Hydrographic Study of Yarmouth Maine Waste Water Treatment Plant Effluent

(Report of Findings from the August 17 – August 22, 2002 Study Period)

FDA Technical Assistance and Training Project

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1.0 INTRODUCTION

1.1 Study Objectives

A hydrographic dye study of the Yarmouth Waste Water Treatment Plant (WWTP) effluent was conducted on August 17-20, 2002, assessing the dilution, time of travel, and dispersion of effluent in the Royal River, Cousins River, and offshore waters. The Yarmouth WWTP outfall is located on the southern shore of the Royal River approximately 1.1 nautical miles (nm) above the confluence of the Royal and Cousins River (Appendix A, Figure 1). The Royal River is located approximately 9 nm northeast of Portland, Maine. The 2002 study objectives were to: 1) determine the bacterial conditions that could arise under a short term lapse in treatment and disinfection; 2) determine the steady state bacterial conditions in the shellfish growing waters that could arise in the event of a long term elimination or lapse in disinfection; and 3) assess the possible applicability of the CORMIX computer model for estimating dilutions in this study and other similar study areas. A draft report for this study was completed but was not finalized until a request was made by the Maine Department of Marine Resources (DMR) in October, 2006. The DMR also requested that further analysis be conducted to possibly determine the location of a 1000:1 dilution as well as guidance that can possibly be used to assist the DMR with developing a State policy addressing WWTP discharge closure zones. Additionally, since this request by DMR in October of 2006, the Yarmouth WWTP has retrofitted the single port outfall with a multi-port outfall which should improve dilution in the near field. These requests and analysis pertaining to the new diffuser have been addressed in this final report.

1.2 FDA Policy on Establishing Closure Zones for WWTP Discharges

It has been the policy of the FDA to size prohibitive zones according to the following scenarios:

Scenario 1: In consideration of effluent discharged from a WWTP under **failure conditions** (such as a loss of disinfection), the prohibitive zone must provide a sufficient amount of dilution to dilute the effluent discharged under failure conditions to the fecal coliform standard of 14 MPN/100 ml within the prohibitive zone (Scenario 1 in Appendix A, Figure 2).

OR

Scenario 2: In order to reduce the size of the prohibitive zone, a conditionally approved zone may be operated **IF** a factor of at least a 1000:1 dilution of effluent is achieved within the prohibited area, **AND** there is sufficient amount of time to close the conditional area to the harvesting of shellfish **BEFORE** the effluent discharged at the onset of a failure can travel to the boundaries of the prohibitive zone (Scenario 2 in Appendix A, Figure 2).

Note: the additional area beyond the prohibitive zone to be closed under WWTP failure conditions must provide a sufficient amount of dilution to dilute the effluent discharged under failure conditions to the fecal coliform standard of 14 MPN/100 ml within the closed (due to failure) zone (consistent with Scenario 1).

Over the years, treatment technologies have improved; however, FDA has maintained a conservative position recognizing that a WWTP may still be subject to failure regardless of the type of treatment system used. FDA does recognize that with the advancement of technologies such as improved monitoring and alarm systems, that it may be possible to operate a conditional area as outlined in Scenario 2 above. This allows additional shellfish growing areas to be harvested under certain conditions.

When a WWTP is operating normally, disinfection has been shown to be effective in reducing the coliform bacteria group (fecal coliform and total coliform) to levels well below shellfishing standards as can be seen in WWTP permit records kept in accordance with the Environmental Protection Agency (EPA) National Pollutant Discharge Elimination System (NPDES) Program. However, human enteric viruses such as Norwalk-like viruses are more resistant to disinfection and thus are not reduced to the same degree as the coliform bacteria group. Thus, the 1000:1 dilution represents the **minimum zone of dilution needed when the WWTP is operating under normal conditions (with disinfection)** with respect to reducing viruses to acceptable levels. Included in this report is the determination of the 1000:1 dilution area for the Yarmouth WWTP (<u>Section 3.14</u>) based on the first day (ebb tide excursion of dye) dye results. However, adjustments to the 1000:1 found on the first day to account for higher WWTP flow conditions as well as addressing the concerns of the significant build-up of dye observed in the Royal River are also discussed as well as the new addition of the effluent diffuser.

2.0 METHODS

2.1 Dye Standard Preparation and Fluorometer Calibration

The dye tracer used in this study was Rhodamine WT, purchased from the Keystone Aniline Corporation, and had a specific gravity of approximately 1.12 (20% as dry dye). Ten (10) standards were prepared from the stock solution of Rhodamine WT dye and distilled water by serial dilution, ranging from 100,000 parts per million (ppm) to 0.1 part per billion (ppb). A Turner Designs 10-AU digital field fluorometer was calibrated and verified using the 100, 10, 1, and 0.1 ppb standards. Prior to calibration, the basic operating level was set using the sensitivity adjustment knobs and a 10 ppb standard at medium scale. The field fluorometer was flushed and blanked during calibration with tap water flow followed by distilled water flushes. The calibration was conducted according to the procedure in the fluorometer user's manual, using a 10 ppb as the reference standard and distilled water as the calibration blank. For the "Subtract Blank" option, "Yes" was selected. The linear operation of the fluorometer was checked using 100, 10, 1, and 0.1 ppb standard solutions. The fluorometer used for the study was borrowed from the Massachusetts Department of Marine Fisheries (DMF) as the FDA fluorometer was being repaired. FDA had worked jointly with DMF on several projects and were familiar their unit's operation. We are very thankful for the use of the fluorometer for the Yarmouth study.

2.2 Tracer Injection

A total of 31.9 liters (8.43 Gallons) of dye was used into the Yarmouth WWTP effluent over a three tidal day period. To facilitate the pumping of dye, 63.7 liters of deionized water was added creating 1:3 dye dilution mixture. A Masterflex model 7553-20 variable speed peristaltic pump (Cole-Palmer Instrument Co.) was used to withdraw the tracer dye solution from calibrated translucent plastic containers, using Masterflex Tygon tubing. A pump head size 7014 was used with a feed rate of 0.21 ml/revolution which was maintained at about 105 revolutions per minute (rpm) head speed. The tracer dye mixture was fed continuously into the effluent following the chlorine detention tank over the three tidal day period.

2.3 Dye Tracing

The plume was followed during the beginning of the study on 8/17/02 as it moved down the Royal River on ebb tide to determine necessary notification time for consideration of a conditionally approved classification based on operation of the wastewater treatment facility. Dye readings were planned on successive days (8/18-8/22) for high and low tides. Reading times varied on some days because of the time needed to complete the boat runs but every effort was made to sample the majority of stations during the same time on the tide as the prior day. Traverses were done on several days, however, key locations were selected so dye readings could be taken to show changes in dye concentration and build up with time at fixed locations. The build up of dye at fixed locations enabled the determination of a steady state concentration of pollutants. This was important to understand the impacts of stopping chlorination during the winter months. At several locations, dye profiles were done to find the vertical distribution of the dye. Salinity and temperature readings were taken at the same time traverses were done to determine the possible effects of stratification on plume location within the water column.

3.0 RESULTS

3.1 Background Readings

Two boat runs were made to determine background fluorometer readings on two separate days (8/15 and 8/16) before commencing the dye feed. Background readings on 8/15 ranged from about 0.5 ppb in the Royal and Cousins River, with a reduction to 0.18 ppb at Buoy 1. The 8/15 background readings are considered high compared to previous FDA dye studies (background has typically been found to range from about 0.01-0.1 ppb on average). Appendix A, Figure 4 shows the background readings taken at near high tide on 8/15 between 18:36 and 19:14. Background readings on the early flood tide of 8/16 were also very high (0.45 to 1.1 ppb) in both the Royal and Cousins Rivers (Appendix A, Figure 5). Background readings reduced with distances easterly and southerly of the confluences of the Royal and Cousins River (about Buoy 10). The reasons for the high background readings in the Royal and Cousins Rivers were not determined (although as seen in previous studies, there tends to be a strong correlation of higher background in areas influenced by urban/industrial land uses). The high and variable background readings required care in data handling in reducing the field dye readings by appropriate background readings as discussed further in the report.

3.2 Tracer Injection

Tracer dye injection began at the Yarmouth WWTP at 0703, 8/17 (Saturday) and ended at 0934 on 8/20 (Tuesday). The injection was continuous for a total of 3 days, 2 hours and 31 minutes. The average WWTP effluent flow rate during the injection was 0.56 MGD. According to data recorded at the WWTP, 1,664,500 gallons of treated wastewater was tagged with dye. There was an unintentional 2 hr-10 minute lapse in dye addition starting about 13:34 on 8/19, due to tubing lying on the raised center of the bottom of the nearly empty dye addition container. The average dye concentration for the ebb tide dye feed between 07:03 (start of dye feed on 8/17) and 1310 (approximate end of the ebb tide on 8/17) was 1051 ppb. A lower dye concentration during this period compared to the average concentration over the course of the entire injection period (1216 ppb) resulted from the higher morning flows on the morning of 8/17. The 1051 ppb concentration was used for calculating the dilutions for the readings taken on 8/17, the first day of the dye feed. The 8/17 ebb tide results were intended to assess the impact on the growing waters during a relatively short term (6.2 hours or less) lapse in treatment or disinfection.. The average overall concentration of 1216 ppb was used for dilution calculations obtained for other days starting with 8/18. This average included the averages of higher concentrations during low flow periods (night and early morning) and lower concentrations during the higher flow periods (morning and evening). The record of dye feed is shown in Appendix B.

3.3 Travel Time

Travel times were not determined precisely at distances from the outfall on the ebb tide. This was due to several factors, including: (1) high background fluorometer readings in the Royal River, making leading edge determinations difficult; (2) the behavior of the dye, i.e., typical reductions in dye concentration with distance was not documented because much of the dye on the first day moved easterly across shallow water over tidal flats exposed at low tide; and, (3) this study demonstrated some of the uncertainties with the use of continuous dye feed results to estimate travel times. Drogues were not used in this study but it should be noted that they are often helpful in certain circumstances and under the right conditions to determine travel times of surface waters. They may be of potential use in future studies of the Yarmouth WWTP effluent if needed.

This study did determine the extent of the dye travel on the 8/17 ebb tide. The total excursion during the 8/17 ebb tide was about 2.36 nautical miles, including the approximate 1.0 nautical mile from the outfall to the mouth of the Royal River. The excursion time was about 6.2 hours. By assuming an average velocity of 0.38 knots (2.36 nm/6.2 hours), the time from the outfall to the mouth would be estimated as 1.0/2.36 x 6.2 = 2.6 hours. The time to the confluence of the Royal and Cousins River (about Buoy 10) was approximately 1.1/2.36 x 6.2 = 2.9 hours (Appendix A, Figure 3).

3.4 Dye Readings on Consecutive Days

Data gathered on consecutive days (8/17 – 8/22) are presented in Appendix A, Figures 6 – 11. Shown are the locations of the transects made with corresponding fluorometer readings (note: all of the data points for the transects are not shown, because readings are recorded in the file each 6 seconds generating large amounts of data). Dye contours were drawn based on the dye values for 2, 1.5, 1, and 0.5 ppb fluorometer readings, where applicable. The precise locations of the contours crossed by the transects were determined by GIS at the longitudes and latitudes from individual readings taken from the files generated during the transects. The use of actual fluorometer readings permitted visual representation of spatial progression of the effluent and build up with time. It should be noted that no allowance was made for background in the figures, however, adjustments were made later in the analyses.

The readings for the consecutive days show the progression of the effluent in a southerly direction. The 0.5 contour on 8/17 was effectively replaced by the 1.0 contour on 8/18. The 1.0 contour continued to progress in a southerly and easterly direction on successive days with a maximum excursion occurring on 8/20. The 1.0 ppb contour extended beyond the bridge connecting Drinkwater Point and Cousins Island. Soon after the dye feed was stopped (09:34 on 8/20), the 1.0 contour was generally replaced by the 0.5 contour (8/21). The 0.5 ppb contour regressed further on 8/22 indicating continued flushing of the dye was occurring.

3.5 Dye Readings at Individual Locations

Dye readings at selected locations are shown in Appendix A, Figures 12-27. Station locations are shown in Appendix A, Figure 1. The raw data taken on site at fixed locations are shown in Appendix C. These figures, put the significance of the background readings in perspective, and although relatively high, the sharp increases in dye concentration as it builds up on consecutive days allow the background to be subtracted, and have confidence in the remaining concentrations. For instance, at Buoy 1 (Appendix A, Figure 12), about 2.13 nm from the outfall, the background fluorometer reading at low tide on 8/16 was 0.25 ppb. The steady build up of fluorometer readings to a high of 1.5 ppb on 8/19 (1.25 ppb after subtraction of background as shown on Figure 12) followed by an orderly reduction with time after the dye feed was stopped on 8/20 demonstrate an expected system response. Therefore, a background value of 0.25 ppb can be subtracted from all the readings for this location with confidence.

However, for Buoys 10, 14, and 16 (Appendix C), the fluorometer readings several days after dye feed was stopped were lower than the background readings that were taken on 8/16 prior to dye injection. (As previously mentioned, the reasons for the high background readings in the Royal and Cousins Rivers on 8/16 were not determined). This indicates that the background on those days were less than the 8/16 background survey. This also suggests that the background during the course of the dye buildup period for these locations may also have been lower, and thus care must be taken considering analysis for these stations.

If the high background values found on 8/16 are assumed for the dye injection period and are used in the calculations for Buoys 10, 14, and 16, and if actual background was less on these days, then the analysis would be accounting for less dye in the system (more background is accounted than what may have actually occurred). This would tend to favor higher dilution values. As the original intent of hydrographic studies is to determine the possible impacts to shellfish growing areas *assuming worst case scenario conditions* (e.g. loss of disinfection, high WWTP flows, and other seasonal conditions that may contribute to the worst case) it thus seems appropriate to consider using the background values obtained on 8/15 which appear to be more in line with the readings obtained on the last day of the study (8/22). Using the background values obtained on 8/15 accounts for more dye in the system and would result in more conservative dilution values.

Perhaps the best and most unbiased way to determine which background value is appropriate is to assess the outcomes using both values to see how well the data “agrees” with the results of other stations (such as Buoy 4 and Buoy 1). For example, if we were to assume a background value at Buoy 10 to be 1.06 (8/16 reading), then the dye readings on the first day of injection (8/17) would result in a value of -0.38, and the last two days of the study (8/21-22) would result in a value of -0.26 and -0.35 respectively (Appendix C). These negative values occurring on three separate days and during the period in which Buoy 10 should be influenced by dye suggests that the original background assumption of 1.06 is too high If we are to use the background value obtained on 8/15 (0.51), then dye is accounted for in the corresponding first day of dye injection (8/17) (0.55), as well as the last two days of the study (0.29 and 0.2 on 8/21 and 8/22 respectively) (Appendix C).

As can be seen in the data for several stations in Appendix C, a large difference in dye readings between high and low tide can occur. This is especially noticeable at Buoys 1, 4, and 10. These readings were taken in the narrow channels, indicating that channels are a main access for offshore water to enter on flood tide. The lower tide dye concentrations (pm) were always greater than the higher tide values at locations downstream of the outfall, namely locations B, C, D, Buoy 4, Buoy 10, and Buoy 12. However, that was not always the case at locations nearer the outfall at Buoy 14, and 16. The reason is probably because of the narrowing uneven lateral distribution during ebb tide so that maximum concentrations may not have been reflected by the traverses and monitoring locations that were mostly confined to the channel. Other factors may have included the close proximity to the outfall and the influence of other dilution factors such as the near field turbulent mixing zone, or the fact that less dye can make it out each tide the further upstream, and thus the greater degree of the wastefield “overlapping” can occur due to the push of the river flow and tidal change.

No traverses or readings were taken in the water to the north of Lanes Island because of the shallow water and existence of tidal flats there (Appendix A, Figure 1). It appears that effluent would not reach the flats to the north of Lanes Island on a single ebb tide. That is based on the finding that the average travel time from the outfall to Buoy 10, approximately at the intersection of the Royal and Cousins River is about 2.9 hours. At the same time water is draining off from the flats. Although current directions were not determined, it is suspected that drainage from the north and northwest of Lanes Island would counteract easterly flow from the Royal River. And since the flats should be fairly well drained by the time the time effluent reached Lanes Island, flow would be expected to follow the channel south of Lanes Island and not to the north of Lanes Island.

Effluent could be carried to the north side of Lanes Island on flood tide. Although dye concentrations were much higher at low tide than on flood tide as discussed above, high tide dye concentrations did continue to increase. At Buoy 4 (Appendix C) high tide dye concentrations increased from about 0.4 ppb on 8/18/02 to about 0.96 ppb on 8/19/02 reflecting build-up. The location of the dye contour lines shown in (Appendix A, Figure 6) also indicated that the higher dye concentration contour (1.5 ppb) is nearer to Lanes Island. The contours decrease with distance south. This indicated that there was dye at low tide on both the westerly and easterly end of Lanes Island that can be carried to the north of the island on flood tide. Although current directions to the north of Lanes Island were not determined, effluent as reflected by dye concentrations at Buoy 4 (0.4 to 0.96 ppb) was available to enter between Fogg Point and the west end of Lanes Island. There is also possibility for water to enter to the north of Lanes Island through the deeper channel on the east side. The 1.5 ppb contour shown in (Appendix A, Figure 6) indicates effluent is available there to enter on flood tide.

3.6 Vertical Distribution of the Dye Concentrations

The relatively shallow depths, low fresh water flow, and tidal mixing would contribute to vertical mixing in the shallower waters. The concentrations shown in Appendix A, Figure 6-11 are values found near the surface. Some stratification was found as demonstrated in the low tide profiles shown at Buoy Station 1 on 8/18 and 8/19/02 (Appendix A, Figures 28 and 29, respectively). The data in the figures were taken from Appendix C. The channel water depth was 13 to 14 feet and the dye concentration reduced rather sharply at the 6 to 10 feet level. There was a slight increase in salinity and decrease in temperature with depth. The slight increase in salinity and decrease in temperature contributed to the decrease in dye concentration with depth. This relationship was seen in the vertical profiles of dye concentration and density with depth for Buoy 1 on 8/18/02 and 8/19/02 (Appendix A, Figures 30 and 31. respectively). As the density of water increased, dye concentration decreased with depth. The calculation of density was based on the relationship between salinity and temperature developed by Crowley in 1968 and presented on page 102 of “Principles of Surface Water Quality Modeling and Control” by Thomann and Mueller, 1987. These vertical readings were taken in the relatively narrow channels.

3.7 Dye Balance at Low Tide (8/17/02)

A dye balance was performed using the dye contours shown at low tide on 8/17 in Appendix A, Figure 6 as the basis for dye concentrations. The estimates of the depths used to compute the volumes were a combination of the predominance of tidal flats that exist at the water depths of MLLW (mean low low water) as shown in Appendix A, Figure 1 at low tide and the predicted tidal elevation at low tide (Table 2), also based on MLLW. The area between the 1.0 and 0.5 ppb concentrations was assigned a dye concentration of 0.5 ppb. The area between the 1.0 ppb and 1.5 ppb was assigned a dye concentration of 1.0 ppb, and the area between the 1.5 ppb contour and Lanes Island was assigned a concentration of 1.25 ppb. The Royal River from the outfall to the mouth was assigned a dye concentration of 1.0 ppb. The assigned concentrations are averages for the area between the two neighboring contours, reduced by the 0.25 ppb background.

A low tide elevation of 0.9 feet was expected on 8/17, meaning that the flats can be expected to be covered with 0.9 feet of water or less with a slope up toward shore. Based on these depths and adjusted contour concentrations the information in the following Table 3 estimates the amount of dye in pounds in each segment. The relatively narrow channels in the Royal River and between the 0.5 and 1.0 Contours were not considered to greatly contribute to increased water volume in the estimations.

Table 2: Tides for the Royal River Study (8/15 through 8/23/02).

Tide: →	High		Low		High		Low	
Date	Time	Elev. (ft)	Time	Elev. (ft)	Time	Elev. (ft)	Time	Elev. (ft)
8/15/2002	5:00	9.6	11:05	0.1	17:26	10.3	23:51	0
8/16/2002	6:06	9.1	12:07	0.6	18:29	10.1	----	----
8/17/2002	7:15	8.7	13:11	0.9	19:35	10.0	0:58	0.1
8/18/2002	8:23	8.6	14:16	1.1	20:38	9.9	2:05	0.2
8/19/2002	9:25	8.7	15:16	1.1	21:37	10.0	3:08	0.1
8/20/2002	10:19	8.8	16:11	1.0	22:29	10.1	4:04	0
8/21/2002	11:08	8.9	17:00	0.9	23:15	10.1	4:54	0
8/22/2002	11:50	9.0	17:44	0.8	23:57	10.0	5:38	-0.1
8/23/2002	12:29	9.1	18:24	0.7			6:18	0

Table 3: Calculation of the Amount of Dye in Estuary at Low Tide (8/17/02).

Segment	Average Depth (ft)	Area (nm^2)	Average Dye Conc. (ppb)	Amount of Dye (pounds)
1.0 - 0.5	1.4	0.58	0.5	0.94
1.0 to 1.5	0.6	0.15	1.0	0.21
1.5 to Lanes I.	0.5	0.18	1.25	0.26
Royal River	0.7	0.14	1.0	0.23
Total Amount of Dye from Balance =				1.64

The relatively narrow channels in the Royal River and between the 0.5 and 1.0 contours were not considered to greatly contribute to increased water volume in the estimations. The estimated amount of dye accounted for in the portions of the estuary, 1.64 pounds, compares well with the total amount of dye discharged during the time from high to low tides. That amount of 1.62 pounds is shown in Table 4. These balance estimations indicate that dye stayed in the system during the ebb tide dye feed on 8/17/02 and was defined by the contours in Appendix A, Figure 11.

Table 4: Dye Balance for the Ebb Tide (07:07 through 13:11 on 8/17/02).

Time	WWTP Totalizer (x 100)	Dye Feed Level (liters)	Effluent Discharged	Dye Concentration	Weight of Dye Used

			(gallons)	(ppb)	(pounds)
7:03	24993932	39.69	----	----	----
13:11	24995780	30.5	184800	1051	1.62

3.8 Projections for Different River Flows

The study was performed during a small river flow of about 21 cfs. Higher flows are expected to cause faster travel times and may influence the path of the water as it exits the Royal River. Changes in river flow however might be a minimal factor at influencing dilution of the effluent in the Royal River to different values than was found during the study. For instance the average intertidal flow calculated above for the water exiting from the outfall to the dam is about 1550 cfs of which only 21 cfs was river flow. So the amount of river flow was only about 1.4 percent of the total estimated average flow, indicating that the intertidal flow was a much greater factor than the river flow. As an example if the river flow was 10 times greater at about 210 cfs, intertidal flow would still be the major factor. One of the reasons is that when the river above the outfall is being filled with saline water on flood tide, the water in that area will only rise to a specific level, somewhat above the tide level at the mouth, and is a combination of the Royal River water and tidal water. So the elevation at high tide near the dam is expected to be only slightly higher at these higher flows than at lower flows. With higher river flows, there could be more stratification, if the River water continued to flow out, even though flood tide water was entering. But when the ebb tide started, the estimated 1150 cfs intertidal flow would probably be increased by the river flow to 1150+(210-21) = 1339 cfs. The result is that the estimated tidal flow could increase from 1150 to 1339 with the demonstrative 10 fold increase in flow.

Overall, without considering stratification and realizing time of travel can be shorter with the higher flows, there would be minor differences in effluent dilution caused by the 10 fold increase in river flow. The reason is that considering the WWTP discharge does not change, the effluent dilution is less in the low river flow (1150 cfs) tidal flow than the higher river flow (1339 cfs). However this difference in effluent dilution is offset by realizing that the dilution of the low river stage tidal flow (1150 cfs) is greater than the example higher river stage tidal flow (1339 cfs). This balance minimizes the importance of considerations for expecting greater effluent dilutions, by projecting the results of the dye study done during low Royal River flows to higher river flows.

The daily flows for the Royal River are shown in Appendix A, Figure 35. There are many river flows higher than the 210 cfs illustrated above. These higher river flows will no doubt change the flow characteristics at the mouth, but stratification may not be a significant factor because some stratification if it occurred could be offset by additional dilution of the effluent. The effects of the river, itself during these high flow conditions may be a factor in classification.

3.9 Projections for Higher Wastewater Treatment Plant Flows

This study, which was conducted between August 17-22, 2002 was during a very low wastewater treatment plant flow period which typically corresponds to the lower river flow periods during the summer months. With the low flow values, the calculated dilution values will be greater than would occur with higher flows. The WWTP flows during the dye addition period of August 17-20, 2002 (about 3 days) are shown in Appendix A, Figure 36. The periodic flow rates were calculated from periodic totalizer readings taken during the dye addition. The average flow during that period was 0.56 mgd. An average maximum flow for the period was 0.92 mgd and is shown in Appendix A, Figure 36. That ratio of maximum flow to average flow is 1.6. The maximum flow rates were taken care in the long term dye addition by realizing that the higher flows, with a constant dye feed rate, would result in a lower dye concentration in the effluent, but that would be balanced by the resulting physical dilution of that effluent being less in the estuary than during average flow (less concentration and less dilution = same dye reading in estuary as average flow and average dye concentration). The result is that the same dye concentration would be found in the estuary regardless of WWTP flow.

The 0.56 flow found during the August 17-20, 2002 dye addition period are compared to average flows that occurred for the year 2002 in Appendix A, Figure 37. In Appendix A, Figure 37 are 3 day running averages for the daily flows from WWTP records. Also shown are actual maximum flows recorded by WWTP officials. The 0.56 mgd flow during the dye addition is the lowest for the year. A projection of the 0.56 mgd up to 1.4 mgd as show graphically would contain all the 3 day average daily flows in 2002. This analysis was then projected to records for the years 1995-2004 as shown in Appendix A, Figure 38. The 0.56 still remains among the lowest flow for that period. However the 1.4 mgd is exceeded several times from 1996 to 2001 and fewer times from 2003 to 2004. It appears from the rainfall records that the year 2002 was relatively dry. A greater frequency and larger rains seem to have occurred prior to 2002 and resulted in greater wastewater flows. Results of infiltration and inflow abatement could have been a factor at reducing the numbers of times a 3 day running average of 1.4 mgd occurred from 2002 to 2004. Rainfall, as expected, appears to be a factor at increasing the average daily flows. With few exceptions, the 1.4 mgd average flow would be satisfactory to project the study results taken during the 3 day dye addition very low flow period of August 17-20, 2005 to other flows. This would result in lower dilutions of effluent than those previously discussed in this report using the study data. The dilution reduction factor would be 1.4/0.56 = 2.5. This is a major factor when extrapolating the effects on the estuary, if there was a waiver on effluent disinfection. It is also a major factor when applying minimum dilution concepts when determining prohibited areas for WWTP effluents.

3.10 Projections for Retrofit of Single Port Outfall with Multi-port Diffuser

Recently (after which this study has been conducted), the Yarmouth WWTP has undergone a retrofit of the outfall from a single port to a multi-port diffuser. Analysis was conducted to determine the overall factor of increase in dilution attributed to the recent upgrades. According to a 1989 EPA dye study, the MEDEP established dilution ratios of 3:1 for acute and 8:1 for chronic for the single port outfall prior to the upgrades. Based on CORMIX modeling conducted by Wright-Pierce, these dilution ratios could potentially improve to 20:1 and 100:1 for acute and chronic respectively based on the configuration of the multi-port diffuser. Thus, comparing the average dilution ratios (5.5 prior to the upgrades compared with 63.5 after the installation of the diffuser), the improved factor of dilution may be on the order of 11.5 (63.5/5/5).

3.11 Short Term Failure - Dilution and Anticipated Fecal Coliform Concentrations at One Ebb Tidal Excursion

Dilution of the dye tagged effluent can be related to all of the low tide dye readings taken from 8/17/02 to 8/22/02. Dilution is physical and is computed by dividing the dye concentration found at locations in the estuary into the dye concentration added to the WWTP effluent. The low tide dye readings found on 8/17/02, the first day of the dye feed, were used to estimate the fecal coliform counts that would occur at the 1.5, 1.0, and 0.5 ppb contours in Appendix A, Figure 6. A background level of 0.25 ppb was subtracted from each of the contours in Appendix A, Figure 6. A 0.25 ppb background was used for all the readings because that value was found at near low tide at Buoy 1, well out into the growing waters in the approximate locations of the dye contours. Although background readings were generally higher in the Royal River, higher dye readings there reduced the significance of background readings. The followings Table 1a-d provides the dilution values at the 0.5, 1.0, and 1.5 ppb contours (see also Appendix A, Figure 6.) for the various scenarios including projections for different flow rates and with the new diffuser. Also shown are anticipated fecal coliform concentrations, if a short term lapse in disinfection should occur (single ebb tide and assuming no decay) under all of the various scenarios. Note that the 0.5 ppb contour is found near Buoy 1. A typical literature based value of 1.4×10^6 FC MPN/100 ml as the anticipated fecal coliform count for this treated but undisinfected effluent was used in comparison to a value of 1.4×10^5 FC MPN/100 ml which may be more reflective of the Yarmouth WWTP.

Table 1a: Dilution and Anticipated Fecal Coliform Concentration on Ebb Tide on 8/17/2002 with a Short Term Lapse in Disinfection at the WWTP – Pre-diffuser and low WWTP flows

Dye Contour (ppb)	Reduced by background (ppb)[1]	Dilution with Respect to FC with no decay[2]	Anticipated Concentration (FC/100 ml)	
			With 1.4×10^6 FC/100 ml[3]	With 1.4×10^5 FC/100 ml[4]
1.5	1.08	973:1	1439	144
1.0	0.58	1812:1	773	77
0.5	0.25	4200:1	330	33

[1] 0.42 background found at Buoy 4 used for contour 1.5 and 1.0 and 0.25 background found at Buoy 1 used for contour 0.5.
[2] 1051 ppb dye concentration in effluent for time period 07:30-13:10 on 8/17/02.
[3] Expected fecal coliform concentration with secondarily treated waste, no disinfection.
[4] May be expected for the Yarmouth WWTP effluent.

Table 1b: Dilution and Anticipated Fecal Coliform Concentration on Ebb Tide on 8/17/2002 with a Short Term Lapse in Disinfection at the WWTP – with diffuser online and low WWTP flows

Dye Contour (ppb)	Reduced by background (ppb)[1]	Dilution with Respect to FC with no decay[2]	Increase in dilution (factor of 11.5) based on diffuser	Anticipated Concentration (FC/100 ml)	
				With 1.4×10^6 FC/100 ml[3]	With 1.4×10^5 FC/100 ml[4]
1.5	1.08	973:1	11190:1	125	13
1.0	0.58	1812:1	20838:1	67	7
0.5	0.25	4200:1	48300:1	29	3

[1] 0.42 background found at Buoy 4 used for contour 1.5 and 1.0 and 0.25 background found at Buoy 1 used for contour 0.5.
[2] 1051 ppb dye concentration in effluent for time period 07:30-13:10 on 8/17/02.
[3] Expected fecal coliform concentration with secondarily treated waste, no disinfection.
[4] May be expected for the Yarmouth WWTP effluent.

Table 1c: Dilution and Anticipated Fecal Coliform Concentration on Ebb Tide on 8/17/2002 with a Short Term Lapse in Disinfection at the WWTP – Pre-diffuser and high WWTP flows

Dye Contour (ppb)	Reduced by background (ppb)[1]	Dilution with Respect to FC with no decay[2]	Decrease in dilution (factor of 2.5) based on increased WWTP flows	Anticipated Concentration (FC/100 ml)	
				With 1.4×10^6 FC/100 ml[3]	With 1.4×10^5 FC/100 ml[4]
1.5	1.08	973:1	389:1	3597	360
1.0	0.58	1812:1	725:1	1932	193
0.5	0.25	4200:1	1680:1	833	83

[1] 0.42 background found at Buoy 4 used for contour 1.5 and 1.0 and 0.25 background found at Buoy 1 used for contour 0.5.
[2] 1051 ppb dye concentration in effluent for time period 07:30-13:10 on 8/17/02.

[3] Expected fecal coliform concentration with secondarily treated waste, no disinfection.
[4] May be expected for the Yarmouth WWTP effluent.

Table 1d: Dilution and Anticipated Fecal Coliform Concentration on Ebb Tide on 8/17/2002 with a Short Term Lapse in Disinfection at the WWTP – with diffuser and high WWTP flows

Dye Contour (ppb)	Reduced by background (ppb)[1]	Dilution with Respect to FC with no decay[2]	Decrease in dilution (factor of 2.5) based on increased WWTP flows	Increase in dilution (factor of 11.5) based on diffuser	Anticipated Concentration (FC/100 ml)	
					With 1.4 x 10^6 FC/100 ml[3]	With 1.4 x 10^5 FC/100 ml[4]
1.5	1.08	973:1	389:1	4474:1	313	31
1.0	0.58	1812:1	725:1	8338:1	168	17
0.5	0.25	4200:1	1680:1	19320:1	72	7

[1] 0.42 background found at Buoy 4 used for contour 1.5 and 1.0 and 0.25 background found at Buoy 1 used for contour 0.5.
[2] 1051 ppb dye concentration in effluent for time period 07:30-13:10 on 8/17/02.
[3] Expected fecal coliform concentration with secondarily treated waste, no disinfection.
[4] May be expected for the Yarmouth WWTP effluent.

In consideration of a failure, a short term lapse in disinfection would result in deteriorated water quality in a single ebb tide (Tables 1a-d above). A short term lapse in disinfection for low WWTP flow periods (considering the single day ebb tide results) could result in fecal coliform counts ranging from 33 – 330 FC/100 ml as far as 0.8 nautical miles from the mouth of the Royal River at the 0.5 ppb contour in consideration of the conditions prior to the WWTP diffuser installation. However, with the new diffuser on-line, these ranges may be potentially reduced by a factor of 11.5 to approximately 3 – 29 FC/100 ml (refer to Section 3.10 regarding the increased factor of dilution). With the diffuser and in consideration of the higher fecal coliform concentrations (1.4 x 10^6 FC/100 ml) this could then mean that the outer boundary of a conditional area could extend past the 0.5 ppb contour and potentially out to the estimated limit of tidal excursion (see Table 1b). If only the lower values of fecal coliform concentrations were considered, which may be more reflective of the Yarmouth WWTP (1.4 x 10^5 FC/100 ml), the outer boundary of the conditional area could extend to the 1.5 ppb contour (see Table 1b).

A short term lapse in treatment for high flow periods in consideration of the conditions prior to the WWTP diffuser installation could result in fecal coliform counts ranging from 83 – 825 FC/100 ml at the 0.5 ppb contour. However, with the new diffuser on-line, these ranges may be potentially reduced by a factor of 11.5 to approximately 7 – 71 FC/100 ml. This would mean that with the diffuser in place and in consideration of the higher fecal coliform concentrations (1.4 x 10^6 FC/100 ml) this could place the outer boundary of a conditional area past the 0.5 ppb contour and potentially out to the estimated limit of tidal excursion (see Table 1d). If only the lower values of fecal coliform concentrations were considered, which may be more reflective of the Yarmouth WWTP (1.4 x 10^5 FC/100 ml), the outer boundary of the conditional area could extend to just beyond the 1.0 ppb contour (see Table 1d).

3.12 Long Term – Stopping Chlorination (e.g. Winter): Dilution Determination and Anticipated Fecal Coliform Concentrations for Consecutive Day Ebb Tidal Excursions

In this study, the long duration of dye injection in conjunction with the several days of data collection enabled steady state fecal coliform calculations in consideration of the winter time practice of stopping disinfection via chlorination to be determined for several of the stations monitored in the Royal and Cousins River and offshore waters out to Buoy 1. As several days may be needed for a system to buildup to a steady state condition, concurrent pathogen die-off may also occur and this was accounted for in the calculations for fecal coliform as demonstrated in Tables 6 and 7 below.

Table 5 below demonstrates the significant build-up of dye in the Royal River over the 3 day injection period. As concentrations build, the overall amount of effluent dilution in the river decreases. Table 5 also considers the decrease in dilution that could also result from the increase in WWTP flow rates. Please refer to figures 12-27 in Appendix A which visually show the measurements and hence build-up of dye over the injection period to steady state through the Royal River at various buoy stations.

Table 5: Total factor decrease in dilution from first day's measurements when considering dye build-up and higher WWTP flow rates

Date	Dye Concentration	Dilution	Factor of decrease in dilution (build-up)	Factor decrease in dilution (higher WWTP flow)	Total factor decrease in dilution (build-up and WWTP flow)
Buoy 1 – Dye Concentration and Corresponding Dilution (at LHSW)					
8/17/02	0.2600	4042	4.2	2.5	6.7
8/18/02	0.8500	1431			
8/19/02	1.2500	973			
Buoy 4 – Dye Concentration and Corresponding Dilution (at LHSW)					
8/17/02	0.1800	5839	6.6	2.5	9.1
8/18/02	0.8800	1382			
8/19/02	1.3800	881			
Buoy 10 – Dye Concentration and Corresponding Dilution (at LHSW)					
8/17/02	0.1700	6182	9.6	2.5	12.1
8/18/02	0.9900	1228			
8/19/02	1.8900	643			
Buoy 12 – Dye Concentration and Corresponding Dilution (at LHSW)					
8/17/02	0.7900	1330	8.0	2.5	10.5
8/18/02	2.1900	555			
8/19/02	7.2900	167			
Buoy 14 – Dye Concentration and Corresponding Dilution (at LHSW)					
8/17/02	No measurement	?	inconclusive	2.5	inconclusive
8/18/02	2.2200	548			
8/19/02	3.1200	390			
Buoy 16 – Dye Concentration and Corresponding Dilution (at LHSW)					
8/17/02	1.9100	550	5.7	2.5	8.2
8/18/02	8.7100	140			
8/19/02	12.7100	96			

The three tidal day dye feed allowed for the observance of increased dye concentrations with time. The dye did build up on consecutive days; however there would be concurrent bacterial die-off. The accumulative reduction in microorganism concentrations is the combined factors of physical dilution and die-off. The combined results are considered to be microbial attenuation. Buoy 1 was selected for analysis because low tide dye concentrations were found there on all the days. The background amount of 0.25 ppb was subtracted from each value. Table 6 shows the data for Buoy 1. Also the day and night time reductions are shown for each day. The day time die-off value used was 3.74/day and the night time value was 0.6/day. The basis is reduction according to the first order decay relationship $L/L_0 = e^{-kt}$. For day 1 on 8/17, the die-off value k=3.74 is used, representing conditions for the morning ebb tide to allow for reduction from high tide when dye addition was started to when readings were taken at about low tide (0.203 days). Then assuming for worst case winter conditions, it was estimated that the elapsed time between readings during subsequent days would be divided as follows: 1/3 of those hours was assumed to occur during daylight and 2/3 of those hours was assumed to occur during night conditions. Thus, the calculations in Columns (F) and (G) divide the hours accordingly. The Table 5 Example Formula Sheet shows the calculations made. The example calculations shown relate to the "Low Tide Build Up of Dye During Injection Period and Corresponding Dilution Curves" found in Appendix A.

The "Low Tide Dye Concentrations and Reductions" figures found in Appendix A also show reduction estimates for the period after dye buildup when the dye injection was stopped (8/20-22). These calculations are of less importance and do not have much bearing on the outcome of management other than to show how quickly the system may recover from a long term lapse in disinfection with respect to reductions in fecal coliform and male-specific bacteriophage (MSB). The procedure for the analysis is explained in spreadsheets found in Appendix D.

Table 6: Buoy 1 - Effective Dye Concentrations During Dye Buildup (1st order decay)

(A)	(B)	(C)	(D)	(E)	(F)	(G)	(H)	(I)	
Date	Time	Dye Injection Lapsed Time (dec. day)	Fluorometer Reading	Dye Conc.[2] (ppb)	Day Die-off (Fraction Remaining)	Night Die-off (Fraction Remaining	Composite (Day and Night)	Accumulated Reduction (Effective Concentration)	Net Dilution[3]
8/16/2002	14:44	0.203	0.25	0					
8/17/2002	11:55	1.319	0.51	0.26	0.468		0.468	0.122	8629:1
8/18/2002	14:43	2.369	1.1	0.85	0.193	0.590	0.114	0.189	6434:1
8/19/2002	15:55	3.369	1.5	1.25	0.052	0.388	0.020	0.197	6170:1

[1] Die-off (k) decay values used: 0.6/day night and 3/74/ day for sunlight

[2] Dye concentration = fluorometer reading – background (0.25)

[3] WWTP dyed effluent concentration of 1051 ppb used on 8/17; WWTP dyed effluent concentration of 1216 ppb used for 8/18-19

(Table 6 Example Formula Sheet)

Example calculations for Buoy 1

(A) Date	(B) Time	(C) Injection lapsed time (dec day)	(D) Fluorometer Reading (ppb)	(E) Dye Conc. (ppb)	(F) Day die off (Fraction Remaining)	(G) Night Die off	(H) Composite Day and Dark	(I) Accum. Reduction (Effective Dye Conc.)
8/16//02	14:44	0.203	0.25	=D6-0.25				0
8/17//02	11:34	1.319	0.51	=D7-0.25	=2.718^(-3.74*(C7)))			=E7*F7
8/18//02	14:43	2.369	1.1	=D8-0.25	=2.718^(-3.74*(C8/3)))	=2.718^(-0.6*(C8*2/3))	=F8*G8	=I7+((E8-E7)*H8)
8/19//02	15:55	3.369	1.5	=D9-0.25	=2.718^(-3.74*(C9/3)))	=2.718^(-0.6*(C9*2/3))	=F9*G9	=I8+((E9-E8)*H9)

Essentially as the dye accumulates as shown in Column (E) the amount of dye for each succeeding day is considered to be the difference in concentration from the day before, and the age of that increase is considered to be the time of reading minus the time the dye feed was initially started (dye injection lapsed time as shown in Column (C). For instance a dye concentration increase from day 2 to day 3 is considered to be 3 days old and the concentration that is 3 days old is the difference in readings between the two days. The amount of effective dye remaining is the sum of the L/L_0 values from the preceding days. That sum of the fractions is considered the amount of the original dye remaining as though it were subjected to the die-off factors. For the first day of injection, only day die-off is considered as the dye was exposed to sunlight during that initial timeframe.

The influence of the die-off factor used in this situation representing the more conservative winter conditions is still very great as demonstrated in Appendix A, Figures 12-13. For instance on August 19, 2002 the accumulated dye concentration at Buoy 1 was 1.25 ppb, but with die-off values used, attenuation was increased so that the dye concentration used for effective calculations of impact on the waters around Buoy 1 was 0.197 ppb. The effective dye concentration was then used to estimate fecal coliform concentrations at that location using an undisinfected, but secondarily treated waste of 1.4×10^6 FC/100 ml and 1.4×10^5 FC/100 ml as shown in Table 7.

Table 7: Anticipated Fecal Coliform Concentrations at Buoy 1 During Dye Buildup Period

Date	Dye Conc.[I] (ppb)	Effective Dye Conc. (ppb)	Effective Attenuation Factor	Anticipated Concentration (FC/100 ml)	
				1.4×10^6 FC/100 ml[II]	1.4×10^5 FC/100 ml[III]
8/16/02	0				
8/17/02	0.26	0.122	8629:1	162	16
8/18/02	0.85	0.189	6434:1	218	22
8/19/02	1.25	0.197	6170:1	227	23

[I] An effluent dye concentration of 1051 ppb was used for the 8/17/02 dye feed period, and an effluent concentration of 1216 ppb was used for the rest of the days (8/18-8/19).
[II] Expected fecal coliform concentration with secondarily treated waste, no disinfection.
[III] May be expected for the Yarmouth WWTP effluent.

Table 7a: Anticipated Fecal Coliform Concentrations at Buoy 1 During Dye Buildup Period – considering high WWTP flow periods

Date	Effective Attenuation Factor [I]	High WWTP Flow Periods – factor decrease	Final dilution at High WWTP Flow Periods	Anticipated Concentration (FC/100 ml)	
				1.4×10^6 FC/100 ml[II]	1.4×10^5 FC/100 ml[III]
8/16/02					
8/17/02	8629:1	2.5	3452:1	406	41
8/18/02	6434:1	2.5	2574:1	544	54
8/19/02	6170:1	2.5	2468:1	567	57

[I] An effluent dye concentration of 1051 ppb was used for the 8/17/02 dye feed period, and an effluent concentration of 1216 ppb was used for the rest of the days (8/18-8/19).
[II] Expected fecal coliform concentration with secondarily treated waste, no disinfection.
[III] May be expected for the Yarmouth WWTP effluent.

Table 8: Anticipated Fecal Coliform Concentrations at Buoy 1 During Dye Buildup for low and high WWTP flow periods and considering new diffuser

Date	Diffuser – factor increase	High WWTP Flow		Low WWTP Flow	
		Anticipated Concentration (FC/100 ml)		Anticipated Concentration (FC/100 ml)	
		1.4×10^6 FC/100 ml[II]	1.4×10^6 FC/100 ml[II]	1.4×10^6 FC/100 ml[II]	1.4×10^5 FC/100 ml[III]
8/16/02					
8/17/02	11.5	35	4	14	1
8/18/02	11.5	47	5	19	2
8/19/02	11.5	49	5	20	2

The above anticipated values were at a fixed location in the estuary at Buoy 1. The information was generated from the low tide data taken at Buoy 1 on consecutive days. These values indicate that steady state fecal coliform concentrations are reached very quickly (2 ½) tidal cycles with the die-off factors used. This is about one day and 6 hours, since dye was started on high tide and the values in the table were calculated on low tide of the following day. Even with less conservative effluent concentrations (1.4 x 10^5 FC/100 ml) impacts from a long term lapse in disinfection or elimination of effluent disinfection may impact growing waters past Buoy 1 as steady state fecal coliform concentrations may range from 23-227 FC/100 ml at Buoy 1 (Table 7 above, Appendix A, Figure 32). Steady state fecal coliform concentrations at Buoy 1 for adjusted higher seasonal WWTP flows may range from 57-567 FC/100 ml (Table 7a above). The adjustment for higher seasonal WWTP flow is discussed in Section 3.19. This analysis would need to be fully assessed if considerations were made to eliminate effluent disinfection

In addition, Table 8 attempts to estimate the build-up concentrations at Buoy 1 under both low flow and high WWTP flow periods with the new effluent diffuser. Steady state fecal coliform at Buoy 1 could range from 2-20 FC/100 ml during low flow periods and range from 5-49 FC/100 ml at high flow periods.

3.13 Additional Classification Considerations

The study has shown that effluent from the Yarmouth wastewater treatment facility traveled about 2.36 nautical miles on a single ebb tide in an easterly direction. The effluent moved along the shoreline as it exited Royal River. This corresponds to the eastern end of the 0.5 ppb contour shown in Appendix A, Figure 6. The dye also moved latterly to the south with decreasing concentrations during it's easterly flow. The waters are shallow along the shoreline to the north as the Royal River exits its mouth. The two contours (1.0 and 0.5 ppb) in Appendix A, Figure 6 are based on the field fluorometer readings. For data work-up and application a background of 0.25 was subtracted from the readings. It is suspected that the Royal River does not flow to the north of Lanes Island on ebb tide, although no dye readings were taken there, due to shallower water. Dye readings north of the 1.0 ppb contour increased to 1.5 ppb in the northerly direction toward Lanes Island. Table 1 shows dilution values of 840:1, 1400:1 and 4200:1 at the 1.5 ppb, 1.0 ppb and 0.5 ppb contours respectively. If an undisinfected effluent were to contain 1.4 x 10^6 FC/100 ml, then 330 FC/100 ml could occur at the 0.5 ppb contour. These concentrations developed on an ebb tide, about 6.21 hours, so little die-off of fecal coliforms would be expected. This indicates that the portion of the growing area encompassed in and north of the 0.5 ppb contour is impacted directly by the Yarmouth WWTP and should continue to be classified as conditionally approved. The Cousins River would also be included because of the movement of the effluent during flood tide.

3.14 Determination of a 1000:1

It should also be noted that in this study the dye concentration readings on the first day did not demonstrate a normal reduction in dye concentration with distance from the outfall, and it was difficult to estimate a dye concentration at the mouth of the Royal River on low tide, the first day of the study (8/17/02) when the dye feed was commenced at high tide. It was difficult to obtain maximum concentrations near the mouth because of the shallow waters and there was an indication that the effluent remained to the southern part of the River. Uniformity in concentrations was not seen when taking dye readings opposite the discharge pipe at the outfall. Maximum dye readings opposite the outfall were far less than the 1051 ppb added to the outfall during the 8/17/02 ebb tide. The reason was not because great dilution occurred there, but because most of the effluent stayed along the southern shore in shallow water and could not be read with the fluorometer. A traverse was made across the channel of the Royal River at Buoy N12, about 0.2 nautical mile upstream of the mouth. The readings varied during the transect, but higher values in the range of 1.3 to 1.6 ppb where obtained. These higher values are consistent with the 1.5 ppb contour found near Lanes Island (Figure 4), indicating the tendency for river flow and effluent to stay near Lanes Island on ebb tide depending on the low tidal elevation and the amount of flats exposed. Although no background readings were taken at the mouth of the Royal River, background readings of 0.42 to 1.06 ppb were made at the mouth of the Cousins River and near Buoy N4. Thus, the 0.42 background found at Buoy 4 was used to determine the dye final concentration of the 1.5 and 1.0 ppb contours and the 0.25 background found at buoy 1 was used to determine dye concentration of the 0.5 ppb contour. The 1000:1 dilution using this approach would place the line somewhere between the 1.0 and 1.5 ppb contour which places somewhere between Buoy 4 and Buoy 13 for the first day of the study.

In consideration of FDA's 1000:1 guidance, the 1000:1 dilution represents the least amount of decrease in contaminant levels needed when the WWTP is operating normally (as intended and with disinfection) with respect to reducing viruses to acceptable levels. As such, the 1,000:1 dilution is to be considered as a minimum zone of dilution near an outfall when the WWTP is properly functioning, and does not apply when establishing a prohibited-conditionally approved boundary which is based on WWTP failure and the condition affecting sanitary quality is something else, such as precipitation. As such, for WWTP's with continuous discharges, one can expect that viruses will be entering the environment on a continuous basis. Thus, there exists the potential for a build-up within the system as this is not a short lived event as like the consideration of a short term failure as discussed above, but rather synonymous with the long term event where build-up of contaminants is more likely. As demonstrated by the dye measurements from 8/17-8/22, there is a considerable amount of build-up in the system. This is shown in Appendix A, Figures 6-11: dye measurements are shown to increase at all of the buoy stations where dye was measured on subsequent days of dye injection. The concentrations at buoys 1 through 16 increase and start to level of after about 2 days of injection thus achieving steady state. Table 7 shows the overall factor of dilution at this steady state dilution in comparison to the initial dilution on day 1 of the injection. The overall factor of decrease in dilution for buoys 1 through 16 range from 4.2 to 9.6. Taken into consideration with the potential for high WWTP flows decreases the factor of dilution in the range of 6.7 to 12.1. This indicates that the dye within this region is not completely removed from the system within a single tidal cycle. The portion of dye that remains in the system mixes with the new dye entering the system thus causing the concentrations to rise and build to a steady state maximum.

For systems that demonstrate a significant amount of pollutant build-up and where data exists to make such determinations, it is prudent that this data be utilized to make the most accurate determination of the 1000:1 as a precautionary measure against viral contamination of harvestable shellfish. Thus, it is recommended that the long term data collected in this study be used not only for determining the steady state build-up of fecal coliform with respect to the practice of terminating chlorination during the winter months, but also to consider how the 1000:1 dilution line will change based on the factor of build-up calculated by dye measurements due to the physical flushing of the system which indicates considerable build-up within a several day period.

In consideration of the diffuser, as previously discussed, the overall factor of increase in initial dilution may approximately be 11.5. Although the diffuser will increase the amount of initial dilution, this factor is equally offset when higher WWTP flows and pollutant build-up effects are considered in a worst case delineation of the 1000:1 line. Thus, under worst case scenarios in consideration of higher WWTP flows and considering the significant build-up within the river, the worst case 1000:1 line should still be placed somewhere between Buoy 4 and Buoy 13, coincidently, the same location as found for the first day of the study.

3.15 Travel Time Considerations

A conditionally approved classification could result in more utilization of shellfish resources. The management plan must require the continuous disinfection of effluent. Notification time is crucial in the management plan for the operation of the growing waters offshore of the mouth of the Royal River. It is estimated that for low flow WWTP conditions, the travel time from the outfall to the mouth is about 2.6 hours. However, even if the response time could match these short travel times, the 1000:1 dilution would need to be met. As demonstrated on the first day of release, the 1000:1 dilution is not met at the mouth of the Royal River but much further down the bay, as far as in the vicinity between the 1.0 and 1.5 ppb contour as shown in Appendix A, Figure 6c. Thus, in this situation, it appears that the 1000:1 dilution determination would be the controlling factor in establishing a conditional area under the conditions prior to the diffuser upgrade and in consideration of low WWTP flow conditions.

3.16 Prohibited Area Required for the Outfall

A prohibited area would continue to be needed for the Yarmouth wastewater treatment plant effluent. The size of that prohibited area will depend on whether conditions at the WWTP will allow for having enough continued confidence in the operation that a conditionally approved area could be adjusted and managed. The following are general considerations.

3.17 Prohibited Area Associated with Conditionally Approved Classification

As previously indicated in Section 1.2, in order to maximize the size of the shellfish growing area and reduce the size of the prohibitive zone, a conditionally approved zone may be managed if three factors are met: 1) adequate dilution of effluent within the prohibitive area in consideration of the WWTP operating under normal conditions (i.e. 1000:1 dilution); 2) sufficient amount of time to close conditional area to harvesting in the event of a failure (a management plan is required); and 3) adequate amount of dilution within the conditional area to dilute effluent discharged under failure conditions (i.e. meeting fecal coliform standard of 14 MPN/100 ml).

A conditionally approved area management plan would include performance standards for the wastewater treatment plant, adequate monitoring and alarms, and a management plan that insures that harvest might be done, but only when the WWTP, disinfection systems, recording devices and alarms are in operation. Added effluent travel time in long outfalls can be considered in the travel time for the estimated arrival of effluent. Notification time is usually the controlling factor in performance standards and management plans. In some situations, alarm and notification procedures for shellfish control officials, the industry doing harvesting, and harvesting and growing area control officials are so effective that notification times can be reduced to a few hours. In some situations the notification times may be so short that adequate effluent dilution does not occur for normally treated secondary treatment. If these situations should occur a minimum effluent dilution of 1000:1 is needed. Even if the notification time between WWTP breakdown and the ceasing of harvest is less than the travel time to obtain the minimum dilution, the location of minimum dilution would control.

3.18 Classification without Conditionally Approved Classification

Prohibited areas for WWTP effluents are larger when not combined with a management plan set up for use with a conditionally approved area. The reason is that allowance has to make for a malfunction at the WWTP. The most serious malfunctions are conditions that can lead to bypass of raw or partially treated wastewater. Many WWTPs now have eliminated the capability of bypassing sewage. In those situations a malfunction defined as a lapse in disinfection could be considered. In classification recommendations in many hydrographic studies, a value of 1.4 x 10^6 FC MPN/100 ml has been applied to describe the FC concentration in undisinfected secondarily treated effluent. That value, when diluted to 14 FC/100 ml, the growing area criteria, results in a dilution of about 100,000:1. This indicates that raw consumption of shellfish exposed to a secondarily treated effluent without disinfection and diluted to 100,000:1 is safe.

Shellfish Control authorities have adapted dilution requirements to particular WWTPs by taking samples of undisinfected effluents for fecal coliform analyses using MPN methodology and procedures. Seasonal differences are considered. Many times data taken are variable. This is evident when the data are plotted on probability paper. The variability of the data can be compared to the slope of the Velz line for 5-tube MPN, or 3-tube MPN, whichever methodology is used. The slope of the line representing the data is compared to the line representing the variability of the MPN test (Velz line). The effluent fecal coliform value of undisinfected WWTP effluent can be graphically determined, by: (1) Plotting the samples on logarithmic probability paper, (2) Go to the 98th percentile value on the probability paper resulting from the plotting of the effluent data, (3): Starting at that 98th percentile extend the Velz line representing the variability (slope) of the MPN test to the 50^{th} percentile. (4) That value at the 50^{th} percentile is taken as the effluent fecal coliform concentration in the event of a disinfection malfunction. That value divided by 14 FC/100ml becomes the target effluent dilution for establishing where growing waters will be beyond the ability of the undisinfected effluent to cause FC counts to be above 14 FC/100 ml. This use of the Velz line in determining the 50^{th} percentile accounts for variability of the treated but undisinfected wastewater. The variability is a very important factor that needs to be included in determinations. A calculated geometric mean value would not allow for this variability.

The data may be variable and not evenly distributed. A straight line is fit for the data points by drawing a straight line through the points, and extending it to the 98^{th} percentile. The Velz line for the 3 or 5-tube MPN is drawn from the 98^{th} percentile and at the 50^{th} percentile the fecal coliform value representing effluent quality about 98 percent of the time is selected. Most time it will be at about the 1.4 x 10^6 value often used when actual data is not available and reported in the literature for secondarily treated but not disinfected effluent (about 1.4 x 10^6 FC/100 ml).

Eight samples of undisinfected effluent were taken at the Yarmouth WWTP from May 2001 to May 2005. Data analyses as above indicated that the treated by undisinfected effluent could be about 88,000. This limited data indicates that the treated effluent prior the disinfection at the Yarmouth WWTP could be less that the 1.4 x 10^6 FC/100 ml expected at many facilities. A value of 88,000 FC/100 ml is very low for undisinfected effluent. Certain practices can cause these low values, such as disinfection for odor control in the wastewater collection prior to reaching the WWTP. This type of operation would reduce the fecal coliform counts of the raw sewage and the reduction would continue through the treatment process for the effluent prior to disinfection. This value is important for two reasons in this case: (1) in establishing the outer boundary of a conditionally approved area and (2) in assessing the impact on growing area water quality if a waiver for discontinuation of effluent disinfection at the Yarmouth WWTP was considered. With the considerations of unusually low effluent fecal coliform values prior to disinfection and to make some allowance for the small number of samples taken, an effluent value of 1.4 x 10^5 was used to supplement the expected fecal coliform concentrations at the dye contours in Appendix A, Figure 6, the anticipated fecal coliform concentrations at Buoy 1 in Table 6.

3.19 Conditionally Approved Growing Waters are not Necessarily Impaired Waters

The recognition that the need for a prohibited area for outfalls and use of the conditionally approved concept whenever an outfall is located in shellfish growing waters is important in considerations for designating waters as impaired with resulting TMDL remediation requirements. This recognition of a status of shellfish growing waters where shellfish harvest would not be allowed (prohibited area) and harvest only when the WWTP is operating satisfactorily (conditionally approved) is not the same as a designated impaired water based on concentrations of materials in the water column. These prohibited and conditionally approved waters would not necessarily have to be designated as impaired and subjected to TMDL requirements. However, these classifications are necessary because of the mere presence of the wastewater treatment plant and outfall. With proper design, operation, maintenance, continuous effluent quality monitoring and alarms to notify of effluent deterioration, a conditionally approved growing area would seldom, if ever need to be closed. The conditionally approved classification would still be needed as recognition that those waters are influenced by operation of the WWTP, and would become contaminated if a malfunction should occur. These conditionally approved waters would not necessarily have to be designated as impaired, however. The conditionally approved waters affected by a WWTP that had relatively frequent breakdowns that required shellfish harvest closures could be difficult to manage and could be designated as impaired; however the conditionally approved area influenced by a WWTP that had very rare breakdowns requiring a closure may not need to be designated as impaired.

3.20 Status of Royal River Above the WWTP Outfall.

The emphasis of the dye study was on the locations and concentrations of the dye in the effluent on ebb tide. Dye readings were not taken in the waters above the outfall on the first day of the study. There is shellfish resource in those waters and there is interest to harvest those waters for depuration. To determine dilution in those upstream waters additional assessment was from a study done previously in 1989 by the Department of Environmental Protection. Dye was continuously fed for 39 hour and 16 min on August 29-30, 1989. The average dye concentration in the outfall was reported to be 310 ppb. The wastewater flow was not shown in the report, although it was done during the anticipated August low flow time of year.

A comparison of the two dye studies are shown in Table 9. The method of fluorometer calibration was not reported for the 1989 study. The quantitative way to calculate the amount of actual dye is the use of 2 Lb of equivalent dry dye per gallon of liquid dye because the Rhodamine WT dye solution is only 20% as dry dye. With use of an approximate specific gravity of 1.2, the amount of dye as dry dye in a gallon is 2.0 lbs/gallon (1.2 x 8.33 x 0.2 = 2). That is the way the August 2002 study was set up and is the standard way for FDA participating studies. Other methods are used. The important consideration is that whatever method is used, the fluorometer is calibrated with the dye used, and that calibrated instrument used in determining dye concentrations in the estuary.

Table 9: Comparisons of 8/29-9/1/89 DEP Study with 8/17-8/22/02 DMR-FDA Study.

Study Period	Dye Feed Duration	Dye Feed Rate	Average Effluent	Amount of Dye	Dye Addition	WWTP Flow	Primary Investigators

	(days)	(ml/min)	Dye Conc. (ppb)	used (gallons)	Location	(MGD)	
8/17-8/22/02	3.10	7.1	1216	8.4	Chlorine Contact Tank	0.56	DMR-FDA
8/29-9/01/89	1.64	9	310	5.6[l]	Manhole after Contact Tank	Unknown	DEP

[l] Calculated.

The dye readings reported in the 1989 study are comparable to what was found in this study report. This indicates that the calibration technique used by DEP may be the same used by FDA, since the dye feed rates are very similar, 7.1 to 9 ml/minute. The low average dye concentration of 310 ppb compared to the 1216 ppb in the 2002 study indicates that there was a considerably higher wastewater flow during that 1989 study. This was not investigated, but the use of the average 310 ppb reported effluent dye concentration was used with dye concentrations found upstream of the outfall on the first high tide after the dye feed was commenced. Dye feed was started about 2 hours before low tide.

The results of that 1989 study as reported for the Royal River above the outfall on the first high tide of the study period are shown in Figure 31. It indicates that effluent is carried upstream. Appendix A, Figure 39 shows that the effluent did travel to the dam on flood tide and the expected dilution is about 310:1. This is as expected.

3.21 Potential Application of the CORMIX Model

The finding of the transition of the effluent from the mouth of the Royal River and its easterly travel and limit of excursion in a southerly direction could not have been assessed with CORMIX model runs. CORMIX is more applicable to situations with definite lateral shoreline restraints or no restraints so the dispersion algorithms could apply. CORMIX would be of limited use in this study for this purpose. However, CORMIX can be used to assess the near field region of initial mixing and to design a retrofit of the outfall pipe with a diffuser which could greatly improve the initial dilution of the outfall pipe. As indicated by Buoy Station 16, the near field mixing region may account for less than a 19:1 dilution. In fact, the CORMIX model was recently used to assess the near field region and determine the increase in both the acute and chronic dilution. As CORMIX is limited primarily to the near field, the far field dilution estimates based on the FDA 2002 dye study were used in conjunction with the CORMIX near field modeling to estimate the increase in dilution attributed to the diffuser.

4.0 CONCLUSIONS

This report attempts to address the original 2002 study objectives stated in the draft report (Carr, 2002) as well as more recent objectives. The 2002 study objectives were to: 1) determine the bacterial conditions that could arise under a short term lapse in treatment and disinfection; 2) determine the steady state bacterial conditions in the shellfish growing waters that could arise in the event of a long term elimination or lapse in disinfection; and 3) assess the possible applicability of the CORMIX computer model for estimating dilutions in this study and other similar study areas. More recently, the DMR also requested that further analysis be conducted to possibly determine the location of a 1000:1 dilution, as well as guidance that can possibly be used to assist the DMR with developing a State policy addressing WWTP discharge closure zones. Additionally, since the 2002 study, the Yarmouth WWTP has retrofitted the single port outfall with a multi-port outfall. Estimates were made to account for the increased initial dilution that may occur with the new diffuser.

This study was conducted during a very low wastewater treatment plant flow period which typically corresponds to the lower river flow periods during the summer months. The 0.56 mgd flow during the dye addition is the lowest recorded for the year. With few exceptions, the 1.4 MGD average flow would be satisfactory to project the study results taken during the 3 day dye addition period to other flows. This would result in overall lower dilutions of effluent. The dilution reduction factor was estimated to be 1.4/0.56 = 2.5 (refer to Section 3.9 for more details). The dilution reduction factor was applied throughout this report to account for the higher WWTP flow periods.

This study was also performed during a small river flow. Higher flows are expected to cause faster travel times and may influence the path of the water as it exits the Royal River. Changes in river flow, however, might be a minimal factor at influencing dilution of the effluent in the Royal River to different values than was found during the study. This is because the amount of river flow compared to the tidal flow is small. Thus, no adjustments were made to account for higher river flow periods (refer to Section 3.8 for more details).

Recently, the Yarmouth WWTP has undergone a retrofit of the outfall from a single port to a multi-port diffuser. According to a 1989 EPA dye study, the MEDEP established dilution ratios of 3:1 for acute and 8:1 for chronic for the single port outfall prior to the upgrades. Based on CORMIX modeling conducted by Wright-Pierce, these dilution ratios could potentially improve to 20:1 and 100:1 for acute and chronic respectively based on the configuration of the multi-port diffuser. Thus, comparing the average dilution ratios (5.5 prior to the upgrades compared with 63.5 after the installation of the diffuser), the improved factor of dilution may be on the order of 11.5 (63.5/5.5). The improved initial dilution as a result of the new diffuser was also considered in the final results (refer to Section 3.10 for more details).

This study determined the extent of the dye travel on the 8/17 ebb tide. The total excursion during the 8/17 ebb tide was about 2.36 nautical miles, including the approximate 1.0 nautical mile from the outfall to the mouth of the Royal River. The excursion time was about 6.2 hours. By assuming an average velocity of 0.38 knots (2.36 nm/6.2 hours), the time from the outfall to the mouth would be estimated as 1.0/2.36 x 6.2 = 2.6 hours. The time to the confluence of the Royal and Cousins River (about Buoy 10) was approximately 1.1/2.36 x 6.2 = 2.9 hours.

In consideration of a short term lapse in disinfection during low WWTP flow periods, fecal coliform counts ranging from 33 – 330 FC/100 ml as far as 0.8 nautical miles from the mouth of the Royal River at the 0.5 ppb contour were estimated for the pre-diffuser situation. However, with the new diffuser operational, these ranges may be potentially reduced by a factor of 11.5 to approximately 3 – 29 FC/100 ml. In consideration of the higher fecal coliform concentrations (1.4×10^6 FC/100 ml) this could then mean that the outer boundary of a conditional area could extend past the 0.5 ppb contour and potentially out to the estimated limit of tidal excursion even with the new diffuser. However, if only the lower values of fecal coliform concentrations are considered which may be more reflective of the Yarmouth WWTP (1.4×10^5 FC/100 ml) the outer boundary of the conditional area could extend to the 1.5 ppb contour (Appendix A, Figure 6A).

In consideration of a short term lapse in disinfection during high WWTP flow periods, fecal coliform counts ranging from 83 – 825 FC/100 ml at the 0.5 ppb contour were estimated for the pre-diffuser situation. However, with the new diffuser operational, these ranges may be potentially reduced by a factor of 11.5 to approximately 7 – 71 FC/100 ml. This would mean that with the diffuser in place and in consideration of the higher fecal coliform concentrations (1.4×10^6 FC/100 ml) this could place the outer boundary of a conditional area past the 0.5 ppb contour and potentially out to the estimated limit of tidal excursion. However, if only the lower values of fecal coliform concentrations are considered which may be more reflective of the Yarmouth WWTP (1.4×10^5 FC/100 ml) the outer boundary of the conditional area could extend just beyond the 1.0 ppb contour (Appendix A, Figure 6A).

At some wastewater treatment plants' effluents in Maine (not Yarmouth), it has been the practice of the Maine Department of Environmental Protection to consider and grant cessation of disinfection during winter months. One of the goals of this study was to determine the impacts of such a practice and to help the Maine Department of Marine Resources (MEDMR) in developing a policy for determining WWTP closure zones. The long duration of the dye injection in this study, in conjunction with the several days of data collection, enabled steady state fecal coliform calculations to be determined for several of the stations monitored in the Royal and Cousins River and offshore waters out to Buoy 1. As several days may be needed for a system to buildup to a steady state condition, concurrent pathogen die-off may also occur and this was accounted for in the calculations for fecal coliforms. Dye study results indicated a significant build-up of dye within the Royal River over the three day injection period (Appendix A, Figures 12-27). As concentrations build, the overall amount of effluent dilution in the river decreases. However, the calculations show that the steady state fecal coliform concentrations are reached very quickly (2 ½ tidal cycles or about 30 hours) with the die-off factors used. The long duration of dye injection in this study in conjunction with the several days of data collection enabled steady state fecal coliform calculations in consideration of the winter time practice of stopping disinfection via chlorination to be determined for several of the stations monitored in the Royal and Cousins River and offshore waters out to Buoy 1. As several days may be needed for a system to buildup to a steady state condition, concurrent pathogen die-off may also occur and this was accounted for in the calculations for fecal coliform. Dye study results indicated a significant build-up of dye within the Royal River over the three day injection period (Appendix A, Figures 12-27). As concentrations build, the overall amount of effluent dilution in the river decreases. However, the calculations show that the steady state fecal coliform concentrations are reached very quickly (2 ½ tidal cycles or about 30 hours) with the die-off factors used.

Estimates for the pre-diffuser situation show impacts from a long term lapse in disinfection or elimination of effluent disinfection may occur in waters past Buoy 1 as steady state fecal coliform concentrations may range from 23-227 FC/100 ml at Buoy 1. Steady state fecal coliform concentrations at Buoy 1 for adjusted higher seasonal WWTP flows may range from 57-567 FC/100 ml. This would mean that the fecal coliform standard of 14 FC/100 ml would be met past Buoy 1 and potentially the full limit of tidal excursion may be needed (Appendix A, Figure 6b). When the increased initial dilution attributed to the new diffuser is considered, steady state fecal coliform at Buoy 1 could range from 2-20 FC/100 ml during low flow periods and range from 5-49 FC/100 ml at high flow periods. If only the lower values of fecal coliform concentrations are considered which may be more reflective of the Yarmouth WWTP (1.4×10^5 FC/100 ml) the fecal coliform standard 14 FC/100 ml would likely be met somewhere between Buoy 4 and Buoy 1. However, these results needed to be taken with caution. The results for Buoy 1 were not maximum concentrations found and thus the overall analysis is considered on the lower side of concentrations as compared to the short term failure analysis which was based on concentration maximums. Data appears to be limited to calculate what the long term impact would be based on maximum concentration values (currently, FDA uses 3-4 in-situ fluorometers which continuously collect data throughout the study period, for days on end if necessary, so that maximum values can be determined). Thus, one should expect that the long term failure results to have a larger impact than the short term failure which is not reflected when using Buoy 1 data. It would be expected that a long term failure would impact past Buoy 1 and potentially out to the full tidal excursion limit.

It should also be noted that in this study, the dye concentration readings on the first day did not demonstrate a normal reduction in dye concentration with distance from the outfall, and it was difficult to estimate a dye concentration at the mouth of the Royal River on low tide, the first day of the study (8/17/02) when the dye feed was commenced at high tide. It was difficult to obtain maximum concentrations near the mouth because of the shallow waters and there was an indication that the effluent remained to the southern part of the River. However, using the maximum dye concentrations found on the first day, the 1000:1 dilution using this approach would place the line somewhere between the 1.0 and 1.5 ppb contour (somewhere between Buoy 4 and Buoy 13) for the first day of the study (Appendix A, Figure 6c)

As demonstrated by the dye measurements from 8/17-8/22, there is a considerable amount of build-up in the system. Dye measurements were shown to increase at all of the buoy stations where dye was measured on subsequent days of dye injection. This indicates that the dye within this region is not completely removed from the system within a single tidal cycle. The portion of dye that remains in the system mixes with the new dye entering the system thus causing the concentrations to rise and build to a steady state maximum. The concentrations at buoys 1 through 16 increase and start to level off after about 2 days of injection towards a steady state maximum. The overall factor of decrease in dilution for buoys 1 through 16 from the initial readings taken on the first day of injection (8/17) to the final readings range from 4.2 to 9.6. When the higher WWTP flows are considered, the overall factor of decrease in dilution could range from 6.7 to 12.1 (refer to Table 5).

When considerations are made to delineate a conditional area based on the 1000:1 and travel time requirements for areas adjacent to WWTP discharges, it is US FDA's recommendation that all available data is used to most accurately determine the placement of the conditional line. The reasoning is that all available data should be used in order to delineate as accurately as possible the conditional area, with the goal of protecting public health from potential viral contamination attributed to shellfish consumption. In this study, the data that was collected to assess the potential practice of ceasing disinfection during the winter months demonstrates significant build-up within the Royal River. As the Yarmouth WWTP operates as a continuous discharge it is expected that the addition of contaminants (such as viruses) are added to the system on a continuous basis. As the dye measurements demonstrated the physical build-up of materials that can occur in this system for continuous discharges of pollutants, then it is expected that the build-up of contaminants (such as viruses) can occur and should be accounted for in the placement of the 1000:1 line if a conditional area is to be considered.

In consideration of the diffuser, the overall factor of increase in initial dilution may approximately be 11.5 (refer to Section 3.10). Although the diffuser will increase the amount of initial dilution, this factor is equally offset when higher WWTP flows and pollutant build-up effects are considered in a worst case delineation of the 1000:1 line. Thus, under worst case scenarios in consideration of higher WWTP flows and considering the significant build-up within the river, the worst case 1000:1 line should still be placed somewhere between Buoy 4 and Buoy 13, coincidently, the same location as found for the first day of the study under low WWTP flow conditions and no considerations of build-up.

At the request of MEDMR, this report provides an analysis of dilution based on dye concentrations on the first day of the dye injection. This analysis does not consider build up within the river, which the US FDA feels is imperative. When considering the diffuser and higher WWTP flows, which were not reflected in the original study, and when build-up within the river is not considered, a determination of the location of the 1000:1 reflective of an ebb tide dye release is not possible due to the difficulties in obtaining maximum dye concentration readings in the Royal River due to the shallow depths. Thus, a comparison between the two situations, i.e. the impact on a single tide versus impact over a several day period after which a build-up reaches a maximum, could not be achieved.

Notification time is also a crucial consideration in the management plan for the operation of a conditional area. It is estimated that for the low flow WWTP conditions, the travel time from the outfall to the mouth is about 2.6 hours. These times could even be less under higher river flows. However, even if the response time could match these short travel times, the 1000:1 dilution would need to be met. As demonstrated on the first dye of release, the 1000:1 dilution is not met at the mouth of the Royal River but much further down the bay as far as in the vicinity between the 1.0 and 1.5 ppb contour. Even if we consider the increased initial dilution from the new diffuser. This increased factor of initial dilution is equally offset if the high WWTP flows along with the significant factor of build-up that can occur in the Royal River are considered. Thus, in this situation, it appears that the 1000:1 dilution determination would be the controlling factor in establishing a conditional area.

Finally, the use of the CORMIX model would not be universally applicable to this situation for determining far field dilution for the Yarmouth WWTP outfall. It could not be relied on to define the change in flow characteristics as the effluent exited the Royal River and entered the bay, nor to determine the path of the dye as was done during the dye study. However, CORMIX could be applied and was applied to evaluate the overall factor of an increase in initial dilution as a result of the WWTP upgrades from a single port outfall to a multi-port effluent diffuser.

5.0 FOLLOW-UP STUDY

A follow-up hydrographic study of the Yarmouth, ME WWTP, which will aim to address some of the issues and problems raised during the 2002 study and to more closely examine recent developments, such as the installation of the multi-port diffuser, is currently planned for May 2010. An analysis will be done of both the initial dye concentrations and the steady state dye concentrations, which, based on the 2002 study, may potentially be seen after approximately 30 hours of dye build-up in the area of the Royal River. This study will also attempt to coordinate dye concentrations with the results of microbiological testing of oysters placed at strategic locations, such as the mouth of the Royal River, the Cousins River, and the 0.5, 1.0, and 1.5 contour lines, for the purpose of assessing viral impacts from the WWTP on the area. The primary goal of the study will be to attempt to locate a 1000:1 dilution line, as well as to determine the time of travel/notification time, for the establishment of a conditional area.

The proposed May 2010 study will take place during a time period of typically higher WWTP flow rates relative to other times of the year. Higher WWTP flow rates better reflect worst-case conditions, as the calculated dilution values in the estuary will be less compared to periods of low WWTP flow rates. As previously indicated, adjustments to the 2002 results were made to account for the lower WWTP flow rates in an attempt to predict dilutions under higher WWTP flow rates/worst case time periods. The low river flows encountered during the 2002 study (conducted in August) were not considered to be a major factor requiring adjustments in the calculations. However, as noted previously, higher river flows are expected to cause faster travel times and may influence the path of the water as it exits the Royal River. Performing the follow-up study in the spring will allow for a better assessment of the worst-case river flow conditions with respect to potentially shorter travel times. Thus, notification time will also be re-examined to account for the new factors/worst-case conditions such as the higher river and WWTP flows typically found in the spring and the installation of the multi-port diffuser. Efforts to decrease the notification time, such as the installation of new monitoring equipment, will be discussed with the Yarmouth WWTP. The eventual placement of a conditional area will need to account for not only a minimum of a 1000:1 dilution, but also allow for an adequate notification time to properly manage the conditional area.

The 2002 study indicated that there may be impacts from the effluent on the Cousins River and the area north of Lane's Island on flooding tides. This study will attempt to determine what those impacts are.

The objectives of the original 2002 study focused on bacterial conditions in the event of a short-term lapse of disinfection due to a malfunction or long-term elimination of disinfection, such as suspending disinfection during the winter months, which is a procedure practiced by some treatment plants in Maine other than Yarmouth. In consideration of a short-term lapse in disinfection for both low and high WWTP flows, an analysis was conducted in this report of the higher and lower fecal coliform values. The higher concentrations are typically what have been reported in the literature for treated undisinfected effluent and the lower concentrations were based on a series of samples of undisinfected effluent collected from the Yarmouth plant. For the higher fecal coliform concentrations (1.4×10^6 FC/100 ml), it was determined that the mean outer boundary of a conditional area could extend past the 0.5 ppb contour and potentially out to the estimated limit of tidal excursion,. However, if only the lower values of fecal coliform concentrations were considered (1.4×10^5 FC/100 ml), the outer boundary of the conditional area could extend to the 1.5 ppb contour. Additional testing will be done in the follow up study in order to better estimate the worse case levels of fecal coliforms concentration in the effluent.

More recently, FDA has conducted studies assessing viral pathogens in conjunction with hydrographic dye studies in support of the development of FDA's guidance and recommendations to determine appropriately sized prohibited closure zones based on the minimum criteria established under part IV. @ .03 E(5)(b)(i) of the National Shellfish Sanitation Program (NSSP) Model Ordinance (Section E. Prohibited Classification), which includes such critical factors as the dispersion and dilution of the wastewater effluent within the growing area and the time of waste transport to the area where shellstock may be harvested. The objective of FDA guidance and recommendations for classifying and managing shellfish growing areas is to minimize the risk posed by sources of anthropogenic pollution, and since 1925, this has been most reliably and uniformly achieved by adequate dilution of the bacterial and viral pathogens intermittently present in fecal wastes and treated wastewater effluents. Thus, in addition to an analysis of fecal coliform concentrations, oysters will be placed in cages at important locations within the anticipated path of the effluent, such as the mouth of the Royal River, the Cousins River, and the 0.5, 1.0, and 1.5 contour lines. These oysters will be tested for concentrations of male specific coliphage (a viral indicator) and viral accumulation in conjunction with the dye study. The additional sampling for viral indicators and viral pathogens will further FDA's knowledge and understanding of viral impacts to shellfish growing waters towards the development of guidance and recommendations, but more specifically will provide insight towards the proper placement of a conditional closure area near the Yarmouth WWTP, which is the primary goal of the May 2010 study.

Signature Record – Review and Approval of Hydrographic Study of Yarmouth Maine Waste Water Treatment Plant Effluent:

Name: Gregory Goblick, Senior Engineer
Agency/Department: USFDA/CFSAN

Signature and Date: Gregory Goblick 5/6/2010

Name: Julie Mayer, Consumer Safety Officer
Agency/Department: USFDA/CFSAN

Signature and Date: Julie N. Mayer 5/6/2010

Name:
Agency/Department:

Signature and Date:________________________________

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Appendix A

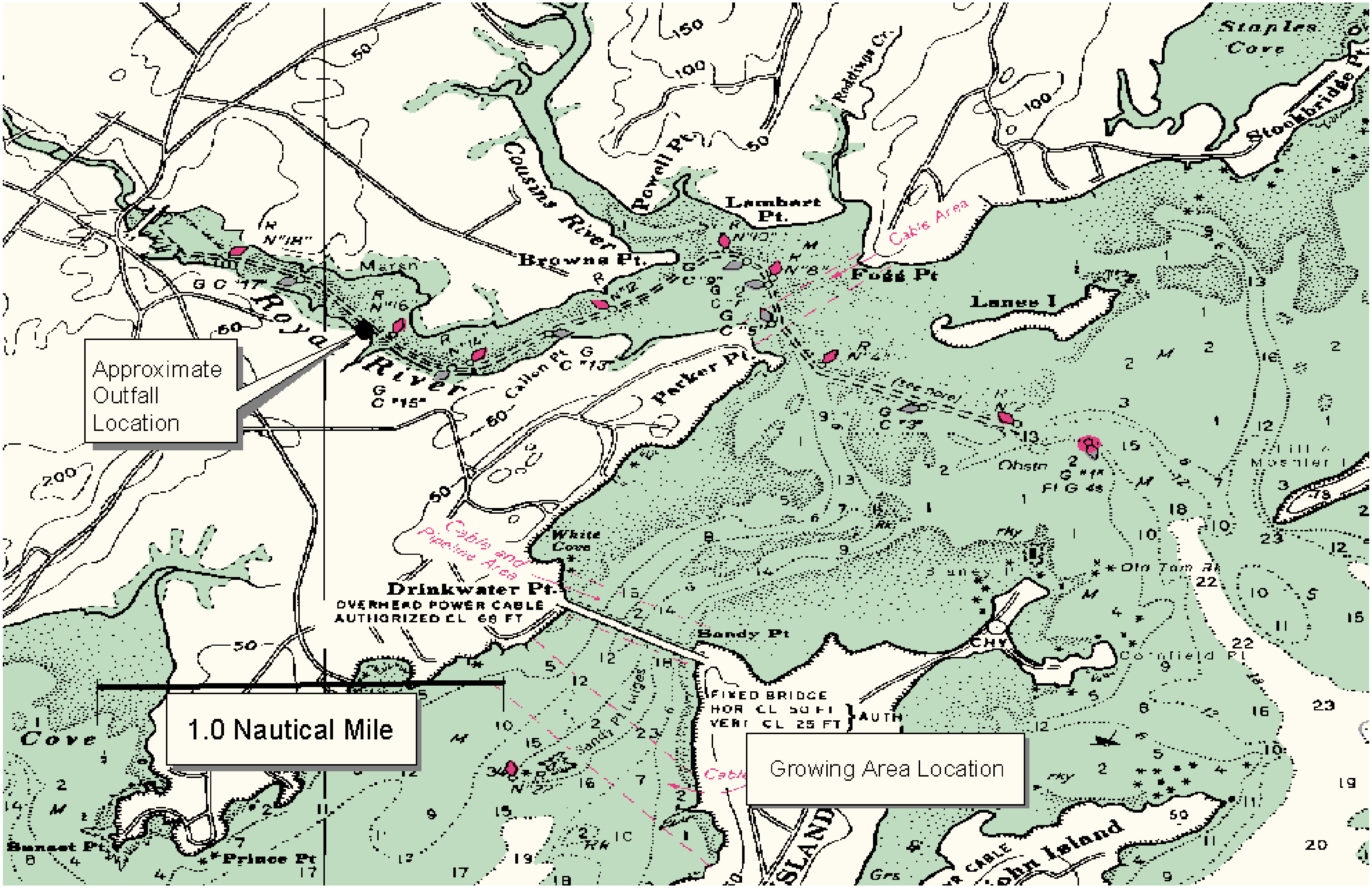


Figure 1: Growing Area Location and Outfall Location

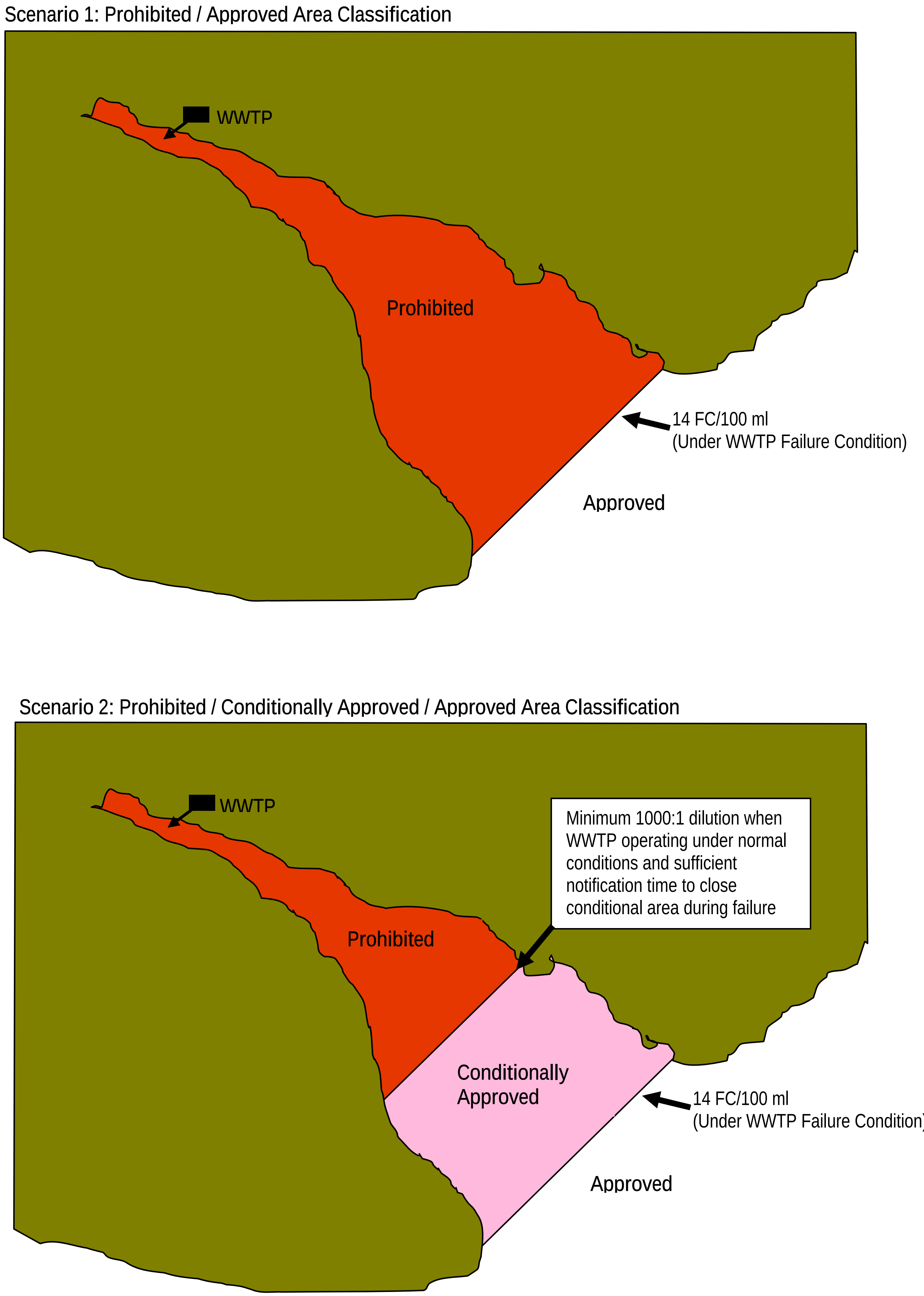


Figure 2: Scenarios for Sizing Prohibitive Buffer Zones

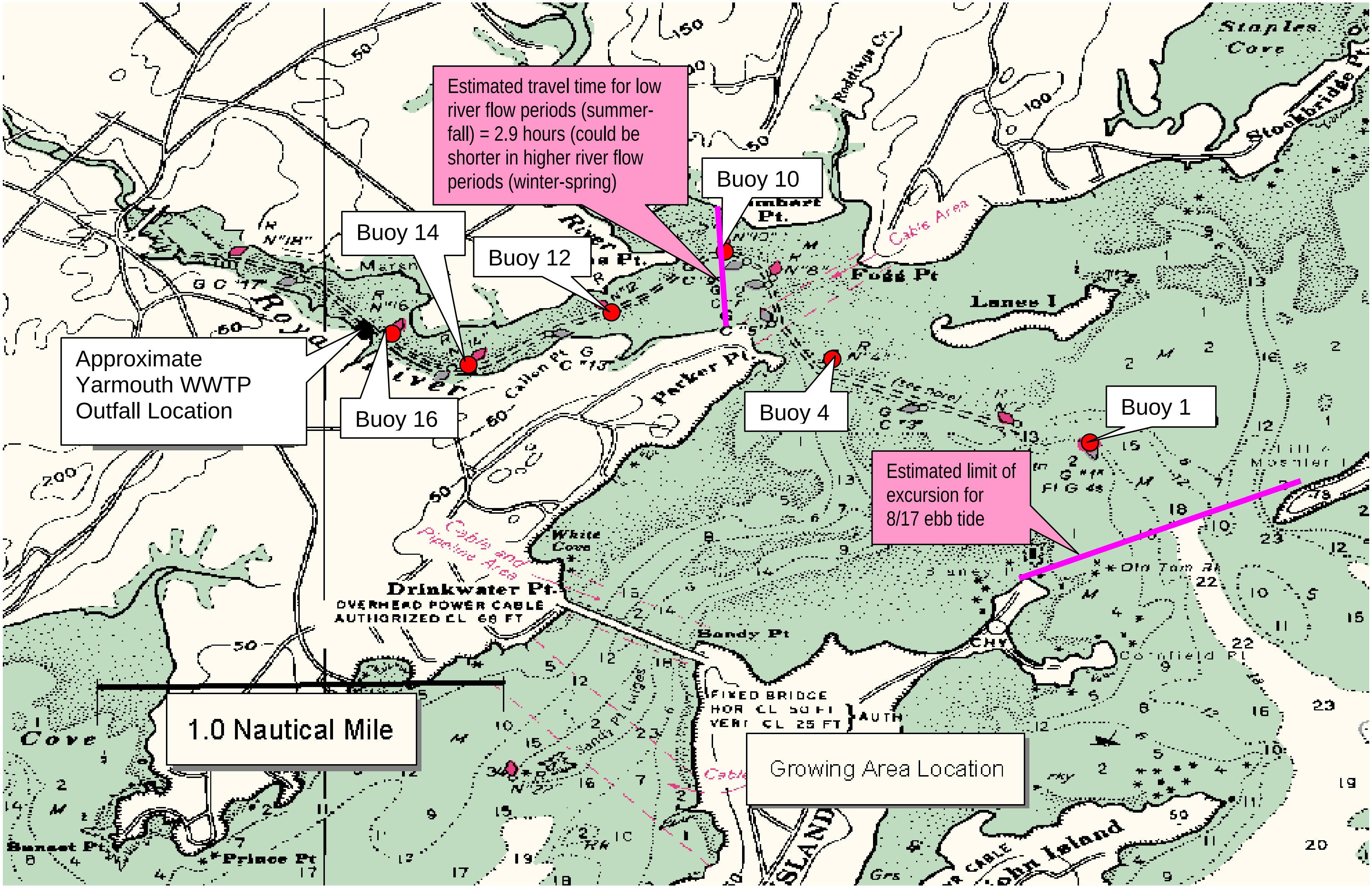


Figure 3: Estimated Travel Time to Confluence of Royal River and Cousins River and Ebb Tide Limit of Excursion (Low River Flow)

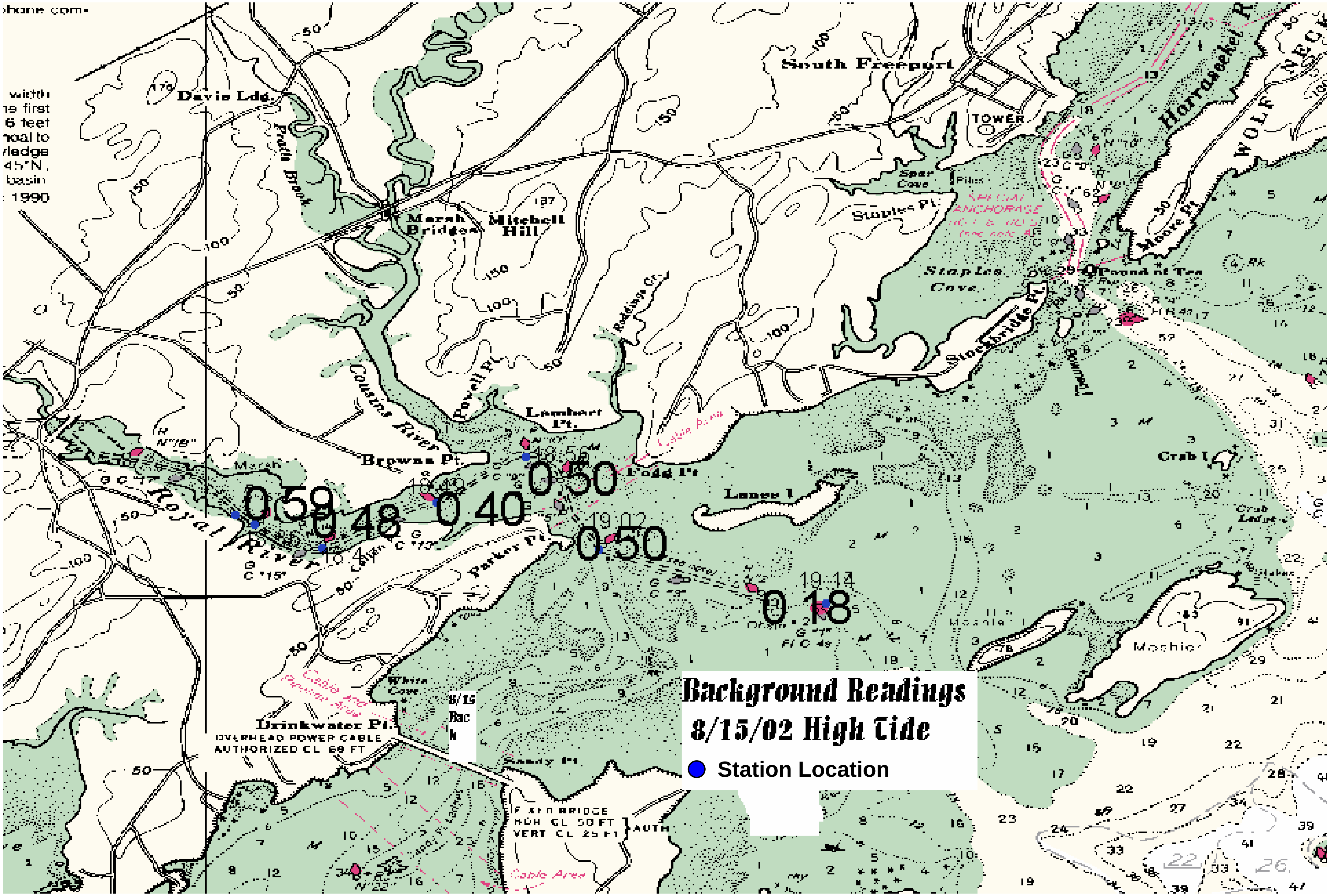


Figure 4: Background at High Tide (8/15/02)

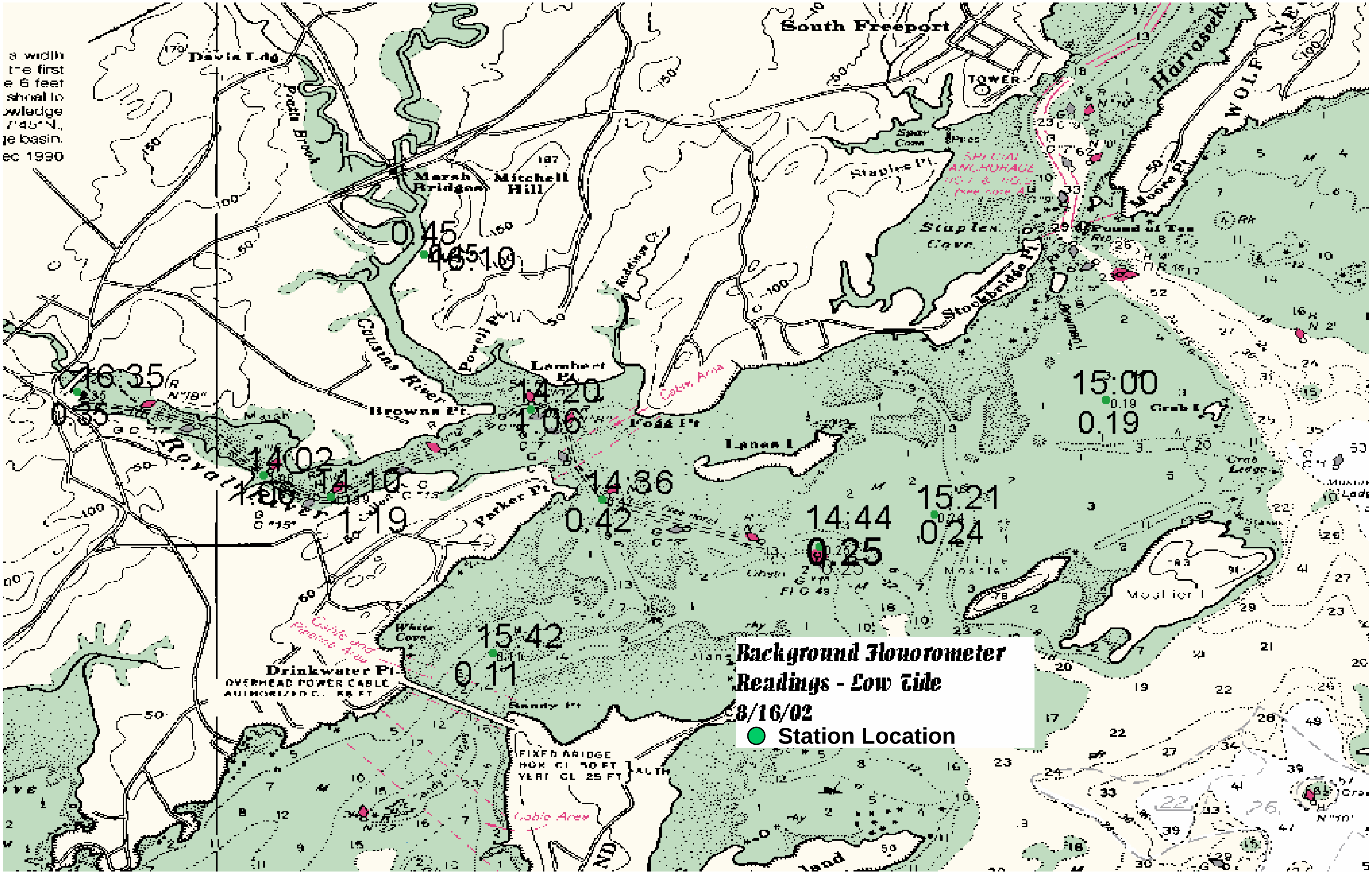


Figure 5: Background at Low Tide (8/16/02)

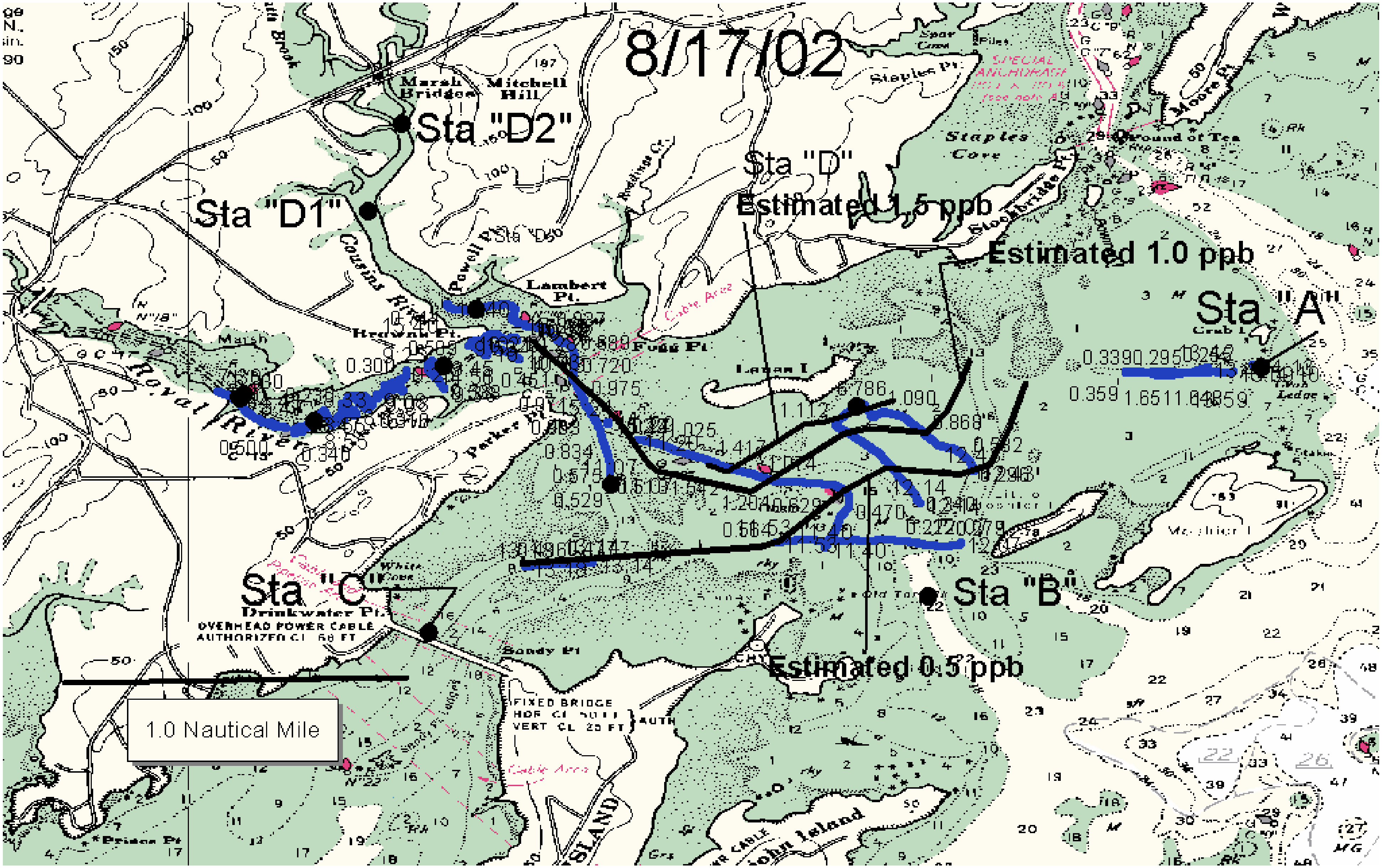


Figure 6: Traverses and Fluorometer Readings (8/17/02)

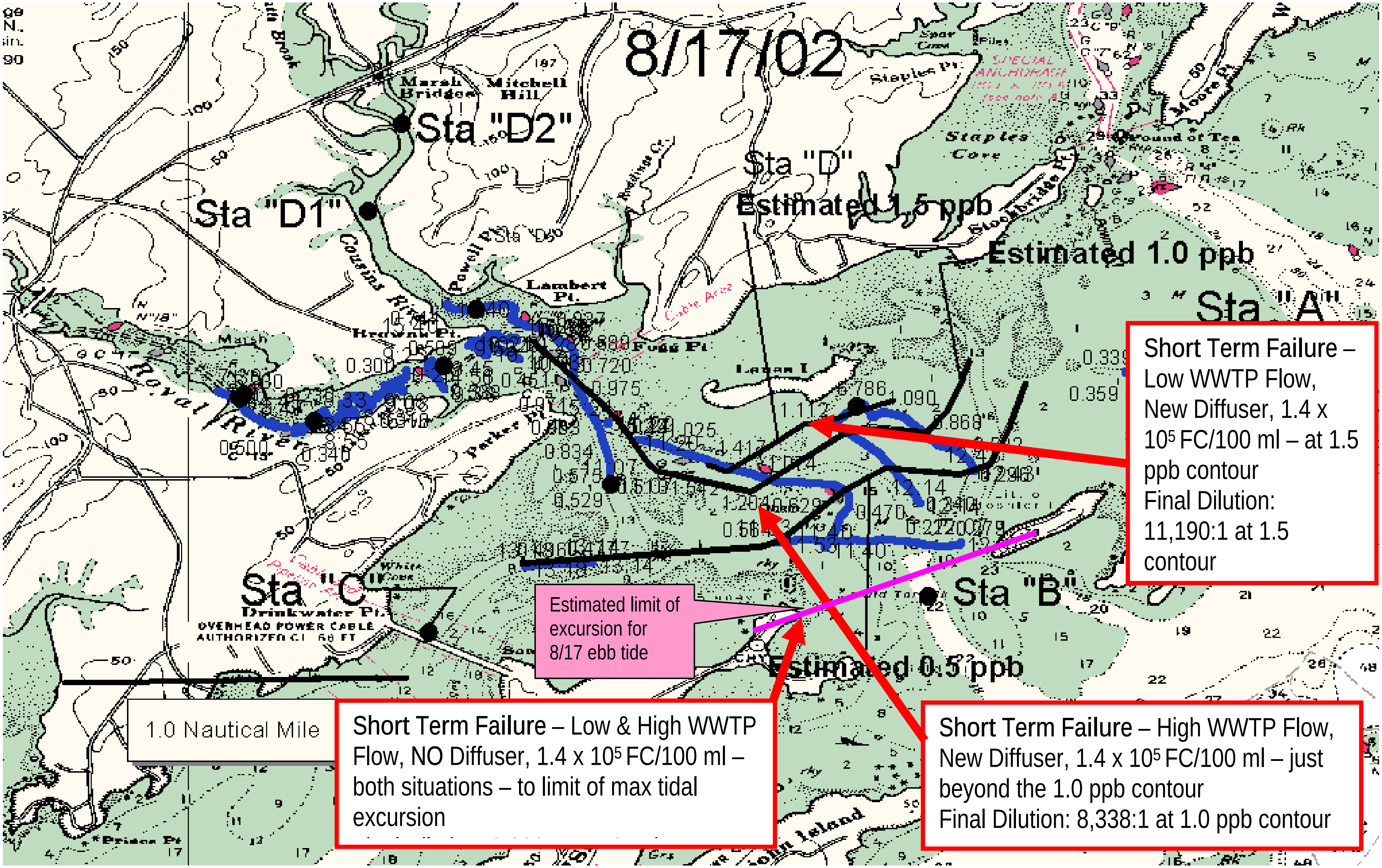


Figure 6a: Short Term Failure Considerations

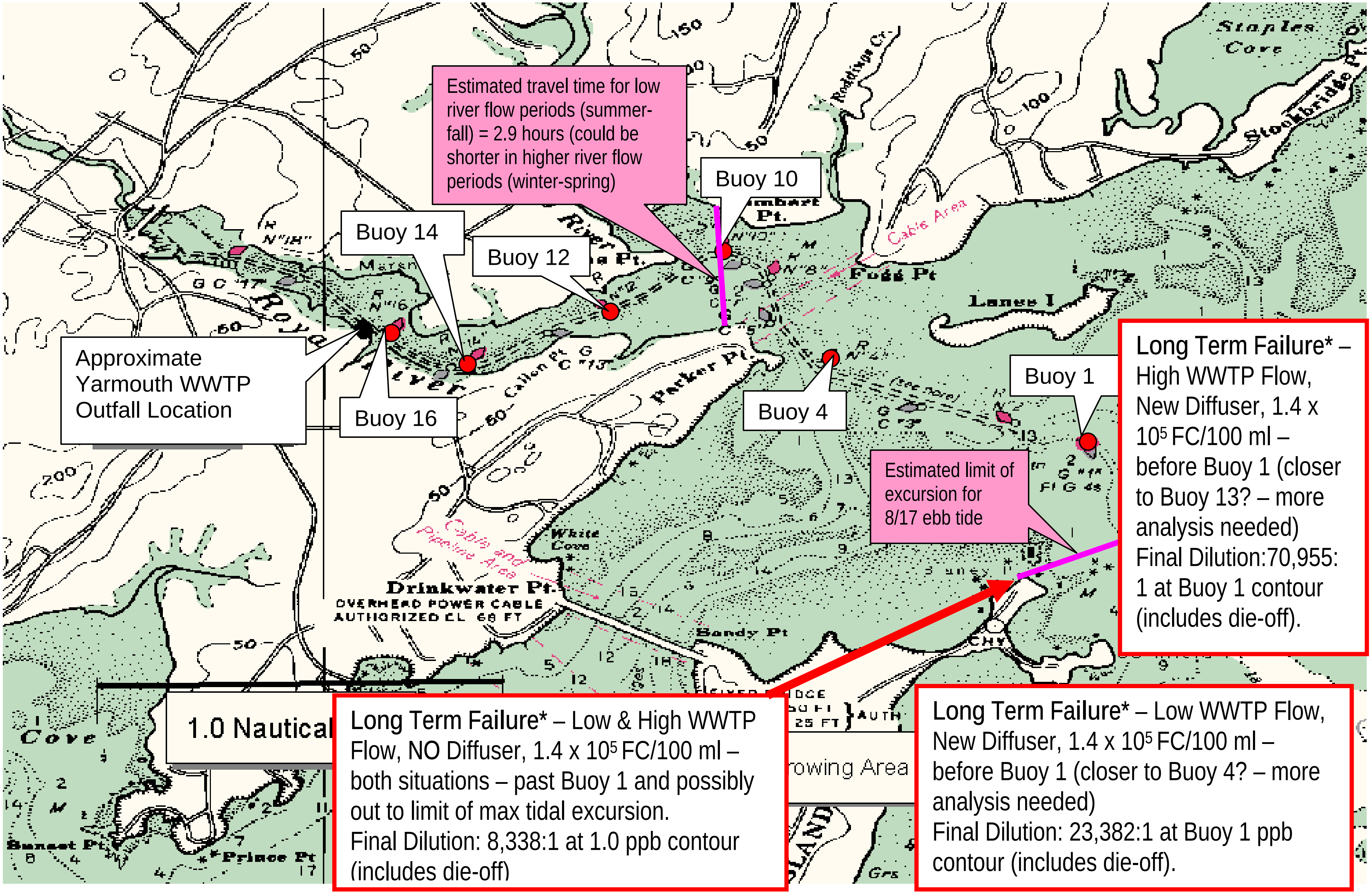


Figure 6b: Long Term Failure Considerations

*** NOTE: Buoy 1 may not represent the highest concentrations found and thus this skews the results on the low side in comparison to the short term failure calculations which are based on the highest concentrations found. It would be expected that the long term failure conditions be worse than the short term and so using Buoy 1 for determining the long term impact may not accurately reflect this.**

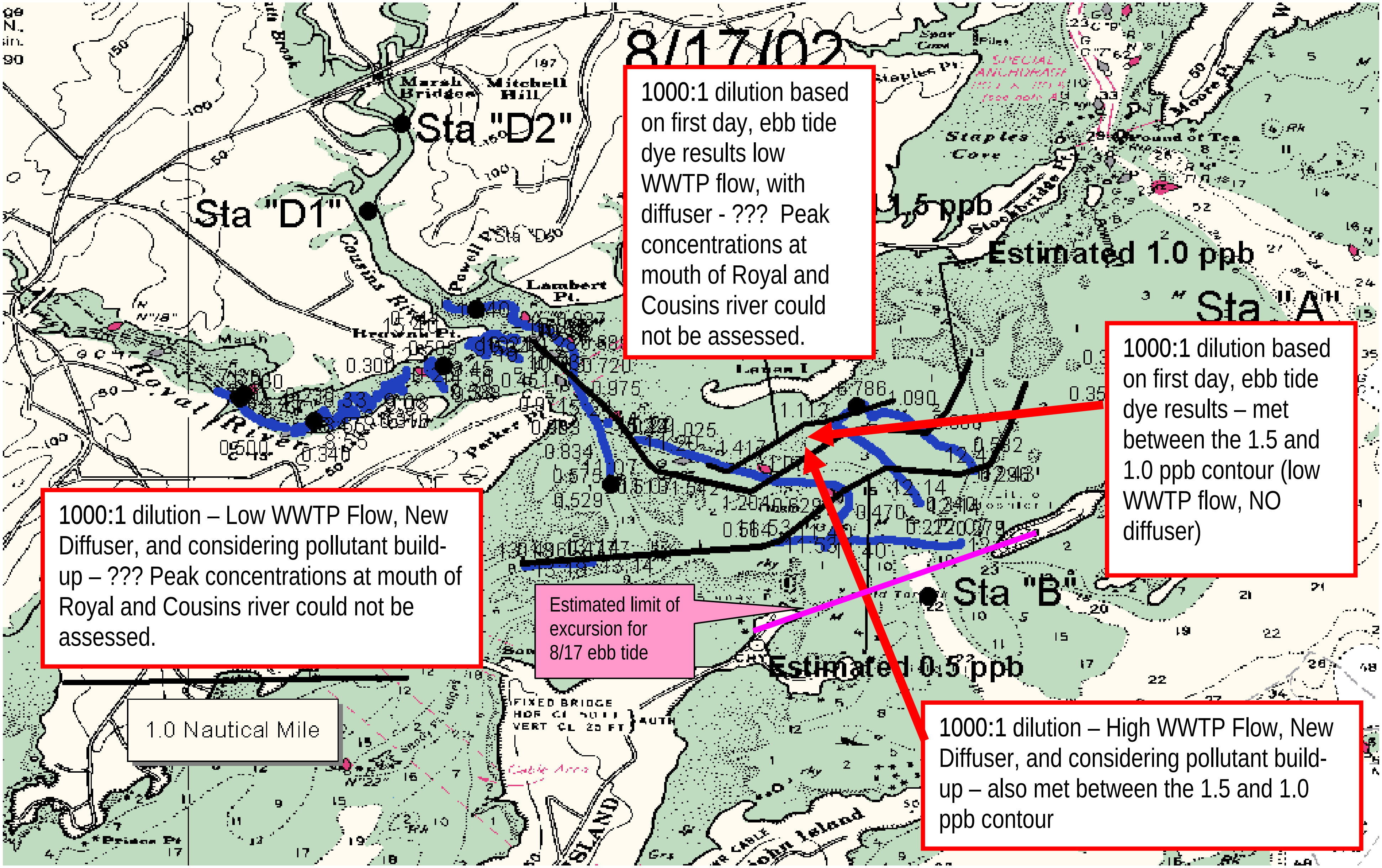


Figure 6c: 1000:1 Considerations

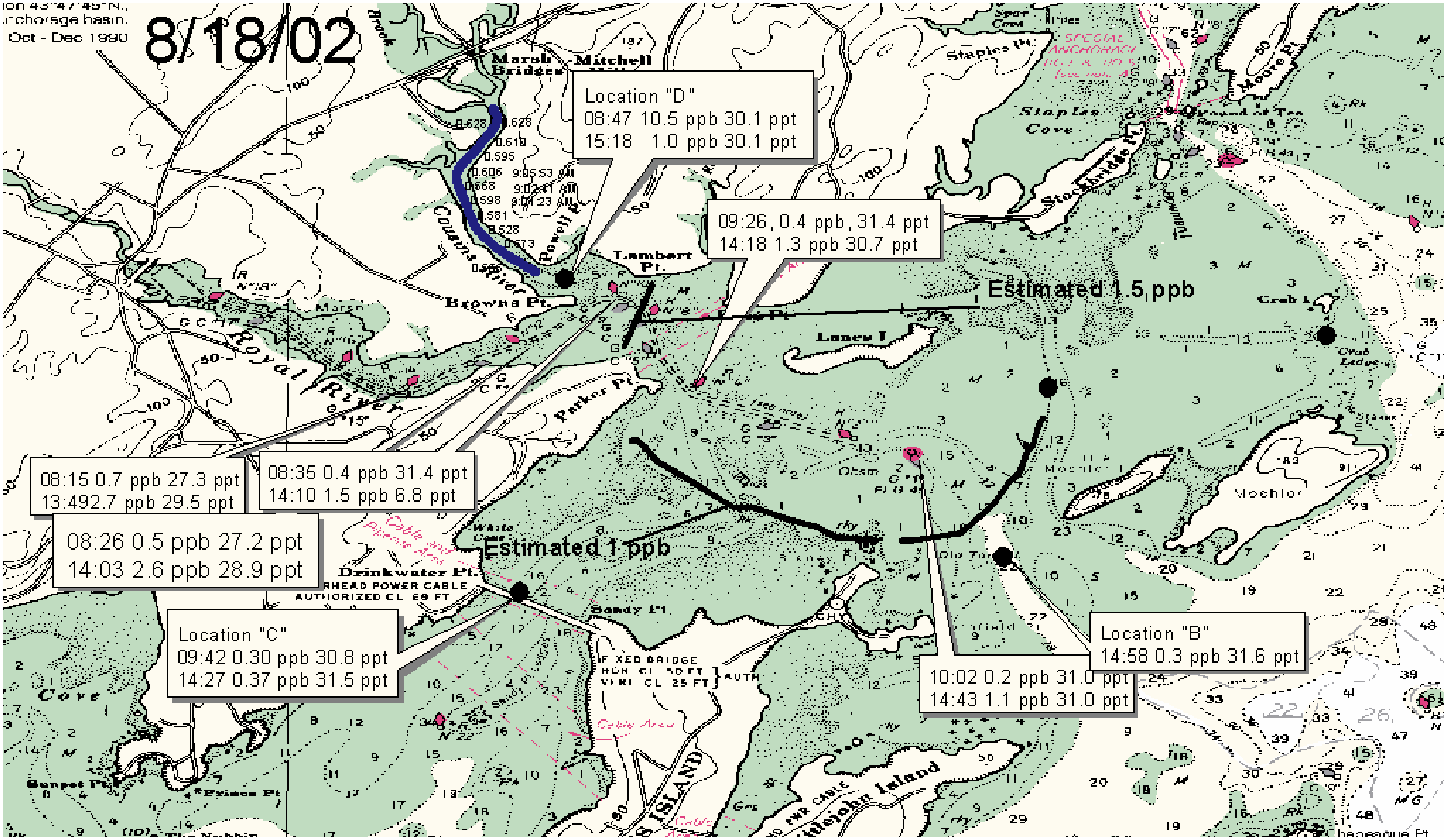


Figure 7: Traverses and Fluorometer Readings (8/18/02)

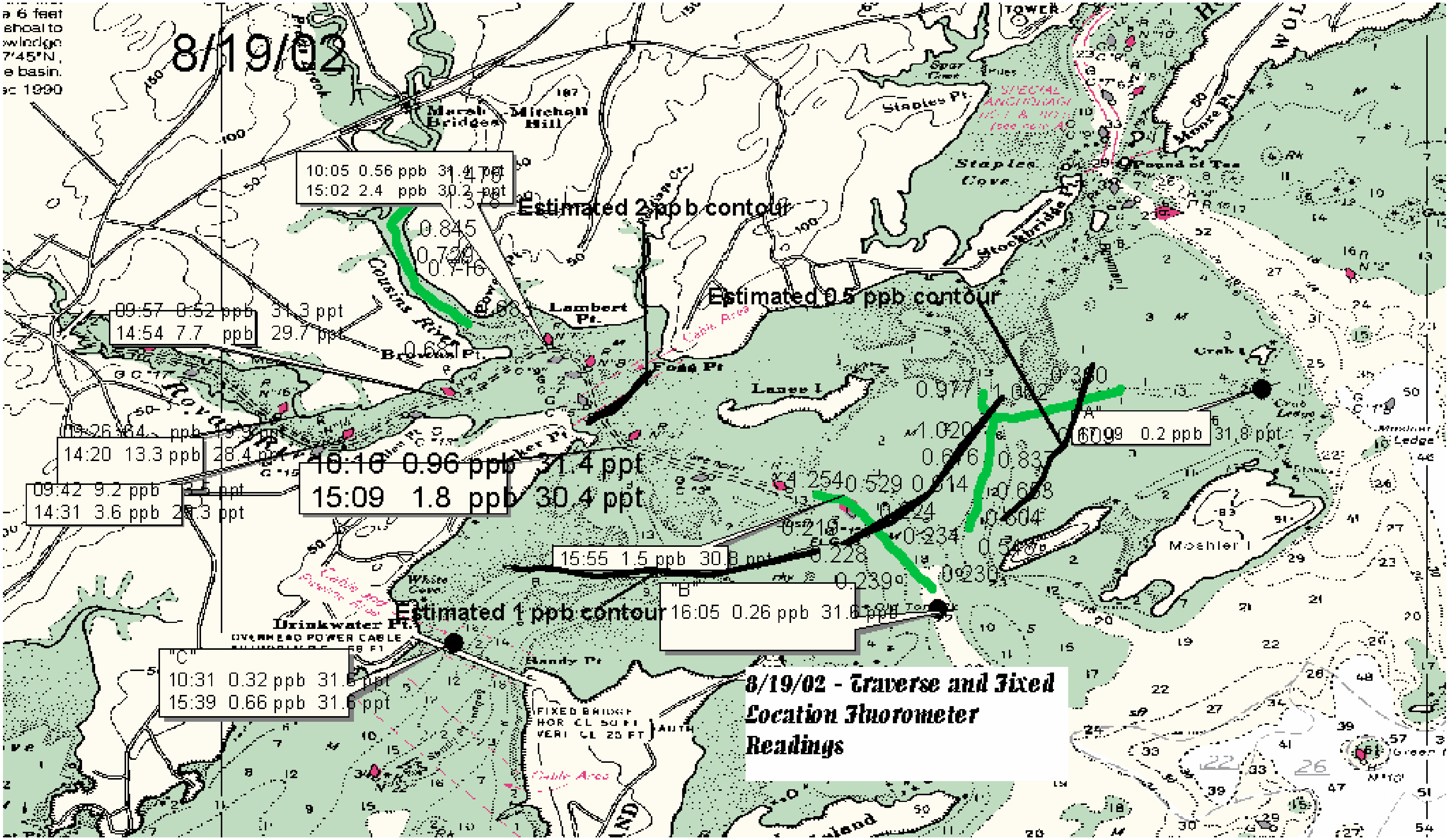


Figure 8: Traverses and Fluorometer Readings (8/19/02)

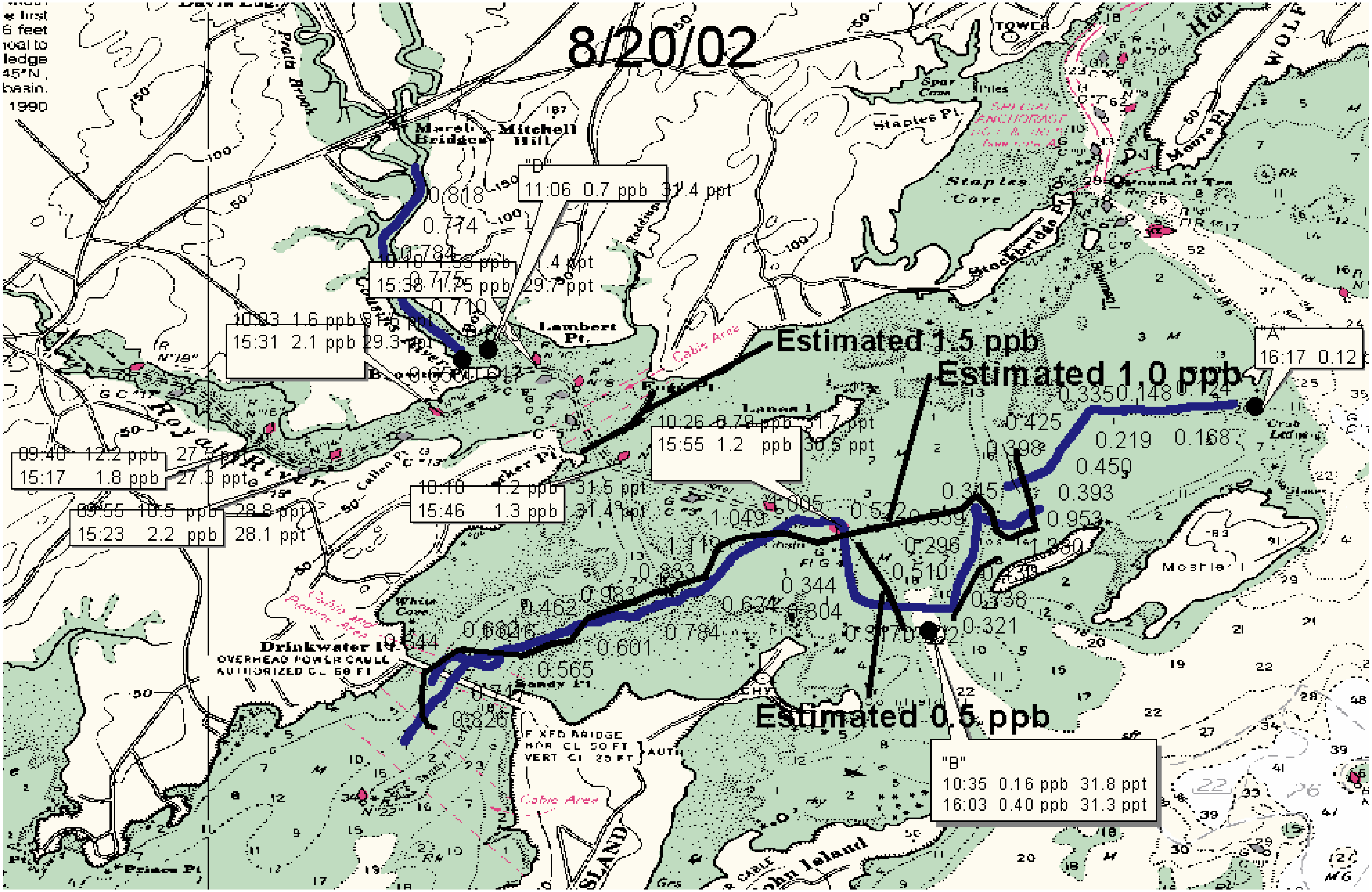


Figure 9: Traverses and Fluorometer Readings (8/20/02)

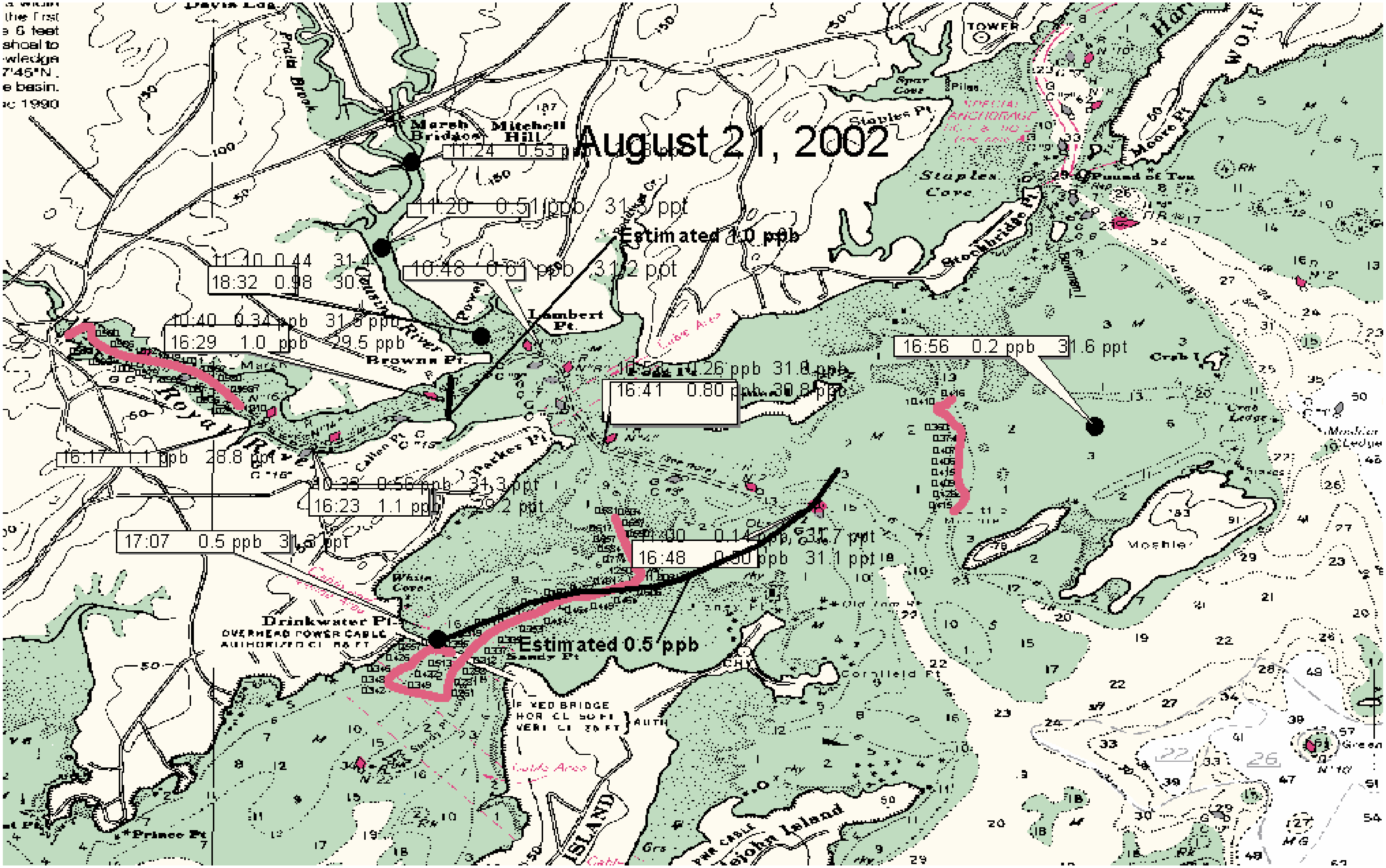


Figure 10: Traverses and Fluorometer Readings (8/21/02)

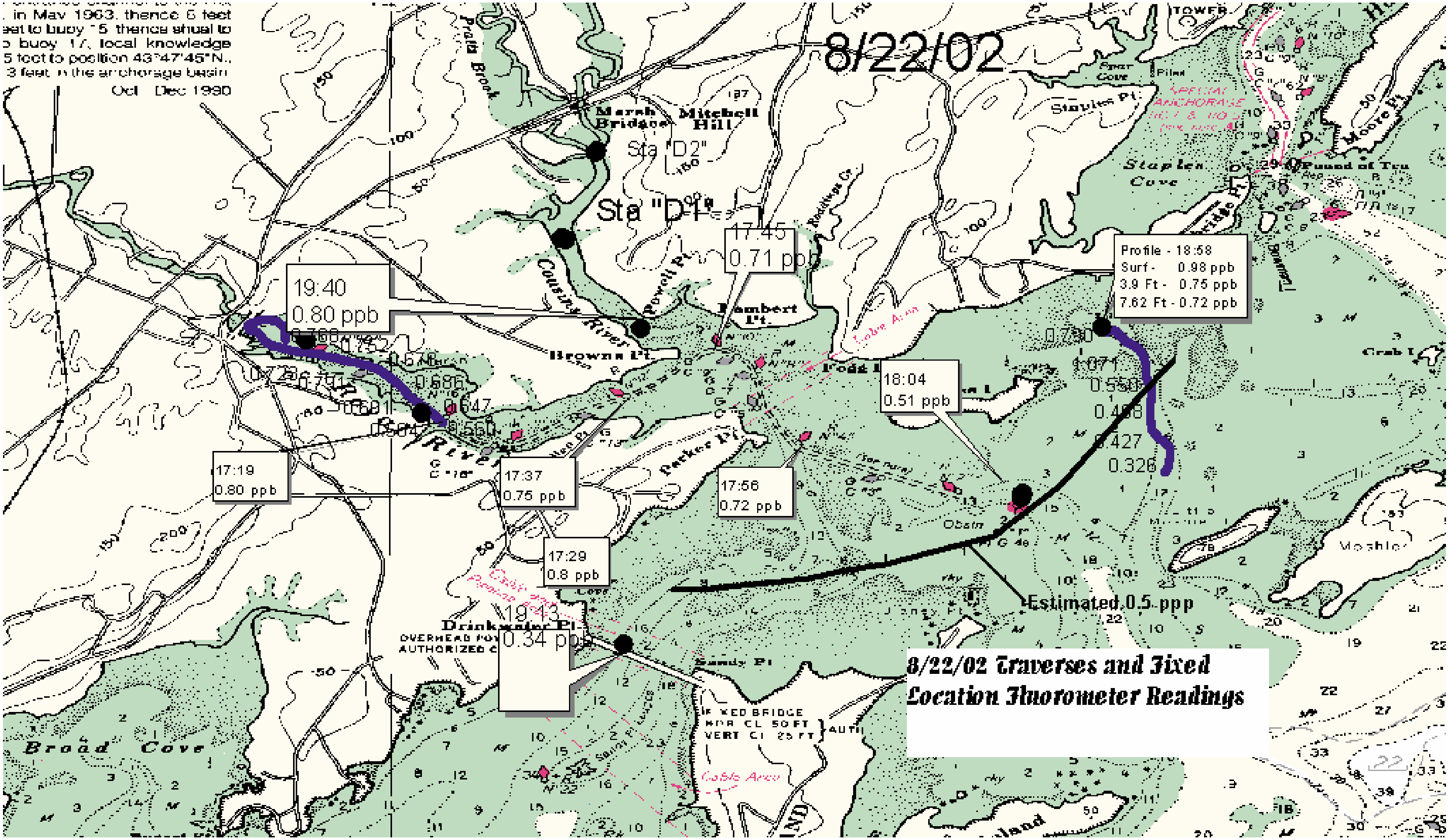
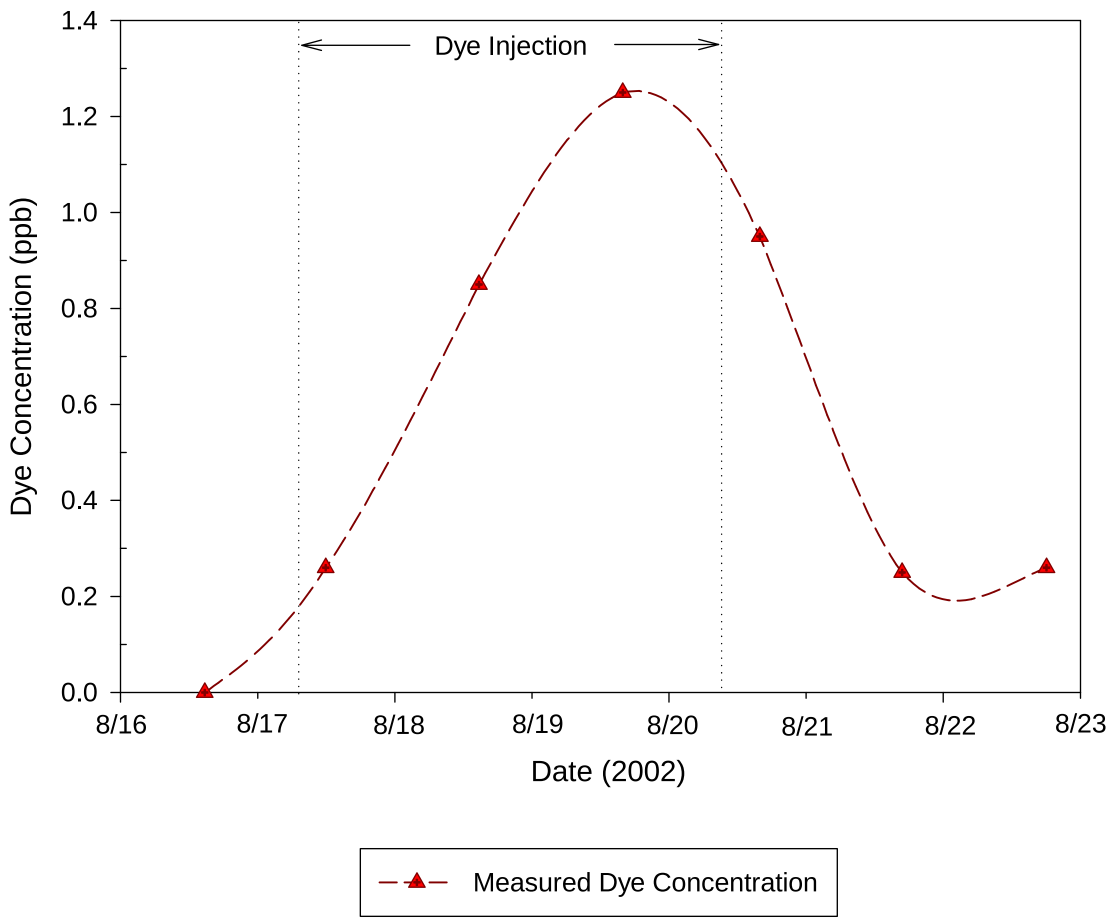
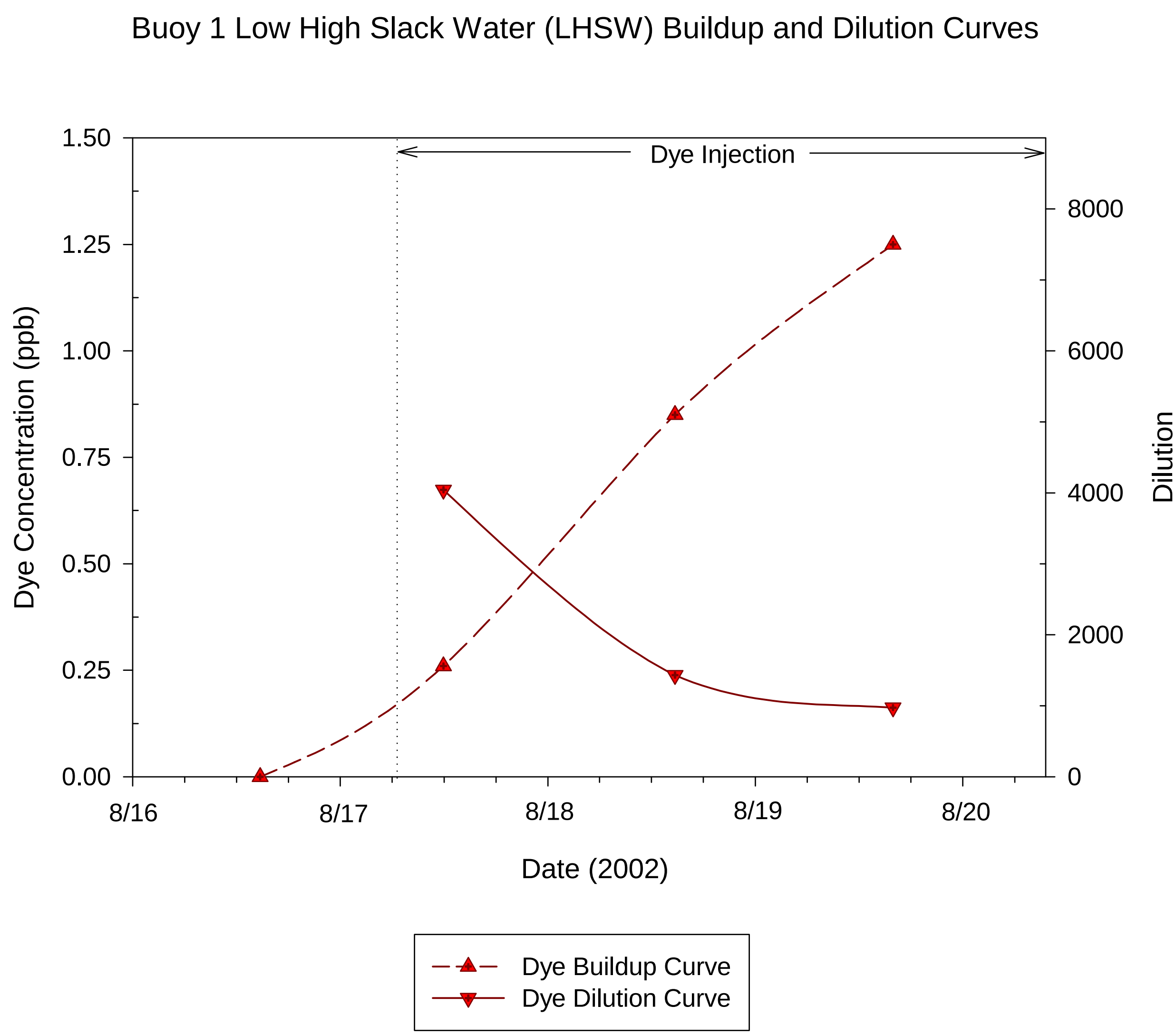


Figure 11: Traverses and Fluorometer Readings (8/22/02)

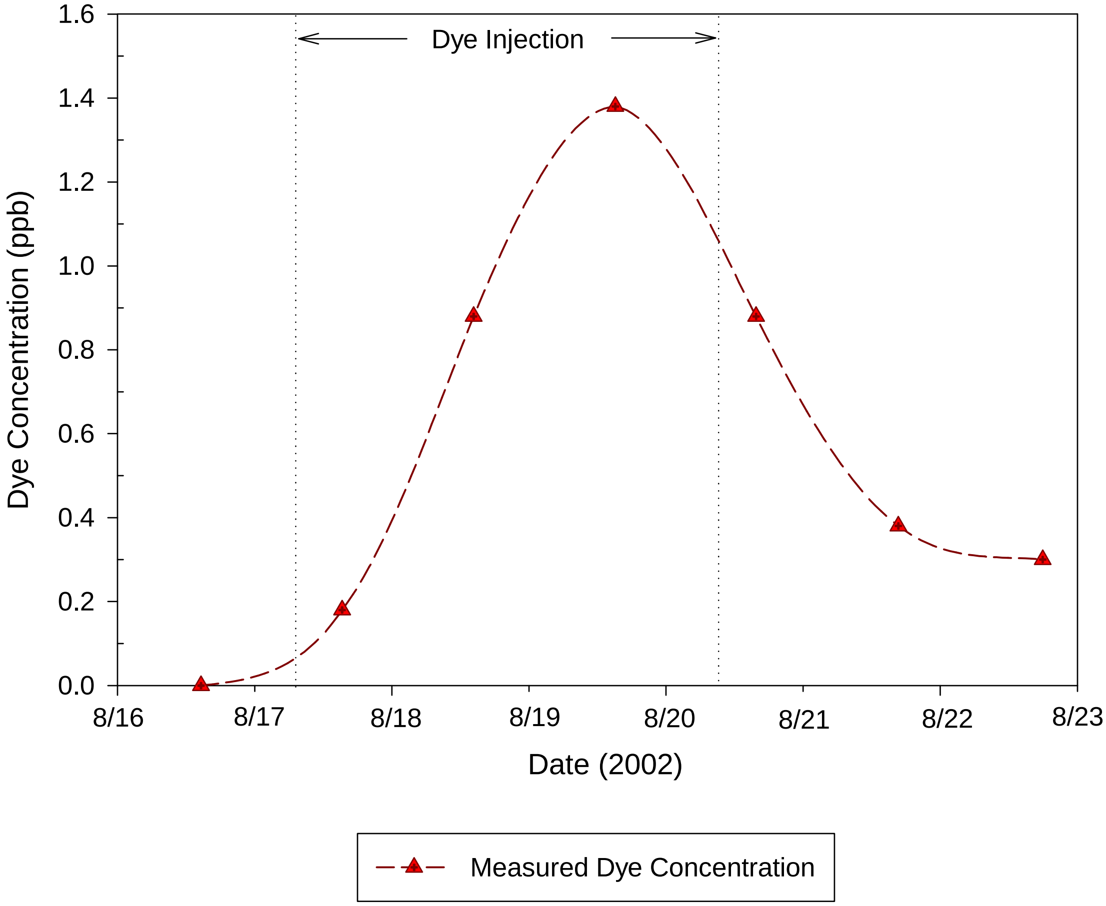
Buoy 1 Low High Slack Water (LHSW) Dye Concentrations



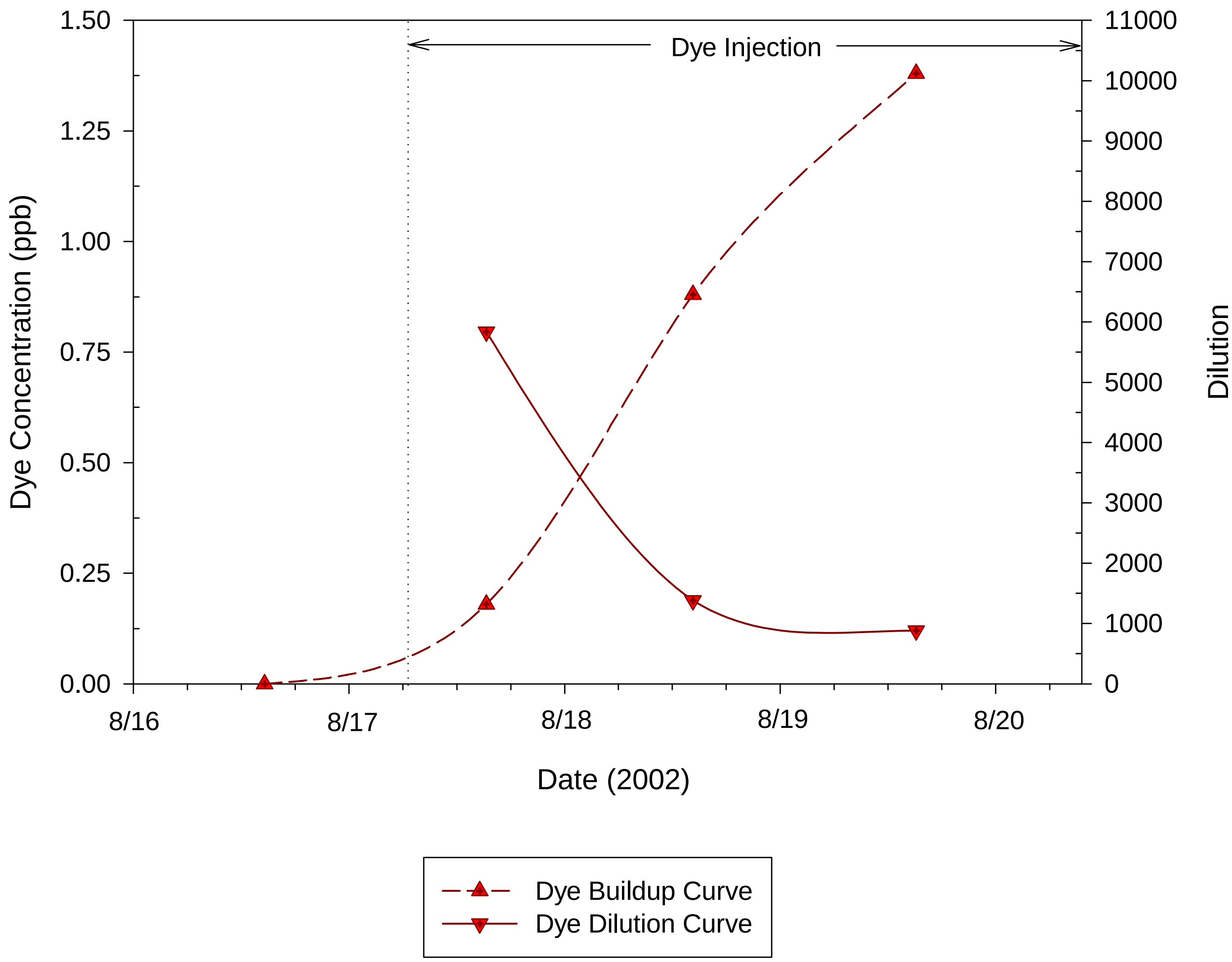


Buoy 1 Low High Slack Water (LHSW) Buildup and Dilution Curves
Dye Injection
1.50
1.25
1.00
0.75
0.50
0.25
0.00
Dye Concentration (ppb)
8000
6000
4000
2000
0
Dilution
8/16
8/17
8/18
8/19
8/20
Date (2002)
Dye Buildup Curve
Dye Dilution Curve

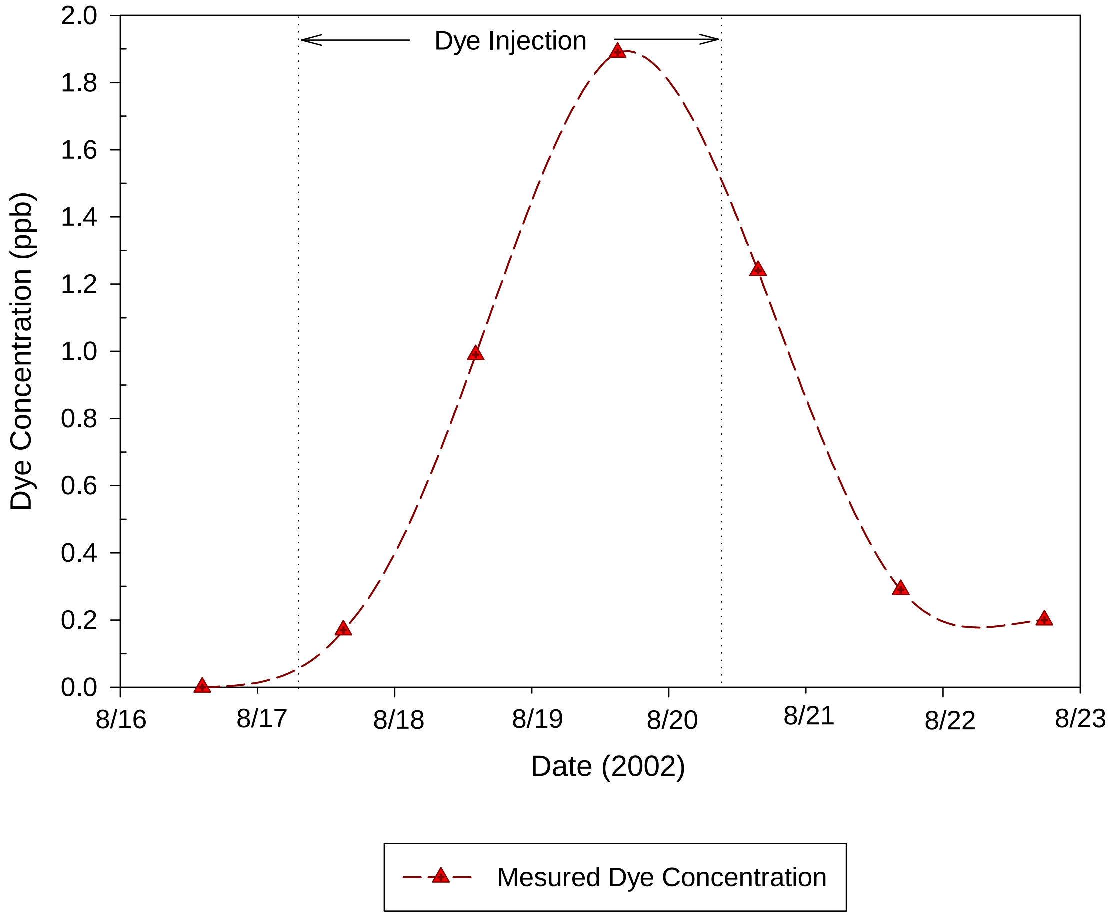
Buoy 4 Low High Slack Water (LHSW) Dye Concentrations



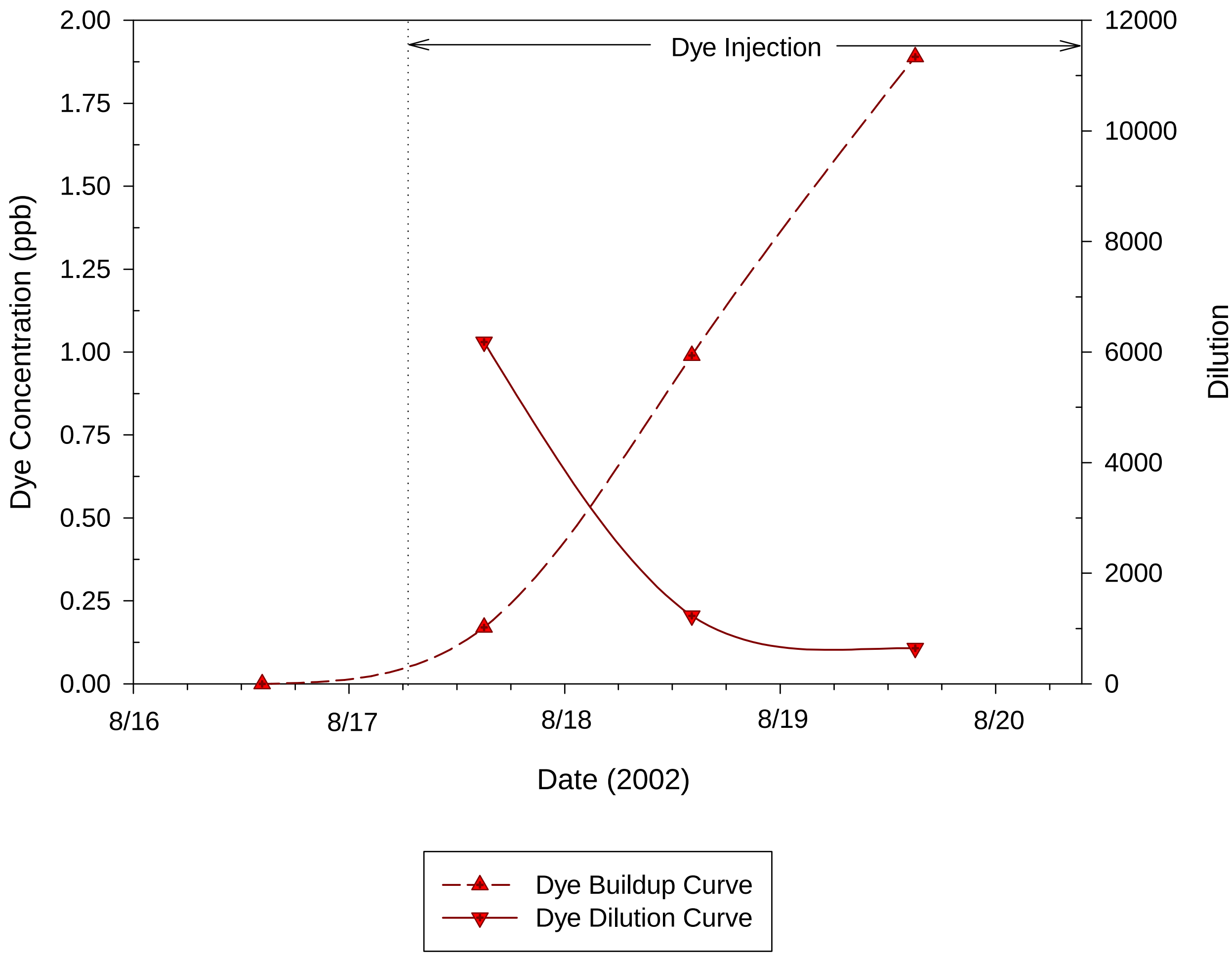
Buoy 4 Low High Slack Water (LHSW) Buildup and Dilution Curves



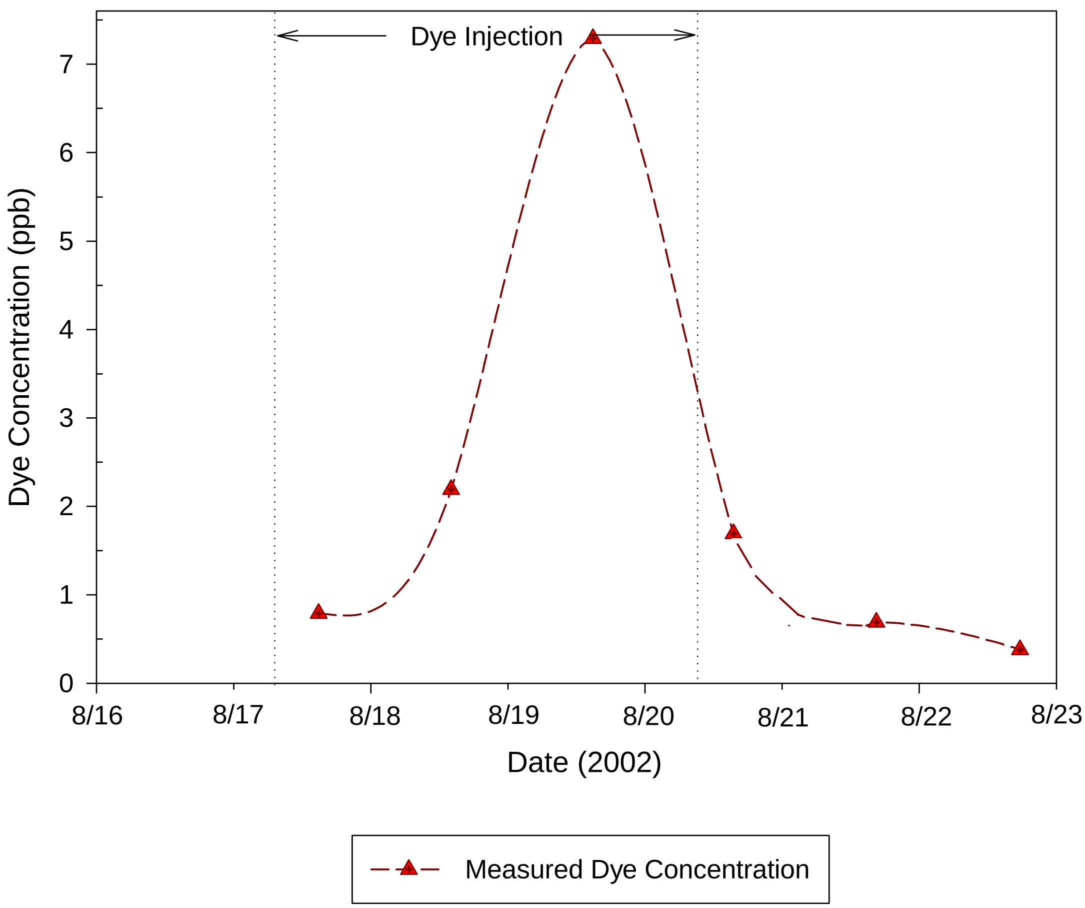
Buoy 10 Low High Slack Water (LHSW) Dye Concentrations



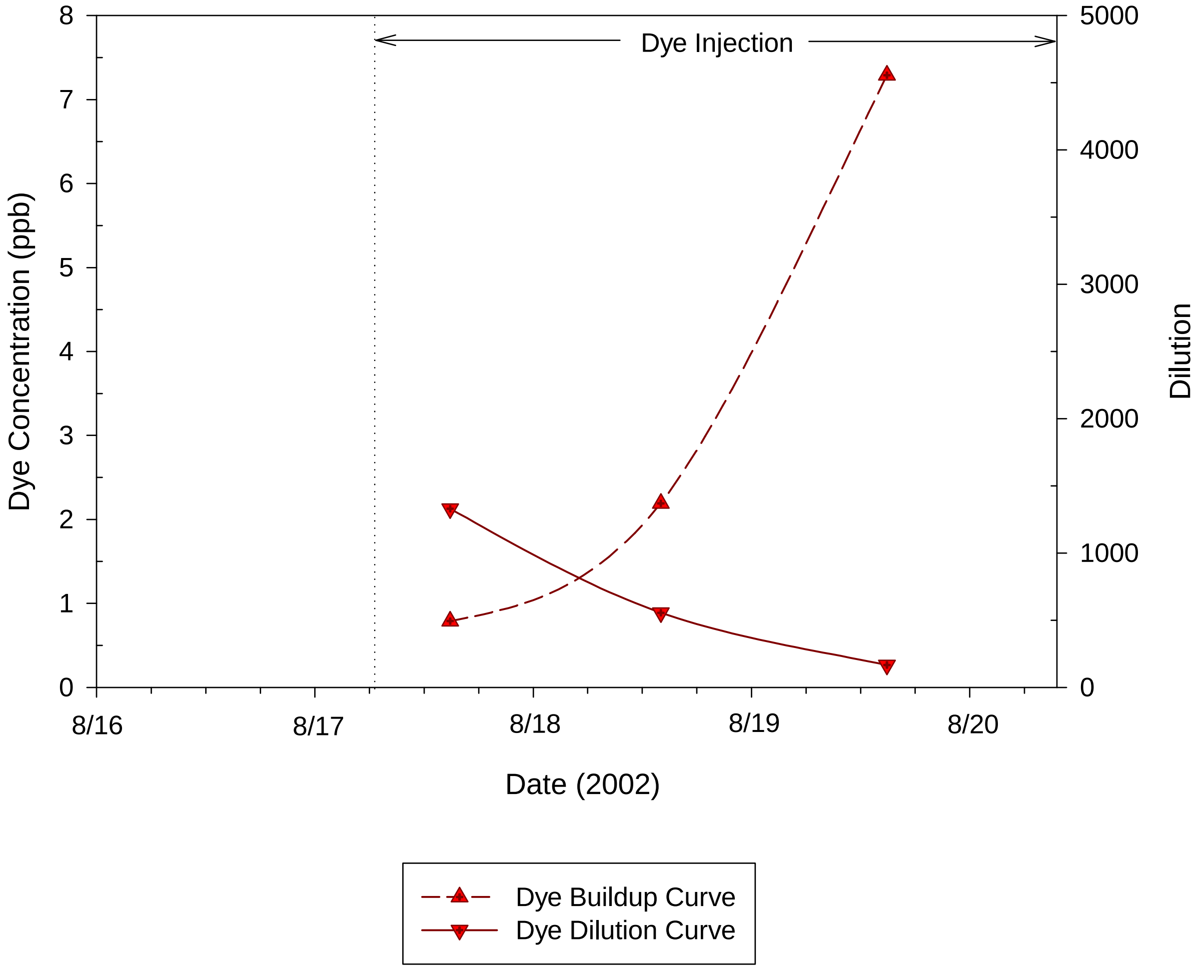
Buoy 10 Low High Slack Water (LHSW) Buildup and Dilution Curves



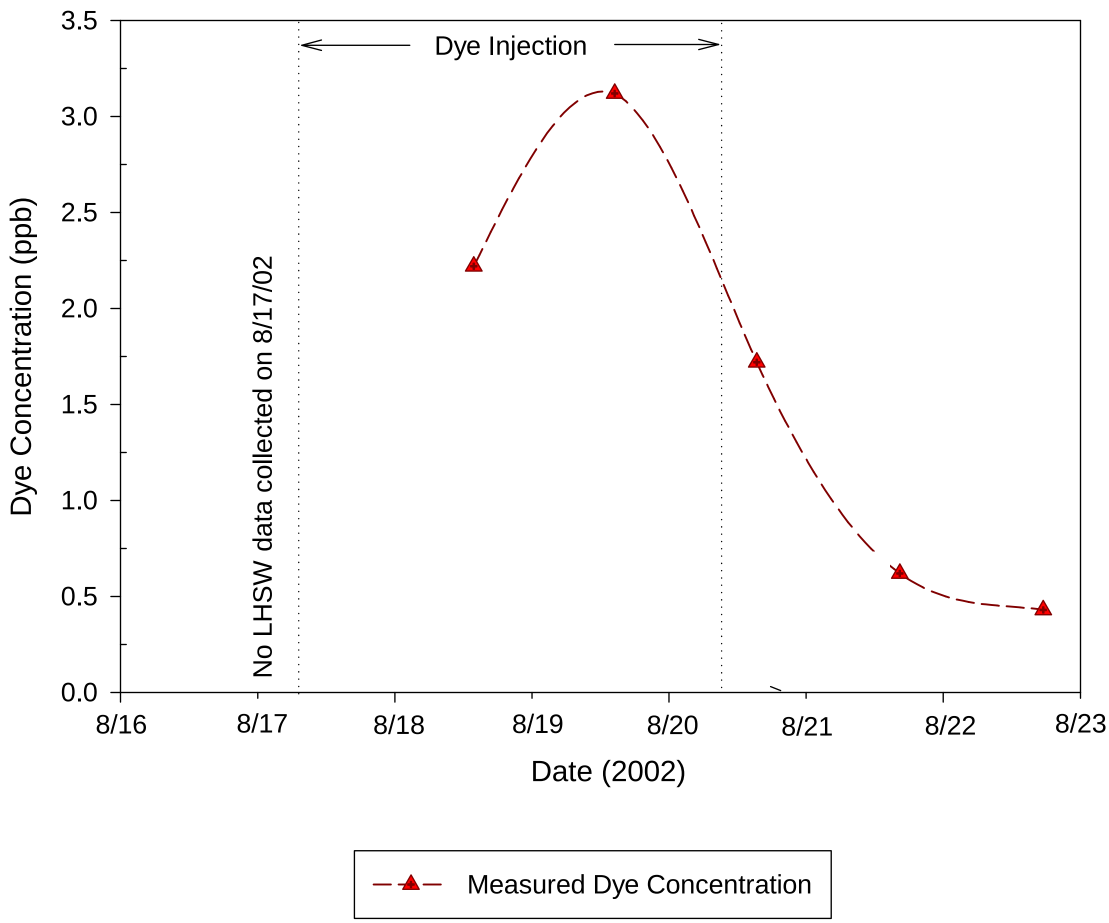
Buoy 12 Low High Slack Water (LHSW) Dye Concentrations



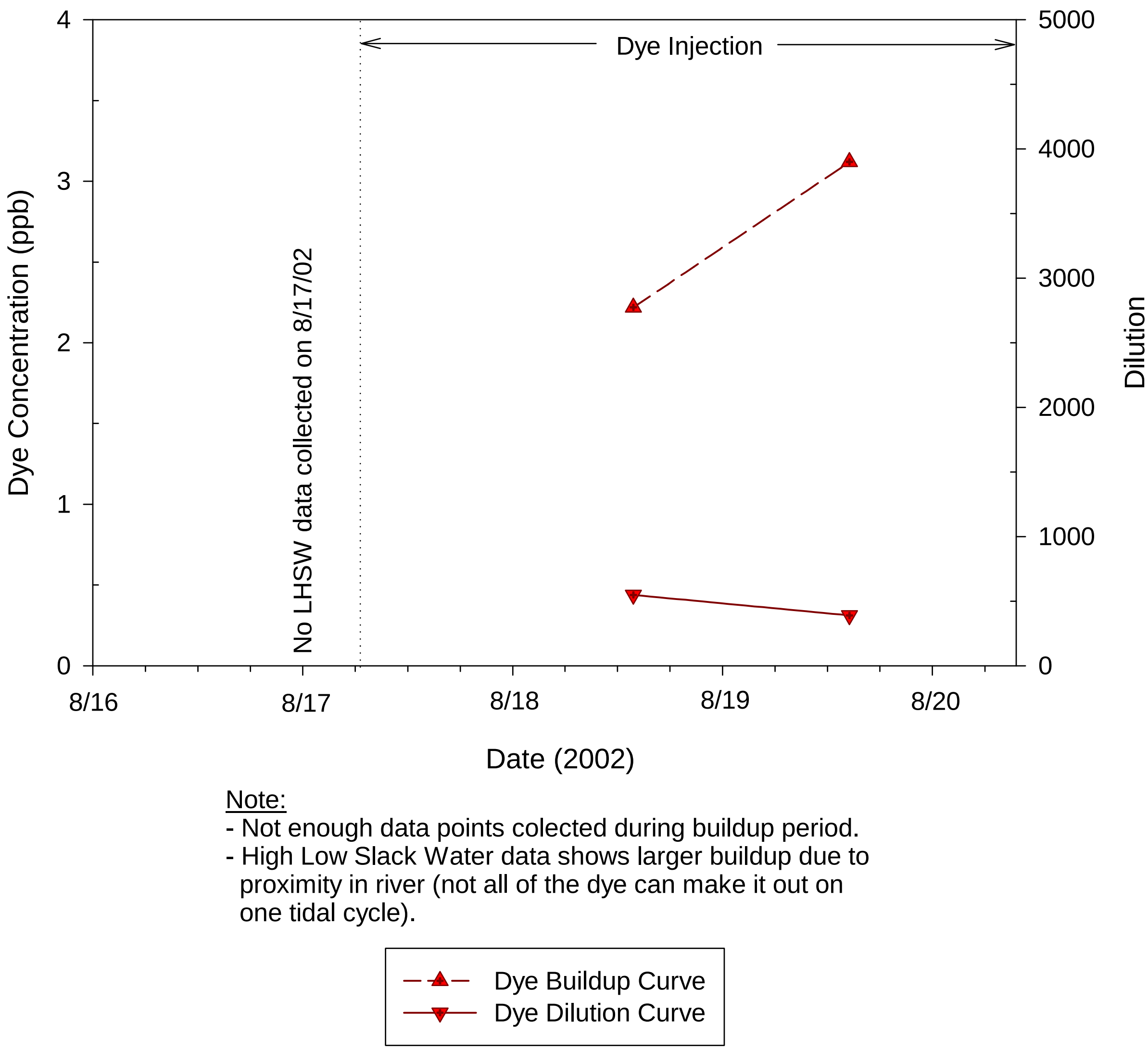
Buoy 12 Low High Slack Water (LHSW) Buildup and Dilution Curves



Buoy 14 Low High Slack Water (LHSW) Dye Concentrations

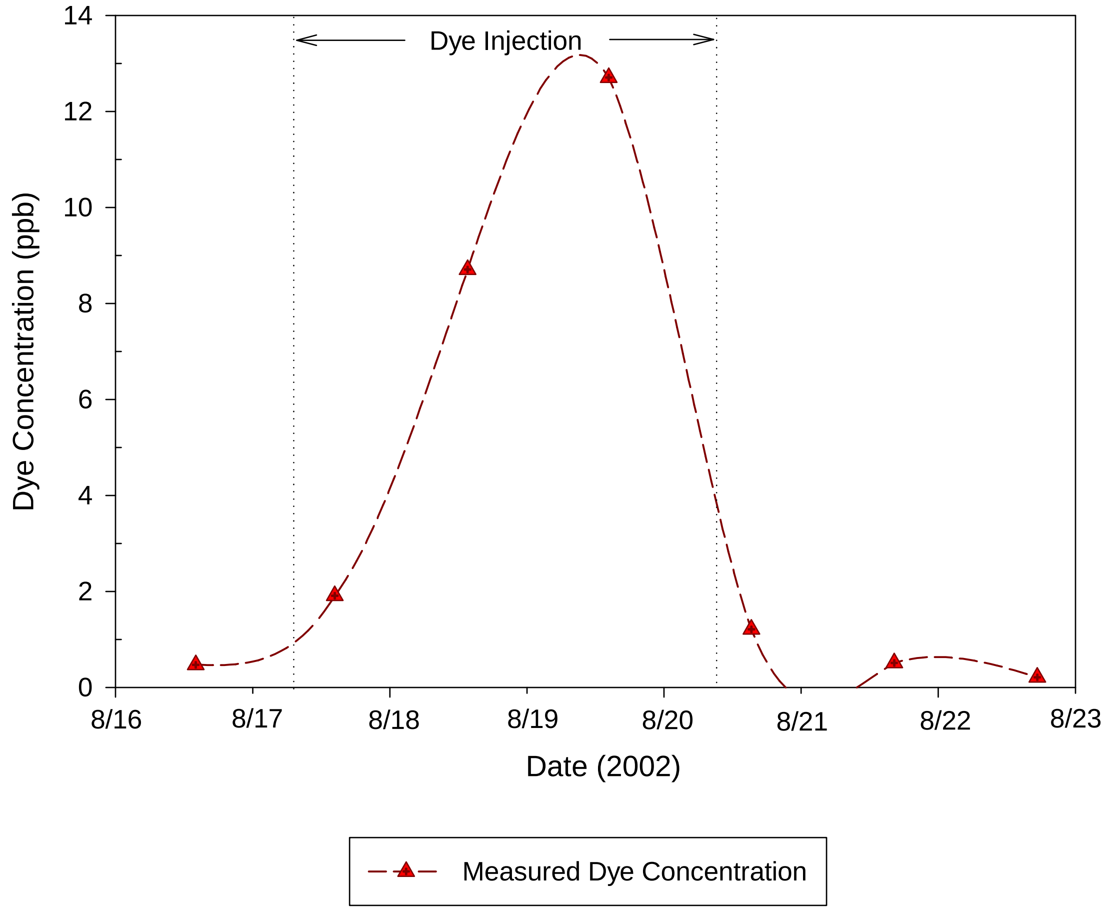


Buoy 14 Low High Slack Water (LHSW) Buildup and Dilution Curves

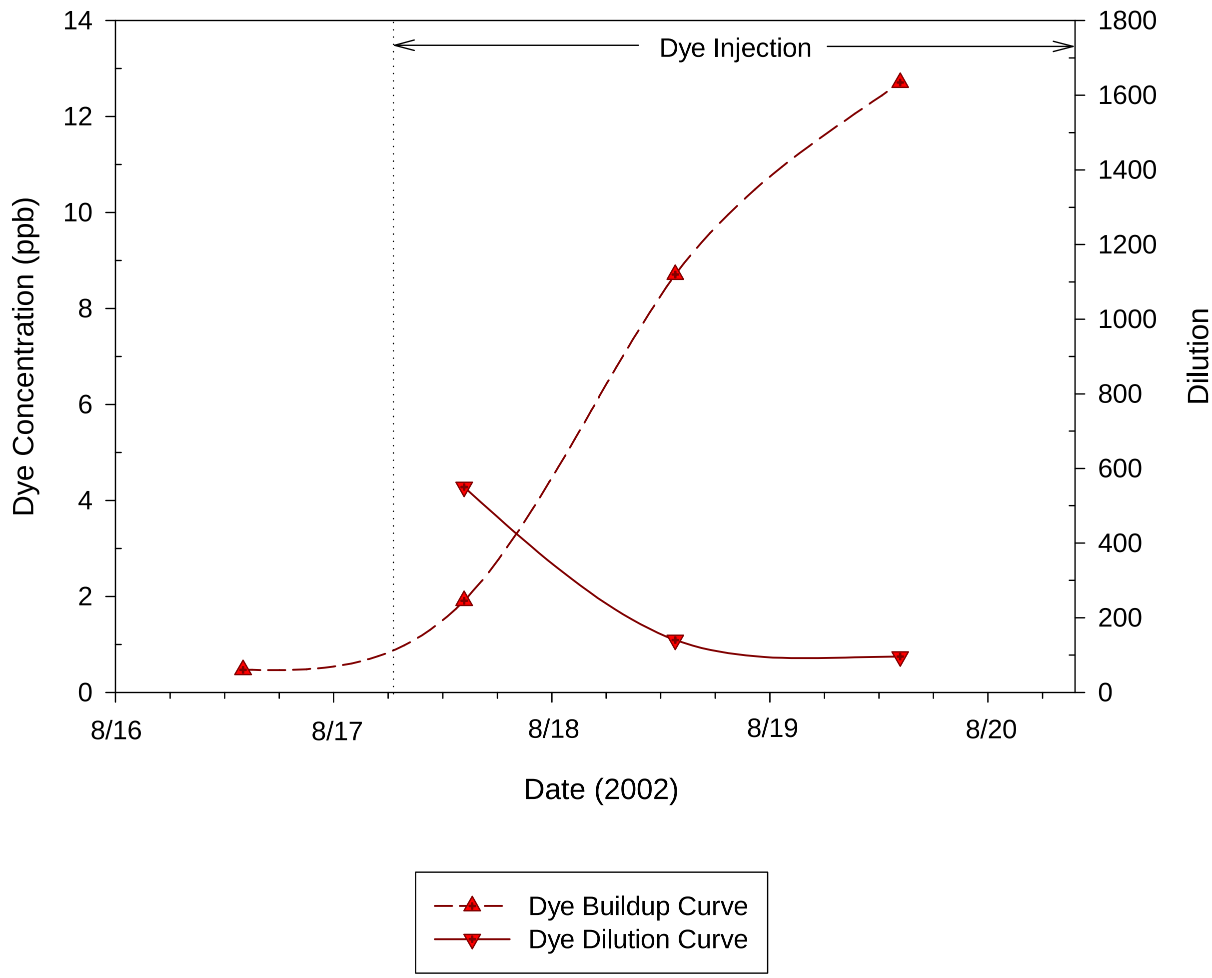


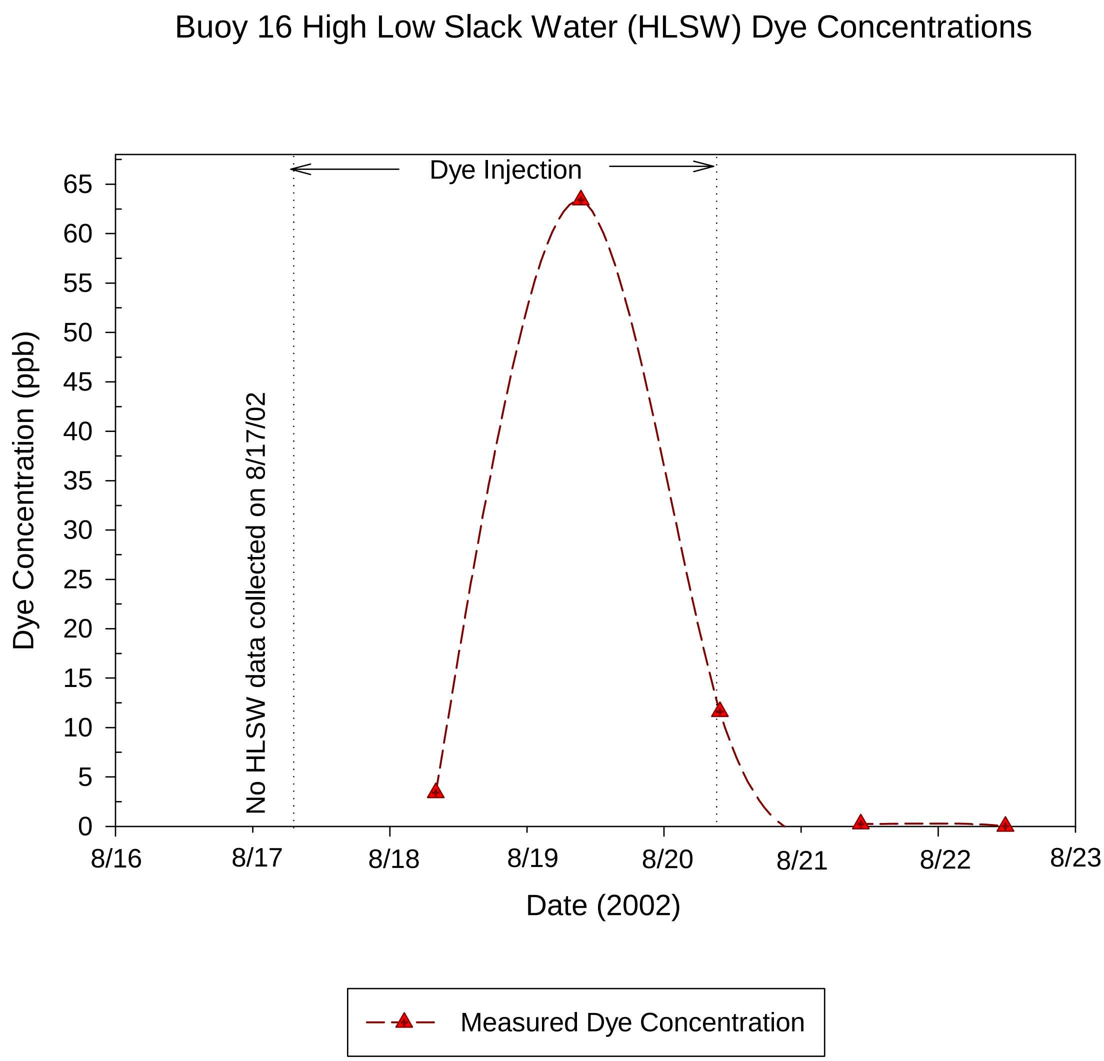
Note:
- Not enough data points colected during buildup period.
- High Low Slack Water data shows larger buildup due to proximity in river (not all of the dye can make it out on one tidal cycle).

Buoy 16 Low High Slack Water (LHSW) Dye Concentrations

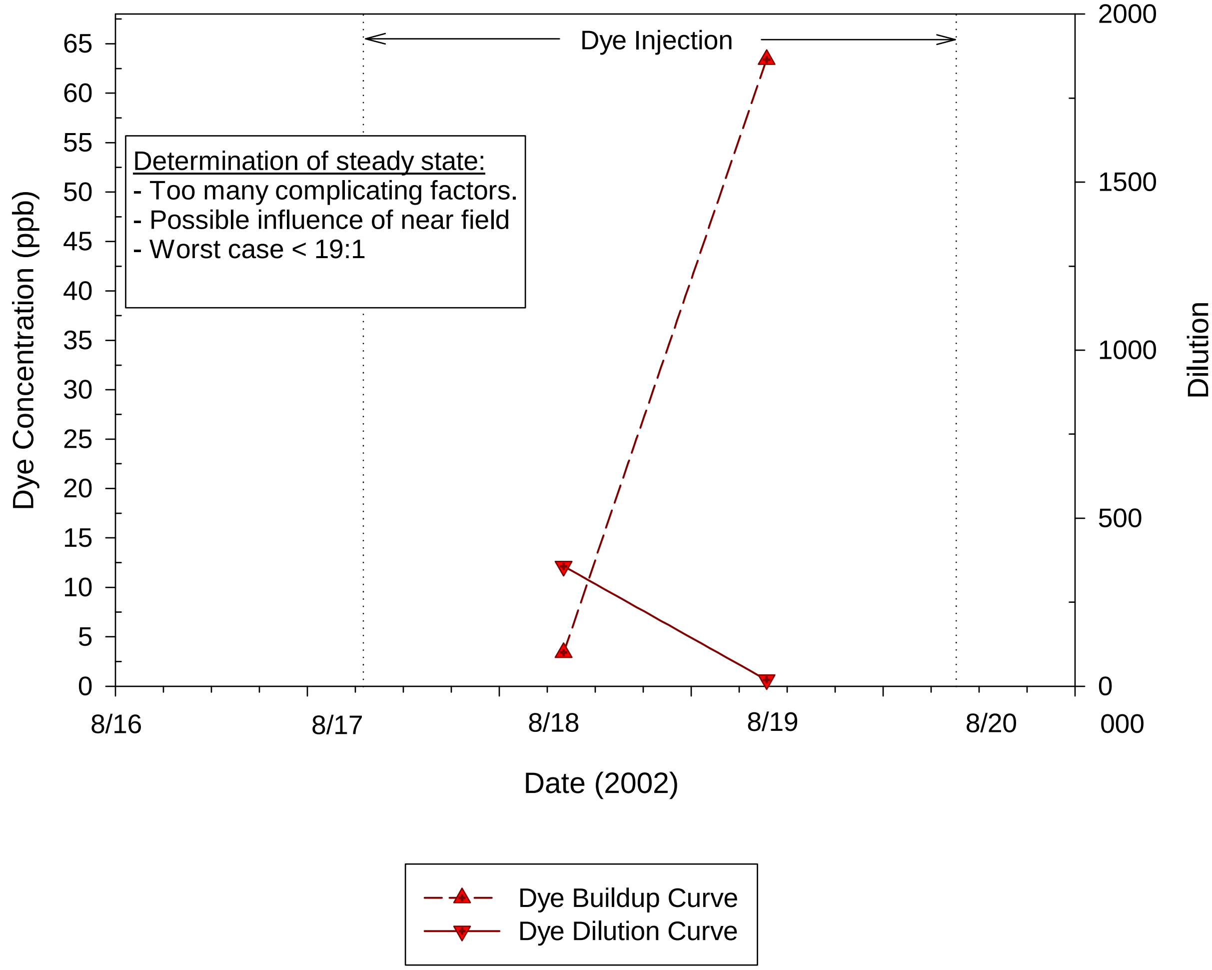


Buoy 16 Low High Slack Water (LHSW) Buildup and Dilution Curves




Buoy 16 High Low Slack Water (HLSW) Dye Concentrations
Dye Injection
No HLSW data collected on 8/17/02
Dye Concentration (ppb)
0
5
10
15
20
25
30
35
40
45
50
55
60
65
8/16
8/17
8/18
8/19
8/20
8/21
8/22
8/23
Date (2002)
Measured Dye Concentration

Buoy 16 High Low Slack Water (HLSW) Buildup and Dilution Curves



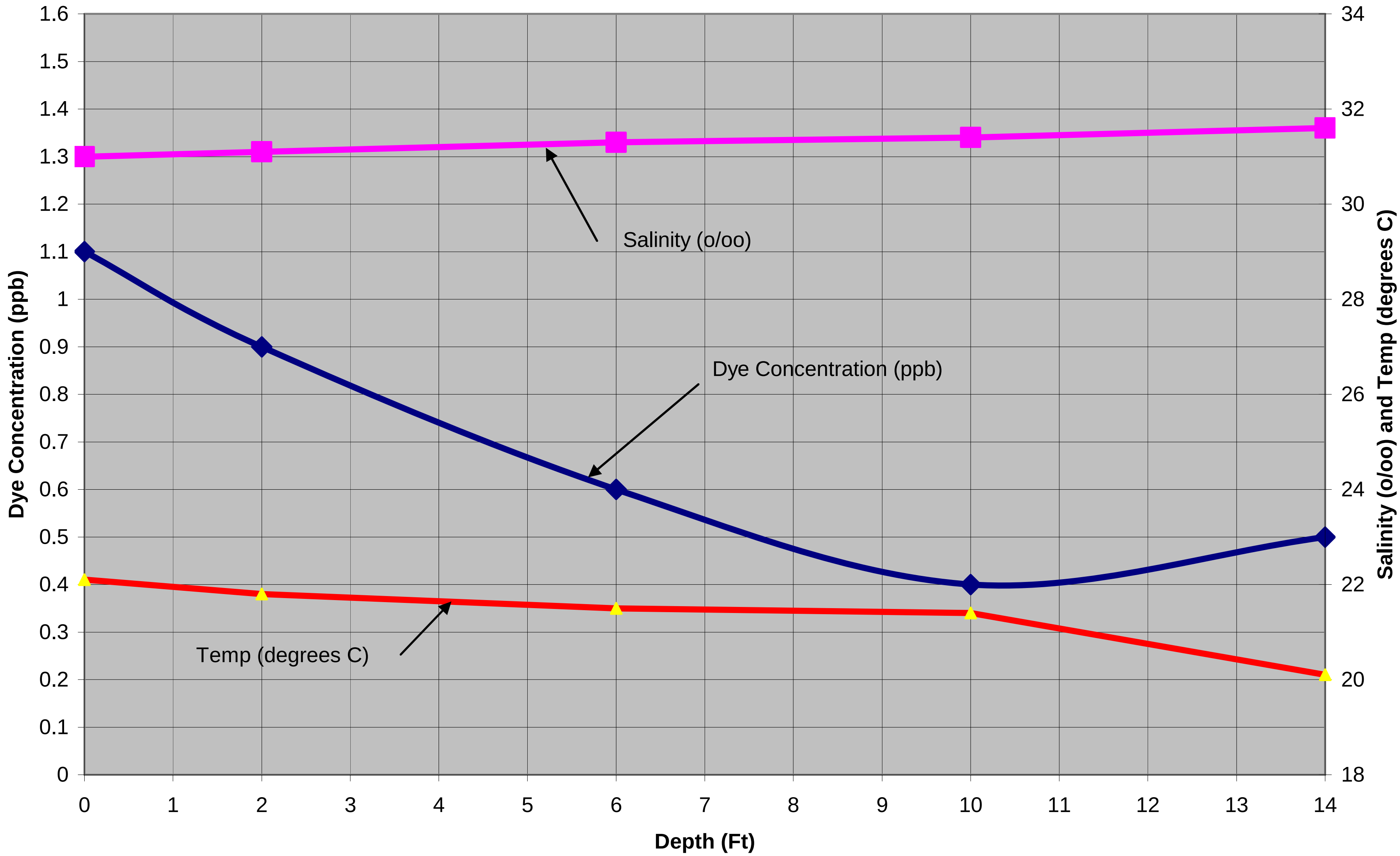


Figure 28: Buoy 1 Profile at 14:43 (8/18/02)

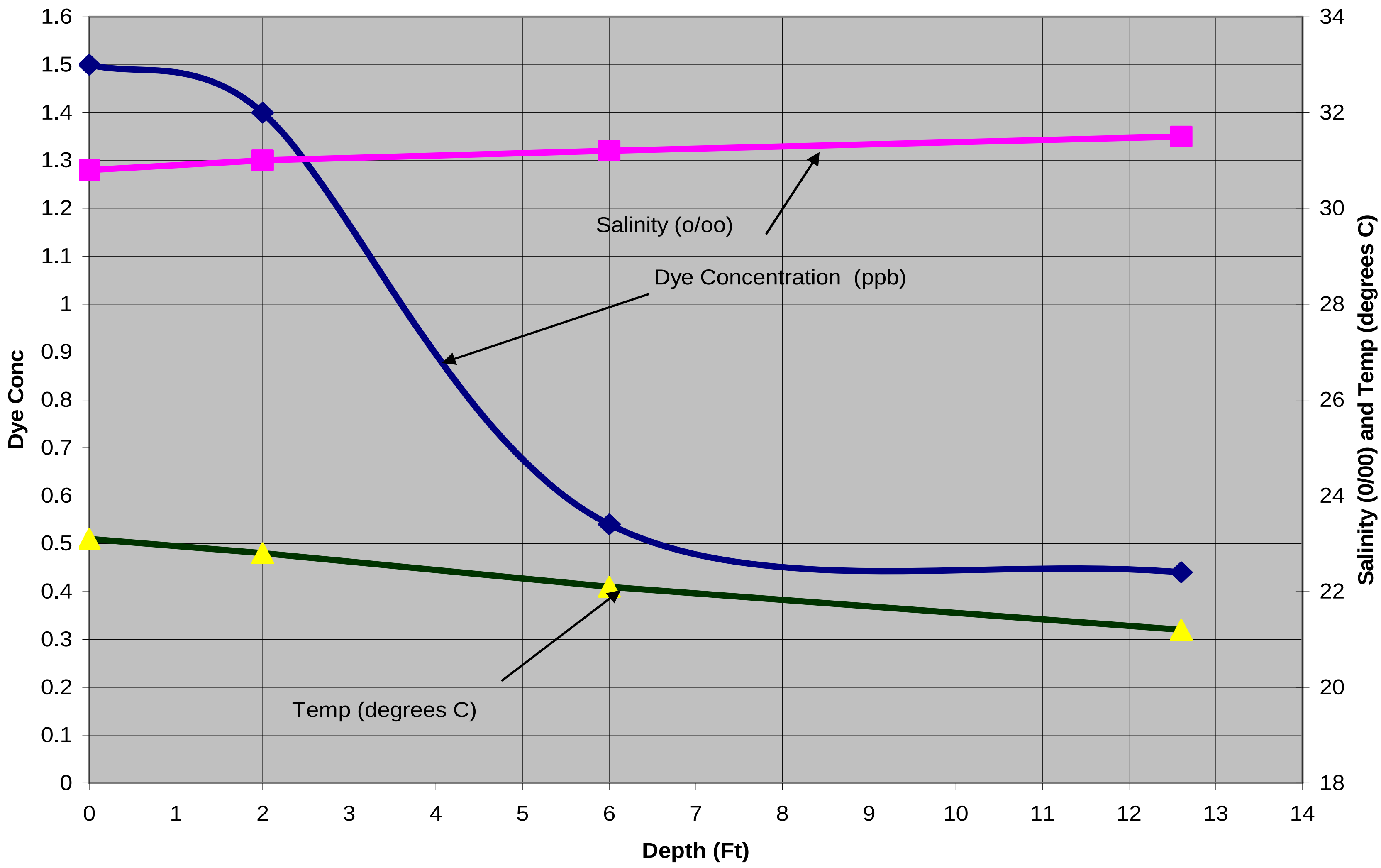


Figure 29: Buoy 1 Profile at 15:55 (8/19/02)

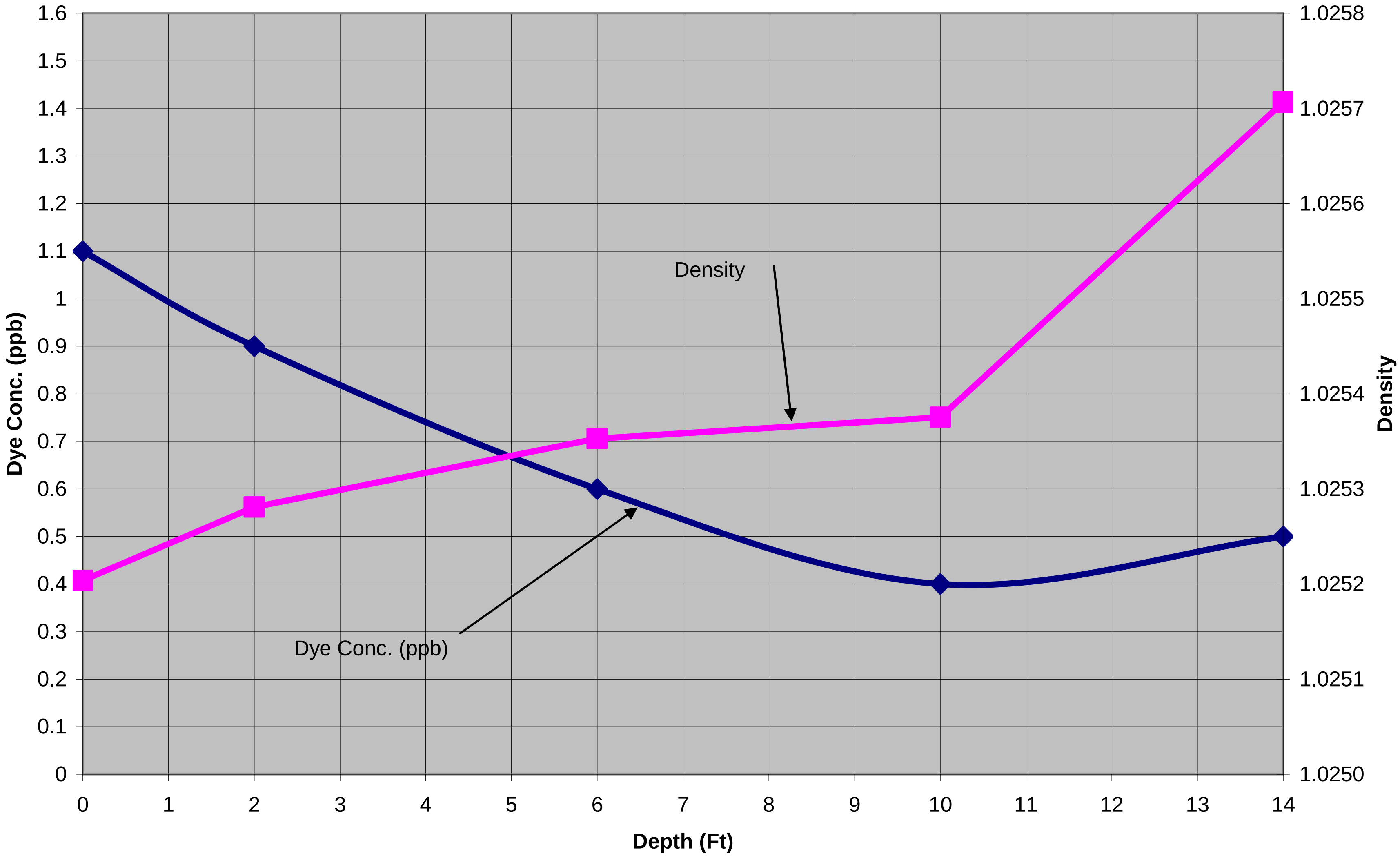


Figure 30: Buoy 1 Dye Readings and Density at 14:43 (8/18/02)

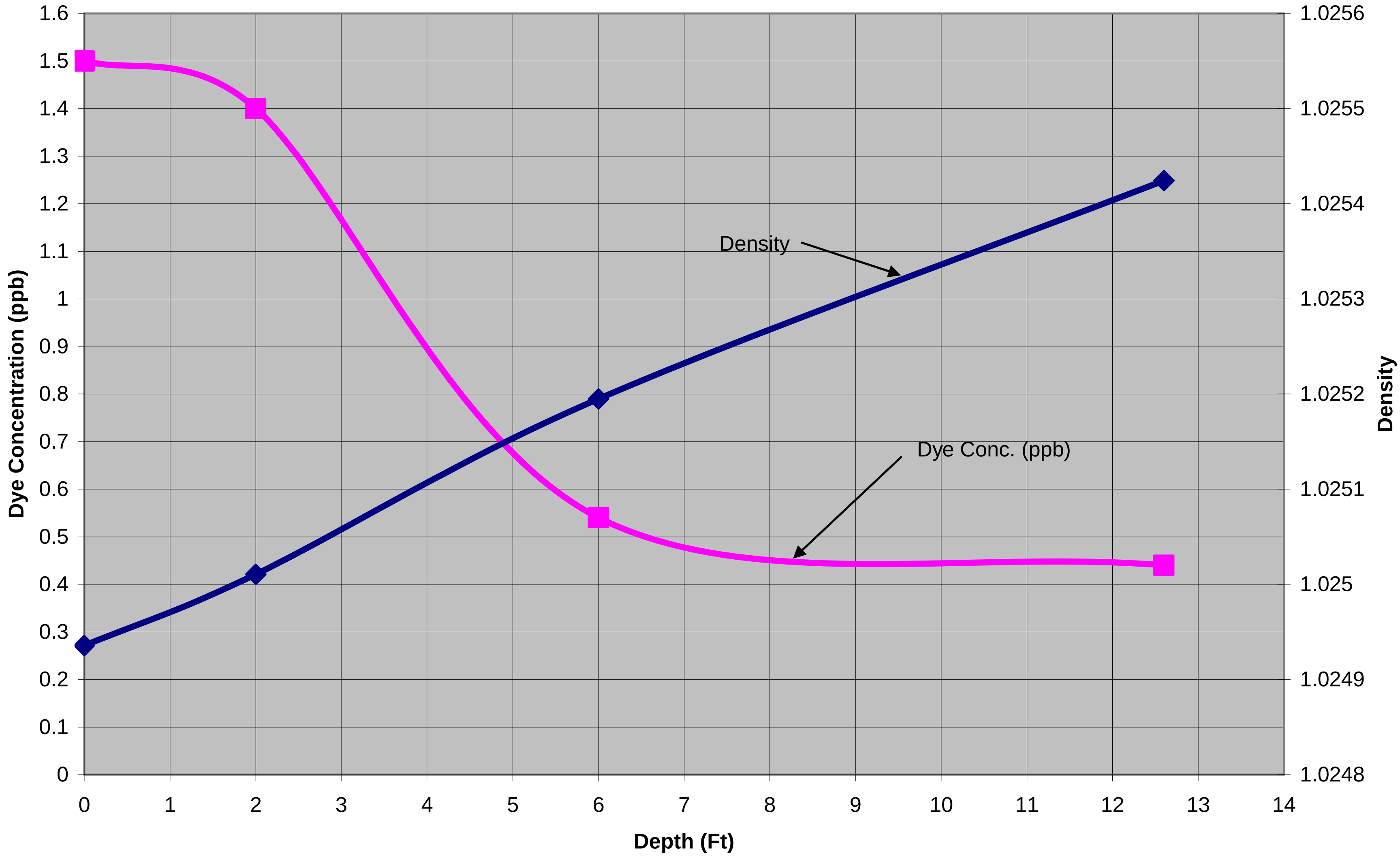


Figure 31: Buoy 1 Dye Readings and Density at 15:55 (8/19/02)

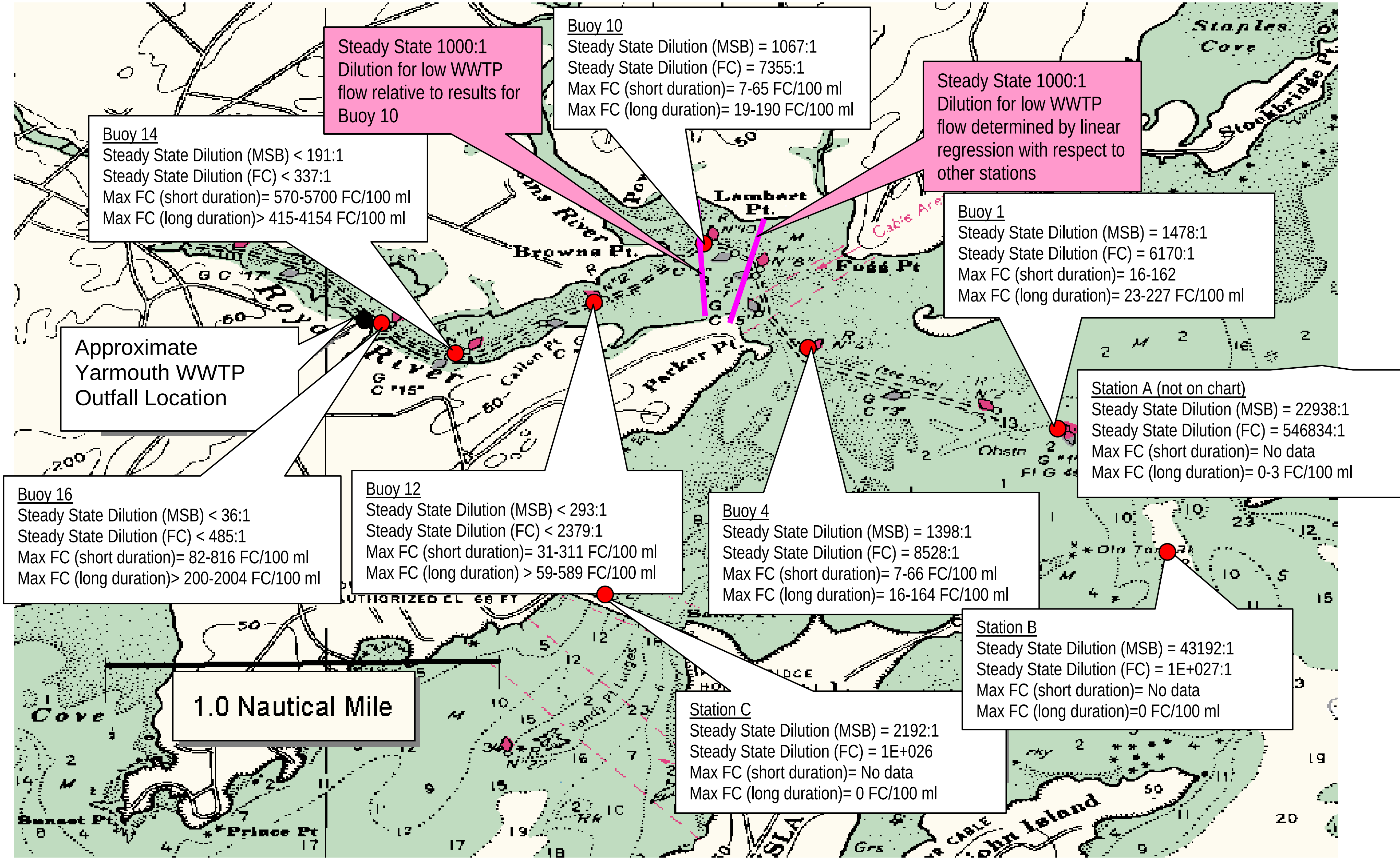


Figure 32: Steady State Dilutions and Maximum FC Concentrations for Short Term and Long Term Lapses in Treatment (Low WWTP Flow)

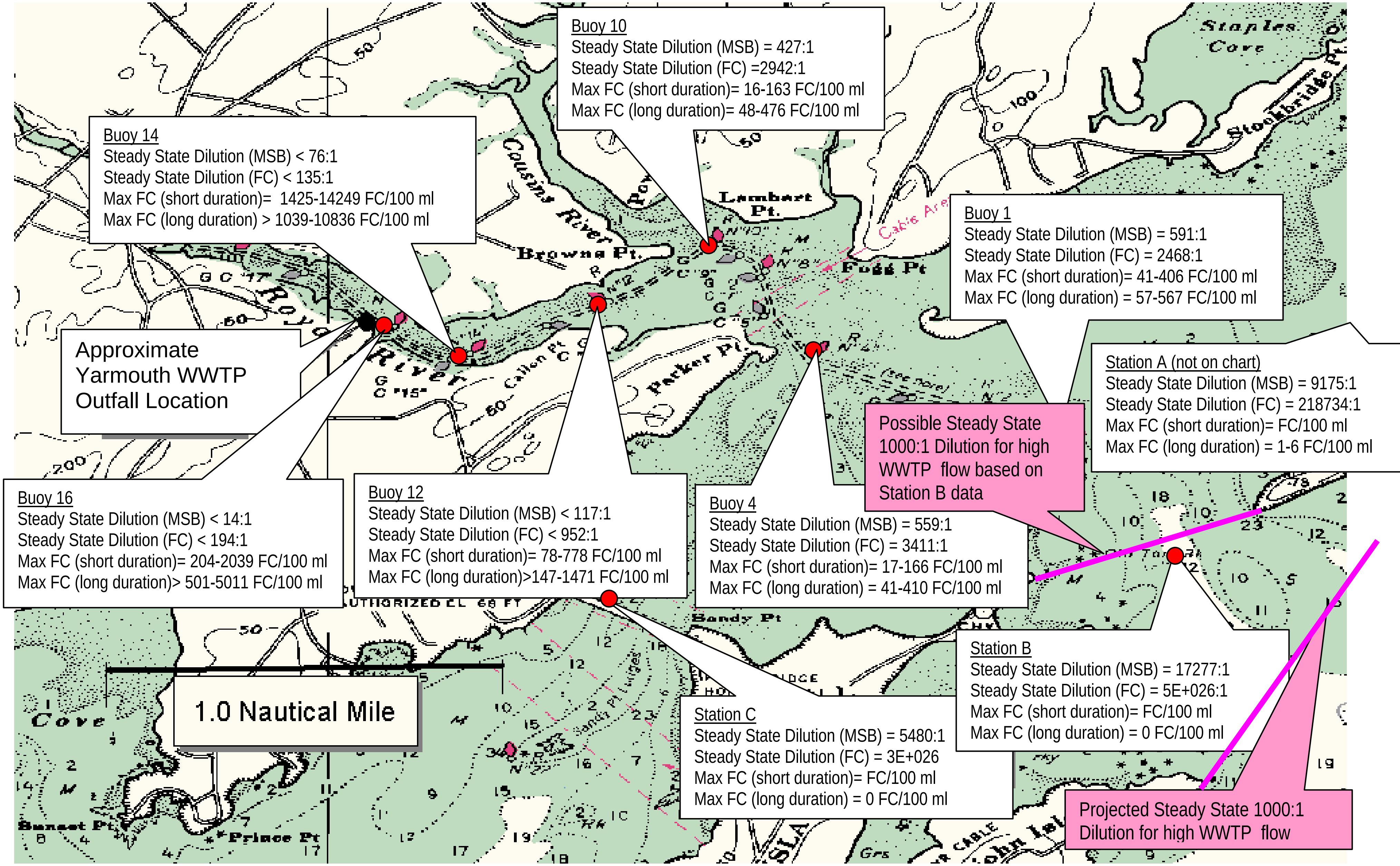


Figure 33: Steady State Dilutions and Maximum FC Concentrations for Short Term and Long Term Lapses in Treatment (High WWTP Flow)

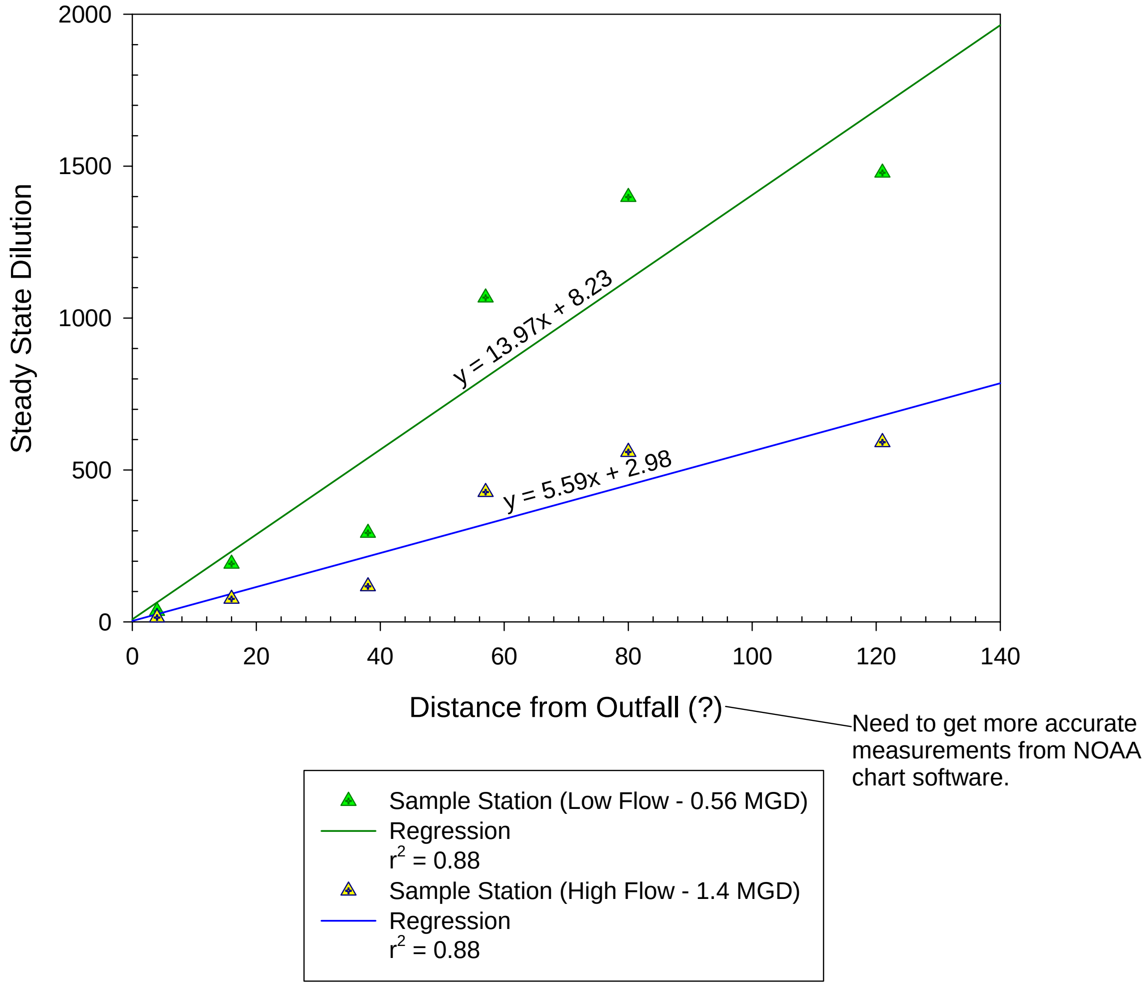


Figure 34: Regression Analysis of Steady State Dilution Values with Distance from Outfall

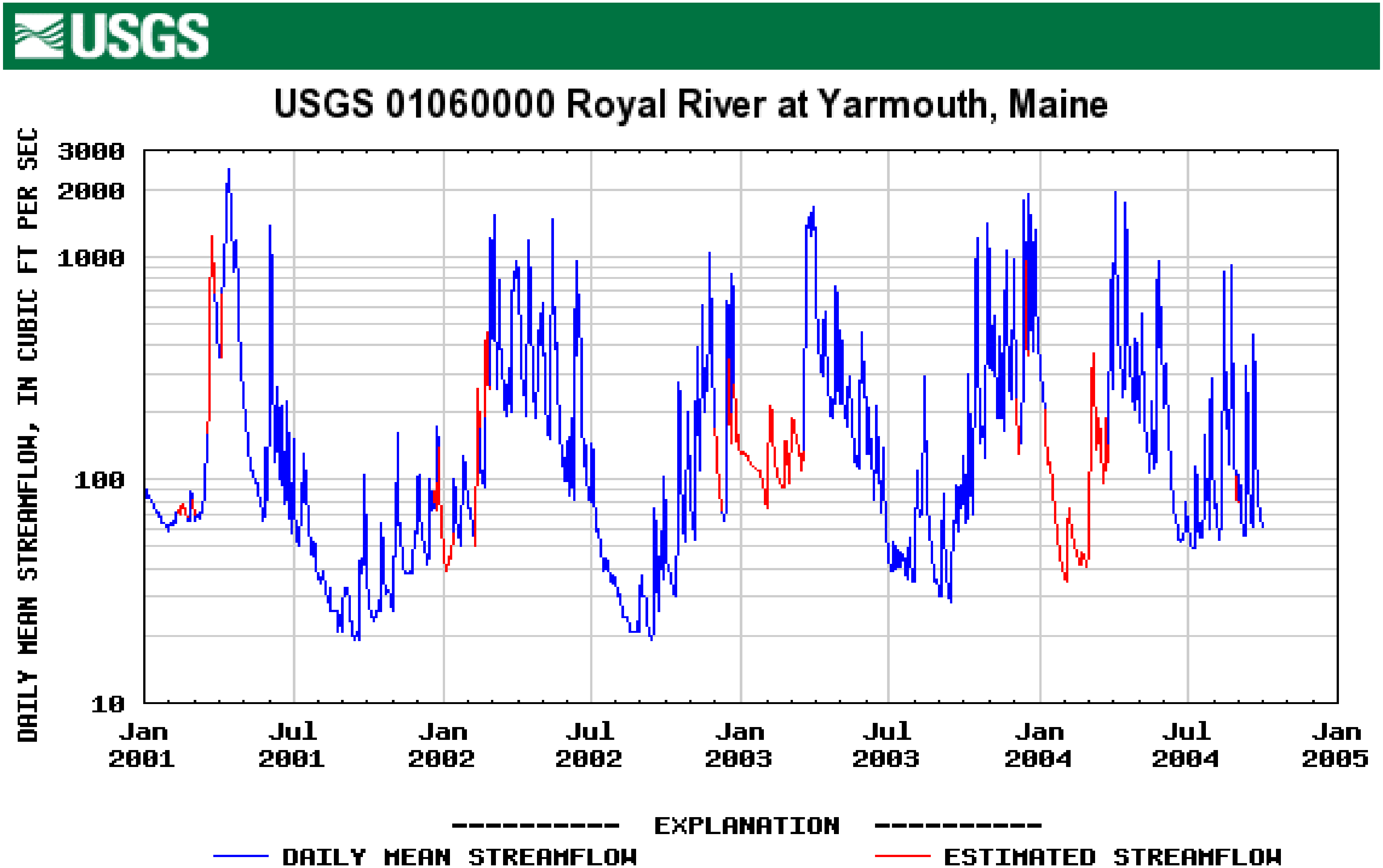


Figure 35 Daily Mean Streamflow for the Royal River (January 2001-2005)

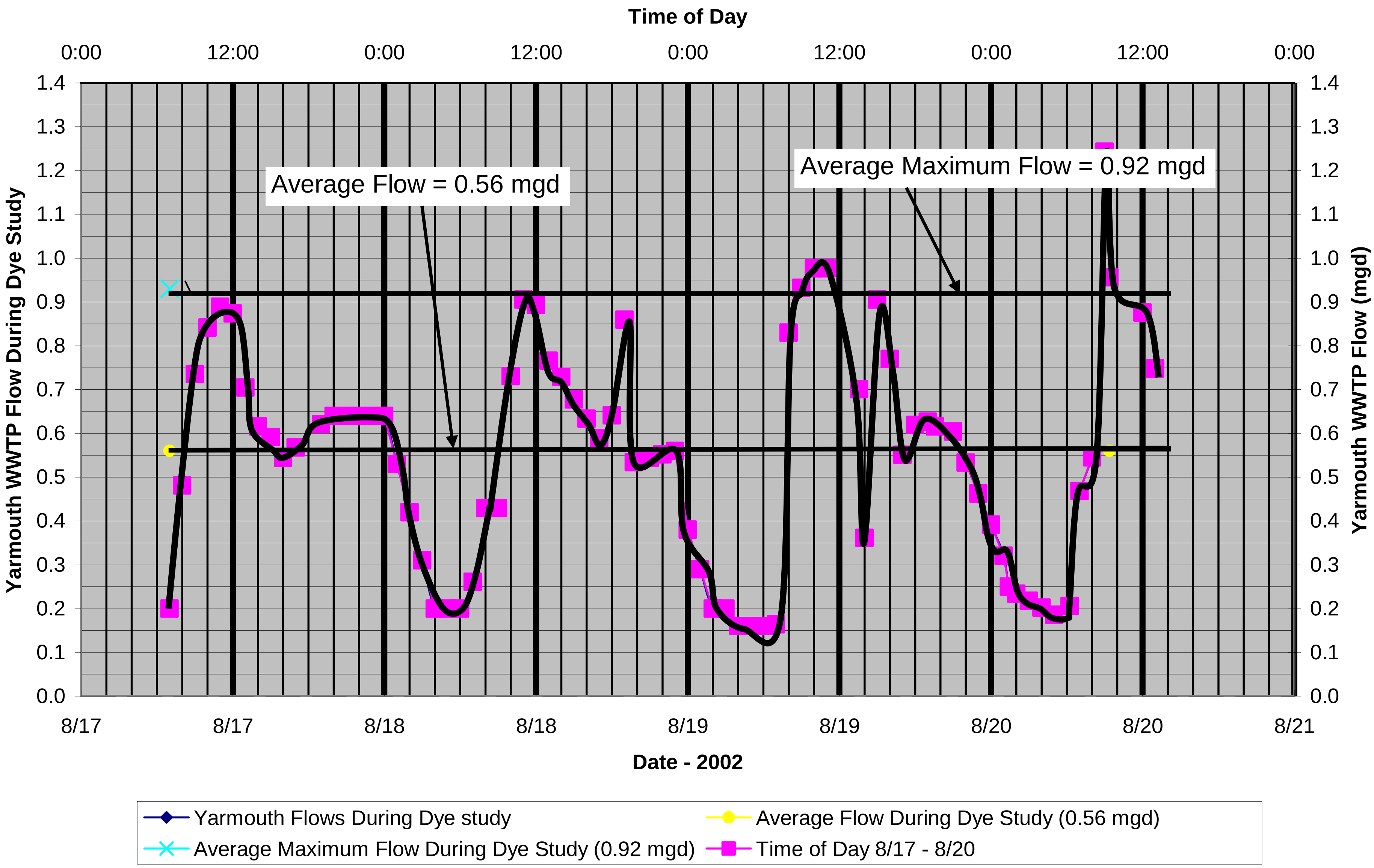


Figure 36: Yarmouth WWTP Flow During Dye Feed (8/17-8/20/02)

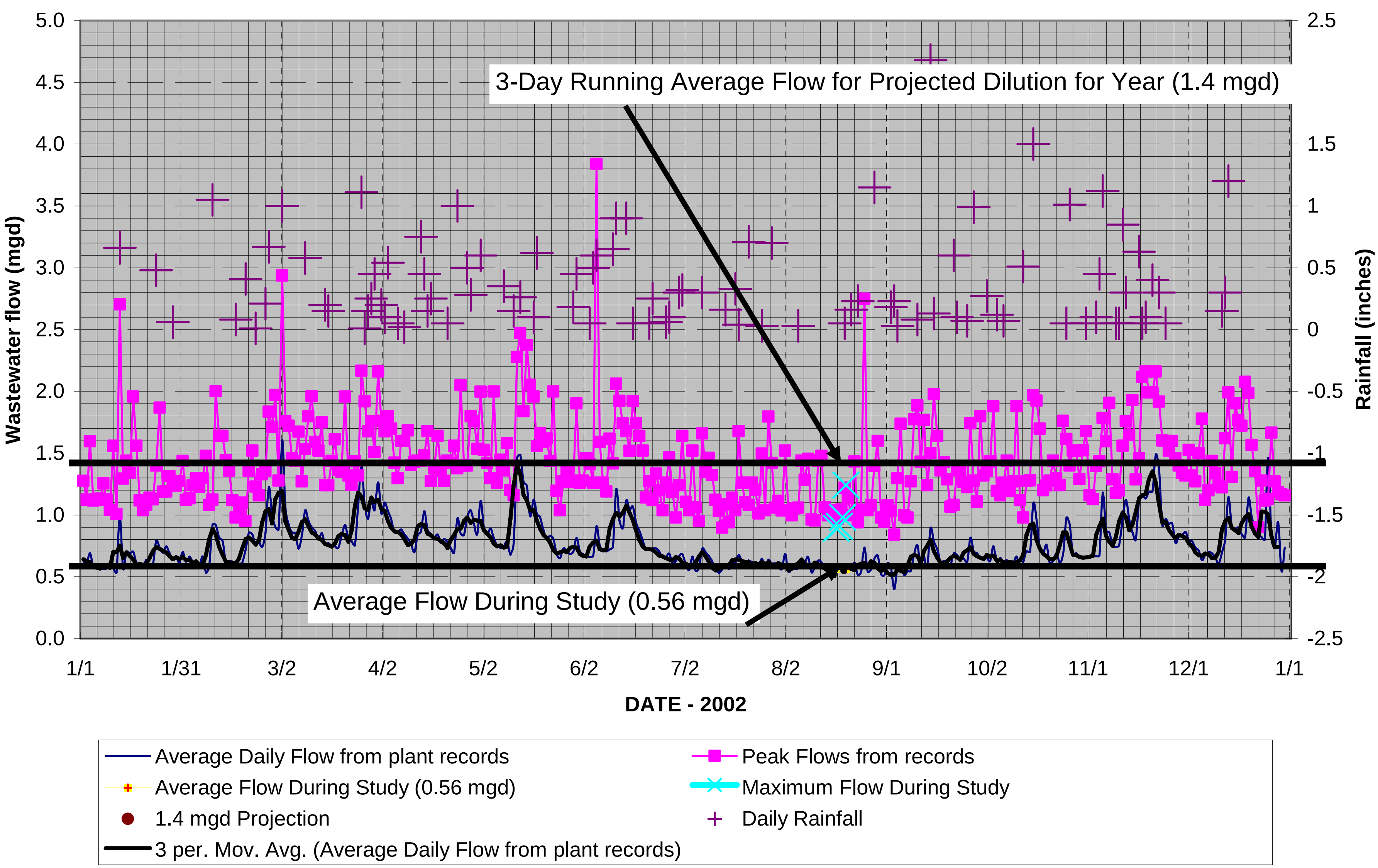


Figure 37: Yarmouth WWTP Flows for 2002

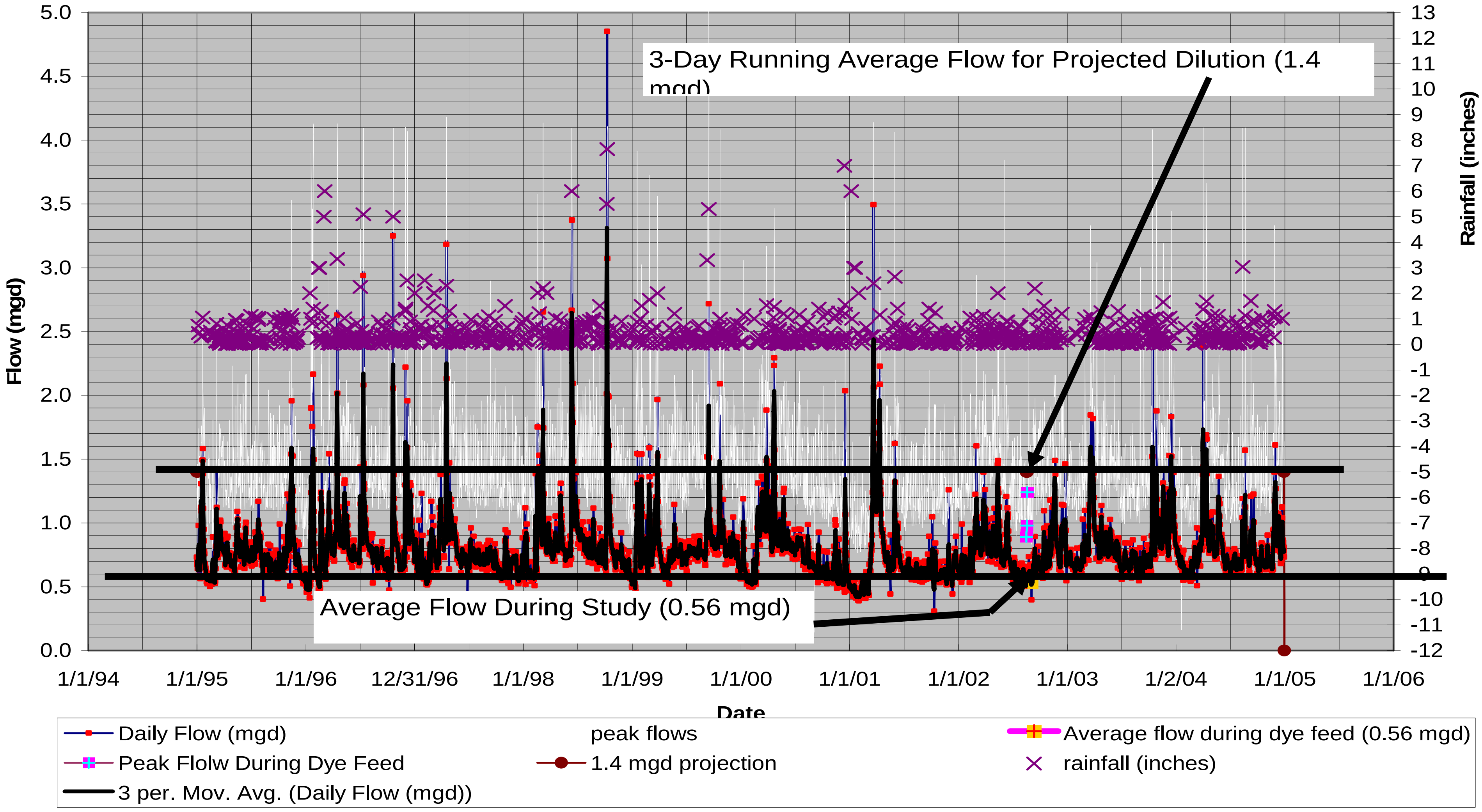


Figure 38: Yarmouth WWTP Average Flow During Study Compared to 3-Day Running Average Flow (January 1995-2005)

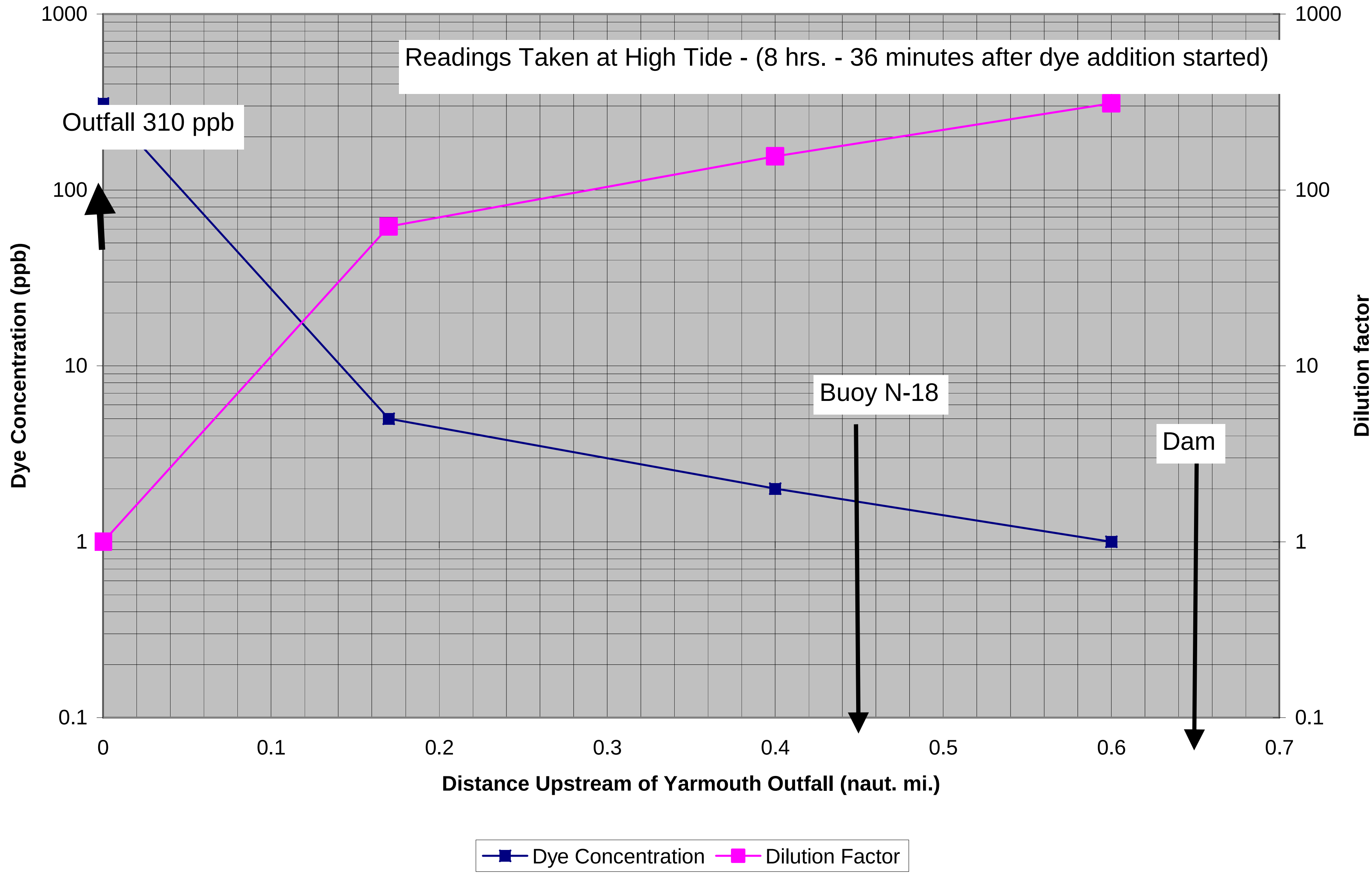


Figure 39: Upstream Dye Concentrations and Dilutions from 8/29/89 Study

Appendix B

Yarmouth WWTP flow rates and Dye Feed Information - 8/17/02 - 8/20/02

Date 2002	Time	Totalizer (x 100) (gallons)	Instant. (mgd)	Jug Level (liters)	Sewage Flow (mgd)	Eff. Dye Conc (ppb)	
8/17	7:00	24993928			0.20		
8/17	7:03			39.69			Start Dye Feed
8/17	7:06	24993936	0.27				
8/17	7:31	24993993	0.43				
8/17	7:58			38			
8/17	8:00				0.48	1448	
8/17	8:05	24994081	0.54				
8/17	8:24	24994170	0.71				
8/17	8:49	24994298	0.71				
8/17	9:00				0.74	947	
8/17	9:11	24994410	0.77				
8/17	9:51	24994629	0.87				
8/17	10:00				0.84	827	
8/17	10:35	24994901	1.01				
8/17	10:44			34			
8/17	11:00				0.89	783	
8/17	11:21		0.998				
8/17	12:00				0.87	797	
8/17	12:08	24995475	0.71				
8/17	12:10			32			
8/17	12:17	24995520	0.7				
8/17	13:00				0.70	988	
8/17	13:11	24995780	0.71				
8/17	13:38			30			
8/17	13:42	24995936	0.7				
8/17	14:00				0.62	1131	
8/17	14:51	24996231	0.58				
8/17	15:00				0.59	1177	
8/17	15:03			28			
8/17	15:38	24996424	0.5				
8/17	16:00				0.54	1280	
8/17	16:25	24996586	0.57				
8/17	16:38			26			
8/17	16:42	24996665	0.56				
8/17	17:00				0.57	1226	
8/17	18:00						
8/17	18:48	24997150	0.58				
8/17	19:00				0.62	1121	
8/17	19:20	24997288	0.64				
8/17	19:32			22			
8/17	19:59	24997455	0.64				
8/17	20:00				0.64	1088	
8/17	21:00				0.64	1088	

8/17	22:00				0.64	1088		
8/17	23:00				0.64	1088		
8/18	0:00		***0.64***		0.64	1088		
8/18	1:00		***0.53***		0.53	1313		
8/18	2:00		***0.42***		0.42	1658		
8/18	3:00		***0.31***		0.31	2246		
8/18	4:00		***0.2***		0.20	3481		
8/18	5:00				0.20	3481		
8/18	6:00				0.20	3481		
8/18	6:04	24999044	0.2	8				
8/18	6:49	24999082	0.2					
8/18	7:00		0.2		0.26	2667		
8/18	7:21	24999140	0.25					
8/18	8:00				0.43	1621		
8/18	9:00				0.43	1621		
8/18	9:10	24999465	0.67	4				
8/18	10:00				0.73	952		
8/18	10:03	24999734	0.81					
8/18	10:47	24999998	0.79					
8/18	10:48	25000006	0.8					
8/18	11:00				0.91	768		
8/18	11:51			34			New Jug	1.26 L/hr
8/18	12:00				0.89	716		
8/18	12:14	25000547	0.87					
8/18	12:45			33				
8/18	12:59	25000793	0.78					
8/18	13:00				0.77	836		
8/18	13:17	25000882	0.65					
8/18	14:00				0.73	879		
8/18	14:23	25001216	0.65	31				
8/18	15:00				0.68	945		
8/18	15:08	25001412	0.68					
8/18	15:25	25001484	0.68					
8/18	16:00				0.63	1011		
8/18	16:40	25001814	0.53					
8/18	17:00				0.59	1087		
8/18	17:13	25001949	0.62					
8/18	18:00				0.64	999		
8/18	18:48	25002372	0.61					
8/18	19:00				0.86	745		
8/18	19:21	25002569	0.74	24.9				
8/18	19:45			24	0.53	1198		
8/18	19:59	25002710	0.64					
8/18	20:00		***0.5252***	0.164732456	0.53	1219		
8/18	21:00		***0.4889***		0.49	1310		
8/18	22:00		***0.4526***		0.45	1415		
8/18	23:00		***0.4163***		0.42	1538		
8/18	0:00		***0.38***		0.38	1685		

8/19	1:00				0.29	2208	
8/19	2:00		***0.2***		0.20	3201	
8/19	3:00				0.20	3201	
8/19	4:00				0.16	4002	
8/19	5:00				0.16	4002	
8/19	6:00				0.16	4002	
8/19	6:08	25004557	0.2		0.16	4002	
8/19	6:25	25004581	0.2		0.16	4002	
8/19	7:00				0.16	3900	
8/19	7:15	25004638	0.24				
8/19	8:00				0.83	771	
8/19	8:23			8.1			
8/19	8:27	25005053	0.88				
8/19	9:00	25005053			0.93	687	
8/19	9:03	25005286	0.92				
8/19	9:46	25005565	0.9				
8/19	10:00	25005660			0.98	656	
8/19	11:00	25006067			0.98	656	
8/19	11:18	25006189	0.95				
8/19	11:58	25006445	0.92				
8/19	12:00				0.88	731	
8/19	12:36	25006676	0.84				
8/19	13:00				0.75	856	
8/19	13:17	25006889	0.67				
8/19	13:34	25006972		1.6	0.70	Dye feed stopped because tilted jug	
8/19	13:54	25007069	0.77				
8/19	14:00				0.36		
8/19	14:35	25007172	0.65				
8/19	15:00				0.91		
8/19	15:02			27		New Jug	1.6 liters of mixture left
8/19	15:27	25007499	0.74				
8/19	15:44	25007590		Dye Feed Started Again - Back flushed dye pump			
8/19	15:48	25007611		27			1.32 L/hr
8/19	16:00	25007675			0.77	871	
8/19	16:16	25007761	0.66				
8/19	16:34	25007830		26			
8/19	17:00	25007929			0.55	1217	
8/19	17:22	25008014		25			
8/19	17:25	25008025	0.59				
8/19	18:00				0.62	1083	
8/19	18:58	25008425	0.68				
8/19	19:00				0.63	1070	
8/19	19:20			22			
8/19	19:35	25008586	0.62		0.62	1090	
8/19	20:00	25008690	0.59				
8/19	21:00		***0.6041***		0.60	1110	
8/19	22:00		***0.5332***		0.53	1258	
8/19	23:00		***0.4624***		0.46	1450	
8/20	0:00		***0.391***		0.39	1713	

			6			
8/20	1:00		***0.320 8***		0.32	2091
8/20	1:25		0.25		0.25	2683
8/20	2:00		***0.234***		0.23	2866
8/20	3:00		***0.218***		0.22	3077
8/20	4:00		***0.202***		0.20	3321
8/20	5:00		***0.186***		0.19	3606
8/20	5:25		0.17			
8/20	6:00					
8/20	6:11	25010355	0.17			
8/20	6:14			7.8	0.21	3261
8/20	6:25	25010375	0.26			
8/20	6:55	25010438	0.34			
8/20	7:00	25010457			0.47	1431
8/20	8:00	25010684			0.55	1230
8/20	8:15	25010741	0.48			
8/20	8:47	25010845	1.17			
8/20	8:53			4		
8/20	9:00				1.24	540
8/20	9:06	25011009	1.16			
8/20	9:22	25011118	0.93		0.96	
8/20	9:34	25011195			End dye feed. Have 3.5 liters of mixture left.	

<u>Summarize dye concentration</u>

Jug number	Start	End	Used
Jug 1	39.7	0	-39.7
Jug 2	34	1.6	-32.4
Jug 3	27	3.5	-23.5

95.6 liters = 25.29 gallons of mixture
=8.43 gallons of Rhodamine WT dye

Sewage dyed = 25011195 at 09:34 on 8/20/02
24993932 at 07:03 on 8/17/02

less a lapse of 2hours - 10 min on 8/19/02

Amount of sewage (gal)	1,664,500
Average dye conc. (ppb)=	1216

Appendix C
Fluorometer Readings at Selected Locations

Dye and Physical Readings from Work Sheets.

Date	Time	Location	Depth (ft)	Flurometer (ppb)	Salin (0/00)	Temp ©	Notes
8/15/2002	18:36	Buoy 16	2	0.59			
8/15/2002	18:41	Buoy 14	0	0.48			
8/15/2002	18:49	Buoy 12	0	0.4			
8/15/2002			2	0.39			
8/15/2002			6	0.41			
8/15/2002			16	0.35			
8/15/2002	18:56	Buoy 10	0	0.5			
8/15/2002			2	0.51			
8/15/2002	19:02	Buoy 4	0	0.5			
8/15/2002			2	0.53			
8/15/2002			12	0.52			
8/15/2002	18:30	Boil	2	0.45			
8/15/2002	19:14	Buoy 1	2	0.18			
8/15/2002			12	0.21			
8/16/2002	14:02	Buoy 16	2	1.06			
8/16/2002	14:10	Buoy 14	2	1.19			
8/16/2002	14:20	Buoy 10	2	1.06			
8/16/2002	14:36	Buoy 4	2	0.42			
8/16/2002	14:44	Buoy 1	2	0.25			
8/16/2002			3	0.49			
8/16/2002			12	0.48			
8/16/2002	15:00		2	0.19			
8/16/2002			12	0.14			
8/16/2002	15:21		2	0.24			
8/16/2002			5	0.25			
8/16/2002	15:42		2	0.11			
8/16/2002			12	0.17			
8/16/2002	16:10		2	0.45			
8/16/2002			3	0.49			
8/16/2002	16:35		2	0.35			
8/16/2002			6	0.35			
8/17/2002	8:48	Buoy 14	0	4.6			
8/17/2002			2	5.3			
8/17/2002			3	6.1			
8/17/2002			4	1.6			
8/17/2002			5	0.25			
8/17/2002			6	0.25			

8/17/2002	14:10	"A"	0	0.19			
8/17/2002			10	0.21			
8/17/2002			20	0.29			
8/17/2002	14:21	Buoy 16	0	2.5			
8/17/2002			2	2.5			
8/17/2002			4	2.3			
8/17/2002			6	2			
8/17/2002	14:52	Buoy 12	0	1.2			
8/17/2002			2	1.2			
8/17/2002			4	1.1			
8/17/2002			6	1.1			
8/17/2002			8	0.9			
8/17/2002			10	0.9			Bot
8/17/2002	15:02	Buoy 10	0	0.65			
8/17/2002			2	0.64			
8/17/2002			4	0.66			
8/17/2002			6	0.67			
8/17/2002			8	0.68			
8/17/2002	15:17	Buoy 4	0	0.6			
8/17/2002			2	0.58			
8/17/2002			4	0.5			
8/17/2002			6	0.55			
8/17/2002			8	0.64			
8/17/2002			10	0.68			
8/17/2002	15:43	"D"	0	0.7			
8/17/2002			2	0.7			
8/17/2002			3.5	0.7		South Wind 0-5 mph	
8/18/2002	7:52	Buoy 16		1.8	28.6	21.9	
8/18/2002	8:02	Buoy 16	0	4	29.6	21.3	
8/18/2002			2	1.2	30	21.2	
8/18/2002			4	1.3	31.2	20.8	
8/18/2002			6	0.7	31.2	20.8	
8/18/2002			8	0.7	31.3	20.7	
8/18/2002			10	0.7	31.3	20.7	
8/18/2002			14	0.7	31.3	20.6	
8/18/2002	8:15	Buoy 14	0	0.7	27.3	21.4	
8/18/2002			2	0.7	30.7	20.5	
8/18/2002			4	0.6	30.7	20.5	
8/18/2002			6	0.6	30.7	20.5	
8/18/2002			8	0.5	31.3	20.4	
8/18/2002			14	0.5	31.4	20.4	
8/18/2002			19	0.6	31.4	20.4	Bot
8/18/2002	8:26	Buoy 12	0	0.5	27.2	20.5	
8/18/2002			2	0.5	31.4	20.4	
8/18/2002			4	0.5	31.5	20.2	
8/18/2002			8	0.4	31.5	19.2	
8/18/2002			12	0.5	31.5	19.9	
8/18/2002			16	0.5	31.5	19.9	Bot
8/18/2002	8:35	Buoy 10	0	0.4	31.4	20.3	

8/18/2002			2	0.4	31.5	20.2	
8/18/2002			4	0.4	31.5	20.1	
8/18/2002			8	0.3	31.6	19.8	
8/18/2002			12	0.3	31.6	19.7	
8/18/2002			16	0.4	31.6	19.6	Bot
8/18/2002	8:47	"D"	0	0.5	31.4	20.7	
8/18/2002			2	0.5	31.4	20.6	
8/18/2002			4	0.5	31.4	20.5	
8/18/2002			6	0.5	31.4	20.4	
8/18/2002			8	0.5	31.5	20.1	
8/18/2002			10	0.4	31.5	20	Bot
8/18/2002	9:26	Buoy 4	0	0.4	31.4	20.6	
8/18/2002			2	0.4	31.4	20.5	
8/18/2002			4	0.3	31.5	20.2	
8/18/2002			8	0.3	31.6	19.5	
8/18/2002			12	0.3	31.6	19.2	
8/18/2002			15	0.2	31.7	18.8	Bot
8/18/2002	9:42	"C"	0	0.3	30.8	20.7	
8/18/2002			4	0.3	31.6	20.3	
8/18/2002			8	0.2	31.6	19.9	
8/18/2002			12	0.2	31.6	18.9	
8/18/2002			16	0.2	31.7	18.1	
8/18/2002			20	0.2	31.7	17.8	Bot
8/18/2002	10:02	Buoy 1	0	0.2	31	20.1	
8/18/2002			4	0.2	31.6	19.2	
8/18/2002			8	0.2	31.7	18.5	
8/18/2002			12	0.2	31.7	17.8	
8/18/2002			16	0.2	31.7	17.6	
8/18/2002			19	0.3	31.7	17.1	Bot
8/18/2002	13:36	Buoy 16	0	9.3	29	24.3	
8/18/2002			2	4.1	29.5	23.6	
8/18/2002			4	1.9	29.7	23.6	Bot
8/18/2002	13:49	Buoy 14	0	2.7	29.5	24	
8/18/2002			2	2.5	29.7	23.5	
8/18/2002			4	1.2	30.6	22.2	
8/18/2002			8	0.9	31	21.3	
8/18/2002			11	0.9	31	21.4	Bot
8/18/2002	14:03	Buoy 12	0	2.6	28.9	24.2	
8/18/2002			2	2.6	29.7	24.2	
8/18/2002			4	1.4	29.9	23.4	
8/18/2002			8	1.2	30.8	21.6	Bot
8/18/2002	14:10	Buoy 10	0	1.5	6.8	23.9	
8/18/2002			2	1.4	14.8	24	
8/18/2002			4	1.4	30.1	23.9	
8/18/2002	14:18	Buoy 4	0	1.3	30.7	23.4	
8/18/2002			2	1.2	30.8	23.4	
8/18/2002			4	1.2	30.8	23.4	
8/18/2002			6	1.2	31	23.1	Bot
8/18/2002	14:27	"C"	0	0.37	31.5	22.2	
8/18/2002			2	0.35	31.4	22.3	

8/18/2002			6	0.36	31.4	21.3	
8/18/2002			10	0.41	31.5	20.7	
8/18/2002			14	0.33	31.5	20.2	
8/18/2002			19	0.3	31.6	20.1	Bot
8/18/2002	14:43	Buoy 1	0	1.1	31	22.1	
8/18/2002			2	0.9	31.1	21.8	
8/18/2002			6	0.6	31.3	21.5	
8/18/2002			10	0.4	31.4	21.4	
8/18/2002			14	0.5	31.6	20.1	Bot
8/18/2002	14:58	"B"	0	0.3	31.6	21.2	
8/18/2002			2	0.3	31.6	21.2	
8/18/2002			6	0.3	31.7	20.6	
8/18/2002			10	0.2	31.7	20	
8/18/2002			20	0.2	31.6	18.4	Bot
8/18/2002	15:18	"D"	0	1	30.1	25	
8/18/2002			2	0.9	30.2	24.8	
8/18/2002			3	0.9	30.2	24.6	Bot
8/19/2002	9:26	Buoy 16	0	64	19.9	23.2	
8/19/2002			2	3.5	30.2	22.1	
8/19/2002			4	5.6	29.8	22.2	
8/19/2002			5	2.6	31	21.5	Bot
8/19/2002	9:42	Buoy 14	0	9.2	3.5	22.8	
8/19/2002			2	10	25.3	22.5	
8/19/2002			4	1.3	30.8	20.9	
8/19/2002			6	1.2	31	20.8	
8/19/2002			8	1.2	31.4	20.6	
8/19/2002			10	1.2	31.4	20.6	
8/19/2002			17	1.2	31.4	20.5	Bot
8/19/2002	9:57	Buoy 12	0	0.52	31.3	20.7	
8/19/2002			2	0.5	31.3	20.7	
8/19/2002			7	0.4	31.6	20.1	
8/19/2002			17	0.44	31.5	19.8	Bot
8/19/2002	10:05	Buoy 10	0	0.56	31.4	21.2	
8/19/2002			2	0.52	31.4	20.8	
8/19/2002			9	0.47	31.6	19.7	
8/19/2002	10:16	Buoy 4	0	0.96	31.4	21.4	
8/19/2002			2	0.49	31.4	21.3	
8/19/2002			8	0.66	31.6	19.8	
8/19/2002			15	0.4	31.7	18.6	Bot
8/19/2002	10:31	"C"	0	0.32	31.6	21.3	
8/19/2002			2	0.32	31.7	20.8	
8/19/2002			12	0.6	31.6	18.6	
8/19/2002			23.5	0.6	31.6	17.7	Bot
8/19/2002	14:20	Buoy 16	0	13.3	28.4	26.7	
8/19/2002		Buoy 16	2	1.8	29.7	24.2	
8/19/2002			4	3.8	29.9	23.8	
8/19/2002	14:31	Buoy 14	0	3.6	29.3	24.9	
8/19/2002			2	2.7	30.1	23.8	
8/19/2002			5	1.6	30.4	23.1	

8/19/2002			10.7	1.6	31.1	21.6	
8/19/2002	14:54	Buoy 12	0	7.7	29.7	24.9	
8/19/2002			2	1.7	30	24.4	
8/19/2002			4	1.5	30.5	22.8	
8/19/2002			8.4	1.6	30.8	21.9	
8/19/2002	15:02	Buoy 10	0	2.4	30.2	45.8	
8/19/2002			2	2	30.2	24.6	
8/19/2002			4	1.6	30.5	24	
8/19/2002			8	1.8	30.5	23	
8/19/2002	15:09	Buoy 4	0	1.8	30.4	23.9	
8/19/2002			2	1.4	30.5	23.9	
8/19/2002			6.5	1	30.9	23.5	
8/19/2002	15:39	"C"	0	0.66	31.6	22.6	
8/19/2002			2	0.42	31.5	22.6	
8/19/2002			9	0.33	31.6	20.7	
8/19/2002			19	0.41	31.6	20.3	
8/19/2002	15:55	Buoy 1	0	1.5	30.8	23.1	
8/19/2002			2	1.4	31	22.8	
8/19/2002			6	0.54	31.2	22.1	
8/19/2002			12.6	0.44	31.5	21.2	
8/19/2002	16:05	"B"	0	0.26	31.6	21.8	
8/19/2002			2	0.24	31.6	21.9	
8/19/2002			9.5	0.29	31.6	21.1	
8/19/2002	17:09	"A"	0	0.2	31.8	20.2	
8/19/2002			2	0.2	31.7	19.7	
8/19/2002			7.7	0.22	31.8	18.7	
8/19/2002			15	0.3	31.8	18.5	
8/20/2002	9:48	Buoy 16	0	12.2	27.5	21.9	
8/20/2002			2	5.9	30.3	21.1	
8/20/2002			4	1.2	31.3	20.6	
8/20/2002			8	1.3	31.3	20.6	Bot
8/20/2002	9:55	Buoy 14	0	10.5	28.8	21.7	
8/20/2002			2	4.2	29.4	21.6	
8/20/2002			10	0.86	31.4	20.4	
8/20/2002			21	0.97	31.4	20.4	Bot
8/20/2002	10:03	Buoy 12	0	1.6	31.5	19.9	
8/20/2002			2	0.57	31.5	19.8	
8/20/2002			8	0.52	31.5	19.8	
8/20/2002			17	0.96	31.5	19.7	Bot
8/20/2002	10:10	Buoy 10	0	1.53	31.4	20	
8/20/2002			2	0.54	31.4	20	
8/20/2002			9	0.38	31.6	19.4	
8/20/2002			18	0.4	31.6	19.2	Bot
8/20/2002	10:18	Buoy 4	0	1.2	31.5	19.7	
8/20/2002			2	0.35	31.5	19.8	
8/20/2002			7	0.28	31.6	19.6	
8/20/2002			15	0.28	31.7	18.3	Bot
8/20/2002	10:26	Buoy 1	0	0.79	31.7	19.1	
8/20/2002			2	0.16	31.7	19.1	
8/20/2002			8	0.16	31.7	19.1	

8/20/2002			18	0.22	31.8	16.7	Bot
8/20/2002	10:35	"B"	0	0.16	31.8	18.8	
8/20/2002			2	0.16	31.7	18.8	
8/20/2002			14	0.16	31.7	18.7	
8/20/2002			24	0.19	31.8	18.5	Bot
8/20/2002	10:52	"C"	0	0.18	31.6	19.4	
8/20/2002			2	0.21	31.6	19.4	
8/20/2002			10	0.17	31.6	19.2	
8/20/2002			22	0.21	31.7	17.2	Bot
8/20/2002	11:06	"D"	0	0.7	31.4	20.3	
8/20/2002			2	0.7	31.4	20.4	
8/20/2002			4	0.62	31.5	20.1	
8/20/2002			9	0.53	31.5	19.8	Bot
8/20/2002	15:17	Buoy 16	0	1.8	27.3	24.4	
8/20/2002			2	1.7	29.2	23.6	
8/20/2002			6	1.5	31.1	21.4	
8/20/2002	15:23	Buoy 14	0	2.2	28.1	24.4	
8/20/2002			2	2.2	28.7	23.5	
8/20/2002			6	1.3	30.7	22.1	
8/20/2002	15:31	Buoy 12	0	2.1	29.3	23.8	
8/20/2002			2	2.1	29.8	23.3	
8/20/2002			4	1.3	30.6	22	
8/20/2002			8	1.36	30.8	21.6	
8/20/2002	15:38	Buoy 10	0	1.75	29.7	23.1	
8/20/2002			2	1.72	29.9	23.1	
8/20/2002			4	1.32	30.2	23	
8/20/2002			7	1.37	30.5	22.2	
8/20/2002	15:46	Buoy 4	0	1.3	31.4	22.5	
8/20/2002			2	1.3	30.3	22.5	
8/20/2002			6	1.3	30.9	22.4	
8/20/2002	15:55	Buoy 1	0	1.2	30.5	21.6	
8/20/2002			2	1.2	30.6	21.5	
8/20/2002			5	1	31.1	21.1	
8/20/2002			10	0.78	31.3	20.4	
8/20/2002	16:03	"B"	0	0.4	31.3	20.6	
8/20/2002			2	0.4	31.5	20.4	
8/20/2002			9	0.3	31.6	19.7	
8/20/2002			18	0.3	31.6	18.3	
8/20/2002	16:17	"A"	0	0.12			
8/21/2002	10:28	Buoy 16	0	0.79	28.4	21	
8/21/2002			2	0.83	30.3	20.7	
8/21/2002			8	0.57	31.3	19.6	
8/21/2002	10:33	Buoy 14	0	0.56	31.3	20	
8/21/2002			2	0.6	31.3	19.6	
8/21/2002			8.5	0.57	31.4	19.6	
8/21/2002			16.2	0.57	31.4	19.4	
8/21/2002	10:40	Buoy 12	0	0.34	31.5	19.6	
8/21/2002			2	0.35	31.5	19.3	
8/21/2002			8	0.36	31.5	19.2	

8/21/2002			16	0.34	31.5	19	
8/21/2002	10:48	Buoy 10	0	0.61	31.2	20.4	
8/21/2002			2	0.54	31.4	19.4	
8/21/2002			8	0.31	31.6	18.8	
8/21/2002	10:53	Buoy 4	0	0.26	31.6	19.2	
8/21/2002			2	0.22	31.6	19.1	
8/21/2002			7	0.22	31.6	18.8	
8/21/2002			15.5	0.22	31.6	18.4	
8/21/2002	11:00	Buoy 1	0	0.14	31.7	18.7	
8/21/2002			2	0.13	31.7	18.7	
8/21/2002			10	0.14	31.7	16.7	
8/21/2002			20	0.19	31.7	16.6	
8/21/2002	11:10	"D"	0	0.44	31.4	19.8	
8/21/2002			2	0.42	31.4	19.7	
8/21/2002			5	0.4	31.5	19.5	
8/21/2002			7	0.41	31.5	19.4	
8/21/2002	11:20	"D1"	0	0.51	31.3	20.1	
8/21/2002			7.6	0.5	31.4	20	
8/21/2002	11:24	"D2"	1	0.53	31.3	20.1	

8/21/2002	16:17	Buoy 16	0	1.1	28.8	23.7	
8/21/2002			2	1.1	29.2	23.3	
8/21/2002			6.2	1	30.7	21.1	Bot
8/21/2002	16:23	Buoy 14	0	1.1	29.2	23.7	
8/21/2002			2	1	29.5	22.8	
8/21/2002			5	0.9	30.9	20.5	
8/21/2002			11	1	31.1	20.4	Bot
8/21/2002	16:29	Buoy 12	0	1	29.5	23.2	
8/21/2002			2	1.1	29.5	22.6	
8/21/2002			5	0.9	30.2	21.9	
8/21/2002	16:36	Buoy 10	0	0.8	30.3	22.4	
8/21/2002			2	0.8	30.3	22.5	
8/21/2002			4	0.8	30.4	22.5	
8/21/2002			7	0.8	30.7	22.7	Bot
8/21/2002	16:41	Buoy 4	0	0.8	30.8	22.1	
8/21/2002			2	0.8	30.9	22.2	
8/21/2002			5	0.8	31	22.5	Bot
8/21/2002	16:48	Buoy 1	0	0.5	31.1	21.2	
8/21/2002			2	0.6	31.1	21.2	
8/21/2002			6	0.6	31.1	21.1	
8/21/2002			14	0.6	31.5	20.7	Bot
8/21/2002	16:56	"B"	0	0.2	31.6	19.7	
8/21/2002			2	0.2	31.6	19.7	
8/21/2002			9	0.2	31.6	19.8	
8/21/2002	17:07	"C"	0	0.5	31.3	21.1	
8/21/2002			2	0.5	31.4	20.9	
8/21/2002			10	0.4	31.6	20	
8/21/2002			19	0.3	31.6	19.5	Bot

8/21/2002	18:32	"D"	0	0.98	30.3	22.3	
8/21/2002			2	1.04	30.4	22.3	
8/22/2002	11:45	Buoy 16	0	0.6	30.4	20.6	
8/22/2002			2	0.6	31.4	19.5	
8/22/2002			4	0.5	31.4	19.6	
8/22/2002			9	0.5	31.4	19.5	Bot
8/22/2002	11:54	Buoy 14	0	0.4	31.4	19.4	
8/22/2002			2	0.4	31.5	19.5	
8/22/2002			10	0.4	31.5	19.2	
8/22/2002			18	0.4	31.5	19.2	Bot
8/22/2002	12:02	Buoy 12	0	0.3	31.5	19.2	
8/22/2002			2	0.3	31.5	19.2	
8/22/2002			9	0.3	31.6	18.7	
8/22/2002			17	0.3	31.7	18.6	
8/22/2002	12:12	Buoy 10	0	0.27	31.6	19	
8/22/2002			2	0.27	31.6	18.9	
8/22/2002			8	0.26	31.7	18.8	
8/22/2002			15	0.26	31.7	18.6	Bot
8/22/2002	12:22	Buoy 4	0	0.24	31.7	18.8	
8/22/2002			2	0.23	31.7	18.7	
8/22/2002			8	0.23	31.7	18.4	
8/22/2002			14	0.22	31.8	17.8	Bot
8/22/2002	12:33	"D"	0	0.3	31.6	19.3	
8/22/2002			2	0.3	31.6	19.1	
8/22/2002			4	0.3	31.6	19.1	
8/22/2002			9	0.3	31.6	18.8	
8/22/2002	12:42	"D1"	0	0.4	31.4	19.8	
8/22/2002			3	0.38	31.4	19.8	
8/22/2002			7	0.38	31.4	19.5	
8/22/2002	12:50	"D2"	0	0.42	31.3	19.9	
8/22/2002			3	0.4	31.4	19.8	
8/22/2002			6	0.4	31.8	19.7	Bot
8/22/2002	17:19	Buoy 16	0	0.8	24.4	21	
8/22/2002			2	0.67	29.8	21.2	
8/22/2002			5.3	0.75	30.2	20.7	
8/22/2002	17:29	Buoy 14	0.27	0.8	27.7	21.4	
8/22/2002			2	0.68	30	20.9	
8/22/2002			4.7	0.65	30.8	20.4	
8/22/2002			9.4	0.91	31.1	20	Bot
8/22/2002	17:37	Buoy 12	0.21	0.75	29.6	21.1	
8/22/2002			2	0.74	29.9	20.9	
8/22/2002			3.8	0.7	30.7	20.4	
8/22/2002			8.4	0.79	31	20.2	
8/22/2002	17:45	Buoy 10	0.48	0.71	30.1	20.9	
8/22/2002			2.8	0.71	30.2	20.8	
8/22/2002			3.6	0.71	30.1	20.8	
8/22/2002			7.4	0.8	30.3	20.7	Bot
8/22/2002	17:56	Buoy 4	0.03	0.72	30.8	20.5	

8/22/2002			2.29	0.71	30.9	20.4	
8/22/2002			6.2	0.71	31	20.2	Bot
8/22/2002	18:04	Buoy 1	0.02	0.51	31.2	20	Green Light
8/22/2002			2.41	0.52	31.2	19.9	
8/22/2002			6	0.5	31.4	19.6	
8/22/2002			12.5	0.41	31.6	19.1	
8/22/2002	18:58	T2	0	0.98			
8/22/2002			3.9	0.75			
8/22/2002			7.63	0.73			
8/22/2002	19:13	"C"	0.08	0.34	31.7	19.5	
8/22/2002			2.01	0.34	31.7	19.5	
8/22/2002			6.9	0.33	31.7	19.3	
8/22/2002			15.4	0.33	31.7	19	
8/22/2002	19:40	Mouth	0.12	0.8	30.6	20.5	
8/22/2002			2	0.81	30.6	20.6	