A Preliminary Analysis of the Relationship between of Submarine Groundwater Discharge (SGD) and Submerged Aquatic Vegetation in the Peconic Estuary

Report submitted by
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1.0 Introduction and Purpose

Seagrass meadows represent an important ecosystem in tropic and temperate waters around the globe. The most common species in the shallow, coastal regions of the North Atlantic Ocean is *Zostera marina*, also referred to as eelgrass. In general, these marine angiosperms act as food source, habitat, nursery ground and shelter for various fish and invertebrate populations. They contribute a significant part to the primary production of the ocean, stabilize coastlines, recycle nutrients, and are widely valued as sensitive indicators of human pollution and perturbations (Bortone, 2000).

Scientific studies on seagrass, and eelgrass in particular, are conducted by various research and commercial institutions, to gain more understanding of the ecology and distribution of these marine plants. In addition, the tremendous decline of eelgrass on the Atlantic coast in the 1930's due to the so-called "wasting disease" gave great motivation for more intensive studies on seagrasses (Larkum et al., 1989). Eelgrass distribution follows natural fluctuation and depends on a number of interdependent factors. Temperature, light availability and water motion are, among others, important abiotic factors. The phytoplankton and algae composition of the ocean water, as well as anthropogenic factors, such as pollution, harvesting, and coastal development, can also influence eelgrass distribution patterns (Thayer et al., 1984). Since eelgrass meadows are of vital importance to regional fisheries, recreation and coastal stabilization, the Peconic Estuary Program in cooperation with Cornell Cooperative Extension (CCE) Marine Program in Riverhead, N.Y., initiated pilot research projects to learn more about the factors that influence eelgrass (*Zostera marina*) distribution, so that eelgrass populations can be restored and managed more effectively.

The main focus of this pilot study is on the influence of abiotic factors, particularly submarine groundwater discharge and the characteristics of the substrate, on the distribution of eelgrass in the Peconic Estuary, Long Island. Submarine groundwater discharge (SGD) is believed to contribute a significant freshwater input to the estuary and can also be a carrier of anthropogenic pollution from inland sources (Rutkowski et al., 1999). A preliminary analysis on the relationship between SGD sediment characteristics, pore water chemistry and eelgrass beds was undertaken with a modest budget.

Four potential study sites were initially chosen. Preliminary information on the magnitude of SGD, as well as the presence of eelgrass was attained. From this preliminary analysis two sites were chosen for more rigorous evaluation. The Northwest Harbor sites I and II were chosen largely due to the fact that

Figure 1-Northwest Harbor Sites I and II

significant differences in SGD and in eelgrass density were found. Figure 1 illustrates the differences in eelgrass density between the two sites; the red line indicates the boundary of the eelgrass beds in the area. The yellow lines indicate the transect locations. Water and soil samples were taken along two transects at Northwest Harbor, during fall 2000 and spring 2001, in order to acquire information about the chemical composition of the water, the grain-size distribution of the sediment at these sites and the magnitude of SGD in the study areas. Differences in eelgrass density is observable along the transects in Northwest Harbor. Any observable differences in the abiotic parameters between the transects could potentially provide preliminary explanations for the absence or presence of eelgrass.

Submarine groundwater discharge at Orient Harbor, Northwest Harbor and Flanders Bay was measured, as was electric resistivity of the pore fluid offshore. From this information ultrasonic seepage meters were placed at suspected seepage zones. The resistivity measurements provide constraints on the spatial extent of the submarine groundwater discharge offshore and its possible affect on the distribution of eelgrass.

2.0 Study Site Description

The location of the four off shore transects are shown in Figure 2. Northwest Harbor on the South Fork of Long Island, N.Y. is part of the Peconic Estuary system.

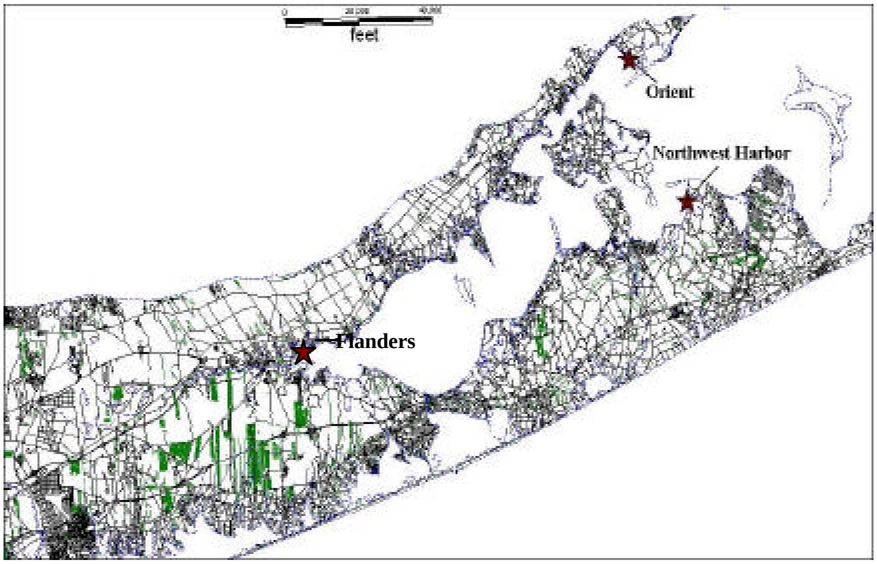

Figure 2—Study Site Locations

This South Fork location is mainly characterized by open space or County Parklands, such as Cedar Point County Park, Northwest Harbor Park, and Grace Estate Preserve (close to Transect I and II). The second candidate area investigated were the eelgrass beds located off Orient in Orient Harbor. Residential and some agricultural sites are located up gradient of this study site. The third candidate site is located in Flanders Bay, south of Laurel in the township of Southold. This site has extensive agricultural activities and moderate density housing up gradient of the discharge area.

3.0 Methods and Techniques

3.1 SGD Mapping and Measurement

The offshore horizontal extent of the submarine groundwater discharge zone was delineated by direct contact resistivity measurements of the bottom sediments and the associated pore water. A probe developed by the Geoprobe Company uses an electrode configuration known as a Wenner array (Figure 3) to measure the resistivity within the bottom sediments. The probe is designed for use in conjunction with a Geoprobe percussion unit, but in this study it was modified to function independently. The resistivity probe was driven manually in the bay bottom by scuba divers at six-inch increments. The unit's string pot originally designed to keep track of depth measurement automatically and also to trigger the electrical measurement had to be modified accordingly. The string pot was mounted on a jig and manually moved along a displacement that would coincide with the depth that the probe was being driven into the bottom sediments. Resistivity measurements were also simultaneously triggered manually. After the resistivity was logged, the diver then drove the probe into the bottom to the next six-inch level. This continued until a freshwater zone was contacted or the probe had been driven to a maximum depth of 2 feet. The diver then moved on to the next offshore position at a horizontal spacing of ~30 feet and the manual probing and logging operations were repeated. During the spring and summer of 2001,measurements were conducted along 4 transects perpendicular to the shoreline. Two transects were conducted in Northwest Harbor, one in Orient Harbor and one in Flanders Bay (Figure 4). The data collected from the resistivity transects was used to determine the extent of groundwater discharge offshore.

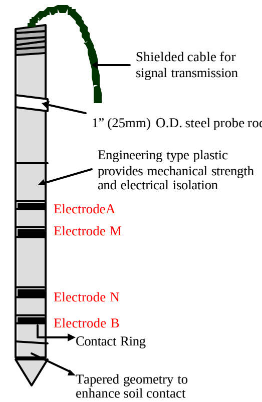

Figure 3 Resistivity Probe

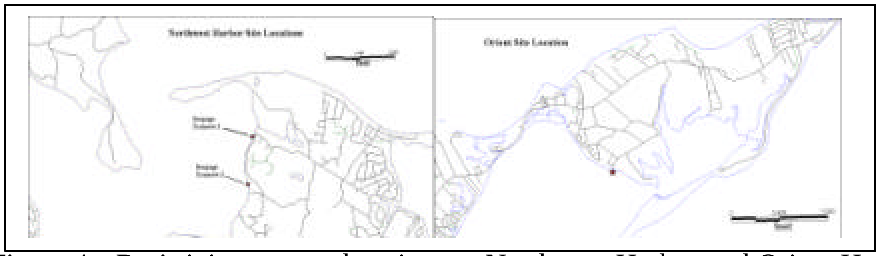

Figure 4—Resistivity transect locations at Northwest Harbor and Orient Harbor

Once the groundwater discharge zone had been mapped out, transient seepage meters were installed along the outcrop to monitor seepage velocities. Paulsen et al. (2001) have presented a detailed description of the ultrasonic seepage monitor used in this study. The SGD is captured by a steel collection chamber that is placed on the seabed, and then directed to a cylindrical flow tube with two piezoelectric opposing transducers. The transducers continually generate bursts of ultrasonic signals (periodic waves with a frequency of 1.7 MHz) from one end of the meter to the other end, while arrival of the ultrasonic signals is continuously monitored by the piezoelectric transducers. The travel time for the upstream propagation of soundwaves against the flow direction is prolonged relative to that for downstream propagation. If velocity of the flow induced by SGD in the tube is small relative to the ambient sound velocity and if the fluctuations of temperature and salinity are negligible, then the flow velocity is directly proportional to the difference between the upstream and downstream arrival times. Taking into account the area ratio between flow tube and collection chamber, the specific discharge of the submarine groundwater can be calculated from the flow velocity in the tube. Figure 5 illustrates the ultrasonic seepage meter system. SGD measurements were made between 10 and 100 feet from mean high tide.

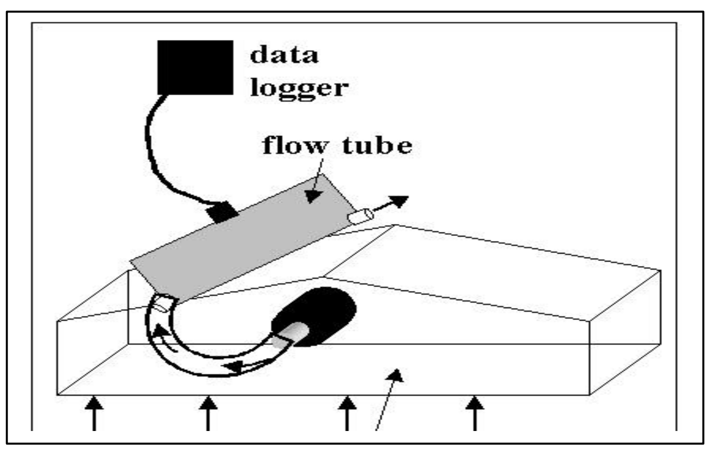

Figure 5- Ultrasonic Seepage meter system

The SGD measurement sites were located within the groundwater discharge zones defined by the resistivity measurement profiles. Measurements were recorded on a data logger and one-hour averages of rates were analyzed. Synoptic tide measurements were made for one tidal cycle.

3.2 Water Analyses

Due to budgetary constraints, water analysis was limited to Northwest Harbor for this pilot study. The size and density of the eelgrass beds between transect I and II was significant and therefore a comparison of ground and pore water fluids between the sites was undertaken. Both transects located at Northwest Harbor (NW I and II) extend100 feet offshore and contained five piezometers installed at the shoreline, 25', 50', 75' and 100 feet offshore. There are also piezometers located approximately 50 feet onshore, with screening intervals of 5-10 feet and 10-15 feet at NWT I and screening intervals of 5-10 feet and 40 feet at NWT II. Water samples were taken from the piezometers in October 2000, and once a month from February to April 2001. The piezometer with the screening interval of 40 feet was sampled only once since it subsequently became clogged with silt. The water sampling was done following the protocol of the Suffolk County Department of Health Services (SCDHS). Before sampling, the wells were purged until water temperature, conductivity and pH had stabilized for 5 to 10 minutes. At least three evacuations of the volume of water in the piezometer were ensured before sampling the onshore wells. Temperature, pH, conductivity, and dissolved oxygen of each sample were measured on site with submersible electrodes. The samples were usually taken at a pumping rate of <1 ml/min from the offshore piezometers. All of these parameters are reported in Appendix 1, Table 1.

The Public and Environmental Health Laboratory of SCDHS analyzed the water samples for nutrient and metal concentrations using the standard inorganic analysis for the nutrients and the EPA method 200.8 for the metal analysis (Appendix 1, Table 2 and 3). Correlation coefficients between distinct metals in the pore water samples were determined to get statistical information about the relationships of these metals. A correlation coefficient of >0.95 is considered to indicate significant correlation between the data in this study.

3.3 Soil Analysis

The soil samples were taken in March 2001 along both transects. They were collected next to the piezometers at the shoreline, 25', 50', 75' and 100 feet offshore. An additional sample was taken within the eelgrass bed 50 feet offshore at NWT II. A CoreProiID with an inner diameter of 4.5cm was used to obtain sediment cores of various lengths, reaching from 10cm to over 30cm. The soil samples were preserved with a plastic sleeve to shield them from contamination and disrubtion. The characteristics of the sediment cores are complied in Appendix 1, Table 4.

3.4 Grain Size Analysis

The grain-size analysis was accomplished on 65g to 100g splits of sediment samples from the Northwest Harbor transect I and II. The samples were first dried at 60º Celsius, and then mechanically sieved through 14 sieves of mesh sizes ranging from 25mm to 0.063mm. This range covers the whole sand fraction (particle size <2mm to >0.063mm) as well as most of the pebble fraction (particle size <64mm to >2mm). The fine fraction (silt and clay, particle size <0.063mm) made up ca. 1% of the total grain-size distribution. According to Fetter (1994) a hydrometer test was not needed since less than 5% of the samples consisted of fines. The results of the grain-size analysis are presented in the form of grain-size distribution curves in Appendix 2.

It is important to mention that only the uppermost 15cm if the sediment core of each sample were analyzed, even though there were sediment cores longer than 15cm. This is necessary to avoid systematical errors that occur when sampling is done across different horizons. The sediment characteristics of the uppermost horizon (down to 20cm depth) are most significant for eelgrass growth since the eelgrass rhizomes mainly branch out horizontally just below the surface of the substrate (Burkholder and Doheny, 1968).

4. Interpretation of Results

4.1 Resistivity Profiles

The groundwater discharge area was located within the first 80 feet of the shoreline at NW I and within 50 feet at NW II (Figure 6). The groundwater discharge area is more robust at the NWI site primarily due to the stronger groundwater drive to that area. Additionally, the bottom sediments in the NW I area are slightly coarser than at the NW II site (see grain-size analysis discussion 4.2). Both areas show a zone of diffusion and mixing beyond the fresh groundwater discharge zone. Site NW I however has a larger mixing zone that will allow the refreshing of the bottom sediments to extend over 200 feet offshore.

NWI NWII

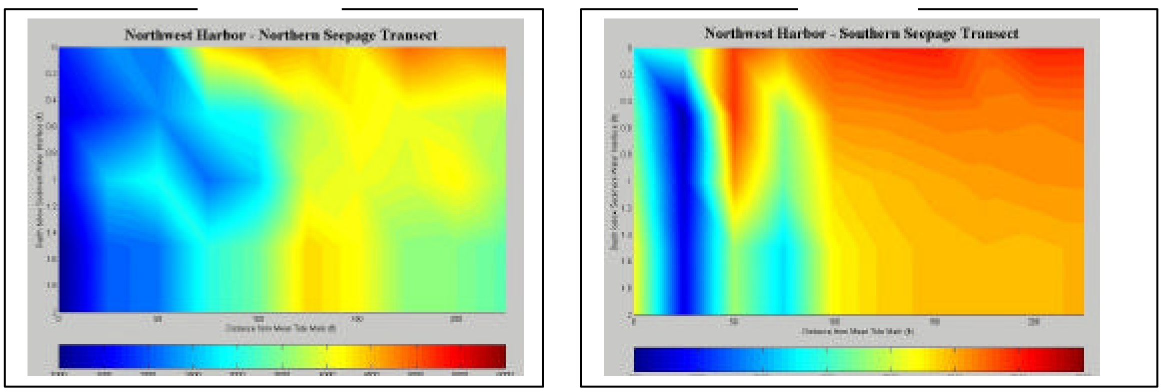

Figure 6—Resistivity Profiles. Note blue areas indicate areas of groundwater discharge

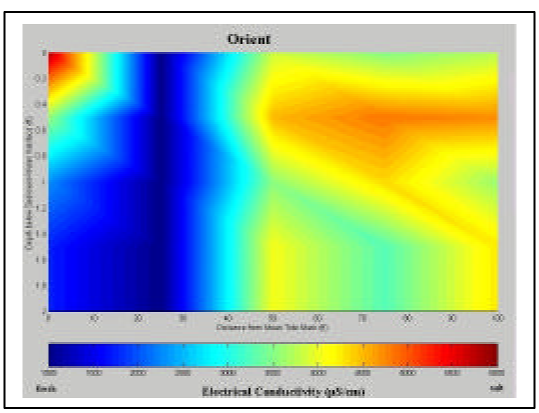

Figure 7—Orient Resistivity Transect

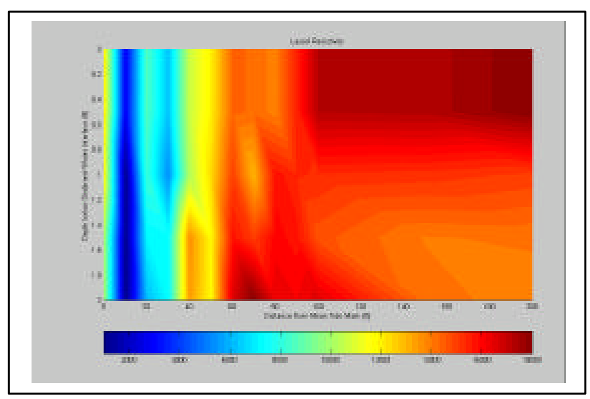

Figure 8—Flanders Resistivity Transect

The Orient Harbor resistivity transect (Figure 7) indicates a fresh water discharge zone extending out about 50 feet from the mean tidemark. Complex upland hydrologic features shift the SGD zone offshore and allow for a small area of saltwater intrusion near the shoreline. Figure 8 is the SGD zone at the Flanders Bay site. The SGD zone is concentrated in the first 50 feet of the shoreline, and no major mixing zone was found along this transect. All sites contained SGD zones of some magnitude. Northwest Transect I was the most robust site with a terrestrial groundwater discharge zone located approximately 70 feet offshore measured from the mean tidemark. All other sites had discharge zones approximately 50 feet offshore measured from the mean high tidemark.

4.2 Seepage Measurements

The rates of submarine groundwater discharge were made at all four sites using ultrasonic time transient seepage meters. The rates of specific discharge are presented in cm/day (Figures 9, 10, 11 and 12) and plotted synoptically with tide stage measurements.

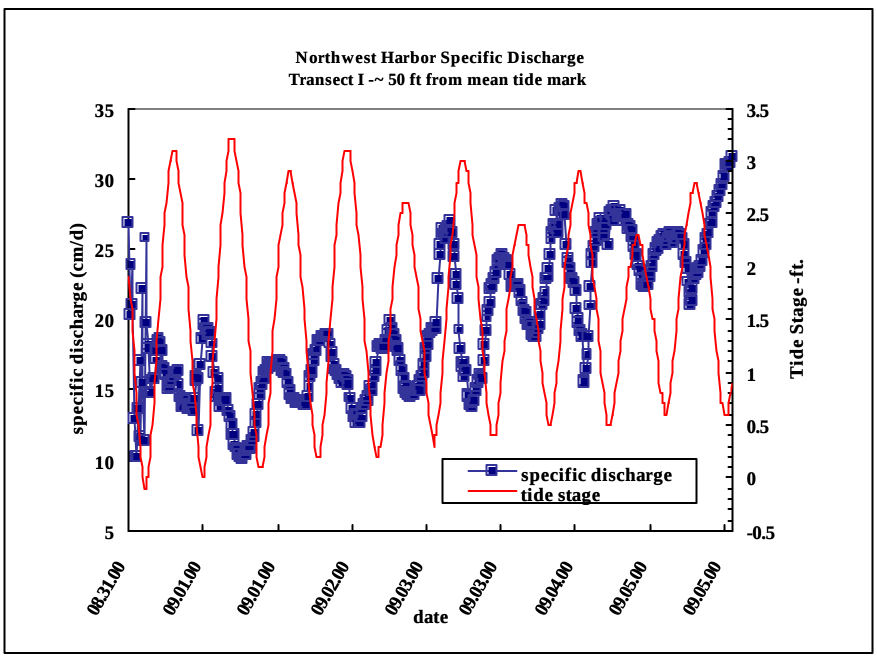

Figure 9- Seepage measurement Northwest Harbor transect I

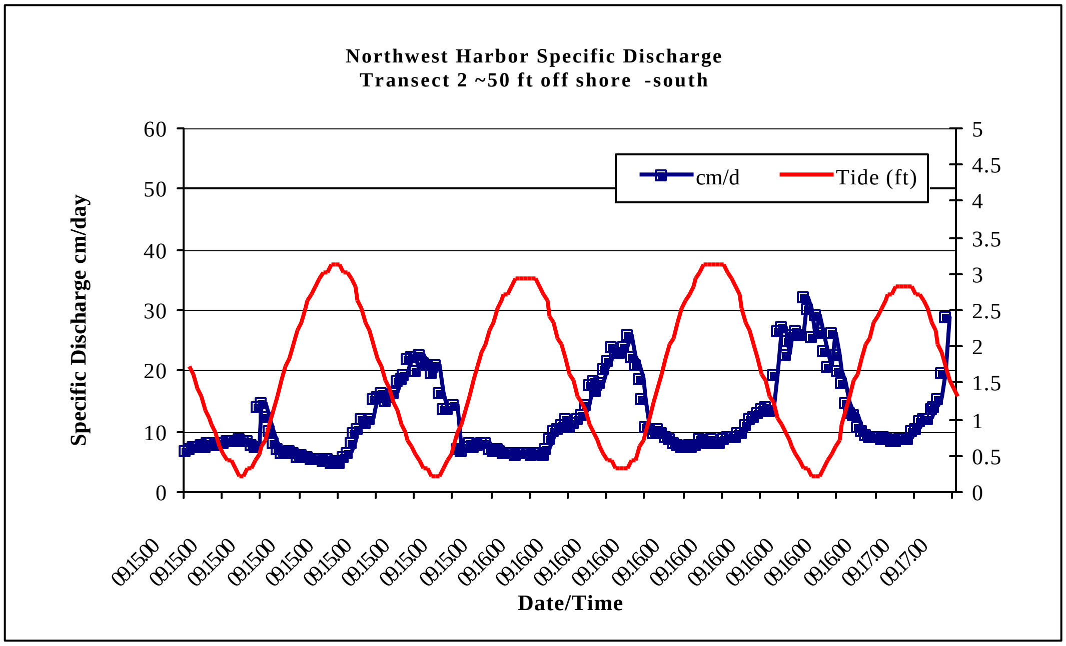

Figure 10—Seepage measurements at Northwest Harbor Transect II

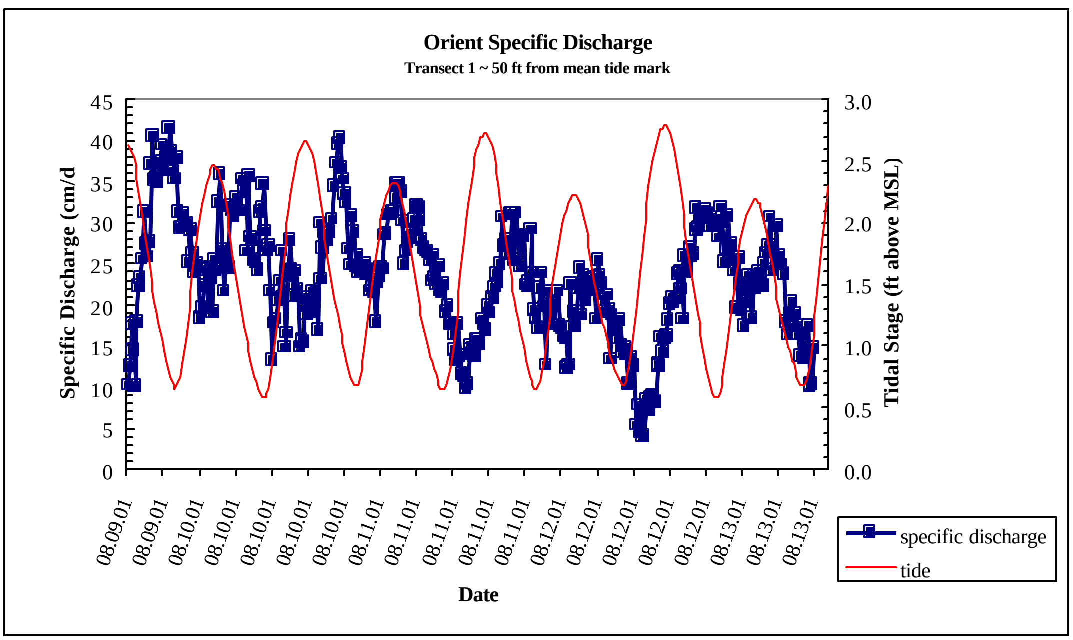

Figure 11- See page Measurement at Orient Harbor

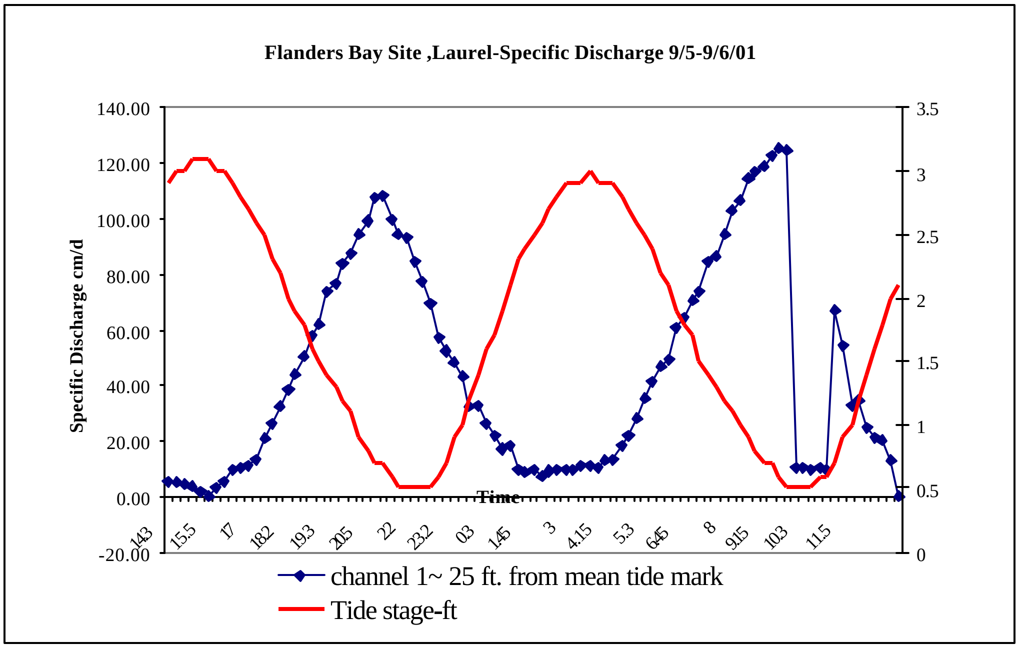

Figure 12- Seepage Measurement at Flanders Site

Specific discharge measurements were made in a time transient manner. Measurements were made every minute and deployment periods usually lasted four days. Fifteen-minute averages on this data are presented along with synoptic tidal measurements in Figures 9 through 12. A strong inverse tidal relationship exists at all sites between tidal stage and the magnitude of specific discharge. The tidal fluctuations will affect the near shore hydraulic gradient and therefore the magnitude of specific discharge (Paulsen et al., 2002, in press).

The average rates of SGD at each site are: Orient site 25cm/day or 168ml/min/m_2; Northwest Harbor transect I 19cm/day or 142ml/min/m_2; Northwest Harbor transect II 12cm/day or 89ml/min/m_2 and Flanders site offshore 10.5cm/day or 73ml/min/m_2 and near shore 45cm/day or 314ml/min/m_2. The maximum rate of SGD measured was 127cm/day, and measured at the Flanders Bay site; the next highest rate was NW I in Northwest Harbor. These rates are comparable with discharge measurements made at other locations in the estuary. SGD rates in the Peconic Estuary can be as high as 300cm/day (West Neck Bay, 1999).

4.3 Water Analyses

In general, the seawater and groundwater sampled along both transects at Northwest Harbor show low nutrient concentrations (see Appendix 1, Table 3). The inorganic nutrients that can possibly limit the eelgrass growth, such as nitrogen (NO_2^-, NO_3^-, NH_4^+) show low concentrations along both transects. Concentrations of nitrate in the groundwater depend mainly on anthropogenic inputs (e.g. agricultural activities, fertilizer application and sewage disposal). The total inorganic nitrogen (TIN) concentration along NWT I and II are presented in Figures 12 and 13. Ammonia takes up the main part of the TIN concentration at both transects. There was about 4 times more TIN (mainly ammonia) found in the 5-10 feet screening well at NWT I (3.4mg Ntot/L) than at NWT II (0.6mg Ntot/L in average). The higher concentrations of TIN at the screening well of NWT I could be the result of anthropogenic sources, such as fertilizer and sewage disposal from the residential areas behind the transect. Figure 13 shows also a general decrease in the total nitrogen concentration from the 5-10 feet screen well onshore to the offshore region (25 to 75 feet offshore well) due to the dilution of the nitrogen in the groundwater when mixing with seawater in the diffusion zone. The total nitrogen increases significantly at 100 feet offshore at NWT II (Figure 14) and slightly at NWT I (Figure 13). This increase could be explained by the mineralization of the eelgrass detritus within the sediment. The products of this process (NO_3^- and NH_4^+) are mainly incorporated into the internal nitrogen cycle of the eelgrass beds, but they also dissolve in the sediment pore water and get transported within the water flow (Hansen et al., 2000).

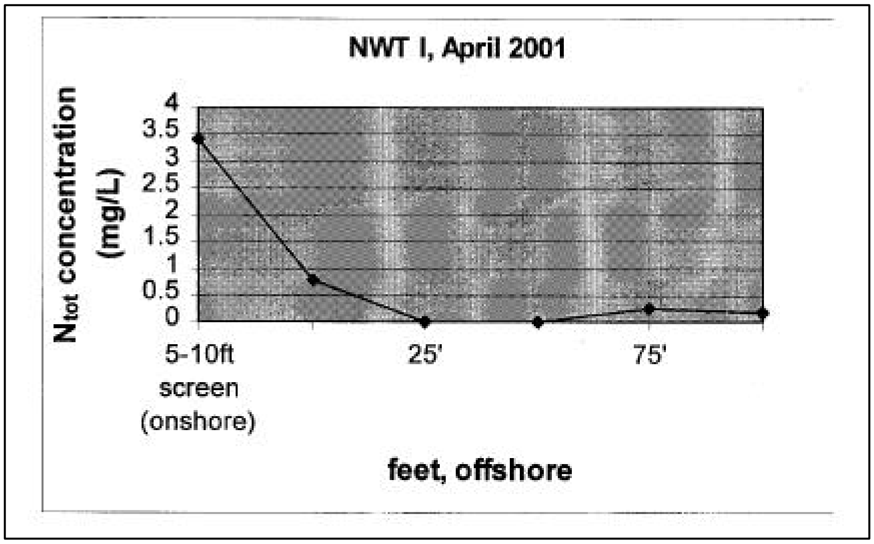

Figure 13—Total nitrogen concentrations NW I transect

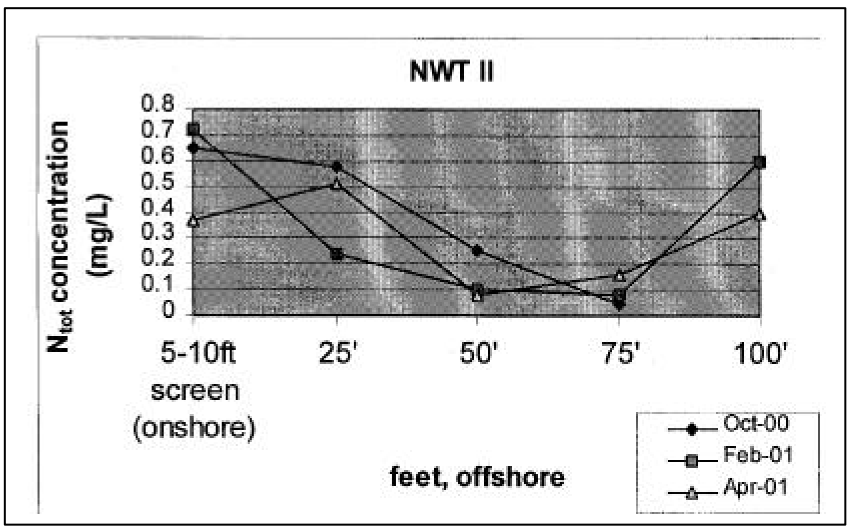

Figure 14—Total Nitrogen concentrations NW II transect

The water samples were analyzed for a large number of metals (see Appendix I, Table 2), but only a few constituents show increased concentrations and will be mentioned in this report. The geochemical carriers Fe, Al and Mn can be found in elevated concentration at both transects. These elements are major soil constituents and the elevated concentration can be traced to the weathering and dissolution of aquifer material material (Montlucon, 1998). Differences in metal concentrations between NW I and NW II were observed. In Figure 15, it can be seen that iron occurs in major concentration (>2mgIL) in the fall and decreases toward the spring months.

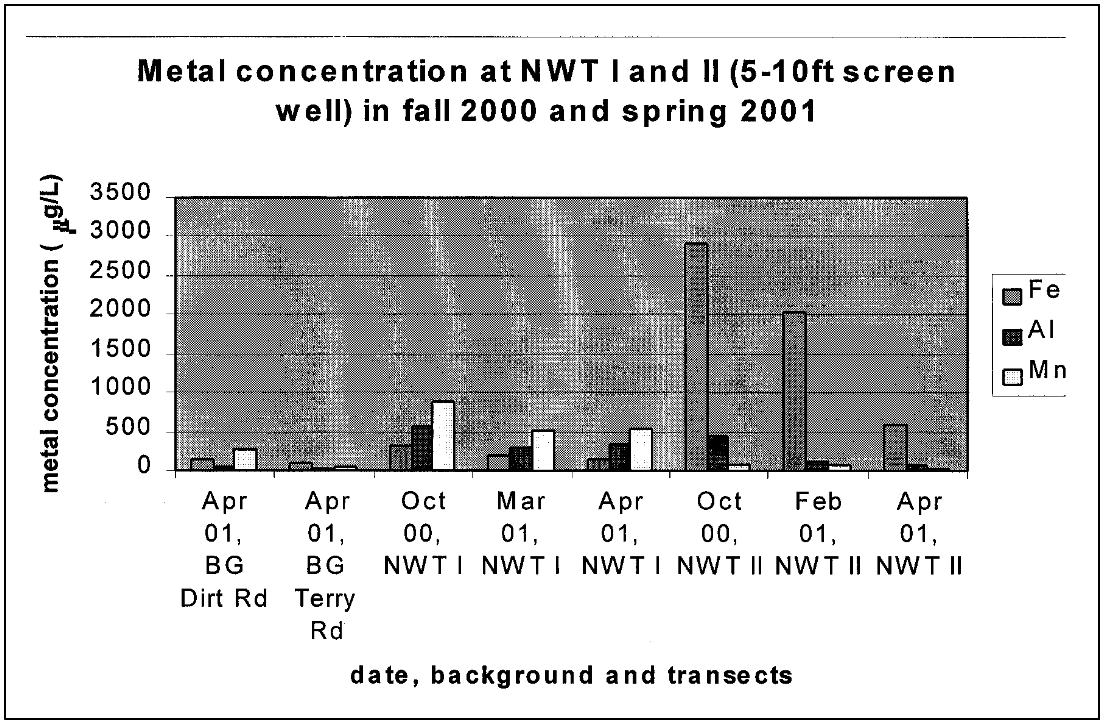

Figure 15—Metal concentrations near shore well NWT I and NWT II

The elements Al and Mn show the same behavior, but only occur in trace concentrations. Langmuir (1997) defines "major", "minor", and "trace" concentrations as ranging above 1mg/L, between 1mg/L and 1 ug/L, and less than 1ug/L, respectively. At NWT I all of the constituents mentioned occur only in trace concentrations. The iron concentration at NWT I is lower than at NWT II, but Al and Mn show slightly higher concentrations at NWT I. Furthermore, the concentrations of Fe, Al, and Mn do not show a declining trend from fall to spring. The water samples taken from the background wells do not show any significantly elevated concentrations of these metals. The elevated iron concentrations at NWT II could be the result of a contamination of the well or iron sources within the sediment (e.g. Hematite). Metals like Fe and Mn are sensitive regarding pH-Eh changes of the solution. They become generally mobilized under the oxic zone around the eelgrass rhizome (McRoy and Helfferich, 1977).

5.0 Summary and Conclusions

The soil analysis revealed a major difference in the grain-size distribution of the substrate between the eelgrass vegetated (NWT II) and the non-vegetated (NWT I) transect at Northwest Harbor. Eelgrass meadows are commonly known for their ability to influence the grain-size distribution of the vegetated sediment. Usually, the sediment within the eelgrass bed consists of more well-sorted and finer material than non-vegetated sediments due to the sieving effect of the eelgrass blades and the stabilizing effect of the root-rhizome system. (Thayer et al., 1984). This can also be seen at Northwest Harbor. The eelgrass distribution at Northwest Harbor seems not to be determined by the grain-size distribution of the sediment, since organic mud layers and plant remnants at the non-vegetated transect support the former presence of eelgrass at this site. The disappearance of the eelgrass probably caused an alteration of the sediment at NWT I to its present condition.

The water analyses show that both the sediment pore water and the groundwater at Northwest Harbor are nutrient limited with respect to phosphate and nitrogen. However, the determination of the N:P ratio could give more information about which of the two elements are really limiting the eelgrass growth at Northwest Harbor (Udy et al., 1999). Further water samples should be analyzed by SCDHS with more P-sensitive equipment or other analyzing methods. Since the groundwater sampled at both of the background wells shows very low nitrogen and phosphate concentrations, the main source of these nutrients might be the sediment and the plant detritus. Therefore, a geochemical analysis of the sediment of both transects should be done in future studies in order to determine the P and N concentration of the substrate.

Finally, a major factor that influences eelgrass growth is light availability, especially in turbid estuarine waters such as at Northwest Harbor. (Udy et al., 1999). Former nutrient increases in the shallow coastal ocean water as well as algae blooms (e.g. Brown Tide) could have decreased the light availability for the eelgrass tremendously, and thus be one vital cause of decline in eelgrass growth and/or biomass at Northwest Harbor.

In conclusion, the water and soil analysis performed during this project could not reveal any differences that would conclusively indicate a sole reason for the presence or absence of eelgrass at the observed sites at Northwest Harbor. Further studies concerning the geochemistry of the sediment, historical and present research regarding the coastal development and possible anthropogenic contamination sources, as well as quantitative measurements of the submarine groundwater discharge at Northwest Harbor could further clarify this relationship.

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