BACK BAY STORMWATER

MONITORING PROJECT

FINAL REPORT

by

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INTRODUCTION

Back Bay is a small embayment located approximately ten miles south of Chesapeake Bay in the Commonwealth of Virginia. Like Chesapeake Bay, Back Bay has experienced a gradual decline in the abundance of its resident biota over the past two decades (Stevenso et al. 1979, Sincock et al. 1965). A study of historical records found annual waterfowl counts to be declining significantly over the period from 1980 to 1990 (Schwab et al. 1989). A similar study on fish found the once noteworthy recreational fishery for Largemouth Bass to be essentially non-existent in recent years (Southwick and Norman 1989). This is a watershed that was once referred to by Butts (1922) as one of the best fishing and waterfowl hunting areas in Virginia. Several attempts have been made to discover the cause of these declines and counteract them through the implementation of Best Management Practices (BMP)

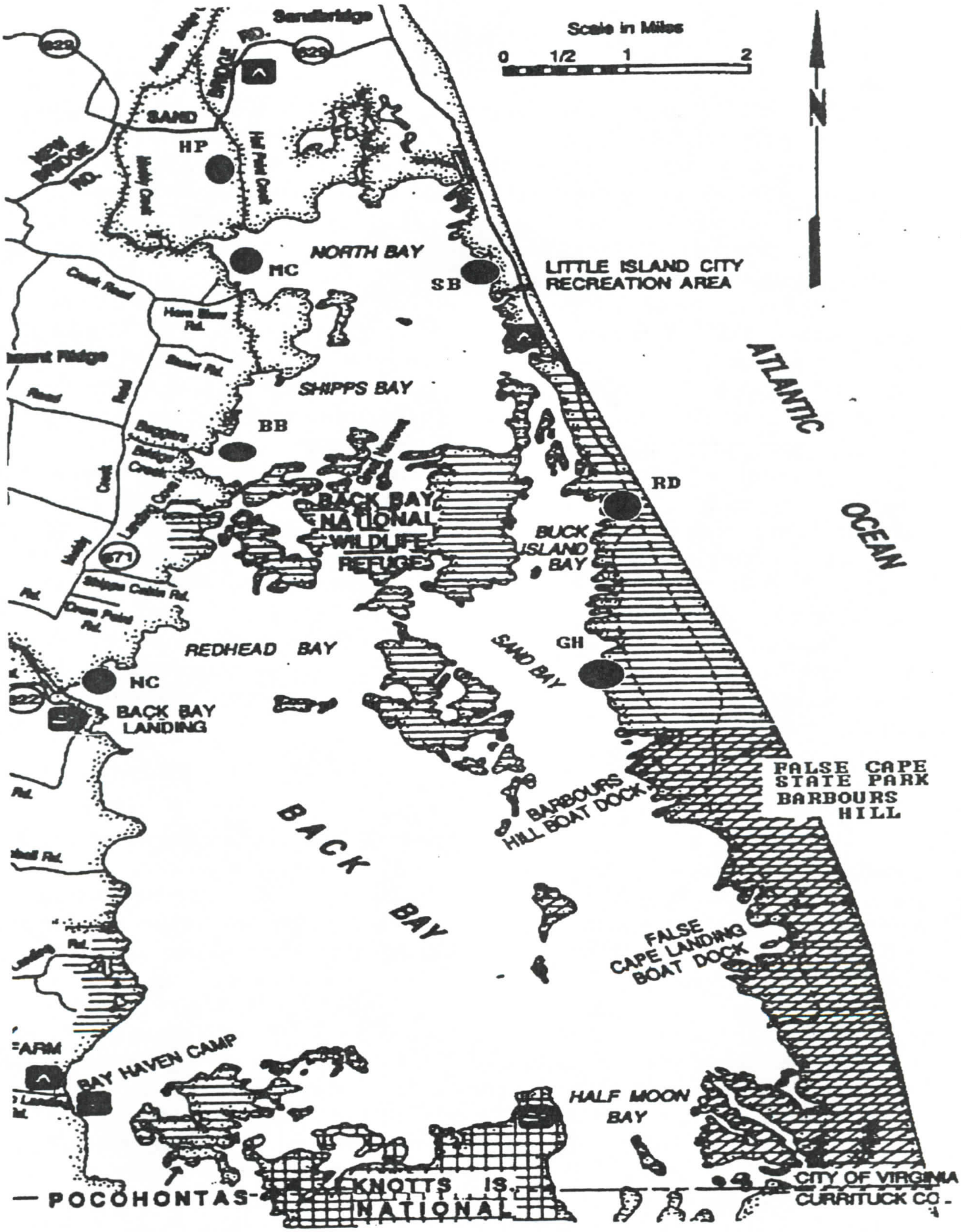
A general symposium on the health of Back Bay was held in 1989 (Marshall and Norman. eds. 1989). One of this symposium's stated objectives was to establish BMP criteria for Back Bay. One issue highlighted during this meeting was an observed historical relationship between both of the above mentioned trends and an observed decline in Submerged Aquatic Vegetation (SAV) (Schwab et al. 1987). This relationship has been attributed elsewhere to the use of SAV beds as sources of food for waterfowl, fish nursery habitat and shelter from predation (Stevenso and Confer 1978). A correlation was found between landings of citation Largemouth Bass and the historical decline in SAV abundance within Back Bay (Norman and Southwick 1989). There is a generally accepted relationship between the concentration of nutrients and solid material present within an aquatic ecosystem and the relative health of SAV (Clark et al. 1973). Several studies have been conducted by Virginia Water Control Board (VWCB) and the Virginia Department of Game and Inland Fisheries aimed at identifying significant levels of both organic material and inorganic toxicants within Back Bay. All of these prior studies utilized a periodic sampling scheme and failed to identify concentrations exceeding present EPA standards (VWCB 1976, Norman and Southwick 1989). However, this type of sampling scheme may over look significant short term loadings of nutrients and solid material into the Bay, particularly those that occur during storm events. The objective of this project was to assess the influx of nutrients and solid material into Back Bay and its tributaries during and immediately following such storm events.

The Back Bay Stormwater Monitoring Project is a cooperative project supported by the United States Fish and Wildlife Service (USFWS) Virginia Field Office, Back Bay National Wildlife Refuge (BBNWR), and Old Dominion University.

Study Area

Back Bay is the northernmost embayment in a connected series that stretches south into North Carolina and includes Currituck, Pamlico and Albermarle Sounds. The closest connection to the Atlantic is 43 km south at Oregon Inlet. Back Bay is located at 75° 52-58" W. longitude and 36° 32-45" N. latitude, and it is entirely within the City of Virginia Beach. The Back Bay watershed measures 27,024 ha and includes four major tributaries: Nanney, Begger's Bridge, and Muddy Creeks on the western side of the Bay and Hellpoint Creek on the northern side. The

FIGURE 1: Map of Back Bay study area. Dots indicate sampling sites.


Sandbridge
SAND
BRIDGE
RD.
NEW BRIDGE RD.
Scale in Miles
0 1/2 1 2
N
HP
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BACK BAY
NATIONAL
WILDLIFE
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ISLAND
BAY
REDHEAD BAY
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HILL BOAT DOCK
BACK BAY
FALSE
CAPE LANDING
BOAT DOCK
FARM
BAY HAVEN CAMP
HALF MOON
BAY
CITY OF VIRGINIA
CURRITUCK CO.
POCOHONTAS
KNOTTS IS.
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eastern side of Back Bay is comprised of a narrow extension of land comprised mostly of emergent wetlands and sand stabilized by rooted vegetation (Figure 1). The northern half of the eastern margin is residentially developed. The remainder of the eastern margin is state and/or federally protected wetlands. Back Bay is bordered by two National Wildlife Refuges (Back Bay and Mackay Island), three Virginia Wildlife Management Areas (Trojan, Pocahontas, and Barbour's Hill Waterfowl areas), one Virginia State Park (False Cape), and two Virginia Beach City Parks (Little Island and Creeds). The majority of the western margin of the Bay is used for agricultural purposes (Marshall & Norman. 1989).

Back Bay is a shallow, flat bottomed aquatic ecosystem consisting of 9960 hectares of open water and 4596 ha of emergent aquatic vegetation. The mean depth is 1.3 m with the majority of the open regions measuring less than 2.5 m in depth. Since being cut off from direct access to the Atlantic ocean, the Bay has had a negligible lunar tide, but it is highly sensitive to wind tides. Water level drops of as much as one meter along the northern and eastern shore have been observed regularly during periods of sustained north northeast winds (John Gallegos BBNWR, personal communication). Measurable winds coming from the north northeast were observed thirty percent of the time by Swift (1989). The climate at Back Bay is mediated primarily by the proximity of the Atlantic Ocean and Chesapeake Bay. Wind speed and direction vary greatly over the year. The average annual wind speed as measured by Oceania Naval Air Station in 1984 was 9.2 kilometers per hour. A comprehensive history of weather patterns at Back Bay can be found in Mann (1984).

Back Bay is classified as an oligohaline system. Annual mean salinity is approximately three parts per thousand. Over-wash during high tide events along the eastern margin of the Bay cause periodic short term increases in salinity, but with no observed effect on the watershed, or its biota (Southwick 1989).

METHODS

Water samples were collected at seven sites along the shore of Back Bay and its tributaries from July 1994 to June 1995. One test site was located at or near the inflow of each of the four primary tributaries (See Study Area Description). In addition, a test site was located near the residentially developed region on the eastern margin of the Bay. Two control sites were located on BBNWR land along the southeastern shore of the Bay, away from all primary sources of allocthonous input (Figure 1).

Samples were collected utilizing seven automated 800sl Portable Water Samplers (American Sigma, Inc.), one unit at each site. The sampling protocol was to collect one 300 ml sub-sample every forty-five minutes for thirty-six hours after sample initiation. Treatment samples were initiated when accumulated rainfall measured 0.25 inches in three hours or less using a balance style external rain gauge to activate the Water Sampler. Control samples were collected by manually activating the Water Samplers after a period of not less than four days with no measurable rainfall. Both types of sampling events (Treatment and Control events) were separated into two eighteen hour periods for chemical analysis. Twenty-four sub-samples were collected in individual 300 ml glass sample bottles during each 18h. sampling period. After the first 18h., the first set of twenty-four sub-samples were removed from the water sampler, and the sampling cycle was manually repeated for a second 18-h period. This protocol resulted in two sets of twenty-four sub-samples; one from the first 18h., and one from the second 18h.

An aliquot was first removed from each of the forty-eight sub-samples for turbidity analysis. The remaining sub-samples from the first 18-h period were then combined into one large sample for all other analysis. This procedure was repeated for the sub-samples from the second 18-h period. All water samples were transported to the Applied Marine Research Laboratory (AMRL)-Water Quality Lab and stored on ice for chemical analysis. All samples were analyzed for the following water quality parameters using standared methods of the United Staes Environmental Protection Agency (USEPA 1983): total suspended solids concentration (Method 160.2), total dissolved solids concentration (Method 160.1), volatile suspended solids concentration (Method 160.4), volatile dissolved solids concentration (Method 160.3), total kjeldalh nitrogen concentration (Method 351.2), total phosphorus concentration (Method 365.3b), orthophosphate concentration (Method 365.3), ammonia concentration (Method 350.1), nitrate/nitrite concentration (Method 353.2). All samples were additionally analyzed for chlorophyll a concentration using the method outlined in the APHA standard methods (APHA, 1989).

The resulting water quality data were analyzed using an unbalanced multivariate Analysis of Variance (MANOVA) design. A temporal model was tested for differences in water quality parameters between treatments and seasons. In addition, a spatial model was tested for differences in water quality parameters between individual sample sites.

The temporal model tested for significant difference between treatments and season for all water quality variables (alpha=0.05). Any significance within this model was further tested using a Least Square Means Test (LSMEANS) for the interaction between treatment and season (SAS Institute Inc. 1989). The alpha level of significance for these comparisons was adjusted using a Bonferroni adjustment for pairwise comparisons to alpha=0.0125 (Snedecor and Cochran, 1980) Both of these analyses was performed for each 18h. sample set separately to look for changes in significance between the sampling periods.

The data set obtained from analysis of the turbidity aliquot was normalized by converting the 48 observations to 24 mean values, one for every two observations in sequence. A thirty-six hour trend for turbidity was plotted using these mean values. These plots are located in Appendix 1.

The spatial model was tested for difference between individual sample sites during both rain events and control events (alpha=0.05). Based on results from the temporal model (See Results and Discussion Section), the spatial model was tested for two separate six month periods. The period from January to May was labeled Winter/Spring, and the period from June to November was labeled Summer/Fall. This data set was not separated for the first 18 hour period and the second 18 hour period as described for the temporal model. This consolidation of time periods was done in order to preserve degrees of freedom within the spatial model. The spatial model was tested using an unbalanced MANOVA followed by an LSMEANS test for all ad hoc pairwise comparisons. The LSMEANS test was followed by a Tukeys Multiple Comparisons Test for significance. This test had a familywise Type I error rate of 5 percent (SAS Institute Inc. 1989).

The level of correlation between water quality parameters was analyzed in order to observe possible couplings between pairs or groups of parameters. This analysis included correlation values for all water quality parameters by site and by treatment. In addition, a Principal Component Analysis was run on all water quality parameters in order to observe possible groupings of parameters at each site. The goal of this sub-set of analysis was to observe whether groupings of certain parameters was in agreement with the findings of the statistical models previously described. In addition, these data would aide in "fine tuning" the data collection protocol for future water quality analysis on Back Bay.

RESULTS AND DISCUSSION

We collected a total of fourteen 36-hour samples from the seven sites on Back Bay. This total included ten treatment samples and four control samples. Missing samples were to have been collected in July, 1994 and December, 1994. Therefore, these two months were omitted from analysis. Data lost on individual water quality parameters during analysis were replaced with a group mean for a given parameter in order to preserve the remaining data for a given observation. For example, if a given observation was missing the data for total suspended solids, the group mean for total suspended solids from either the control or treatment group was placed in that data position, so that the computer statistics package would not "ignore" the entire observation when running the MANOVA.

Statistical analyses on the temporal model were performed on the first half of the 36-hour samples (hours 1-18) and the second half (hours 19-36) separately. Statistical analyses on the spatial model was performed on the Winter/Spring period from January to May and the Summer/Fall period from June to November separately.

Temporal Model

The multivariate temporal model indicated more seasonal effects ($p=0.001$) than treatment effects ($p=0.0345$) on water quality during the first 18 hours. During the second 18 hours, the model indicated significant interaction effects between season and treatment ($p=0.0027$) on water quality. The univariate results for each water quality parameter yielded some insights to the difference between periods.

Turbidity is a measure of water clarity and is related to the suspended solid concentration in a water sample. Turbidity means for the first 18-h period varied significantly among seasons ($p=0.0085$) but not treatments. During the second 18-h period, the effects of a season-treatment interaction were significant ($p=0.0034$). Pairwise comparisons showed that turbidity means tended to be higher for storm events than for control events from September to February. Means were lower for storm events than for control events from March to May. These pairwise differences were marginally non-significant (High: Sept.-Nov. $p=0.037$, Jan.-Feb. $p=0.013$; Low: Mar.-May $p=0.028$).

Total Suspended Solids (TSS) is a mixture of colloidal clay and coarse suspensions of soil particles and organic material (Norman and Southwick, 1989). No significant difference among TSS observations was observed during the first 18-h period. During the second period, TSS exhibited significant differences due to the interaction of season and treatment ($p=0.0013$). TSS means were significantly lower for observations taken during storm events and at test sites from March through May when compared to control treatments (Pairwise comparison p=0.0018). No significant difference was observed among treatments during any other season.

Volatile Suspended Solids (VSS) is that component of TSS which is combustible at 550 degrees centigrade. It is comprised primarily of solid organic material (APHA 1989). Means for VSS showed significant difference among seasons during the first and second 18-h period (p=0.0001). Pairwise comparisons showed that VSS means were higher during the months of September, October, and November. (p=0.0125).

Total Dissolved Solids (TDS) is comprised of inorganic ionic material and dissolved organic compounds. The inorganic component is a general measure of salinity (APHA 1989). The TDS means exhibited significant difference among treatments for both the first and second 18-h periods. Pairwise comparisons showed TDS means to be significantly lower during storm events and at test sites (p=0.0001). Volatile Dissolved Solids (VDS) showed an equivalent pattern (p=0.0001). VDS is that portion of TDS samples combustible at 550 degrees centigrade, and contains the organic component.

Sample means for Chlorophyll a showed significant difference among treatments during the second 18-h period (p=0.0396). Sample means for chlorophyll a were higher during storm events and at test sites during the second 18-h period. No significant difference among chlorophyll a means was observed during the first 18-h period.

Total Kjedalh Nitrogen (TKN) includes ammonia and organic nitrogen forms such as urea, amino acids and polypeptides. Means for TKN showed no significant difference with respect to season or treatment variables. However, according to Boyd (1979), the concentration of TKN should not exceed 1.0 mg/l in unpolluted waters. The EPA reference level for TKN is 0.9mg/l. (VWCB 1976.). Individual observations for TKN taken from Back Bay routinely exceeded these values. Means for TKN data are given by month in Figure Two.

Ammonia is present in aquatic systems primarily as disassociated ammonium ions. It is readily taken up by phytoplankton and aquatic plants, and is usually present in small quantities as an excretory product of larger animals (Boyd 1976). Means for ammonia showed significant difference among seasons during the first 18-h period (p=0.0001). Pairwise comparisons showed means to be higher during the months of January through May and at its lowest level during the months of June through August. This pattern was also observed during the second 18-h period.

Total phosphorus includes all forms of phosphorus converted to orthophosphate for analysis. Means for total phosphorus showed no significant difference among seasons or treatment during the first 18-h period. During the second 18-h period, significant difference was observed among interactions of treatment and season (p=0.048). Pairwise comparisons showed means to be higher for samples taken during storm events and at test sites during the months of January and February (p=0.0125). No significant difference among treatments was observed during any other month.

Orthophosphate is an inorganic, ionic form of phosphorus. It is readily available for uptake by phytoplankton and aquatic plants. It is usually cycled through an aquatic system relatively quickly (Boyd 1979). No significant difference was observed among seasons or treatments during the first 18-h period. During the second 18-h period, orthophosphate mean values showed significant difference among treatments (p=0.0302). Pairwise comparisons showed orthophosphate means to be on order of magnitude higher during storm events and at test sites during this period.

Nitrates and nitrites together are a common inorganic form of nitrogen found in aquatic systems. Concentrations of both forms have been found to be highly dependent on the land use practices within the watershed (Southwick and Norman 1989). Nitrate/nitrite means showed significant difference among seasons during the first 18-h period (p=0.0001). Pairwise comparisons showed mean values to be highest during the months of March through May and lowest during the months of June through August. During the second eighteen hour period, nitrate/nitrite means showed significant difference among both seasons (p=0.0001) and treatments (p=0.0499). Pairwise comparison showed mean values to be an order of magnitude higher during storm events and at test sites. Independent of treatment, nitrate/nitrite means were higher during the months of January through May.

Spatial Model

The multivariate spatial model showed significant differences among sites for both the Winter/Spring period (p=0.011) and the Summer/Fall period (p=0.0001). The interaction between site and treatment was not significant for either period (W/S p=0.98, S/F p=0.47). The univariate results for individual water quality parameters yield some details of these significant findings in the multivariate model.

During the Winter/Spring period, only TSS and VSS showed significant difference between sites (p<0.003). During the Summer/Fall period, TDS and VDS showed significant difference between sites (p<0.002). In addition, a significant difference between sites was observed for both ammonia (p=0.049) and orthophosphates (p=0.005) during the Summer/Fall period.

Pairwise comparisons (LSMEANS) on these data for the Winter/Spring period showed that TSS tended to be highest at the sites located at Muddy Creek and Refuge Dock and lowest at the sites located at Beggars Bridge and Hellpoint Creek. VSS tended to be highest at sites located at Muddy Creek and Green Hill. The mean values for TSS and VSS at Muddy Creek were noticeably higher than the next highest site value. Although these mean values were marginally non-significant.

Pairwise comparisons for the Summer/Fall period showed that TDS and VDS tended to be highest at the sites located on the eastern margin of Back Bay. These were sites located at Green Hill, Refuge Dock and Sandbridge. Both parameters tended to be lowest at the site located in Hellpoint Creek. Ammonia tended to be highest at the sites located at Refuge Dock and Nanney Creek. It tended to be lowest at the site located at Green Hill. Orthophosphates were highest at the site located at Nanney Creek. The remaining sites had essentially identical for orthophosphate levels. The significance of this parameter within the model was based completely on the order of magnitude difference between the mean orthophosphate level at Nanney Creek and that of every other site (p=.015). In general, the mean values for all the nutrient parameters (ammonia, orthophosphates, and nitrates/nitrites), during both seasonal periods, were highest at Nanney Creek (Figure 3) .

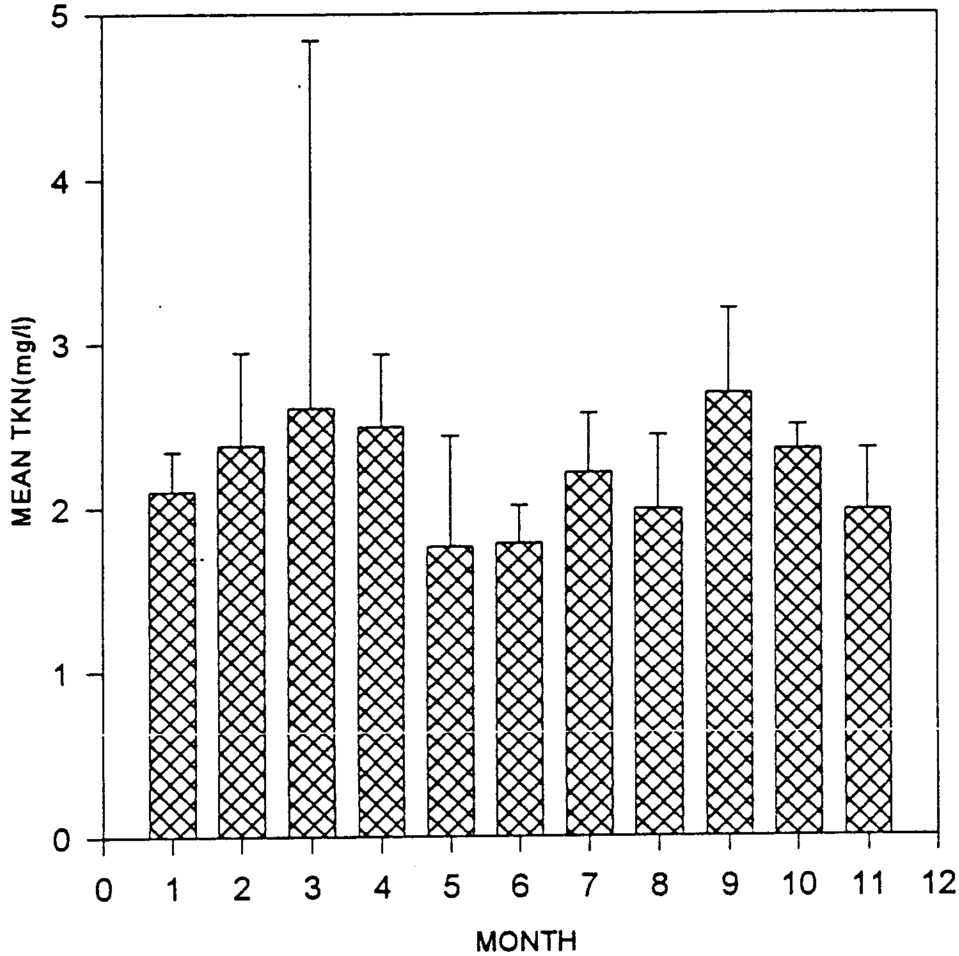

FIGURE 2: TKN mean concentrations for each month of sampling with standard error bars.

Correlation Analysis

Correlation analysis demonstrated a significant relationship between TSS and TKN at all sites except Nanney Creek and Green Hill ($r>0.50$, $p<0.05$). In addition, TSS was highly correlated with VSS and Turbidity at all sites. TDS and VDS showed a negative *correlation with* nutrient parameters at all sites, although these correlations were significant only at Nanney Creek and Beggars Bridge ($p<.015$).

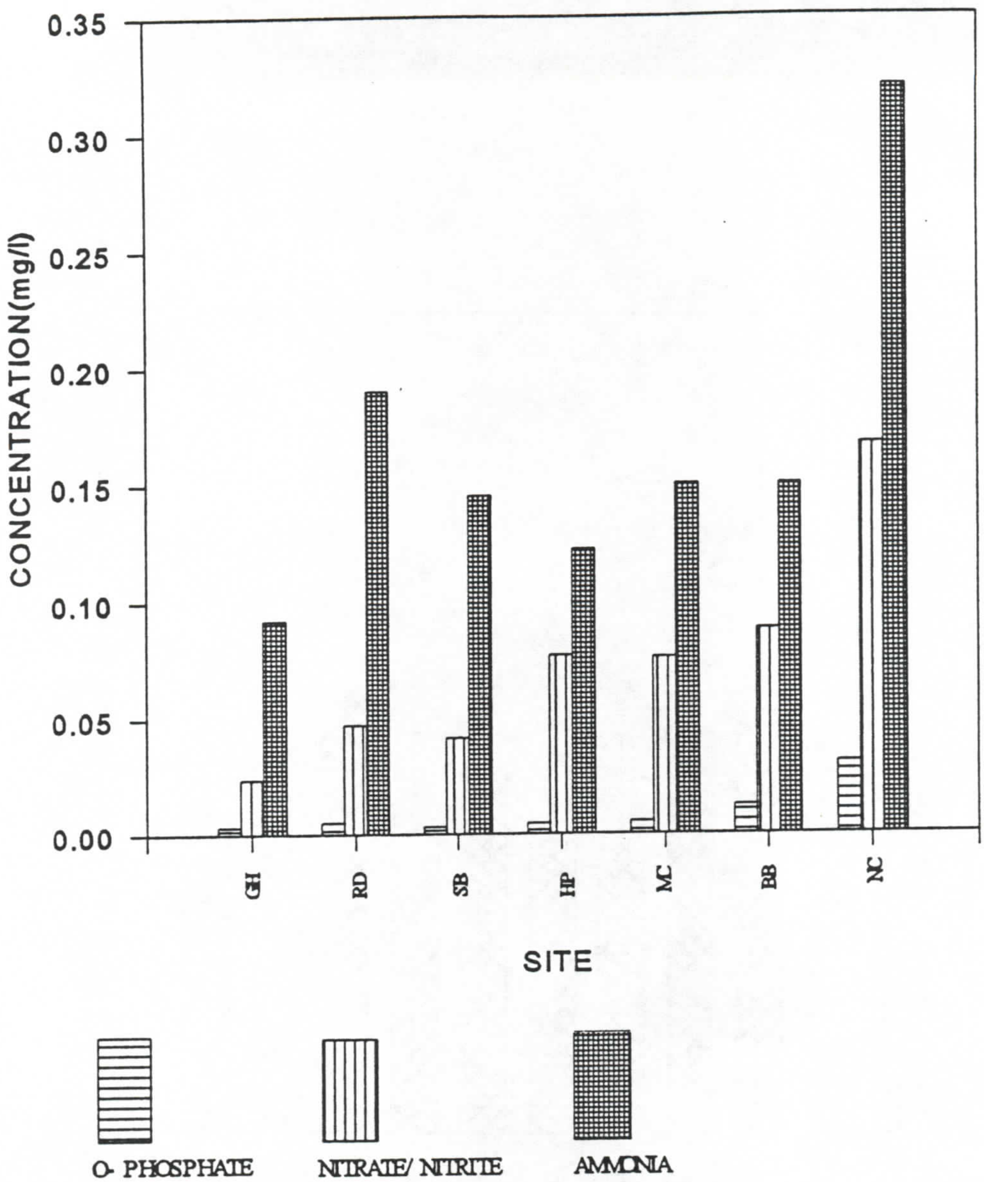

FIGURE 3: Mean concentrations of orthophosphate, nitrate/nitrite, and ammonia for each site. GH-Greenhill, RD-Refuge Dock, SB-Sandbridge, HP-Hellpoint, MC-Muddy Creek, BB-Beggers Bridge, NC-Nanney Creek.

Principal Component Analysis (PCA) demonstrated that a large amount of variation in water quality, at Nanney Creek and Beggars Bridge, was related to nutrient patterns. At Nanney Creek, the first principal component explained 52% of the total variation in water quality. This component was a positive function of ammonia, orthophosphates, nitrates/nitrites, TKN and total phosphorus, and a negative function of TSS, VSS, TDS, VDS and turbidity. At Beggars Bridge site, the first principal component explained 39% of the total variation in water quality. This component was a positive function of orthophosphates, nitrates/nitrites, ammonia, TKN, TSS and VSS, and a negative function of TDS, VDS and chlorophyll a.

Principal Component Analysis by treatment demonstrated a large amount of variation during control samples to be related to changes in solids concentrations. For control events, the first principal component explained 32% of the variation in water quality. This component was a positive function of TSS, VSS, turbidity, TKN, and ammonia. The second principal component explained 22% of the variation in water quality during control events. This component was a positive function of TDS, VDS and a negative function of ammonia, TKN, nitrates/nitrites, orthophosphates, and total phosphorus. The first principal component for rain events explained 40% of the variation in water quality during rain events and at test sites. This component was a positive function of ammonia, nitrates/nitrites, orthophosphates and TKN, and a negative function of TSS, VSS, TDS, VDS, and chlorophyll a.

Within the temporal model, most dependent variables showed significant differences among seasons, treatments or both. The majority of the differences were observed in the second 18-h period. Only TKN showed no difference during both periods. In addition, the difference observed in turbidity means was only marginally significant. This finding may indicate that TKN concentration and turbidity are more influenced by other factors, such as wind patterns. Monthly mean values for TKN data are given in Figure 2. Means by season are given for some other dependent variables (OPO4, nitrate/nitrite) in Figure 4.

Increased concentrations of nutrients within the open water of Back Bay may be the primary cause of historic declines in submerged aquatic vegetation (SAV). Increased nutrient concentrations can combine with other physicochemical factors to decrease water clarity and cause increases in phytoplankton density. These factors can slow submerged vegetation growth and reduce suitable habitat (Clark et al. 1973). However, limited periodic sampling for concentrations of nutrients and solid material may not yield conclusive results. Often, monthly or seasonal trends will not draw an accurate picture of nutrient level fluctuations. This is particularly true if sharp increases in concentration occur during and immediately after rainfall. Under these conditions, the tributaries and surrounding watershed of a lotic water system may act as a "nutrient bank" holding material until water flow increases sufficiently to flush it out into the main water body. The effect that such a flushing may have on SAV health is dependent on its length and severity.

Statistical analysis showed that almost all nutrients, as well as solid concentrations changed from season to season. Most were highest in the winter and spring and lowest during the summer. The exception to this was volatile suspended solids which peaked in the fall. This is most likely explained by an increase in organic material due to seasonal leaf fall and emergent plant die-back. In addition to these seasonal trends, several nutrients increased in concentration after rain events. Both nitrate/nitrite and orthophosphate concentrations increased significantly 19-36 hours after the initiation of rain fall. This trend was observed in the winter and the spring. total dissolved solids also displayed a treatment effect. The TDS concentrations decreased quickly after the initiation of rain fall during all seasons. This finding may be explained by the effect of increased freshwater input to this oligohaline system.

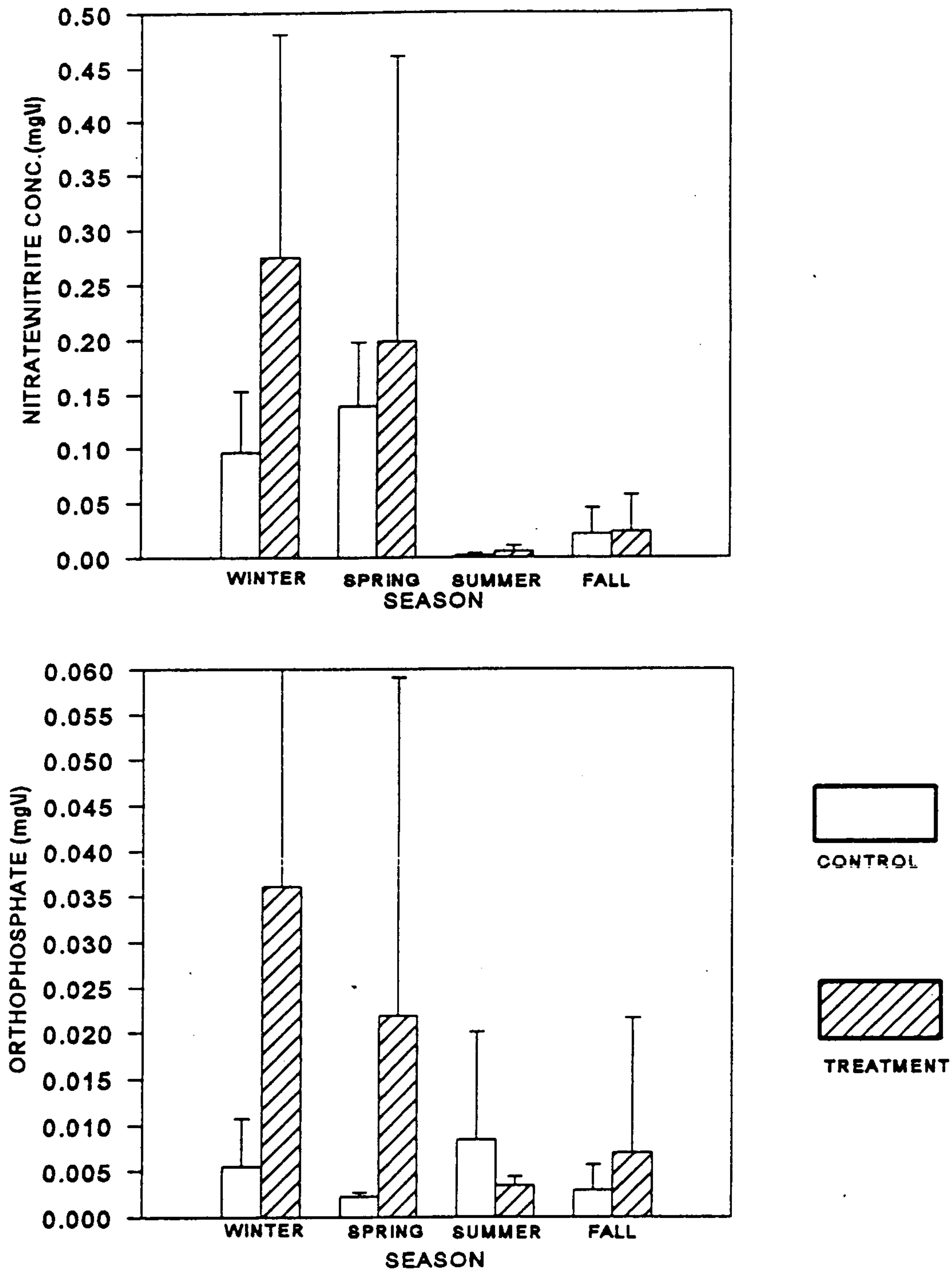

FIGURE 4: Mean concentrations of orthophosphate and nitrate/nitrite given for control and treatment samples by season.

Turbidity data for Back Bay contained a great deal of variability not related to treatment parameters. In addition, variance among seasons was significant for the first 18 hours, but not for the second 18 hours. There is some qualitative evidence that 36 hour turbidity trends are dependent on wind speed and wind direction in some combination with rain fall and other factors. Additional analysis for a relationship between weather patterns and turbidity levels may yield a more complete picture.

Organic nitrogen concentrations showed no significant trends with respect to season or treatment. However, the mean concentrations for TKN did show mild peaks in the spring and fall, and were consistently above the EPA reference level for unpolluted waters (VWCB 1976). This is further evidence of elevated nutrient loadings within Back Bay (Figure 2). The lack of significance for organic nitrogen within the statistical model may be due to its high ambient concentrations coupled with its residence time within the system. Thus, any inputs of organic nitrogen during rain events may be hidden from statistical detection by the highly elevated levels already in the system.

Within the spatial model, the most significant difference between sites was observed in the solids parameters. Suspended solids (TSS, VSS) were significantly higher at Muddy Creek during the drier, windier Winter/Spring period. In contrast, the dissolved solids (TDS, VDS) were significantly higher on the entire eastern margin of Back Bay during the rainier Summer/Fall period. It should be noted that both of the "tropical storm" level rain events, which resulted in seawater over-wash along the eastern margin into Back Bay, were during the Summer/Fall period.

Significant spatial differences were observed for orthophosphates and ammonia during the Summer/Fall period, but not for the Winter/Spring period. What is interesting to note is that neither parameter changed significantly in value from seasonal period to seasonal period at Nanney Creek. In fact, the significance observed for these parameters at this site is a result of the mean concentrations for these parameters dropping at all other sites. The mean levels for ammonia and orthophosphates at Nanney Creek simply dropped less from the Winter/Spring period to the Summer/Fall period than did the mean values for all other sites. This provides strong indications that the region around Nanney Creek may be an important non-point source of these nutrients for Back Bay (Figure 3).

These findings are supported by the correlation analysis. The significant relationship between TKN and TSS at all sites except Nanney Creek would be expected for a lowland system such as Back Bay. The high level of tree cover around the margin of the Bay would provide a consistent allocthonous organic input within the suspended solids entering the water column. The decoupling of nutrient levels, including TKN, from the solids parameters occurs during storm events, and at Nanney Creek and Beggars Bridge sites. At Nanney Creek, and to a lesser extent Beggars Bridge, PCA analysis indicates that fluxes in nutrient concentration explain more of the seasonal and treatment variation than do fluxes in total solids concentration. In addition, the significant negative relationship between dissolved solids (TDS/VDS) and nutrient levels at Nanney Creek and Beggars Bridge provide evidence that, when dissolved solids concentrations are low (i.e. during rain events), nutrients concentrations are high. The consistency of the relationship between rain events and low TDS/VDS concentrations lends support to the idea that water quality is adversely affected by rainfall and runoff. These relationships are consistent at all four of the test sites on the northern and western margin of Back Bay (See Site Map). The lack of significance in the TDS-Nutrient relationship at sites other than Nanney Creek and Beggars

Bridge may be a result of a lack of sensitivity within the data set. More observations may provide a clearer picture of these relationships at the other sites.

IMPLICATIONS FOR MANAGEMENT

The large proportion of agricultural land within the Back Bay watershed is expected to have some effect on the water quality of the system. Back Bay is a small, shallow water body surrounded by fluvial low lands. The majority of the watershed is drained by canals in order to be useful for agriculture. This suggests that these nutrients could remain in the soil and drainage canals for long periods if they are present in concentrations in excess of the needs of terrestrial flora. Nitrate, nitrite and orthophosphate are inorganic nutrient forms, and are quickly recycled through both terrestrial and aquatic systems by plankton and/or vascular plants. They are also primary constituents of many commercial fertilizers (Boyd, 1979). Trends seem to indicate that during the winter and spring, these nutrients are present in significant excess within the watershed. This correlates with data regarding land use within the watershed. Corn, the primary crop in the area, requires fertilizer applications regularly from January through April (Barney Bright BBNWR co-op farmer, personal communication). In addition, these nutrients appear to reside outside the open water system until sufficient rain flushes them into the Bay. The approximate 18 hour lag prior to increase in concentration supports this hypothesis. However, this lag also makes increased nutrient loadings more difficult to monitor. Often, periodic sampling protocols for water chemistry monitoring involve instantaneous sampling, and may even be scheduled to avoid inclement weather. The spatial differences tend to support the findings of the temporal model. Nanney Creek shows an increased concentration of nitrates/nitrites and orthophosphate over all other sites. Lack of data limited the analysis of 'between treatment' variation at each site. However, the significant relationship between low dissolved solids concentrations and rain events, combined with the significant negative relationship between dissolved solids concentrations and nutrient concentrations, provides some evidence for a direct connection between rain and high nutrient levels at these two sites. Further data collection should be attempted in order to clarify this relationship.

The implementation of Best Management Practices within Back Bay and its watershed includes the objective of initiating recovery among endemic species of SAV. The evidence is strong that the halt of declining water quality is a major step towards realizing this objective. In general, there is evidence that nitrate/nitrite and orthophosphate concentrations are significantly higher during rain events and in the period from January to May. In addition, there is evidence that the region around the mouths of Nanney Creek and Beggars Bridge is a more important non-point source for these nutrients than other regions within the Back Bay watershed. If the objective of halting the decline in endemic SAV's is to be realized, this monitoring of the dynamic relationship between nutrient concentrations and rain events should be continued. Future monitoring could include the following recommended changes in data collection.

Monitoring should focus more closely on the region surrounding Nanney Creek and Beggars Bridge. This might include an increased sampling schedule and/or placing more sampling sites within this region. In addition, it is advisable that a weather station be established in this region to monitor other weather patterns besides rain fall. It is evident that weather on Back Bay is spatially variable, and the weather monitoring station located at BBNWR Office may not provide accurate data for the Nanney Creek-Beggars Bridge portion of the watershed. Weather patterns on the western margin of Back Bay should be closely monitored in the future. Such increased data collection would aid in obtaining the sensitivity necessary to provide a clear picture of the relationship between rain fall and declining water quality. In this way, we may gain insight on what is best for both Back Bay and those organisms, including ourselves, who use this valuable system.

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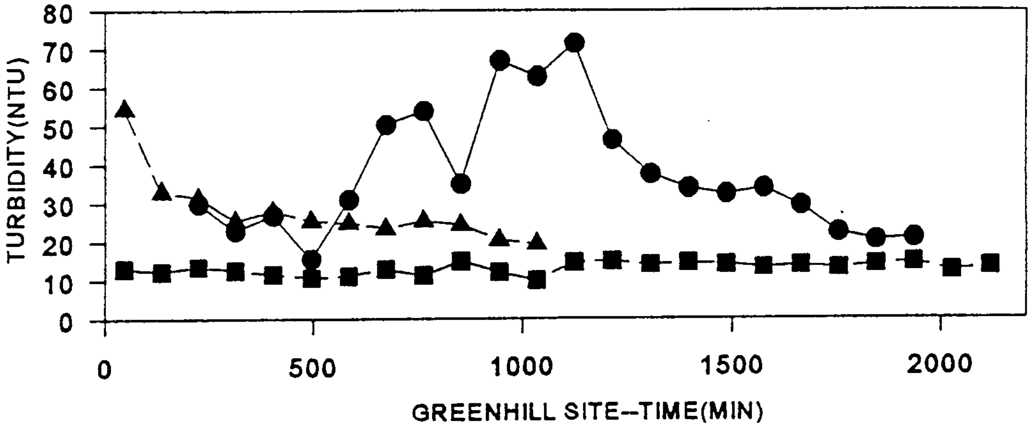
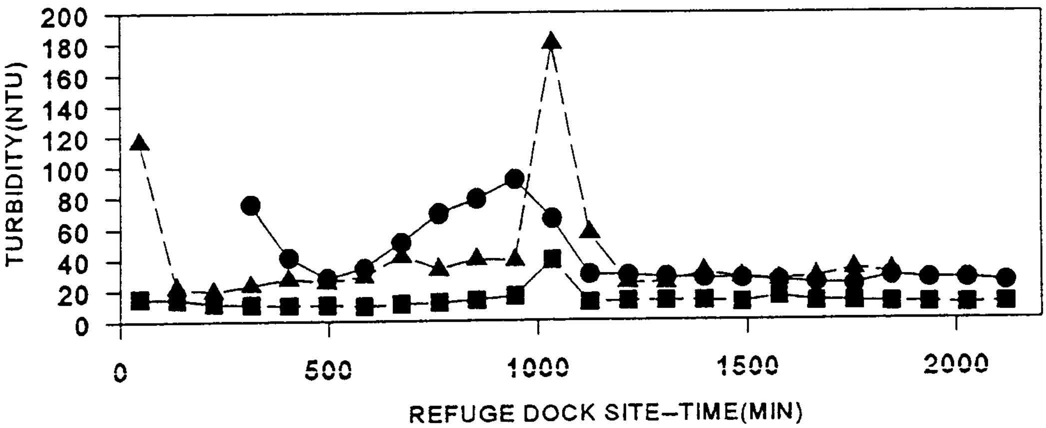
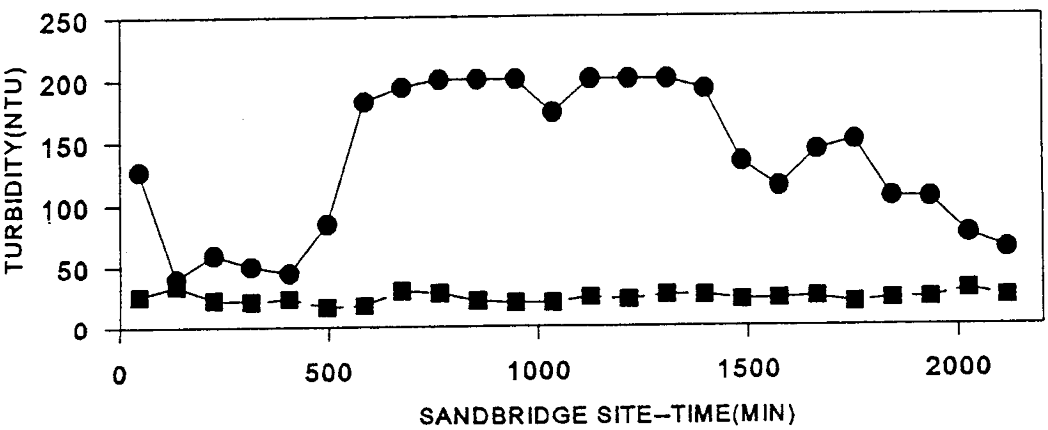
APPENDIX 1: 36 HRS TURBIDITY TRENDS-1ST QUARTER

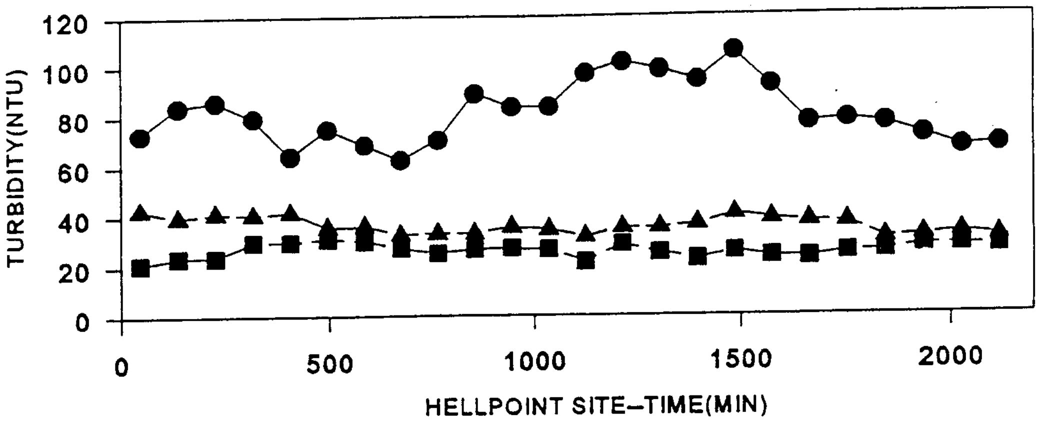


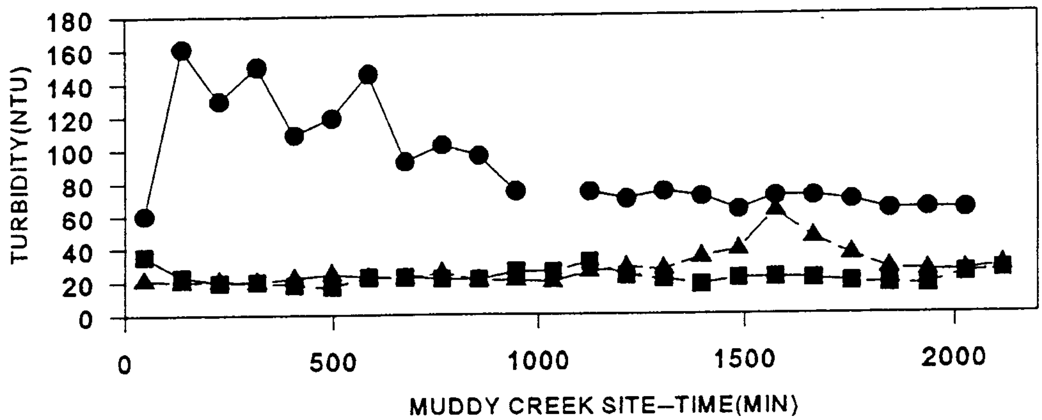


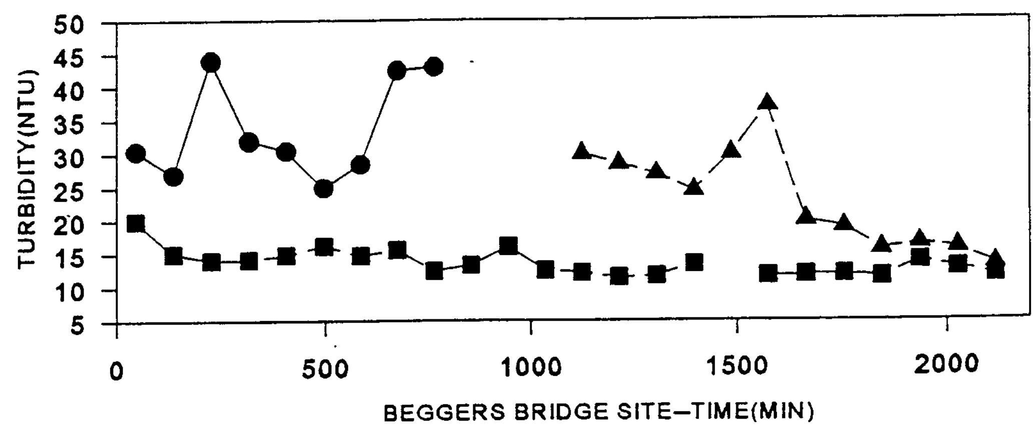


CIRCLE: SEPTEMBER 1994 SQUARE:AUGUST 1994 TRIANGLE:JULY 1994(CNTRL)

QUARTER ONE CONT.







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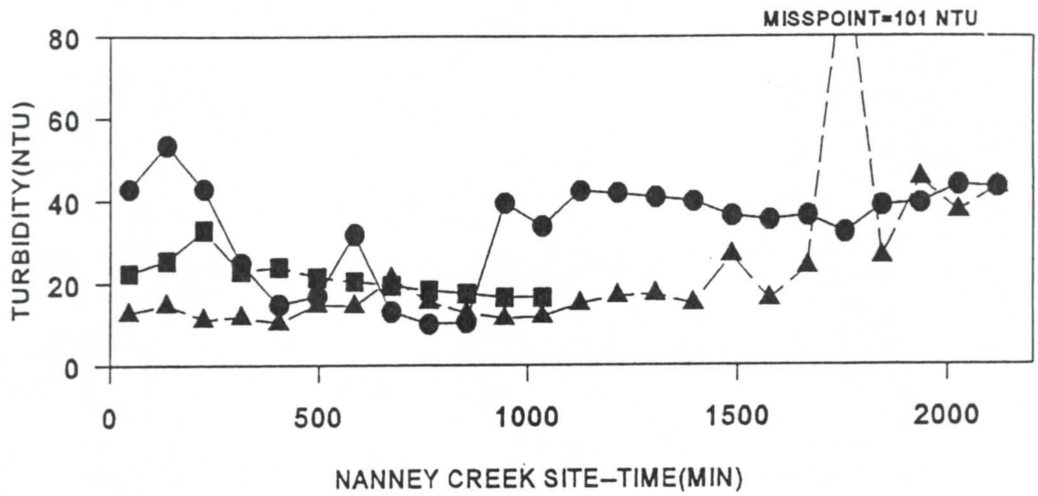

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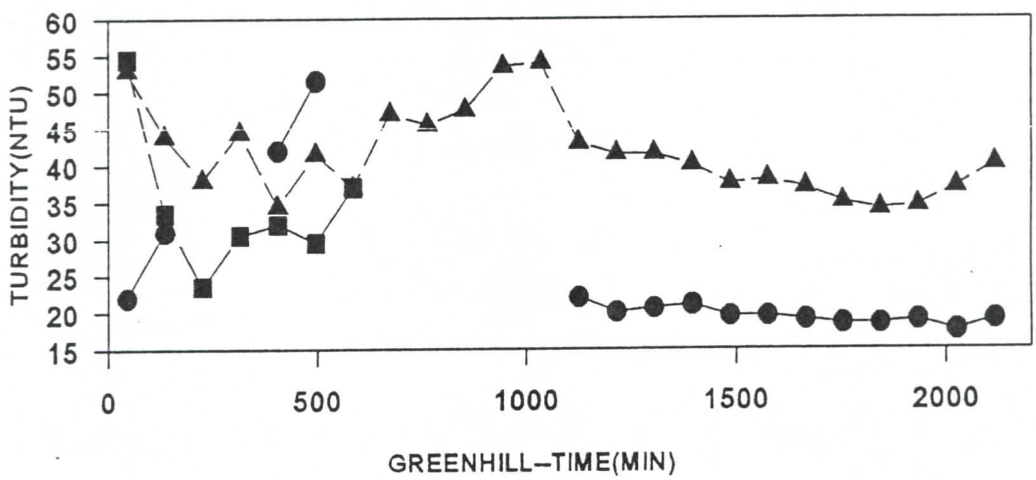
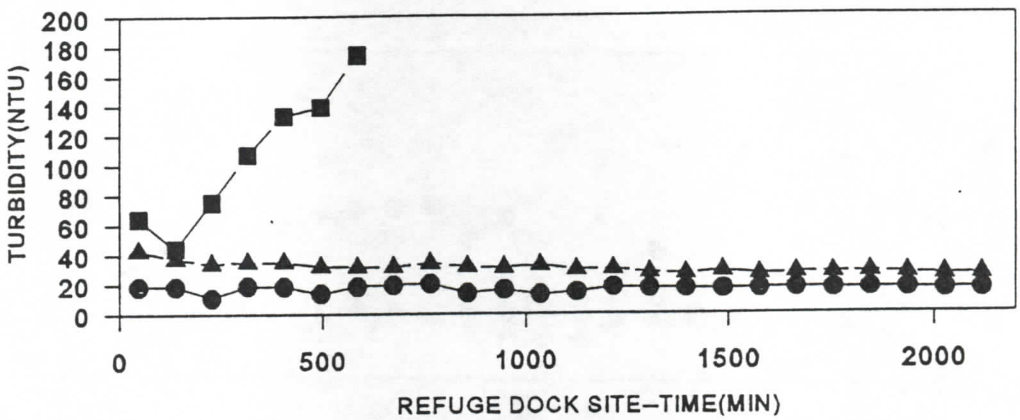
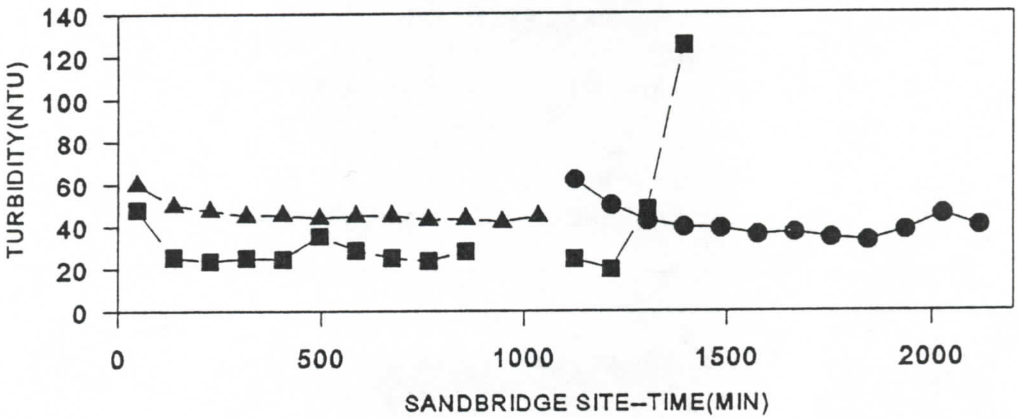
APPENDIX 1 CONTINUED: QUARTER TWO

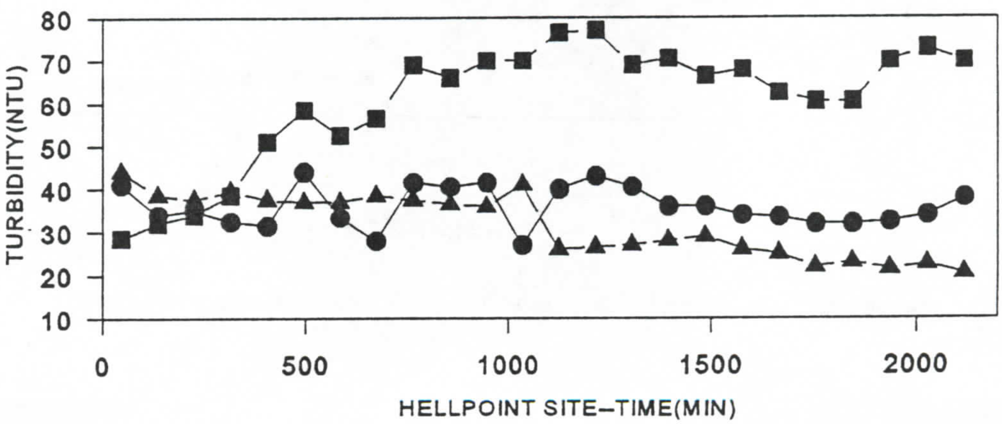


QUARTER TWO: CIRCLE-OCT 1994 SQUARE-NOV 1994 TRIANGLE-NOV 1994(CNTRL)

QUARTER TWO CONT.







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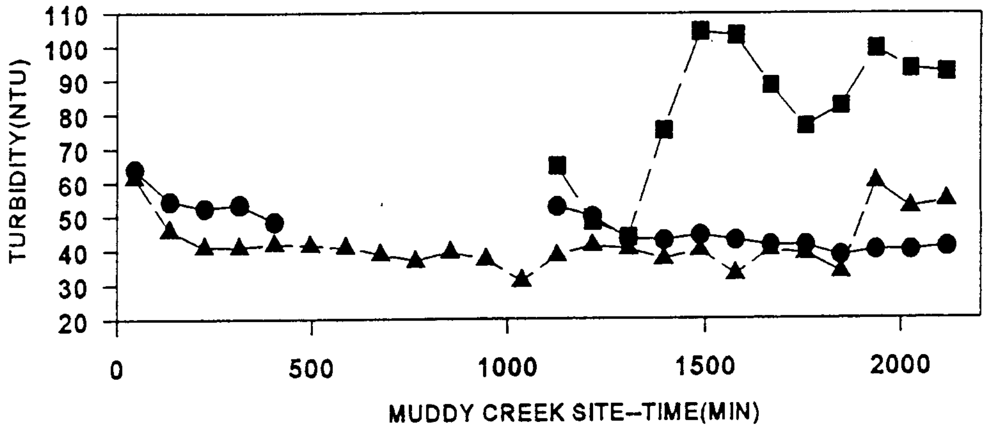
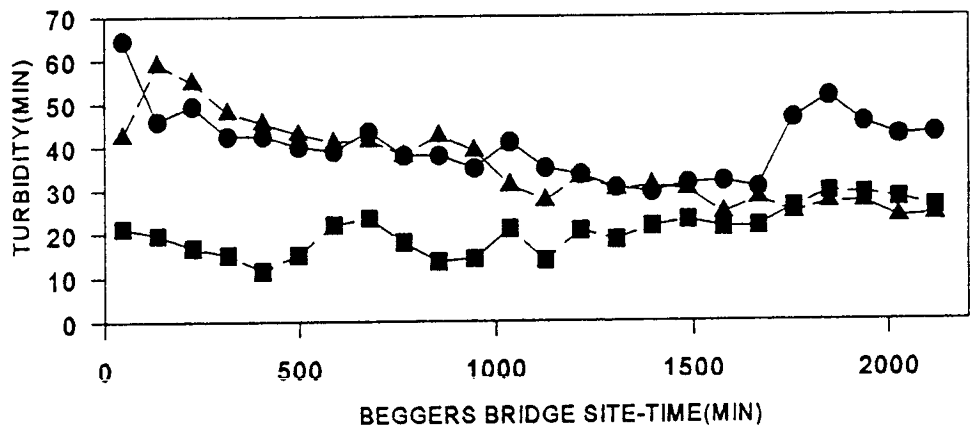
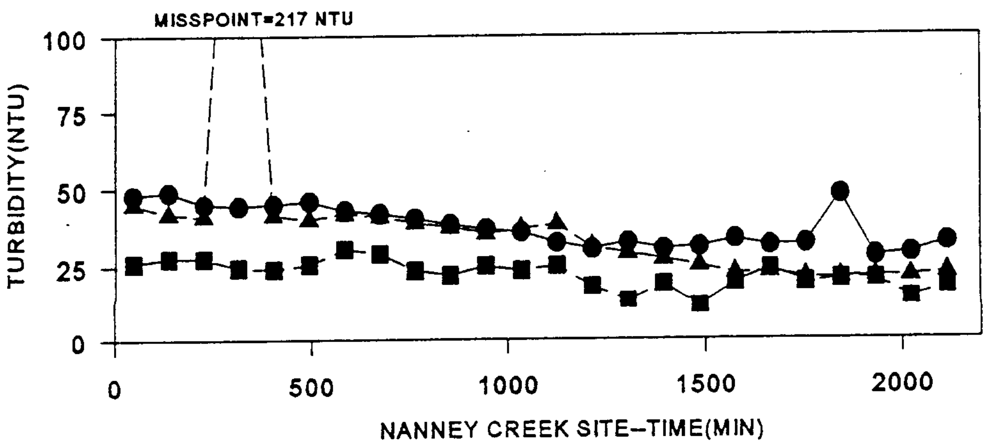
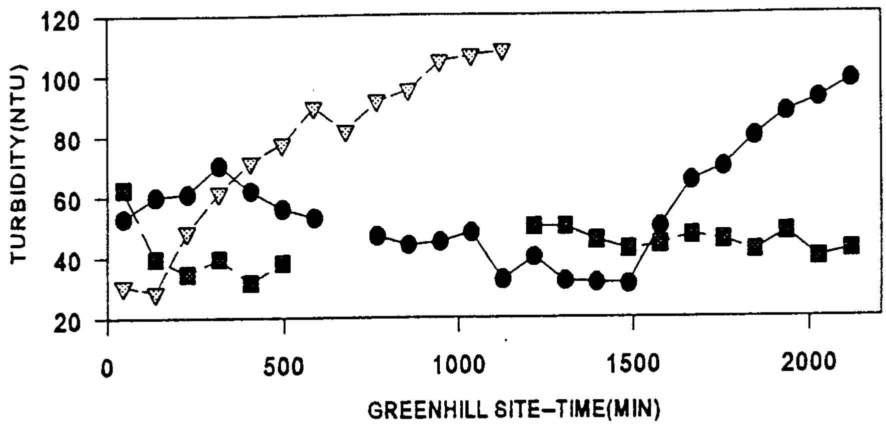
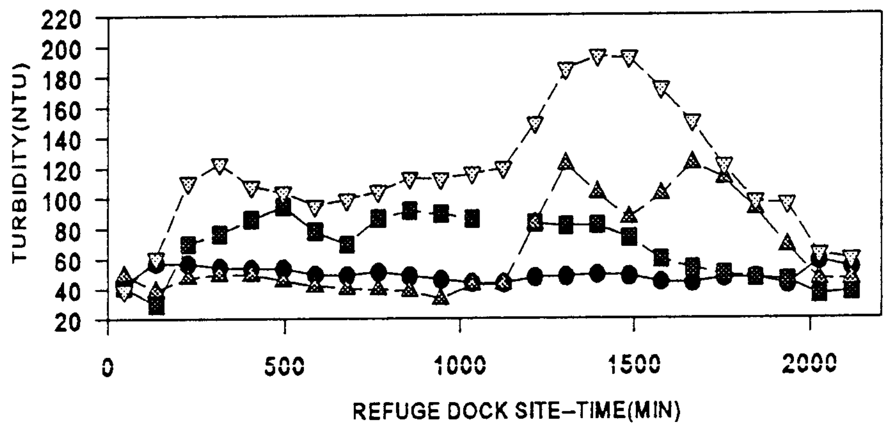


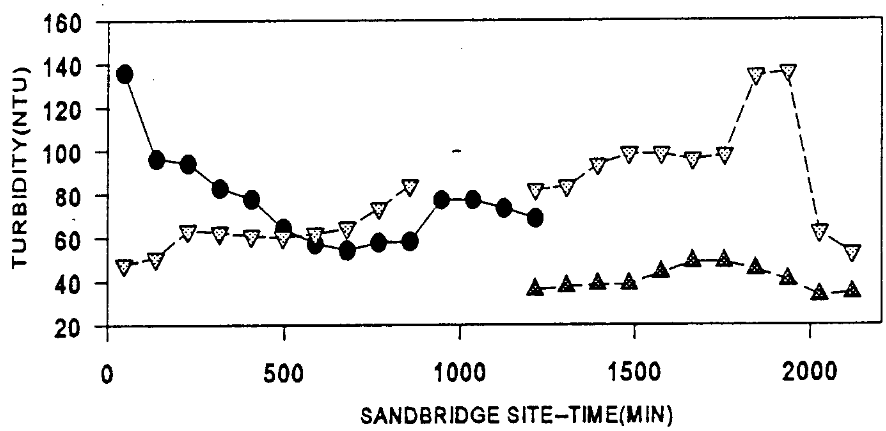




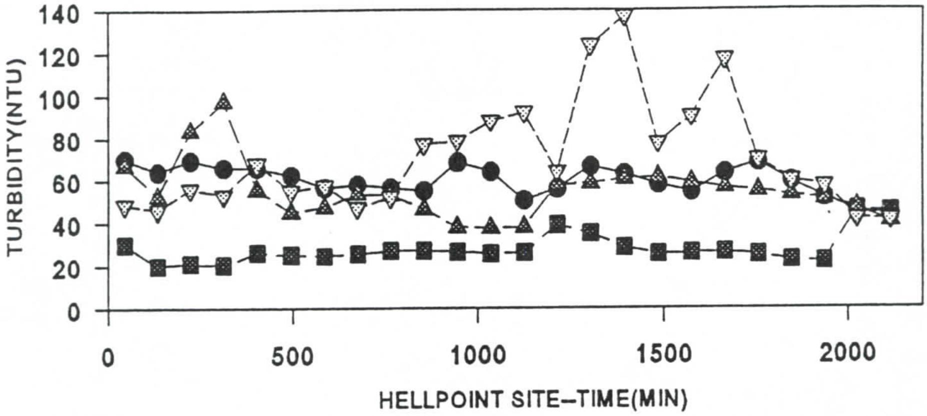
CIRCLE:OCTOBER 1994 SQUARE:NOVEMBER 1994 TRIANGLE:NOVEMBER 1994(CNTRL)

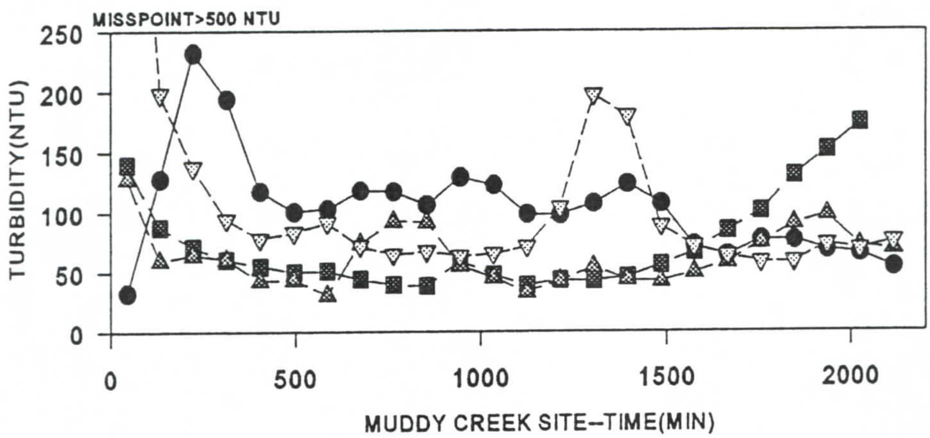


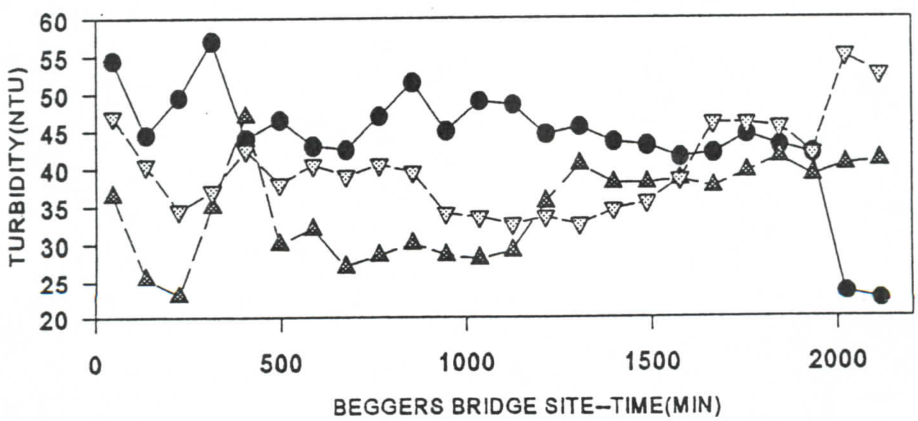




CIRCLE:JAN 1995 SQUARE:FEB 1995 UP TRIANGLE:MAR 1995 DWN TRIANGLE:APRIL 1995(CNTRL)







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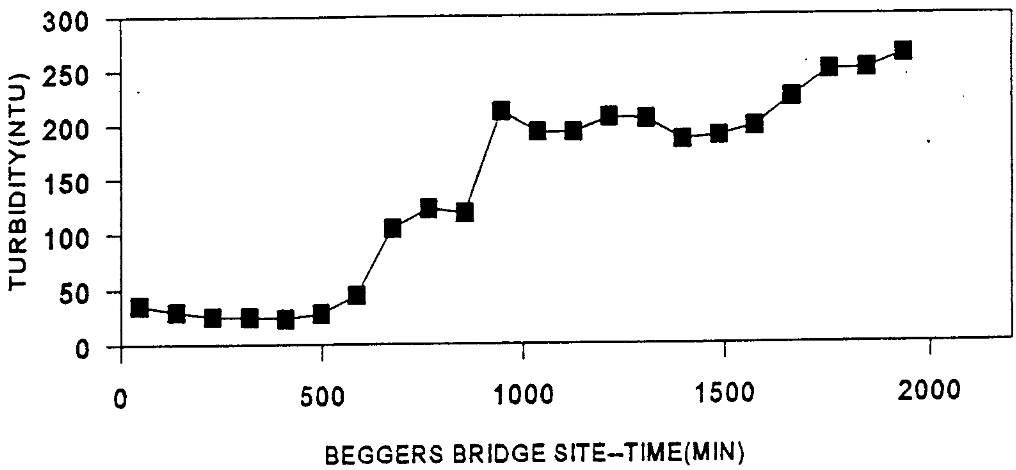
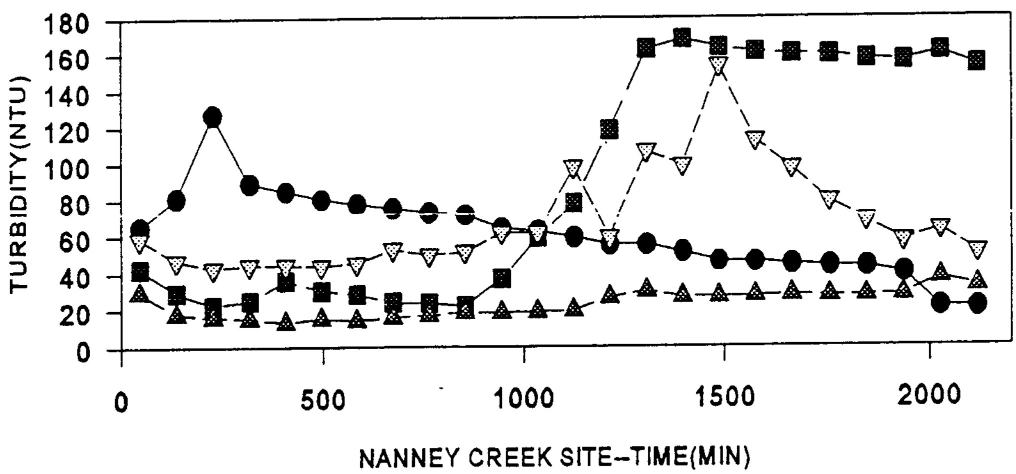
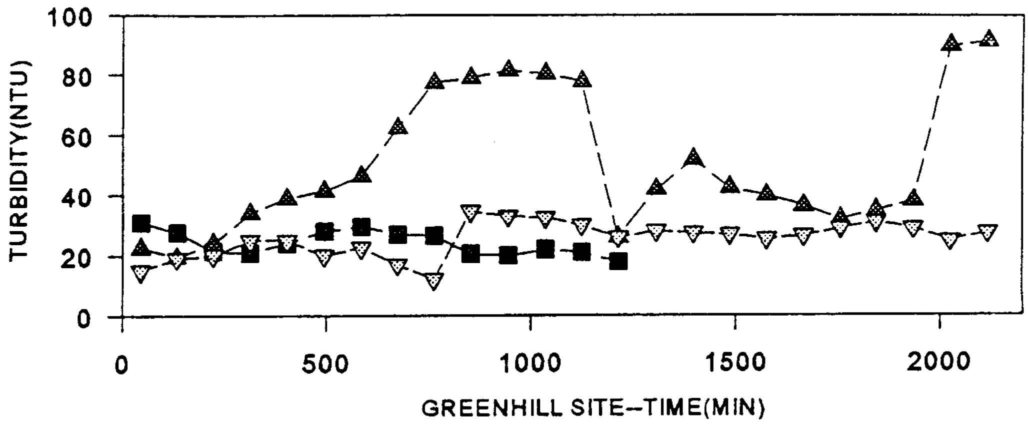
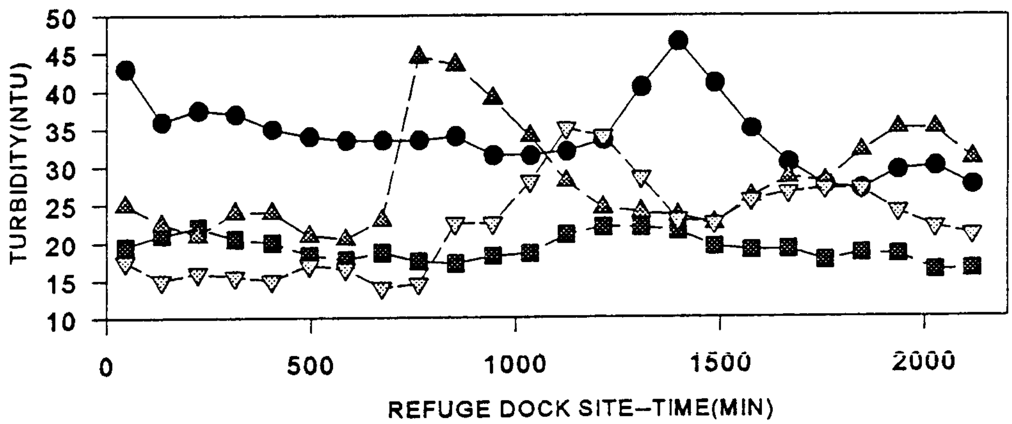
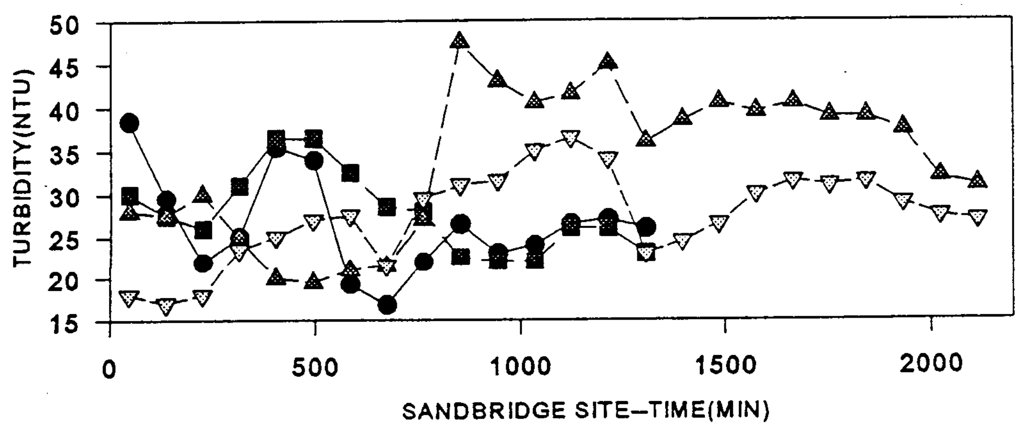

300
250
200
150
100
50
0
TURBIDITY(NTU)
0
500
1000
1500
2000
BEGGERS BRIDGE SITE--TIME(MIN)


180
160
140
120
100
80
60
40
20
0
TURBIDITY(NTU)
0
500
1000
1500
2000
NANNEY CREEK SITE--TIME(MIN)

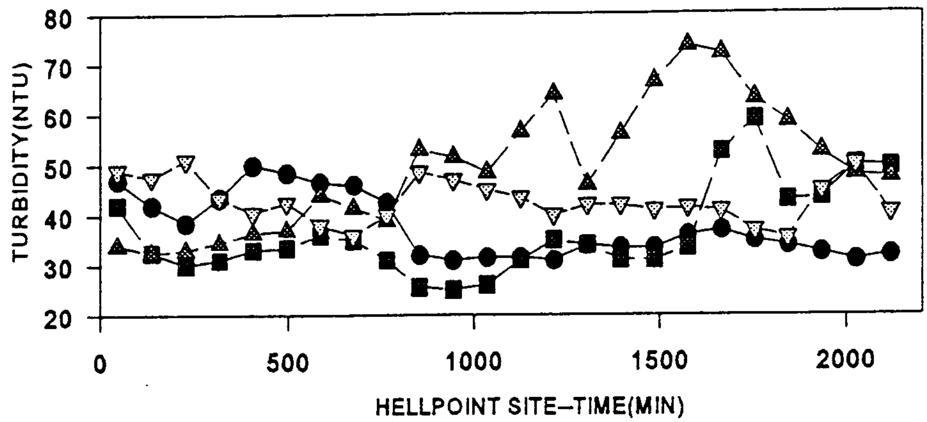
APPENDIX 1 CONTINUED: QUARTER FOUR

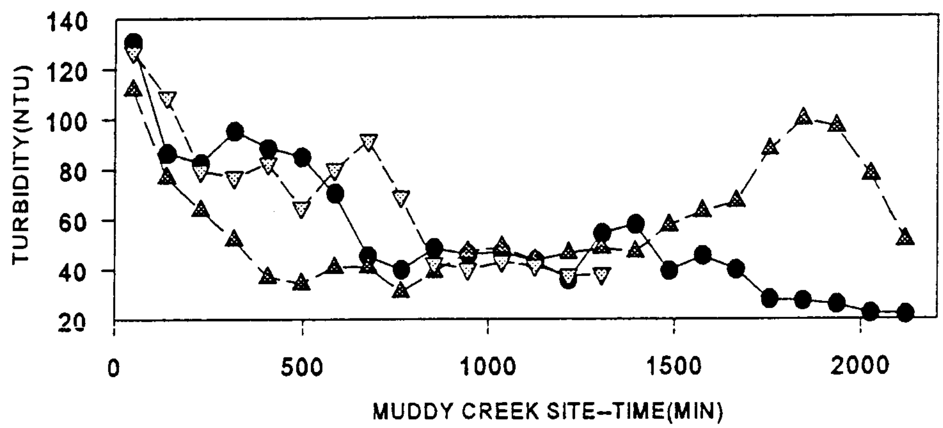


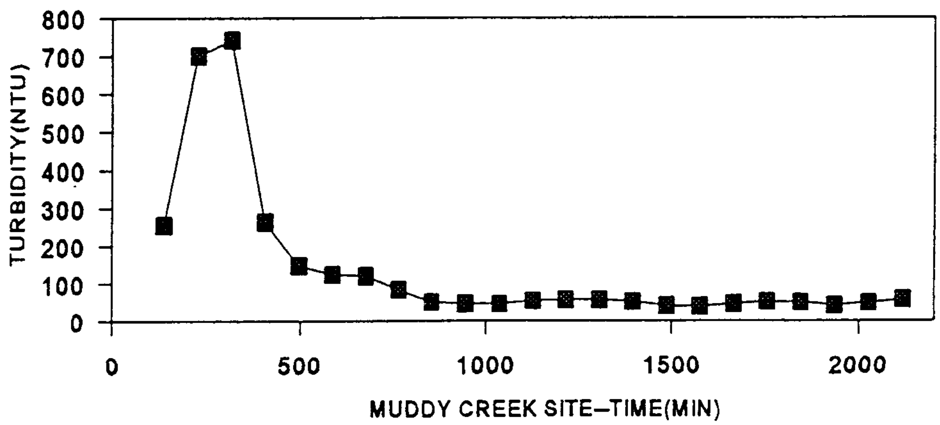




CIRCLE:APR 1995 SQUARE:MAY 1995 UP TRIANGLE:JUNE 1995 DNTRIANGLE:JUNE 1995(CNTRL)







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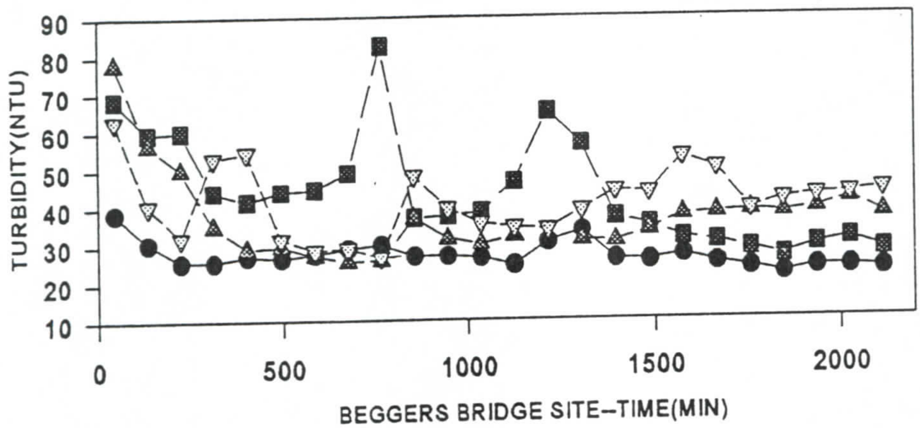

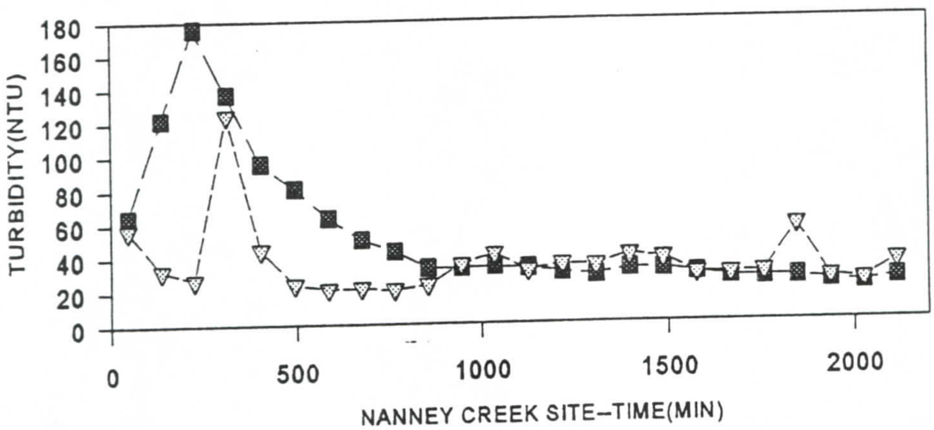

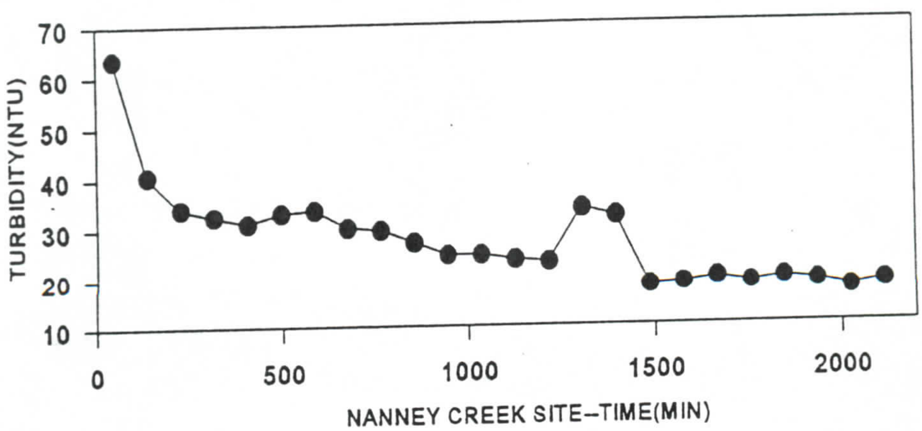

CIRCLE:APR 1995 SQUARE:MAY 1995 UP TRIANGLE:JUNE 1995 DWN TRIANGLE:JUNE 1995(CNTRL)