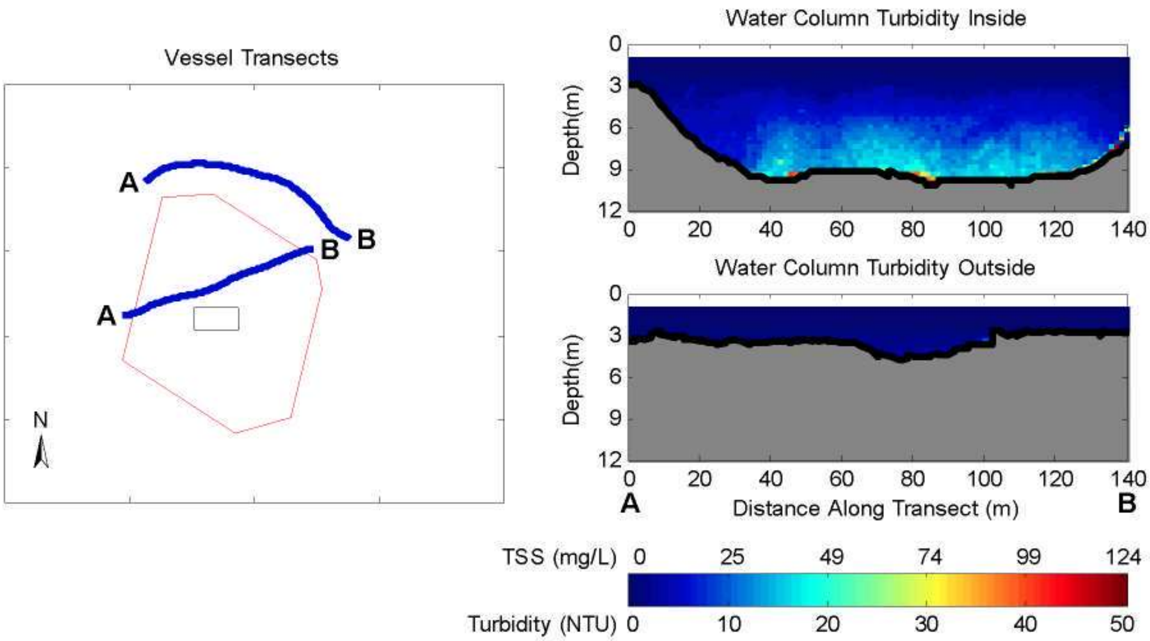

Figure 4-5. Observations from 50 to 53 Minutes after Release During May 27, 2009 Disposal into the New Bedford Harbor CAD Cell. The left panel shows concurrent inner and outer vessel transects. The right panel shows vertical slices of calibrated turbidity and TSS measured with ADCP along each vessel transect.

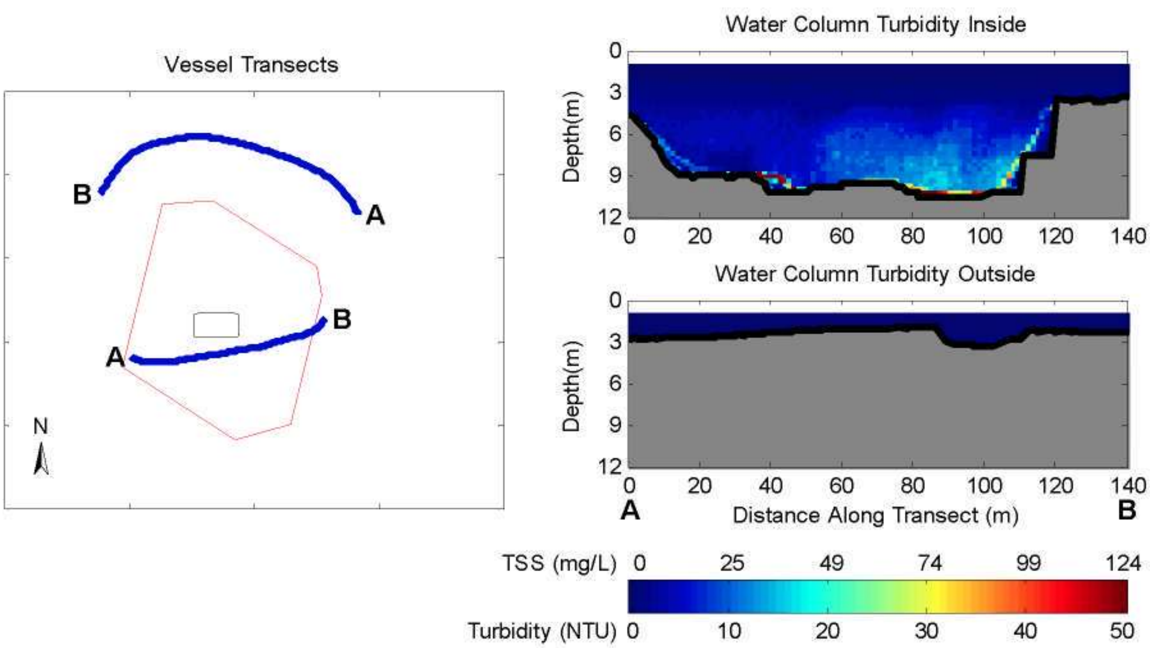

Figure 4-6. Observations from 54 to 57 Minutes after Release During May 27, 2009 Disposal into the New Bedford Harbor CAD Cell. The left panel shows concurrent inner and outer vessel transects. The right panel shows vertical slices of calibrated turbidity and TSS measured with ADCP along each vessel transect.

Turbidity Survey May 27, 2009

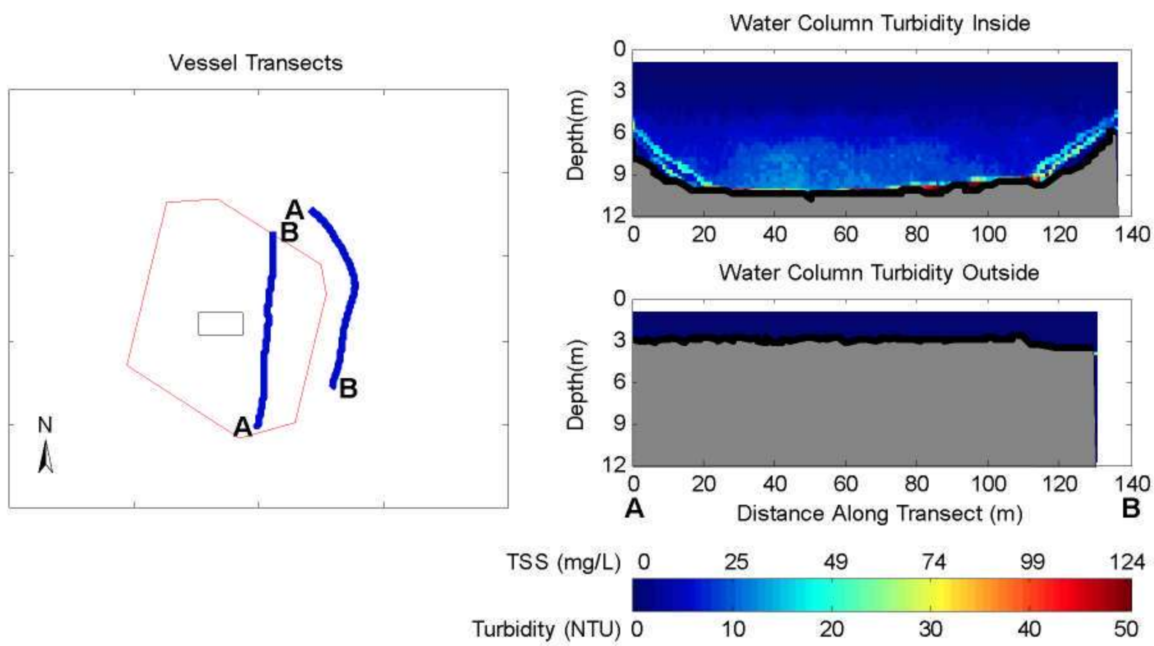

Figure 4-7. Observations from 63 to 67 Minutes after Release During May 27, 2009 Disposal into the New Bedford Harbor CAD Cell. The left panel shows concurrent inner and outer vessel transects. The right panel shows vertical slices of calibrated turbidity and TSS measured with ADCP along each vessel transect.

Part 5: Turbidity Survey July 8, 2009

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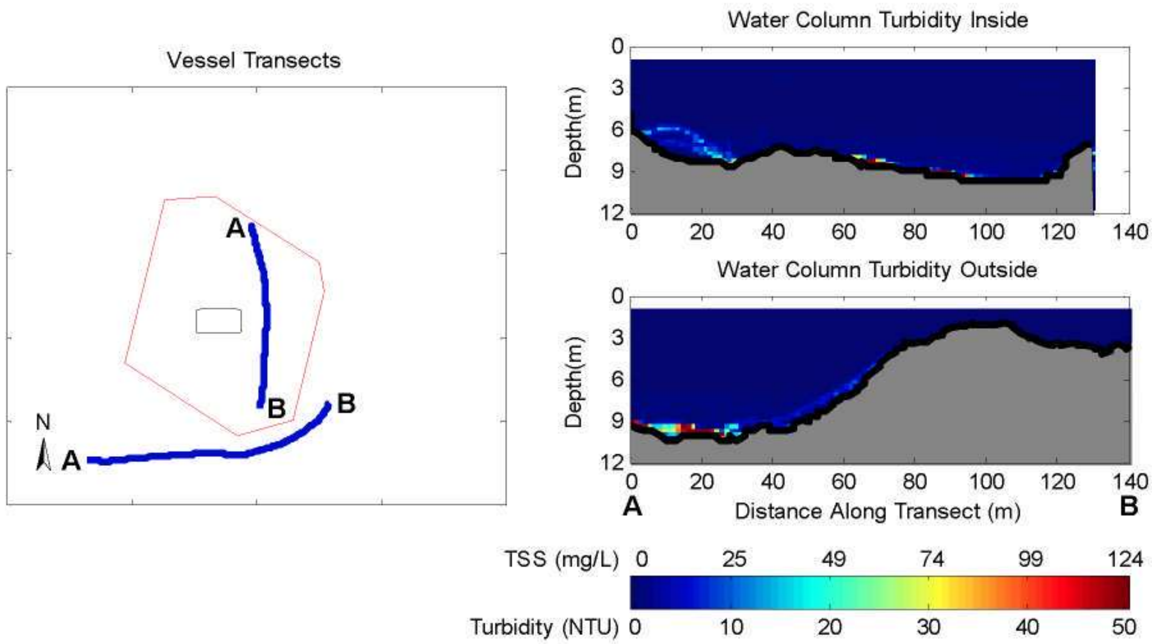

Figure 5-1. Observations Before Release During July 8, 2009 Disposal into the New Bedford Harbor CAD Cell. The left panel shows concurrent inner and outer vessel transects. The right panel shows vertical slices of calibrated turbidity and TSS measured with ADCP along each vessel transect.

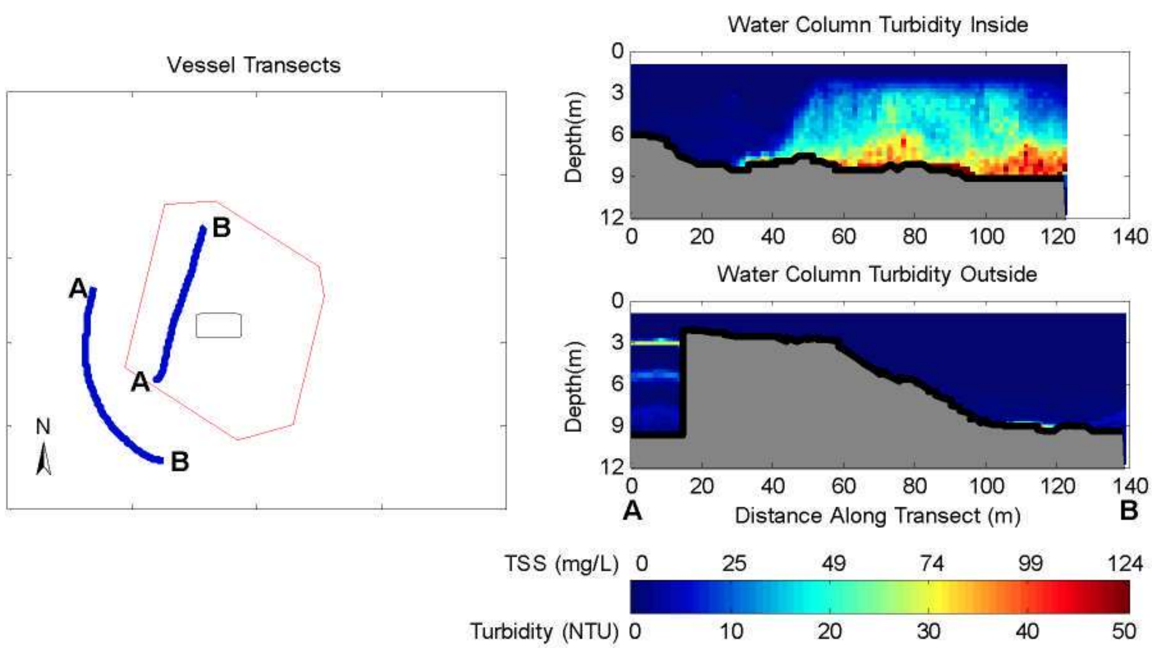

Figure 5-2. Observations from 1 to 4 Minutes after Release During July 8, 2009 Disposal into the New Bedford Harbor CAD Cell. The left panel shows concurrent inner and outer vessel transects. The right panel shows vertical slices of calibrated turbidity and TSS measured with ADCP along each vessel transect.

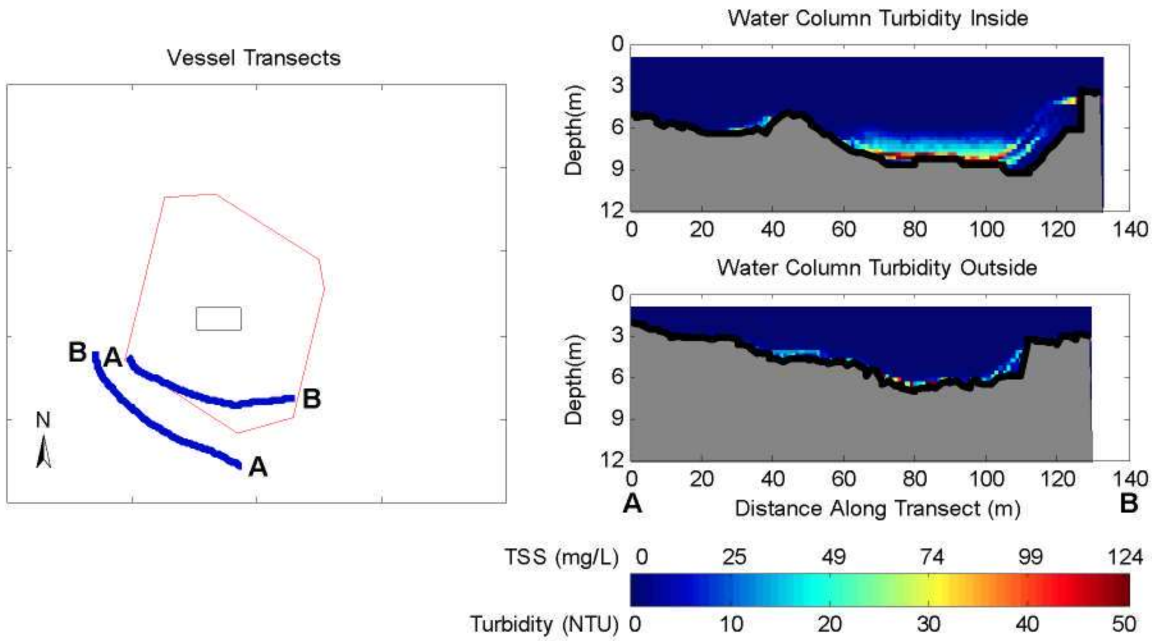

Figure 5-3. Observations from 9 to 16 Minutes after Release During July 8, 2009 Disposal into the New Bedford Harbor CAD Cell. The left panel shows concurrent inner and outer vessel transects. The right panel shows vertical slices of calibrated turbidity and TSS measured with ADCP along each vessel transect.

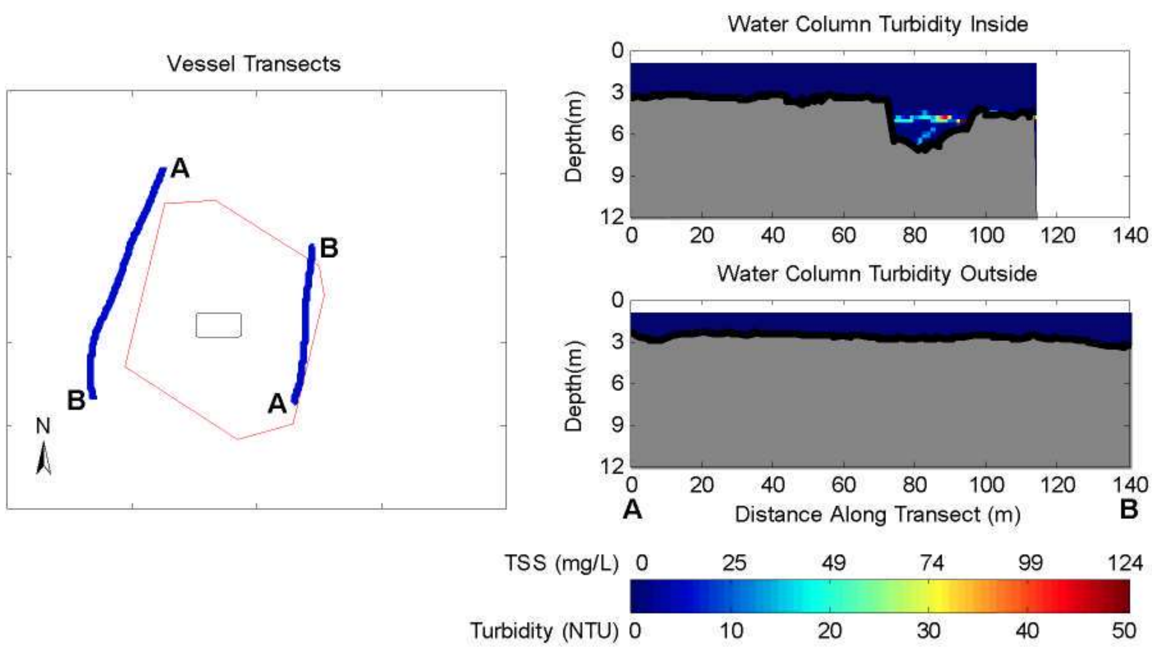

Figure 5-4. Observations from 15 to 18 Minutes after Release During July 8, 2009 Disposal into the New Bedford Harbor CAD Cell. The left panel shows concurrent inner and outer vessel transects. The right panel shows vertical slices of calibrated turbidity and TSS measured with ADCP along each vessel transect.

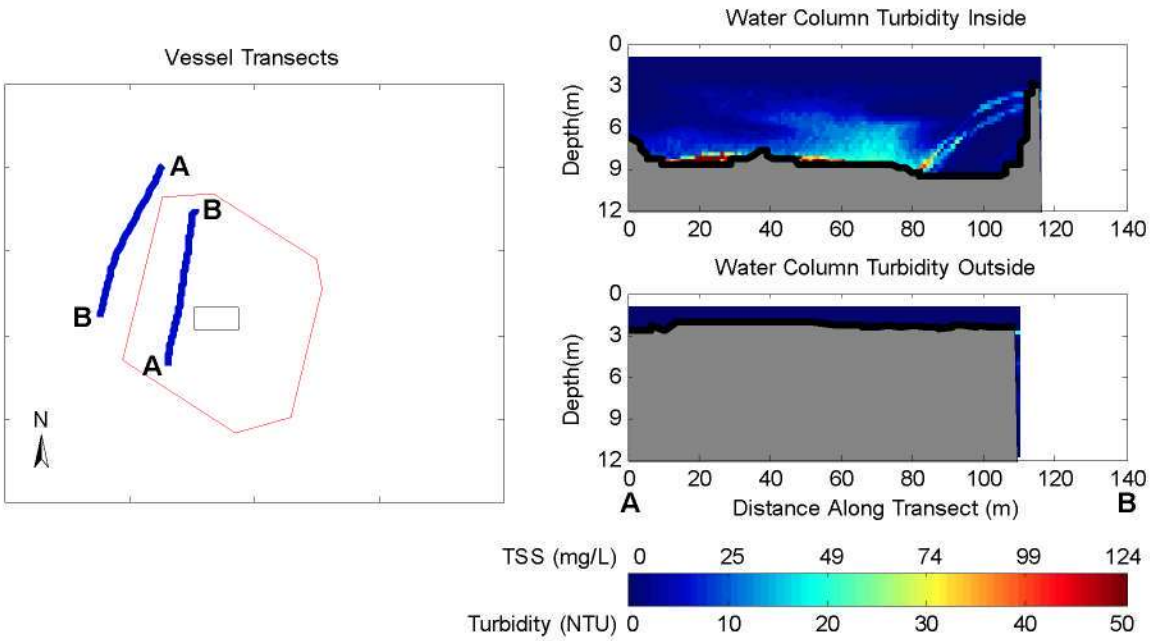

Figure 5-5. Observations from 26 to 29 Minutes after Release During July 8, 2009 Disposal into the New Bedford Harbor CAD Cell. The left panel shows concurrent inner and outer vessel transects. The right panel shows vertical slices of calibrated turbidity and TSS measured with ADCP along each vessel transect.

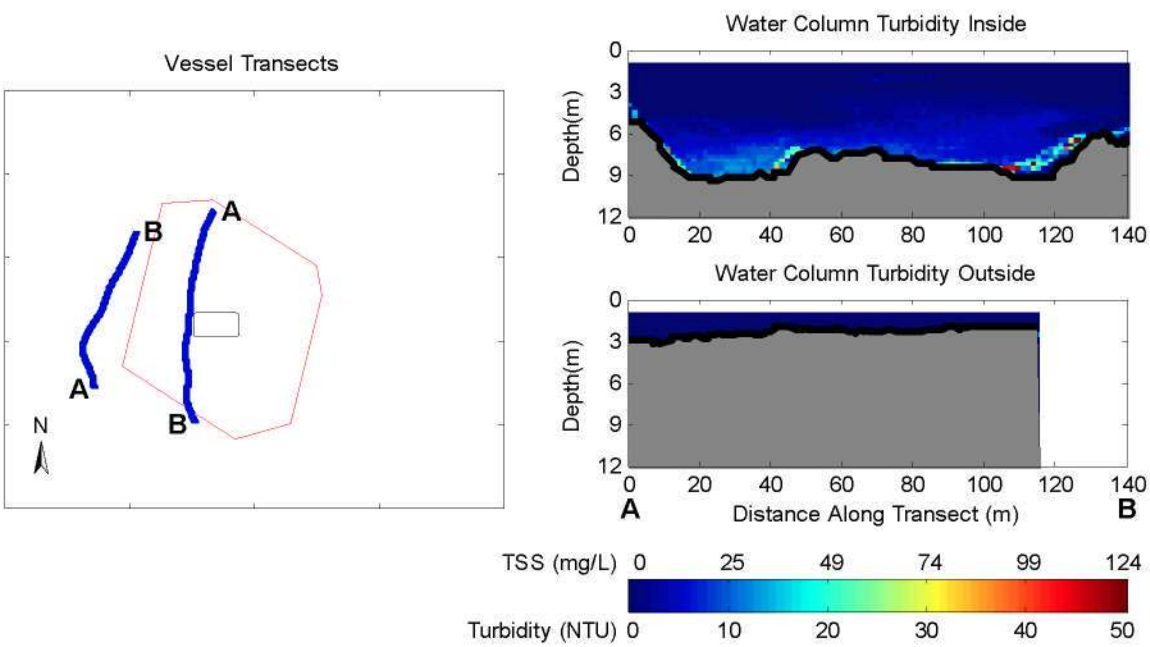

Figure 5-6. Observations from 46 to 49 Minutes after Release During July 8, 2009 Disposal into the New Bedford Harbor CAD Cell. The left panel shows concurrent inner and outer vessel transects. The right panel shows vertical slices of calibrated turbidity and TSS measured with ADCP along each vessel transect.

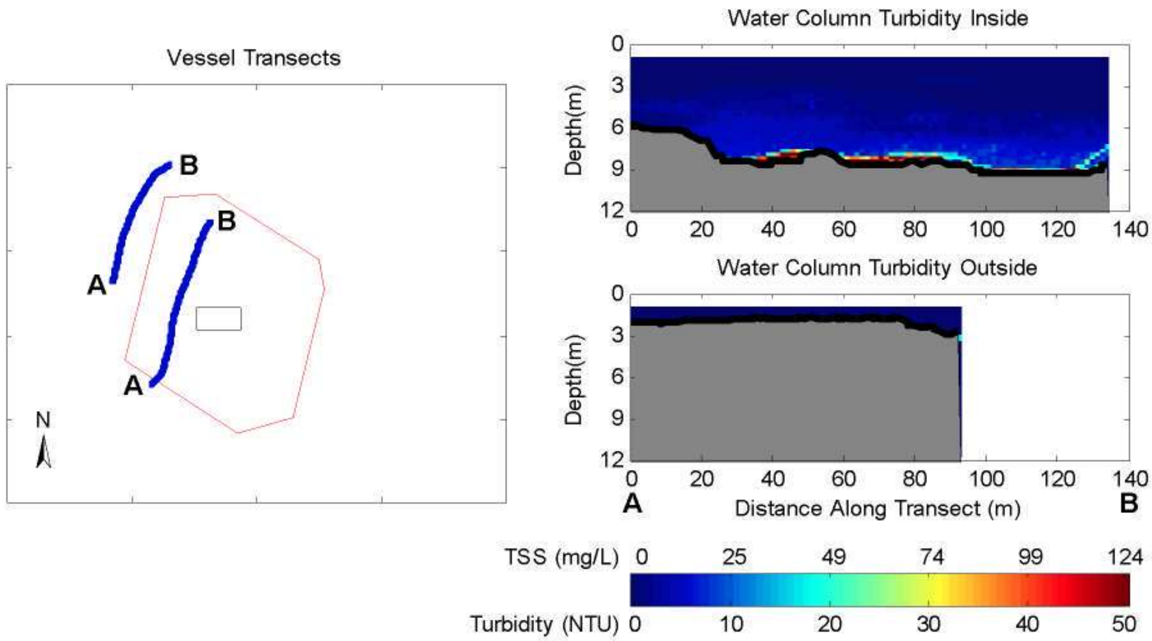

Figure 5-7. Observations from 58 to 61 Minutes after Release During July 8, 2009 Disposal into the New Bedford Harbor CAD Cell. The left panel shows concurrent inner and outer vessel transects. The right panel shows vertical slices of calibrated turbidity and TSS measured with ADCP along each vessel transect.