PECONIC ESTUARY
Water Quality Status and Trends

Prepared for the

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Department of Health Services
Division of Environmental Quality

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TABLE OF CONTENTS

TABLE OF FIGURES

TABLE OF TABLES

APPENDICES

1 Executive Summary

The Suffolk County Department of Health Services (SCDHS) has been monitoring the Peconic Estuary for over four decades (1966-2010). They collected over 18,000 water samples at 158 marine, stream and point source sites and conducted 600,000 measurements of analytes within these water samples. The data was analyzed to determine if trends could be identified and whether efforts to improve water quality in the Estuary have been successful.

1.1 Overall Water Quality Trends

There are three important milestones in the recent history of the Peconic Estuary, the onset and cessation of the Brown Tide (1985 and 1995) and the adoption of the Comprehensive Conservation and Management Plan (Peconic Estuary Program, 2001).

Spatial trends were evident in the data. The constricted western embayments receive less exchange from the ocean and more input from high nutrient – low dissolved oxygen tributaries than the eastern embayments. Generally, nitrogen and temperature decrease from west to east and dissolved oxygen increases. Water quality in the western estuary, however, has improved over the past 30 years.

Moderately improving water quality is evident in Reeves Bay. Water quality in central Flanders Bay and Great Peconic Bay improved. Water quality improvements in Little Peconic Bay were most notable in Noyac Bay. Many parameters improved or remained unchanged in Gardiners Bay West. A number of parameters improved in Coecles Harbor, whereas north, central, and east Gardiners Bay essentially remained unchanged as did Block Island Sound.

Waters Included in the nitrogen TMDL showed improvement in several embayments including the Lower Peconic River, White Brook, Birch Creek, Mill Creek, Hubbard Creek, and in the Peconic River at Grangebel Park. Little changed in Flanders Bay or in Terrys Creek. Overall water quality improvements occurred in the western estuary, followed by Gardiners Bay and West Neck Harbor. The range of dissolved oxygen concentrations in the western estuary declined after 1998 as did the morning minima, both signs of improving water quality.

The **Brown Tide**, first detected in the Peconic Estuary in June of 1985, had serious consequences for a variety of marine organisms, particularly commercially important shellfish. After approximately ten years, these toxic algal blooms have virtually disappeared, but new hazardous algal blooms have emerged. The conditions that gave rise to its appearance and disappearance remain undefined. Research did, however, suggest that higher concentrations of dissolved organic nitrogen relative to inorganic nitrogen favored Brown

Tide blooms. Dissolved organic nitrogen (DON) increased in Reeves Bay, West Flanders Bay, and Flanders Bay prior to the onset of Brown Tide. Levels of DON declined in most stations of Little Peconic Bay and stations east of Pipes Cove since 1998-2000 and the decline of Brown Tide (last bloom in 1995). Brown Tide frequency and intensity declined since the early 1990s suggesting that conditions driving the blooms have changed. As no definitive cause of the blooms or their decline has been determined, it is unclear what management actions would be most likely to reduce the likelihood of future blooms.

The **Comprehensive Conservation and Management Plan** (CCMP) set a course for water quality improvements for the impaired portions of the Peconic Estuary and measures to protect areas where good water quality prevailed (Peconic Estuary Program, 2001). The CCMP included measures to manage Brown Tide, nutrients, habitat and living resources, pathogens, toxic pollutants, and critical lands. The CCMP identified several parameters that may serve as 'indicators' of good water quality including salinity (>26 psu), a lower ratio of DON to DIN, and lower total nitrogen. An analysis of monitoring data collected after 1995 found that salinity exceeded 26 psu in most stations more than 60 percent of the time and in many stations more than 90 percent of the time. The ratio of dissolved organic nitrogen (DON) to dissolved inorganic nitrogen (DIN) was high in many stations more than half the time. Since the CCMP, total nitrogen is generally lower, nitrate and nitrite are much lower, DON and phosphorus are similar or lower, chlorophyll-a is generally lower, fecal coliform has generally decreased, and dissolved oxygen is generally higher or much higher. These are all indications of improving water quality.

Nutrient concentrations are critically important to the intensity of Brown Tide and other algal blooms. A nitrogen Total Maximum Daily Load (TMDL) was established for the Peconic Estuary of 0.45 mg/L in the summer and 0.5 mg/L the rest of the year. The analysis of monitoring data revealed that total nitrogen exceeded 0.5 mg/L on the north side of the estuary, Lower Peconic River, and Flanders Bay more than 90 percent of the time since the Brown Tide period. The same was true for the summer (>0.45 mg/L). Since the CCMP (2001), however, the analysis shows a clear decline in water column total nitrogen in many embayments of the Estuary and stable conditions in other areas.

Habitat and living resources have benefited from nitrogen reductions that in turn reduced algal blooms and chlorophyll-a concentrations. Fewer and less intense algal blooms improve water clarity, which is important to eelgrass survival. A decrease in algal blooms leads to higher DO concentrations, which benefits benthic and pelagic organisms. Reduced algal activity also reduces the accumulation of organic material in the water column and in the sediments, leading to an increase in benthic oxygen concentrations as microbial degradation declines. Less re-mineralization results in less nutrient release to the water column.

Pathogen concentrations declined significantly at approximately half of all stations. Efforts since the CCMP successfully reduced bacterial loading to the Estuary. Pathogen reductions make it possible to expand areas certified for shellfish harvesting. Pathogen reductions are likely tied to fewer duck farms, improved stormwater management by area municipalities and public education on the need to clean up after pets

Toxins such as organic compounds, pesticides, and herbicides are rarely detected in the Peconic Estuary. Pesticide use may have declined with farming acreage, but there are a greater number of different pesticides are now found in groundwater.

1.2 Point Source Nitrogen Trends

Nitrogen from wastewater treatment plants contributes only one percent of the 5.4 million pounds of nitrogen entering the Estuary annually, just slightly more than from stormwater runoff. By contrast, the atmospheric contribution represents more than half the annual nitrogen load and groundwater 40 percent. Treatment plant nitrogen is two percent and groundwater 93 percent of the total nitrogen load, if the atmospheric load is not included.

Nitrogen from duck farming peaked in the late 1950s and early 1960s with 14 farms on tributaries to and the shores of Flanders Bay, the Peconic River, Meetinghouse Creek, Sawmill Creek, Reeves Creek, and Terrys Creek. Given groundwater travel time of 20-30 years and more, duck waste deposited upland on farm fields during the 1950s and 1960s would only have appeared in the Estuary in the 1980s, during the peak Brown Tide years. The last duck farm is Crescent Farm in Aquebogue, which produces one million ducks per year. The nitrogen load from those ducks is estimated to exceed that of the Riverhead STP.

1.3 Nitrogen and Phosphorus Analyte Trends

Ammonia declined in more than a quarter of stations, with many located in western Flanders Bay and the mouth of the Peconic River. Ammonia increased in only four stations, all along the shores (or creek mouths) of the North Fork. Total Kjeldahl nitrogen (TKN) increased at a number of stations in the open-water central portions of the Estuary and the eastern boundary but decreased at even more locations in the estuary, creeks and small embayments. Dissolved organic nitrogen (DON) was stable for all stations except for an increase in Meetinghouse Creek during the 1976-2008 non-summer period. If non-summer DON reflects primarily groundwater input, groundwater input has therefore remained relatively unchanged. Non-summer DON increased significantly for the Brown Tide period only in West Neck Bay. Non-summer DON increased significantly for the 1996-2008 period only at the Peconic River station (#200017).

Nitrate increased over the entire three decades in only eight of the stations, primarily in Great Peconic Bay and Flanders Bay, and declined in another quarter of the stations, remaining unchanged in the balance of the stations. Total nitrogen for 1976-2008 declined in 44 percent of stations and increased in only five stations.

Ortho-phosphorus declined significantly across the Estuary, rising only at in Bullhead Bay. Total phosphorus (particulate and dissolved phosphorus) decreased at nearly 70 percent of stations.

1.4 Non-Point Source Nitrogen Loading

Non-point sources for nitrogen loading to the Estuary include the atmosphere, groundwater, and stormwater. Atmospheric nitrogen represents 56 percent of the total nitrogen loading to the Estuary. The most recent data (2003-2009) from the Southold collection station indicates that ammonium deposition increased. Groundwater nitrogen loading comes primarily from agricultural (41 percent) and residential (40 percent) sources (Nuzzi & Waters, 1999). Put in perspective, agricultural loading was more than 30 times that of the Riverhead wastewater treatment plant. Stormwater nitrogen accounts for only 0.9 percent of nitrogen loading to the Estuary.

1.5 Benthic Nutrient Flux

Benthic nutrient flux remains difficult to estimate, but may be a significant source of water column nitrogen. Bacteria degrade organic matter and release the nitrogen into the water column. The internal source of organic matter is primarily algal blooms, while external sources include wastewater, stormwater, and waterfowl waste. Benthic flux from historic accumulations of organic matter, particularly former duck farms, may slow or cease as new material ceases to be added. The relative contribution of benthic flux has yet to be determined.

1.6 Dissolved Oxygen Trends

Dissolved oxygen standards were not met in the pre-Brown Tide years in the mouth of the Peconic River, Sawmill Creek, Meetinghouse Creek, Reeves Creek, and Mill Creek. Dissolved oxygen concentrations remained problematic in the same locations from 1986 to 1995, but far less often. Many additional sampling locations were added from 1996 to 2008. Dissolved oxygen (DO) levels improved in the lower Peconic River, Sawmill Creek, Reeves Creek, and Mill Creek, but numerous locations continued to experience low DO particularly along the north shore of the Estuary.

Data from the sondes (continuous monitoring units) in 2005 showed that the Peconic River experienced the greatest summer decline in DO of the four sonde stations (Peconic River, Flanders Bay, Great Peconic Bay, and West Neck Bay) and the largest range of concentrations (a symptom of eutrophication). West Neck Bay DO remained above the 5.0 mg/L regulatory standard through most of the summer. Super-saturation was evident in West Neck Bay, likely a result of a fall algal bloom.

1.7 Conductivity Trends

Conductivity is a measure of the concentrations of electrolytes in seawater including salts that are measured as salinity and others. Conductivity can reflect nutrient concentrations, declining with lower concentrations of nitrates and phosphates. Conductivity did decline in 13 stations (48 percent), primarily in the heads of a number of creeks and in the upper Peconic River. Some of those creeks also had declining coliform, possibly from improved stormwater management. Lower conductivity may also reflect increasing groundwater flow, possibly a result of greater public water use. Conductivity increased in six stations (22 percent); four in the lower Peconic River, two in Terrys and Sawmill Creeks, and two in creeks that drain into North Sea Harbor. Increasing conductivity might be a reflection of increased nutrient loads (nitrates and phosphates).

1.8 Total Organic Carbon and Chlorophyll-a Trends

Total organic carbon made up of particulate and dissolved organic carbon, declined across much of the Estuary. All stations in the western and eastern boundaries shows significant improvements while 50 to 67 percent of the central stations showed improvements. Improvements to the Riverhead wastewater treatment plant and the closure of all but one duck farm in the 1980s may also be responsible for the decline in organic carbon.

Chlorophyll-a declined in 32 percent of stations and 66 percent were unchanged. Results for nanoplankton were even more favorable with 82 percent of stations showing improvements. Declines were evident at the mouth of the Peconic River and in western Flanders Bay, locations that experienced the greatest water quality impairments in the past. Results reflect declining algal blooms and improving water quality.

1.9 Coliform, Trace Metals, and Synthetic Organic Compounds

A variety of other parameters not related to eutrophication were evaluated. General observations are as follows.

Total and fecal coliform declined in 57 and 48 percent of stations, respectively. Conductivity decreased in many stations with declining coliform, suggesting improved stormwater management.

Trace metals were evaluated by using cadmium as a surrogate. It increased 20 percent based on a more limited dataset. Its source is unknown, though trace metals are usually a component of stormwater runoff.

Synthetic organic compounds like polycyclic aromatic hydrocarbons (PAHs) that are synthesized from petroleum and generated from its combustion were below the detection limit 100 percent of the time for all stations.

Herbicide and pesticide concentrations for compounds like alachlor and aldicarb were below the detection limit and water quality standard 100 percent of the time at all stations. The remaining herbicide and pesticide constituents were detected in some samples with the highest detection being metalaxl, a fungicide, at 9.9 percent of the time. Other herbicides and pesticides were detected, but were generally well below relevant standards.

1.10 The Value of the County Program

Suffolk County is known on Long Island, in the region, and elsewhere for its north fork and south fork communities and especially for access to the Peconic Estuary where boating, fishing, swimming, and beach activities attract over a million tourists each year.

Good water quality is a key attraction not only for the tourists, but for the residents as well. It is vitally important to recreational fishermen that the Peconic Estuary support a healthy fishery. The boating and fishing industries support large numbers of direct and indirect jobs for at least eight months of the year and generate significant tax revenue for local municipalities. Fishing and boating rely on clean water.

The Peconic Estuary also supports a growing shellfish aquaculture industry, with 100,000 acres potentially available for cultivation. Good water quality is required not only to grow the bivalves, but also to market them successfully. The value of the clams, oysters, and scallops that can be grown on these leases runs into the millions of dollars. The industry also generates jobs for growers and various support industries as well. Good water quality is also important to the real estate industry. Waterfront home are most valuable when they front on attractive, clean, and high quality waterbodies.

Recognizing and responding quickly to water quality concerns is effective only if there is a long-term monitoring program with 'boots on the water.' Water quality and resource issues uncovered by the County's program have generated millions of dollars of academic research by local scientists that has advanced our understanding of the Peconic Estuary. It has also generated important connections between the regulatory, academic, environmental, and for-profit communities in their common desire to preserve and protect the natural resources of the Estuary.

Anticipating impacts to groundwater and ultimately to surfaces waters will be an important responsibility of the County's as land use continues to change in the Peconic Estuary watershed. These impacts can be anticipated and therefore mitigated, but only through the continued collection of adequate data. As groundwater travels slowly to the Estuary, there is time to investigate potentially adverse environmental conditions and to formulate a plan to reduce those impacts. The County's Office of Ecology is the logical entity to take on this responsibility. The program, operated by the County Health Department's Division of Environmental Quality, can and should proceed with the kind of sampling and analysis program that documents the connection between land use and estuarine water quality. This data is invaluable when researchers, planners, advocacy groups, business interests, and decision makers plot the best course for the future of the Peconic Estuary.

1.11 Future Program Changes

A continuation of the post-CCMP water quality management effort should be a primary focus of the program. Tracking bloom occurrences and supporting research into harmful algal blooms, particularly red tides, is recommended. An annual report should be issued by the Bureau of Marine Resources on the Peconic Estuary Water Quality Assessment program noting changes from prior years, new and ongoing research. The report should be posted on the County's website. Data should be made available on the web for all interested parties to utilize through an on-line mapping utility and search engine. An option for providing water quality data via the Internet is the existing Suffolk County on-line mapping utility, or Suffolk iMap, which could be enhanced with a water quality data search engine.

Redirecting portions of the sampling effort will help focus the program on portions of the Estuary where waters remain impaired. To do so, the program should eliminate some stable stations and retain others as reference stations for future research purposes. Sampling frequency can be reduced at the stable stations that are retained and increased at those stations where water quality remains problematic. The continuous monitoring effort can be suspended and the YSI sondes dedicated to time-limited special projects by the County or other researchers. A network of groundwater monitoring wells should be installed and sampled inside the Peconic Estuary contributing area with an emphasis on areas upgradient of impaired creeks and embayments.

An increased focus on land use and its impact on the Estuary through groundwater are important as nutrient reductions are best achieved through improved land use management. Exclusive of atmospheric deposition, the vast majority of nitrogen entering the Estuary is from groundwater (93%) and *not* point sources like stormwater (0.9%). Management of nitrogen loading to the groundwater that flows to the Estuary should be a priority. A focus on nitrogen loading from sources other than the STPs may be most fruitful. Agricultural and septic system nitrogen loading are the two largest contributors. Sewering can reduce nitrogen concentrations from 45 to 10 mg/L or lower with advanced systems, while further treatment plant upgrades to the Riverhead STP for $18 million will reduce nitrogen only marginally. As groundwater nitrogen from all onsite systems inside the contributing area reaches the Estuary, sewering of at least all hamlet centers should be a priority. The program should work closely with County and town planning departments to identify priority areas for sewering or onsite system management. More extensive groundwater sampling and analyses by the County and other entities will help land use planners manage the impacts of agriculture and residential development and help elected officials make decisions on wastewater management. Greater information on groundwater constituents would also increase the feasibility of conducting groundwater pollutant mitigation. Mitigation will be needed to reduce the 25-50 years of historic nitrogen that will continue to flow to the Estuary via groundwater.

Preparing for climate change should be part of the County's future efforts in the Estuary. The County should record the climate change parameters identified by the Long Island Sound Study that are considered the 'core parameters' including those it currently measures: pH, temperature, and salinity, and those collected by others: precipitation, streamflow (Peconic River), sea level, wind speed and direction, and relative humidity. It should investigate the impact of increased precipitation to determine if there is a relationship between precipitation trends, sea level, groundwater elevations, and nitrogen concentrations in groundwater and in the Estuary. The County should track the work of others on the impacts of sea level rise on coastal environments and monitor the impacts of sea level rise on Peconic Estuary tidal wetlands.

2 Introduction

The Peconic Estuary (Figure 2-1) includes more than 100 bays, harbors, embayments, and tributaries, some of which continue to experience water quality problems that affect natural resources (many of which have commercial value) and recreational opportunities. Major issues include nutrient enrichment, low dissolved oxygen, and harmful algal blooms including the 'Brown Tide' microalgae (*Aureococcus anophagefferens*) and the microalgae *Cochlodinium polykrikoides*. Bay scallop populations have declined, eelgrass beds have been lost, and acres of clam and oyster beds have been closed due to high bacterial levels. Pesticides, heavy metals, and other contaminants that are found in stormwater runoff and groundwater are making their way to the Peconic Estuary and climate change now threatens shorelines and aquatic habitats.

In 2007, Peconic Estuary Program (PEP) established a nitrogen Total Maximum Daily Load (TMDL) to set the nitrogen load reductions necessary to comply with dissolved oxygen standards for the Estuary. Similarly, work by the PEP led to pathogen TMDLs for 20 Estuary waterbodies to address the impairments associated with coliform levels.

The Suffolk County Department of Health Services (SCDHS) has been monitoring the Estuary for over four decades (1966-2010). They collected over 18,000 water samples at 158 marine, stream and point source sites and conducted 600,000 measurements of analytes within these water samples.

A major product of the County's early efforts was the Long Island 208 Study (which provided water quality data for the Comprehensive Waste Treatment Management Plan (Koppelman, 1978). Sampling was limited to 34 sites in the western portion of the Estuary, which were sampled only three times. Sampling for the 208 Study continued from 1977-1985 from two to eight times per year. The County expanded the scope and frequency of their monitoring efforts when Brown Tide (BT) first appeared in 1985 and again in 1988 under the Brown Tide Comprehensive Assessment and Management Program (BTCAMP). After the establishment of the Peconic Estuary Program (PEP) in 1994, more sites were added and sampling frequency increased. By 1996, 83 sites (40 marine/estuarine, 40 stream, and three STP locations) were monitored regularly.

Figure 2-1. Peconic Estuary Contributing Area

The County completed over 15 years of monitoring under the PEP. This report will evaluate the data for long-term trends in water quality from the sampling initiated for the 208 Study (1976-1985), through the expanded Brown Tide data collection program (1985-1996) to the current sampling program (1997-present) which supports the Peconic Estuary Program. The data collected by the County has been used to support the following research and management efforts:

- LI 208 Study
- Brown Tide and other harmful algal bloom research
- Brown Tide management program
- National Estuary Program nomination
- Water quality monitoring efforts
- Eelgrass management studies
- Sub-watershed management plans
- Development of Total Maximum Daily Load's (TMDLs)

The County wishes to have the data evaluated to assess the status and historic trends for the following key water quality parameters:

- Nitrogen and phosphorus nutrients
- Chlorophyll *a*
- Dissolved oxygen
- Water clarity (Secchi depth, photosynthetically active radiation, total suspended solids)
- Toxics (metals and organics)
- Pathogens (coliform and other bacteria and viruses)

The County wishes to assess conditions in the Estuary relative to the Peconic Estuary Program's Comprehensive Conservation and Management Plan (CCMP) and established TMDLs. The goal is to evaluate the monitoring program to determine what changes might be made to generate additional information and reduce redundancy.

3 Methodology

Monitoring data has been collected in the Peconic Estuary, including the Peconic River and tributaries, since 1966. Station locations and parameters have been added and dropped over the years based on specific monitoring program objectives at the time. While this leads to some breaks in continuity, the overall dataset is very extensive and comprehensive. Using this dataset, the analyses included:

- Characterizing existing water quality,
- Identifying and evaluating trends in key parameters,
- Assessing the extent to which goals of the Peconic Estuary Program's (PEP) Comprehensive Conservation and Management Plans (CCMP) have been met,
- Describing relationships related to the occurrence of Brown Tide,
- Assessing impacts of climate change, and
- Identifying areas where future monitoring should be expanded, redirected, or improved.

This effort required a variety of techniques from simple statistical summaries to more complicated assessments of trends and correlation. This document summarizes the techniques used, provides the results, and discusses some of the conclusions that can be drawn from the data.

The initial effort focused on calculation of basic statistical measures, such as count, average, median, minimum, and maximum (Appendix A). This analysis can provide insight into the relative magnitude of parameters between stations, the duration of monitoring, etc. Datasets included in this analysis are:

- Suffolk County Department of Health Services Bureau of Marine Resources (BMR) Stream and Marine Monitoring
- OWR Stream Monitoring
- YSI Continuous Monitoring
- Atmospheric Deposition
- Point Source Discharge
- Groundwater

The BMR dataset is by far the most extensive of the sources, both temporally and spatially. The other datasets provide insight into different aspects of the data, interactions between sources, or results at a different temporal scale. A summary of the information included in each data set is provided in Table 3-1.

Table 3-1. Data Sources

Dataset	Period of Measurements[1]	Number of Locations	Number of Parameters	Notes
SC BMR	1966 - 2009	135	347	Many stations or parameters were sampled infrequently or not at all during much of the time period.
OWR	1970 - 2004	15	149	Many stations or parameters were sampled infrequently
YSI	2002 - 2008	5	3	Periods vary by location. 15-minute intervals.
Atmospheric Deposition	1983 - 2009	2	13	
Point Source Discharge	2008 – 2011	6	2	Nitrogen, BOD only
Groundwater	1987 - 2006	40	23	

[1] Maximum period

3.1 Data Processing

The monitoring efforts in the Peconic Estuary have varied in spatial extent and focus over time since the program was modified to meet specific objectives and needs. Different locations have been sampled at different frequencies for different parameters. The intermittent nature of the monitoring is not necessarily an issue but can affect the types of analyses that can be performed. For example, trend analyses were calculated for a number of stations and parameters for different periods around Brown Tide occurrences. Many measurements are required to calculate a meaningful trend. If a station had breaks in the sampling, trends may have only been calculated for the overall sampling period and for some of the Brown Tide occurrence periods.

Data processing was also required to allow for calculation of statistics and evaluation of related parameters. Many of the measurements were recorded as being less than the detection level of the analytical method being used. Since the true value is not known, but the value is likely not the detection limit or zero, a value of ½ of the detection level was used instead. This is considered an acceptable compromise for the calculation of statistics (USEPA, 1996).

Although organic nitrogen is relevant to this study, it was not always directly measured. Prior to 2000, dissolved Kjeldahl nitrogen was measured. Dissolved organic nitrogen (DON) can be calculated by subtracting ammonia from the dissolved Kjeldahl nitrogen value. Similarly, from 2000 only dissolved nitrogen was measured. DON is calculated by subtracting nitrate-nitrite and ammonia from the dissolved nitrogen value. Similar approaches were used to calculate total organic nitrogen, nitrate-nitrite, total nitrogen, and total phosphorus if they were not directly reported. Data from stations 200009 and 200092 were combined into a single dataset based on information from SCDHS that these stations were co-located.

Once the data were processed, statistical measures were calculated for each. As noted, many parameters were monitored infrequently, and statistics were not calculated for all parameters. As the CCMP focused on nutrient issues, the data analysis focused on parameters related to the development of Brown Tide and eutrophication. Nitrogen, phosphorus, and their species, such as nitrate, DON, and orthophosphorus, are typically the most important constituents related to algal growth. Assessing changes in these constituents might help understand the triggers for future algal blooms. The actual blooms can be measured by counting algal cells, which was done for the Brown Tide alga, *Aureococcus anophagefferens*. A less direct but simpler method for quantification of algal populations is the measurement of chlorophyll-a, which is the major pigment contained in algal cells. Other parameters, such as temperature and Secchi depth, provide an understanding of environmental conditions that may be related to algal growth, but are also important for assessing conditions that support aquatic life. Cadmium was included as an indicator of changes in other metals. The selected parameters used in the analyses are shown in Table 3-2. Detailed statistics for these parameters are provided in Appendix A.

Table 3-2. Parameters used in Trends Analysis

▪ Field pH	▪ Total Nitrogen
▪ Temperature	▪ Nitrate-Nitrite
▪ Salinity	▪ Ammonia
▪ Total Suspended Solids	▪ Dissolved Oxygen
▪ Secchi Depth	▪ *Aureococcus anophagefferens*
▪ Total Phosphorous	▪ Chlorophyll A – Total
▪ Dissolved Phosphorous	▪ Chlorophyll A – Fractionated
▪ Total Phosphate	▪ Silicates
▪ Total Kjeldahl Nitrogen	▪ Total Coliform
▪ Dissolved Kjeldahl Nitrogen	▪ Fecal Coliform
▪ Dissolved Organic Nitrogen	▪ Cadmium

3.2 Trend Analysis

One of the goals of this study is to determine if water quality in the Peconic Estuary has improved. Another goal of post CCMP Estuary management is to "*develop and implement an integrated long-term monitoring plan for water quality and habitats/living resources issues with a coordinated data management strategy."*

Brown Tides occurred from 1986 through 1995. The CCMP was implemented in 2001 to improve water quality in the Estuary, with the anticipation that those improvements would also reduce the chances of Brown Tide reoccurrence. Temporal evaluation of data can be used, in part, to determine whether efforts such as the CCMP have had an impact. Formal trend analyses can be used to determine whether there are significant upward or downward trends in nutrients (nitrogen and phosphorus) and algae, which is indicated by trends in chlorophyll-a and dissolved oxygen.

Statistical evaluation of trends in chronological data can be pursued in a number of ways. One of the most-used trend analysis methods for environmental data is the Mann-Kendall test (Gilbert, 1987) (Gibbons, 1994) described in more detail in Section 3.4. This is a nonparametric method, so there are no distributional assumptions, missing data values (non-detects) are easily handled, and irregularly spaced sampling intervals are permitted (but not favored). This technique can be viewed as a nonparametric test for a zero slope in the linear regression of time-ordered independent data versus time.

Mann-Kendall Trend tests for total period and for pre-Brown Tide years (1976-1985); Brown Tide years (1986-1995); and post Brown Tide years (1996-2008) for BMR marine and stream stations were calculated for a subset of the parameters of interest for stations identified through discussion with SCDHS. The station selection was based on the frequency and consistency of sampling over time. The parameter subset focused on parameters that were most directly related to algal growth and eutrophication. Not all parameter/station combinations had sufficient data to calculate a trend and were therefore not reported. Stations with less than 10 observation in the for pre-Brown Tide years (1976-1985); Brown Tide years (1986-1995); and post Brown Tide years (1996-2008) were dropped from the evaluations. Stations with less than 20 observations for the full period (1976-2008) were also dropped from the evaluation. Trend estimates for a total of 4,576 station, parameter, and time periods were calculated. A summary of the trend results by conclusion are provided in Table 3-3, Table 3-4, and Table 3-5. The complete set of results is provided in Appendix B.

Of the 22 parameters evaluated, 12 showed no significant trend over their monitoring period for a majority of the stations. This suggests a stable system, which is not surprising given that many of the parameters are greatly influenced and moderated by concentrations in the ocean. Five parameters showed a majority of stations that had significantly decreasing concentrations while no parameters had a majority of stations with increasing concentrations. *Throughout this report, the discussion refers **only** to those stations where a statistically significant trend was identified (e.g., "percent of stations" refers only to the percent of stations exhibiting a significant trend for that parameter.)*

Table 3-3 suggests that conditions may be improving. Chlorophyll-a, total phosphate, bacteria, and total organic carbon all decreased while dissolved oxygen increased at a majority of stations. Organic nitrogen and silicates showed the most frequent increase at the greatest number of stations with about 30 percent of stations showing an increase.

Table 3-3. Summary of Mann-Kendall Tests with a Conclusion of "No Significant Change"

Parameter	**Total**	**Percentage**
Ammonia	44	63%
Aureococcus anophagefferens	4	31%
Chlorophyll A - Fractionated	5	18%
Chlorophyll A - Total	25	66%
Dissolved Kjeldahl Nitrogen	15	37%
Dissolved Organic Nitrogen	19	46%
Dissolved Oxygen	47	76%
Dissolved Phosphorous	17	89%
Fecal Coliform	24	41%
Field Conductivity	8	30%
Field pH	2	67%
Nitrate-Nitrite	41	69%
Organic Nitrogen	11	34%
Orthophosphate	31	63%
Silicates	18	62%
Temperature	67	83%
Total Coliform	32	50%
Total Kjeldahl Nitrogen	20	41%
Total Nitrogen	40	50%
Total Organic Carbon	10	33%
Total Phosphorus	18	27%
Total	**508**	**100%**

Table 3-4. Summary of Mann-Kendall Tests with a Conclusion of "Significantly Decreasing"

Parameter	Total	Percentage
Total Suspended Solids	10	83%
Ammonia	22	31%
Aureococcus anophagefferens	9	69%
Chlorophyll A - Fractionated	23	82%
Chlorophyll A - Total	12	32%
Dissolved Kjeldahl Nitrogen	19	46%
Dissolved Organic Nitrogen	14	34%
Dissolved Phosphorous	1	5%
Fecal Coliform	33	57%
Field Conductivity	13	48%
Field pH	1	33%
Nitrate-Nitrite	13	22%
Organic Nitrogen	12	38%
Orthophosphate	17	35%
Silicates	2	7%
Temperature	14	17%
Total Coliform	31	48%
Total Kjeldahl Nitrogen	19	39%
Total Nitrogen	35	44%
Total Organic Carbon	20	67%
Total Phosphorus	46	69%
Total Suspended Solids	1	8%
Total	**357**	**100%**

Table 3-5. Summary of Mann-Kendall Tests with a Conclusion of "Significantly Increasing"

Parameter	Total	Percentage
Ammonia	4	6%
Chlorophyll A - Total	1	3%
Dissolved Kjeldahl Nitrogen	7	17%
Dissolved Organic Nitrogen	8	20%
Dissolved Oxygen	15	24%
Dissolved Phosphorous	1	5%
Fecal Coliform	1	2%
Field Conductivity	6	22%
Nitrate-Nitrite	5	8%
Organic Nitrogen	9	28%
Orthophosphate	1	2%
Silicates	9	31%
Total Coliform	1	2%
Total Kjeldahl Nitrogen	10	20%
Total Nitrogen	5	6%
Total Phosphorus	3	4%
Total Suspended Solids	1	8%
Total	**87**	**100%**

Additional information regarding trends at specific locations or over the pre-Brown Tide years (1976-1985); Brown Tide years (1986-1995); and post Brown Tide years (1996-2008) are provided in Appendix B.

Additional information on the location of changes was performed by compiling trend results by stations for the following areas:

- Quintant 1 – Western Estuary, Peconic River, and Western Tributaries
- Quintant 2 –Central Estuary and Tributaries
- Quintant 3 – Northeastern Estuary and Tributaries
- Quintant 4 – Southeastern Estuary and Tributaries
- Quintant 5 – Eastern Boundary

Trend data results were also compiled for waters included in the nitrogen and pathogen TMDLs as shown below:

- Lower Peconic River and Tidal Tributaries
- Western Flanders Bay and Lower Sawmill Creek
- Terrys Creek and Tributaries

These results are provided in Appendix B. The timing of the changes will be discussed in more detail as part of a ‘box and whisker’ analysis described later in this document.

Groundwater data was collected in the area at 40 locations. These data were evaluated for trends although data collection was limited and sporadic for these monitoring locations. Results are provided in Appendix B.

Trend analyses were not performed for point and nonpoint sources due to limited data availability. Monitoring is performed at a number of locations below point sources discharges, however. These data were analyzed and trend results are summarized in Appendix B. Atmospheric deposition trends were also calculated (Appendix B).

3.3 Box and Whisker Plots

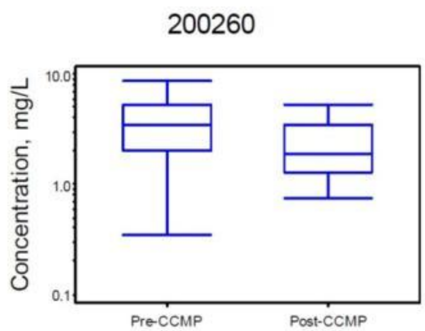
Box and whisker plots present information on the central tendency, variability, and skewness for a sample data set by sketching the center 50% of the concentrations with a box, and then illustrating the typical tail regions of the distribution with whiskers. For atypical concentrations that extend further from the center than the whiskers, individual data symbols are plotted. Specifically, these box and whisker plots are constructed as follows:

- The height of the box represents the interquartile range (IQR). The IQR is the distance between the 25th and the 75th percentiles.
- The horizontal line in the box interior represents the median.

- The vertical lines issuing from the box extend to the minimum and maximum measured values (as long as these minimum and maximum values do not extend further from the box than a distance of 1.5 times the interquartile range).
- Individual data symbols are used for concentrations that exceed the whiskers.

An example of a box and whisker plot is provided in Figure 3-1. This plot shows the total nitrogen concentrations during the pre- and post-CCMP periods. The absolute range, 25th percentile, median, and 75th percentile of concentrations are all higher for the pre-CCMP period. A downward shift alone would suggest that concentrations are generally improving. A shift in the median, 75th percentile, and maximum concentrations suggests an overall improvement.

Figure 3-1. Example Box and Whisker Plot for Total Nitrogen at Station 200260



Box and whisker plots can be an informative method to compare different datasets. Each box shows the 25th, 50th (median), and 75th percentiles, while the ends of the whiskers show the 5th and 95th percentiles, and the dots represent the minimum and maximum for a given parameter. Side-by-side comparison can quickly demonstrate difference in characteristics in stations, periods, and parameters. Due to the resource requirements and challenges of presenting all of the box and whisker plots for each station and analyte, a subset of stations representing different areas throughout the system was selected. Box and whisker plots were generated for the following:

- Summer (April – September) versus non-summer (October – March) box and whisker plots for total N, organic N, inorganic N, organic N: inorganic N ratio, DO, temperature, salinity and chlorophyll-a.
- Pre-CCMP (2001 and earlier) versus post CCMP (2002 and later) box and whisker plots for total N, organic N, inorganic N, organic N:inorganic N ratio, DO, temperature, salinity and chlorophyll-a.

The complete set of box and whisker plots separated into marine and stream stations are provided in Appendix C. Box and whisker plots for seasonal and annual averages are provided in Appendix D.

3.4 Mann-Kendall Trend Evaluations

The data were evaluated for temporal trends in the data to determine whether significant increasing or decreasing trends were indicated by the available data. Statistical evaluation of trends in chronological data can be pursued in a number of ways. One of the most utilized trend analysis methods for environmental data is the Mann-Kendall test (Gilbert, 1987); (Gibbons, 1994). This is a nonparametric method, so there are no distributional assumptions, missing data values (non-detects) are easily handled, and irregularly spaced sampling intervals are permitted. This technique can be viewed as a nonparametric test for a zero slope in the linear regression of time-ordered data versus time.

The calculated probability for the test is provided. It represents the probability that any observed trend would occur purely by chance (given the variability and sample size of the data set). A significance level of 0.05 was used for comparisons with this probability and the resulting decision is reported. This could be a significantly increasing or decreasing trend or no significant change (over time). For each constituent chosen, the test was performed for all the results combined as well as by periods: 1976-1985, 1986-1995, and 1996-2007. In addition to these traditional Mann-Kendall tests, two additional variations were performed on all the combined results. The first of these was the seasonal Mann-Kendall test, which can provide an unbiased trend evaluation when seasonal effects are present. The second variation involved adjusting the data for seasonality prior to performing the traditional Mann-Kendall test. This adjustment was performed by subtracting the seasonal mean (for each season, constituent, and location) from the result and then adding the grand mean (for each constituent and location). The following quarters were used and treated as equivalent to the four seasons: November-January, February-April, May-July, and August-October.

3.5 Correlation Evaluation

Pearson and (nonparametric) Spearman correlation coefficients (based on ranks of the data) were calculated for annual averages of selected constituents. The nonparametric approach (Spearman) may be the preferred approach for these comparisons, but since so many practitioners rely exclusively on the Pearson coefficients (perhaps due to the greater ease of calculating these), they were included as well.

The correlation coefficients measure the strength of a linear relationship between two data sets, that is, how much association exists between an increase or decrease in the concentration of one parameter and the concentration of another parameter. These correlation coefficients range from -1 to 1. A zero value would indicate no observed correlation, whereas more negative or positive values indicate increasing correlation, either inverse or direct, respectively. While these coefficients are well-recognized statistics to measure correlation, it can be difficult to appraise the meaning of the magnitude of these coefficients.

To offer perspective on these coefficients, the probability that each correlation is significant was calculated and compared to a significance level of 0.05. If the calculated probability was below 0.05, the correlation was determined to be significant. This is analogous to concluding that we have 95 percent confidence that the true correlation coefficient is not zero. The significance of the Pearson coefficients depends on an assumption of normality, which is not appropriate for the water quality data that in general exhibit a skewed distribution. The Spearman coefficients are nonparametric (no distributional assumption required) and are the recommended statistical measure to use for these correlations.

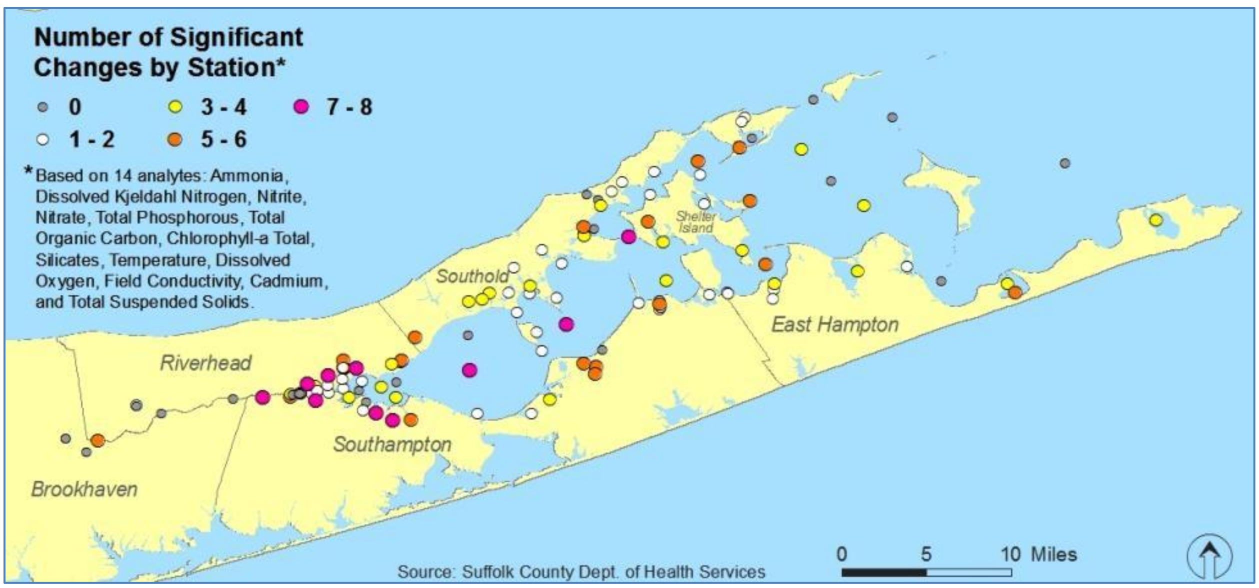
Another approach to gain perspective on the coefficients is to consider the square of the coefficients, which are listed as percentages. These relate to the percent of overall variability explained by the analyte. That is, given the large amount of variability between different results, what percent of that overall variability appears to be explained by that particular analyte. These percentages are approximate and are not additive (*i.e*., one cannot predict the percent of overall variability with the inclusion of multiple chemicals by adding the percentages of individual analytes).

4 Temporal Trends

4.1 Significant Temporal Trends in the Estuary

Temporal trends in the Estuary are mapped in Figure 4-1. The figure shows at a glance those areas of the Estuary where water quality has changed in a statistically significant manner. The map simply shows the number of parameters that changed over the monitoring period. In general, far more change occurred in the western Estuary where, at eight stations, there were 7-8 parameters that had changed. At several other western stations there were between three and six parameters that changed. Five to six parameters changed at three North Sea Harbor stations. West Neck Harbor and the station off Paradise Point also showed significant changes. Changes were evident in western Gardiners Bay where 5-6 parameters changed at each of four stations.

Figure 4-1. Number of significant changes by station



__Temporal Trends__ – The most changes occurred in the western estuary, followed by Gardiners Bay and West Neck Harbor.

4.2 Trends Relative to Brown Tide Occurrences

A number of Harmful Algal Blooms (HABs) have appeared in the Peconic Estuary over the last several decades. Brown Tide (*Aureococcus anophagefferens*) appeared first in 1985 and bloomed periodically through 1995. The County monitors two areas (Flanders Bay and West Neck Bay) for Brown Tide.

Research on the causes of the Brown Tide (BT) blooms (as summarized in the Literature Review) found that blooms were not associated with anomalous chlorophyll-a, dissolved oxygen, or inorganic nutrients. A suggestion was made that the blooms may be related to groundwater discharge volume. According to researchers, low groundwater discharge was associated with higher dissolved organic nitrogen from microbial decomposition in sediments and BT blooms. High groundwater discharge leads to higher dissolved inorganic nitrogen in the Bay and mixed blooms. They suggested that the death and decay of 'normal' mixed phytoplankton blooms might supply the organic nutrients for a subsequent BT bloom. The unanswered question: if this were so, then why have there been no BT blooms since 1995?

As noted above, trend analyses were performed for the primary constituents of interest, *i.e*. total nitrogen, total Kjeldahl nitrogen, etc. A more detailed review of the dissolved organic nitrogen results for pre-Brown Tide years (1976-1985); Brown Tide years (1986-1995); and post-Brown Tide years (1996-2007) periods was done. The analysis first removed the potential effects of algal blooms on nitrogen by only utilizing data from the non-algal growth period from September through April. The resulting data was somewhat sparse and any stations with insufficient data for all periods were dropped from the analysis. A Mann-Kendall test was then performed for each of the periods individually. As shown in Table 4-1, the majority of the stations showed no significant trends within any of the periods. Only two stations showed a significant increase, the Peconic River (2000017) during the post-BT period and West Neck Bay (060119) during the BT period.

Another approach to the data relative to Brown Tide was to generate time series charts for dissolved organic nitrogen. Following are charts for the TMDL stations (Reeves and West Flanders Bay, Flanders Bay, Lower Peconic Bay, Great Peconic Bay, and Sag Harbor East). Note that the scales are different between many of the charts. All the stations had concentrations of dissolved organic nitrogen that varied from zero to as high as 2 mg/L, though at most stations values remained under 1 mg/L. Find more extensive temporal plots in Appendix E.

Table 4-1. Trends Pre-BT, BT, and Post –BT Periods

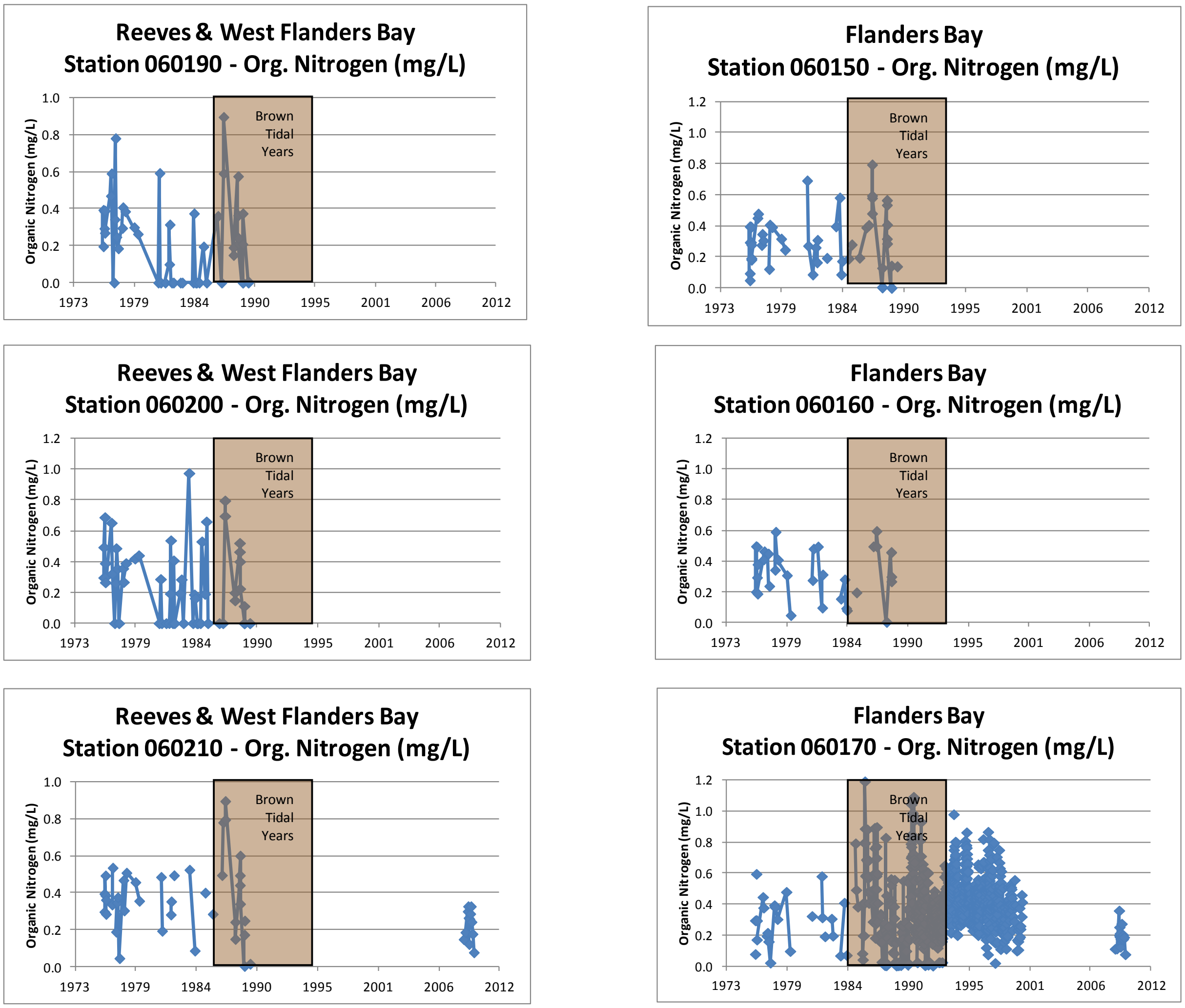
Parameter	Station	(1976-1985)	(1986-1995)	(1996-2008)
DON Non-Summer	200010		No Significant Change	No Significant Change
DON Non-Summer	200017		No Significant Change	Significantly Increasing
DON Non-Summer	200020		No Significant Change	No Significant Change
DON Non-Summer	200021		No Significant Change	No Significant Change
DON Non-Summer	060113		No Significant Change	No Significant Change
DON Non-Summer	060114		No Significant Change	No Significant Change
DON Non-Summer	060115		No Significant Change	No Significant Change
DON Non-Summer	060116		No Significant Change	No Significant Change
DON Non-Summer	060118		No Significant Change	No Significant Change
DON Non-Summer	060119		Significantly Increasing	No Significant Change
DON Non-Summer	060121		No Significant Change	No Significant Change
DON Non-Summer	060130	No Significant Change	No Significant Change	No Significant Change
DON Non-Summer	060170	No Significant Change	No Significant Change	No Significant Change
DON Non-Summer	060220	No Significant Change	No Significant Change	No Significant Change
DON Non-Summer	060240	No Significant Change	No Significant Change	No Significant Change

Dissolved organic nitrogen increased in all the three stations (060190, 060200, and 060210) in Reeves and West Flanders Bay (Figure 4-2) just before or at the onset of the Brown Tide. Most values prior to the onset of BT peaked at no higher than 0.4-0.5 mg/L. At the onset of the BT, values reached 0.8-1.0 mg/L. No data is available for these stations after 1989 (except a brief period for station 060210).

Similarly, dissolved organic nitrogen also peaked in 1987 at the three stations in Flanders Bay (060170, 060160, and 060150). The dissolved organic nitrogen concentration in 1987 was approximately twice that of the pre-Brown Tide years (Figure 4-2).

The time series for dissolved organic nitrogen in Little Peconic Estuary Bay (stations 060105, 060108, 060121, and 060125) has a bit more scatter (Figure 4-3). Dissolved organic nitrogen at Station 060105 continued to reach 0.8 mg/L as late as early 1998, but the majority of the concentrations in the mid to late 1990s were between 0.2 and 0.6 mg/L. The situation was similar at station 060108. At station 060121, however, there were two dissolved organic nitrogen peaks during the Brown Tide years that reached 0.9 mg/L. In late 1997, dissolved organic nitrogen began to decline reaching less than 0.1 mg/L by 2001. It remained low until more recently when a slight increase to 0.2 mg/L was evident.

Figure 4-2. Dissolved Organic Nitrogen in Reeves & West Flanders Bay and Flanders Bay



In the Great Peconic Bay at stations 060120 and 060130, dissolved organic nitrogen remained under 0.4-0.5 mg/L until the onset of Brown Tide, when it climbed above 0.7 mg/L, reaching 1.0 mg/L in 1990 at station 060130 (Figure 4-4).

A dissolved organic nitrogen decline is evident at station 060121 in Little Peconic Bay, station 060170 in Flanders Bay, and station 060130 in Great Peconic Bay. At all three stations, dissolved organic nitrogen began to decline in late 1997, reaching less than 0.1 mg/L by 2001, remaining low until 2008-2009 when a slight increase to 0.2 mg/L is evident.

Figure 4-3. Dissolved Organic Nitrogen in Little Peconic Bay

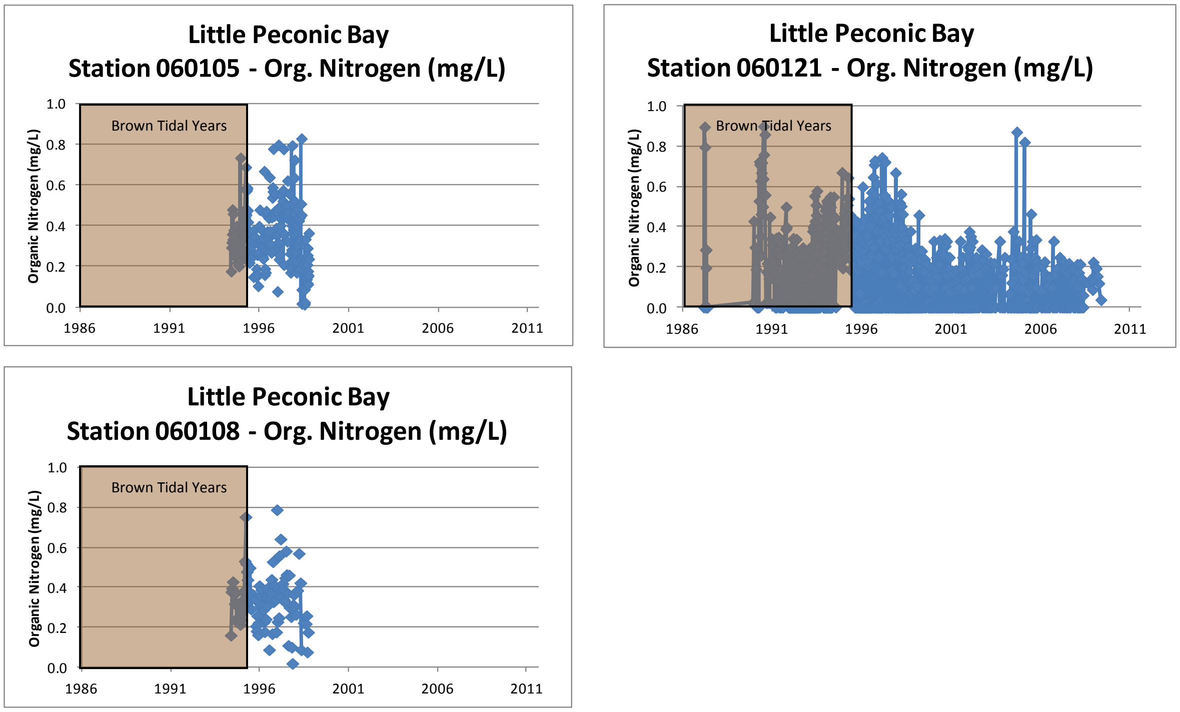
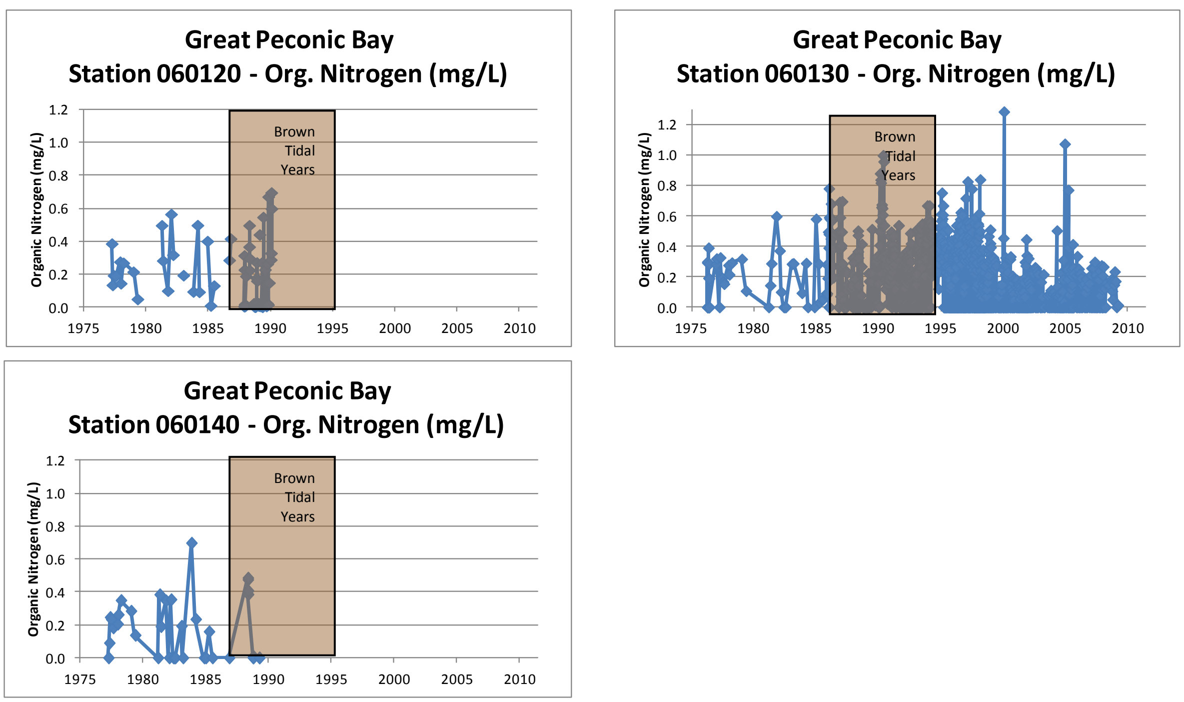
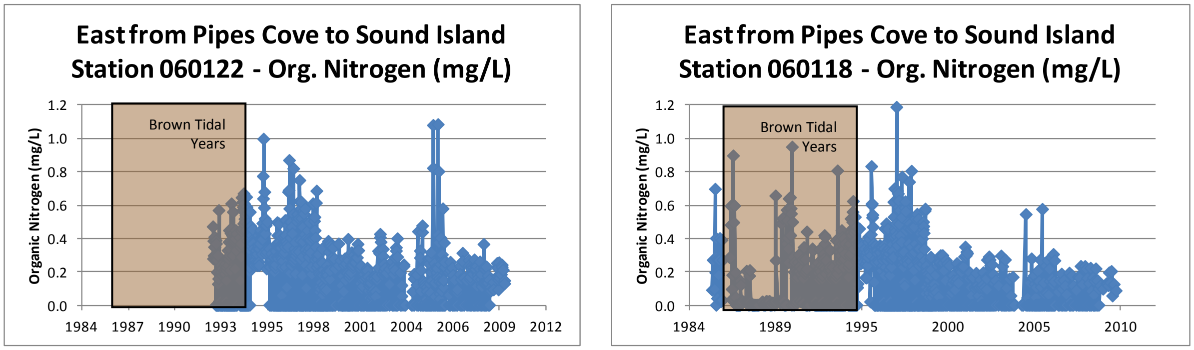


Figure 4-4. Dissolved Organic Nitrogen in Great Peconic Bay



Further east at station 060118 (Figure 4-5), dissolved organic nitrogen reached 1.0 mg/L several times during the Brown Tide years. At stations 060118 and 060122, like the other stations described above further west in the Estuary, dissolved organic nitrogen began a decline in 1997-1998 and remained very low until 2008-2009, when a slight increase was evident (Figure 4-5).

Figure 4-5. Dissolved Organic Nitrogen east from Pipes Cove to the Sound Island station



Trends Relative to Brown Tide *– Research suggests that blooms might be related to groundwater flow and the ratio of dissolved inorganic nitrogen (DIN) to dissolved organic nitrogen (DON). DON increased in Reeves Bay, West Flanders Bay and Flanders Bay prior to the onset of Brown Tide. DON declined in most stations of Little Peconic Bay and stations east of Pipes Cove since 1998-2000.*

4.3 Pre and Post CCMP Trends

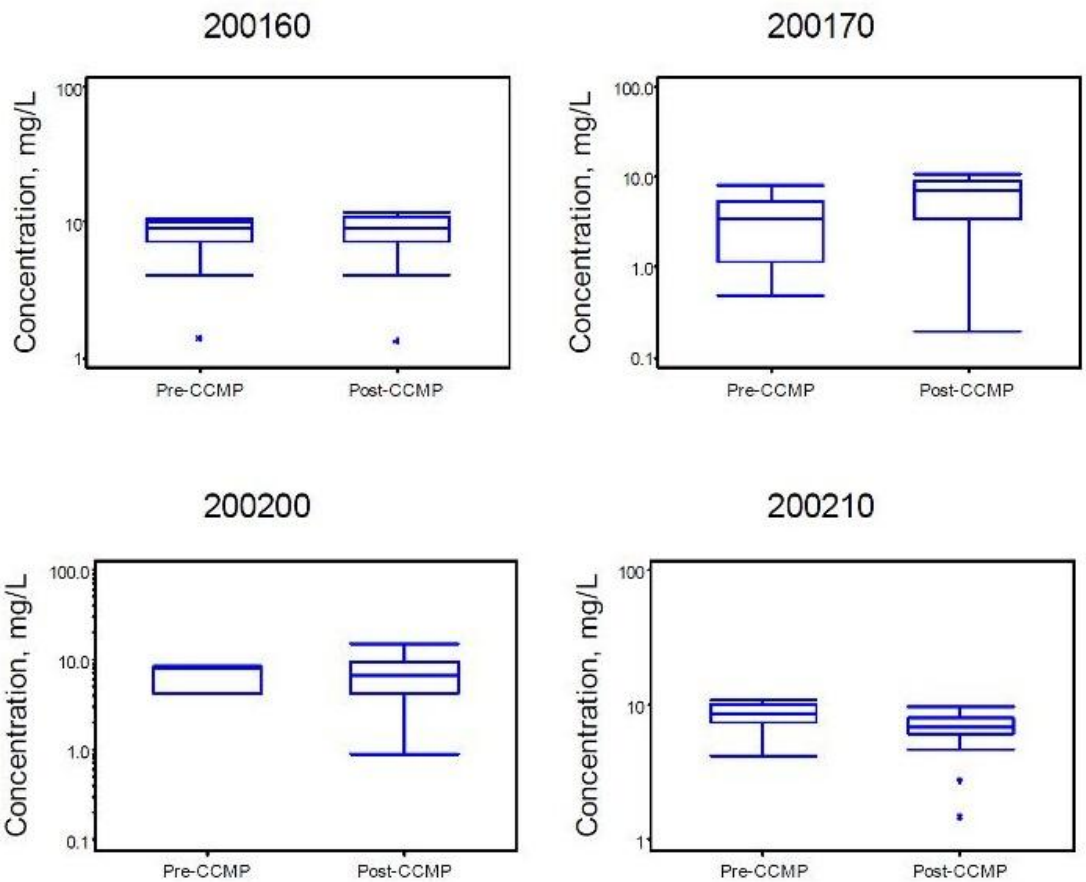
Box plots were created for *Aureococcus anophagefferens*, chlorophyll a, dissolved oxygen, fecal coliform, nitrate and nitrite, organic nitrogen, dissolved organic nitrogen, Secchi depth, total nitrogen, total phosphorus, temperature, and total organic carbon for pre- and post-CCMP periods as provided in Appendix C. This information and the results of the trend analyses were used to evaluate the temporal changes in the estuary and the impacts of the CCMP. Table 4-2 shows general conclusions of the CCMP on those parameters.

An example of the box and whisker plots is provided in Figure 4-6 and Figure 4-7. Figure 4-6 compares total nitrogen concentrations for pre- and post-CCMP periods in tributaries draining to the north side of Great Peconic Bay and Little Peconic Estuary Bay. Figure 4-7 shows nitrogen, temperature, and dissolved oxygen measurements in Great Peconic Bay. Total nitrogen concentrations at stations 200160 (Brushes Creek) and 200170 (Deep Hole Creek) are notably higher after the CCMP was developed. Station 200200 (West Creek) shows similar concentrations for both periods whereas 200210 (East Creek) shows notably lower concentration since the CCMP went into effect.

Table 4-2. Changes to Parameters Pre-CCMP and Post CCMP

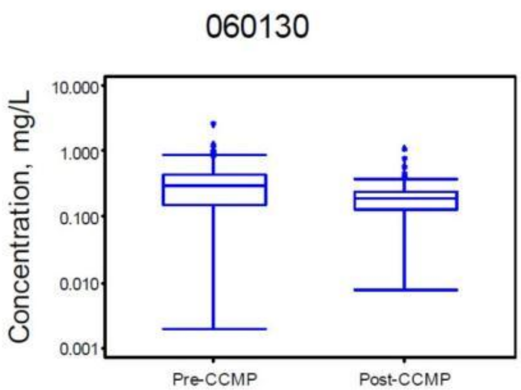
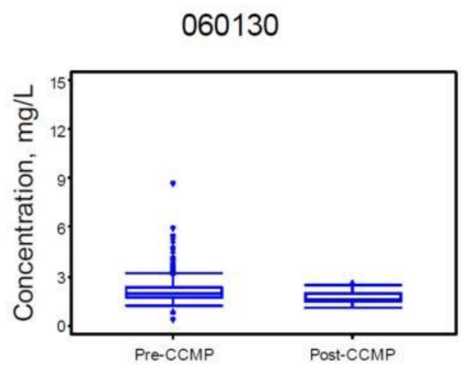
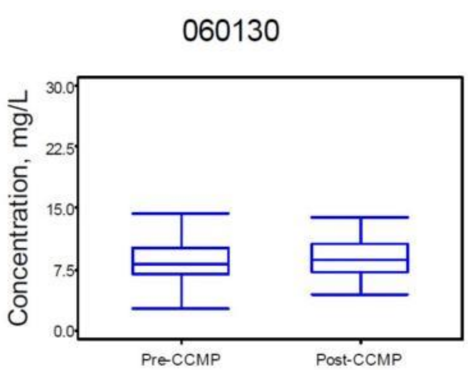
Parameter	Result	Comment
A. anophagefferens	Consistently lower	Improved
Cadmium	No conclusion due to insufficient data	
Chlorophyll a	Generally lower	Improved
Dissolved oxygen	Generally higher or much higher	Improved
Fecal coliform	Generally decreasing	Improved
Nitrate and nitrite	Generally higher	
Secchi Depth	No conclusion due to insufficient data before CCMP	
Total nitrogen	Generally lower	Values for Stations 200130, 200160, and 200170 are higher post-CCMP Generally lower due to lower DON
Organic nitrogen	Similar or slightly lower	Decrease greater than increase in NO3
Total phosphorus	Generally much lower	Improved
Temperature	Generally lower	Greater decrease in tributary measurements
Total organic carbon	Occasionally decreasing	
Dissolved organic nitrogen	Similar or slightly lower	

Figure 4-6. Comparison of Total Nitrogen Measurements for Select Tributary Stations



Nitrogen concentrations at the Great Peconic Bay station (060130) decreased in the post-CCMP period and were lower than the concentrations observed at the tributary locations (Figure 4-7). Total organic carbon also appears to have decreased while dissolved oxygen measurements increased. Each of these results suggests that water quality is improving.

Figure 4-7. Comparison of Measurements for Great Peconic Bay (Station 060130)

Total Nitrogen	**Total Organic Carbon**
	
Dissolved Oxygen	
	

***Trends Pre- and Post-CCMP** – Since the CCMP, total nitrogen is generally lower, nitrate and nitrite are generally higher, dissolved organic nitrogen and phosphorus are similar or lower, chlorophyll-a is generally lower, fecal coliform is generally decreasing, and dissolved oxygen is generally higher or much higher.*

4.4 Western Estuary Diurnal Variations in Dissolved Oxygen

Western Estuary diurnal fluctuations were evaluated for stations 060170, 060220 and 060240. Limited conclusions were drawn from these analyses. As expected, dissolved oxygen is higher during the daytime and drops during the night. It can be seen however that anoxic periods occur during both day and night and the algal blooms can cause super-saturation during the day (See Figure 4-8). The range of DO values declined after 1998 as did the AM minima, both signs of improving water quality.

A significant amount of variability is seen within a day but also on a larger timescale. Dissolved oxygen levels can be influenced by a number of factors including water temperature, algal blooms, inflows from the watershed, and mixing with the open ocean. A review of the data on an annual basis also shows a high level of variability (see Figure 4-9). These data suggest that the mean concentrations may be declining but the minimum values are increasing.

Western Estuary Diurnal Variations in dissolved oxygen *– The range of dissolved oxygen values in the western estuary declined after 1998 as did the range in morning minima, both signs of improving water quality.*

Figure 4-8. Western Estuary Diurnal Dissolve Oxygen

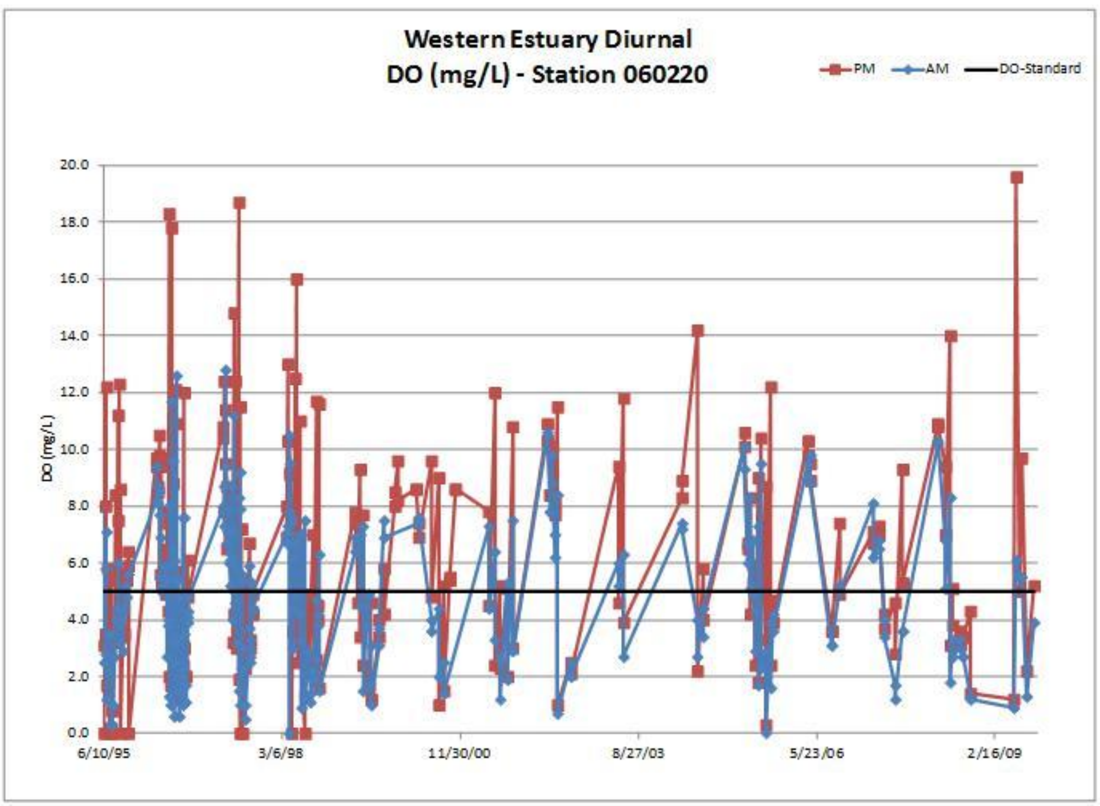
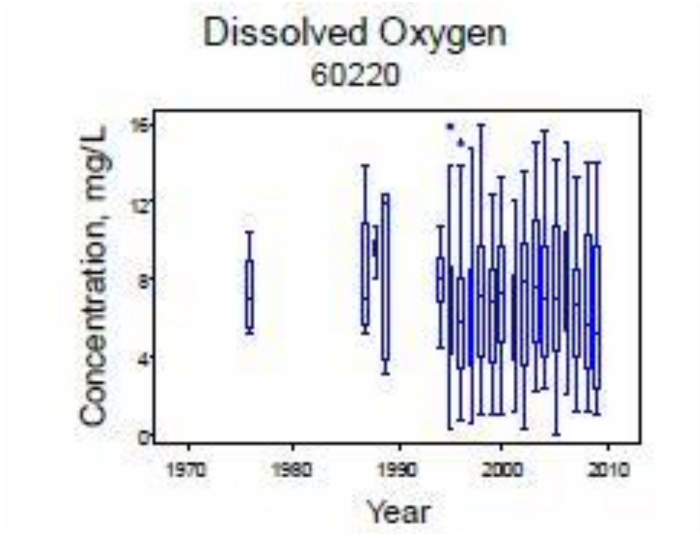


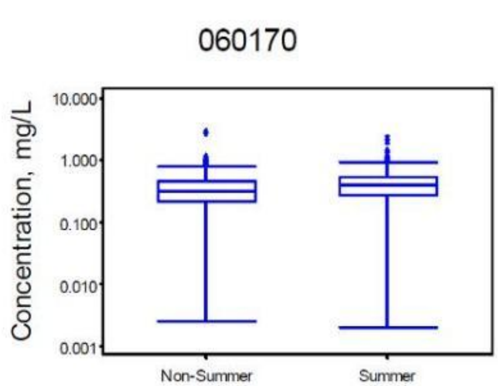
Figure 4-9. Annual Ranges of Dissolved Oxygen at Station 060220 (Meetinghouse Creek)

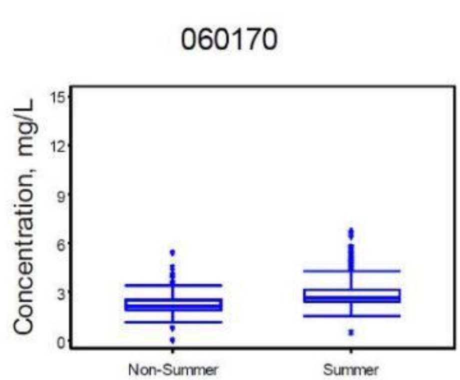


4.5 Summer vs. Non-Summer Comparison

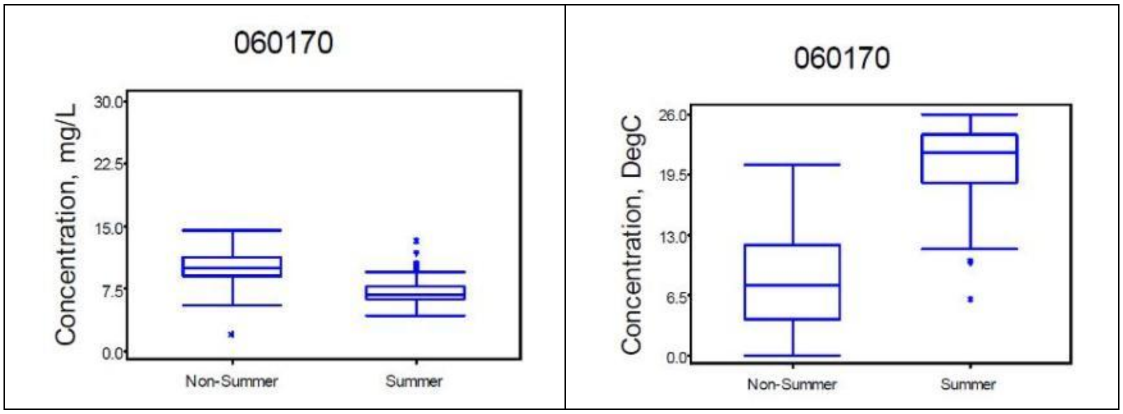
Summer and non-summer data were compared. This was done using the box and whisker plots as provided in Appendix C. An example is provided in Figure 4-10. With the exception of dissolved oxygen and temperature, which would be expected to change, little discernible difference is seen between summer and non-summer periods for total nitrogen, dissolved organic nitrogen, coliform, and cadmium.

Figure 4-10. Comparison of summer and non-summer measurements at 060170 (Flanders Bay)

<table>
<tr><th>Total Nitrogen</th><th>Dissolved Organic Carbon</th></tr>
<tr><td>


</td><td>


</td></tr>
<tr><th>Dissolved Oxygen</th><th>Temperature</th></tr>
</table>



Summer vs. Non-Summer *– There is little difference between summer and non-summer values for total nitrogen, dissolved organic nitrogen, coliform, and cadmium concentrations in the Estuary.*

5 Trends by Embayment

Mann-Kendall trend analyses for station/parameter combinations with sufficient data to determine long-term trends were compiled for stations in five ‘quintants.’ These quintants group stations in regions of the Estuary and allow for a focused comparison of stream and marine results. This can provide insight into how specific regions of the Estuary have changed as well as if changes in watershed contributions have affected Estuary conditions. The quintants evaluated are:

- Quintant 1 – Western Estuary, Peconic River, and western tributaries
- Quintant 2 – Central Estuary and tributaries
- Quintant 3 – Northeastern Estuary and tributaries
- Quintant 4 – Southeastern Estuary and tributaries
- Quintant 5 – Eastern boundary

5.1 Quintant 1 - Western Estuary

Quintant 1 includes stations in the western Estuary, Peconic River, and western tributaries. This area represents the largest drainage area in the basin and has historically contributed the greatest quantity of pollutants from surface runoff. A majority of stations, 58 percent, show no significant trends in water quality conditions. Approximately one-third show a decrease in parameter concentrations. Complete results are provided in Appendix B.

Stable or moderately improving water quality is evident in a majority of the stations in Quintant 1 (Figure 5-1 and Table 5-1). Only one parameter, field conductivity, showed an increase in more than 15 percent of stations. Significant decreases in ammonia, fractionated chlorophyll a, field conductivity, nitrate-nitrite, orthophosphorus, total nitrogen, and total phosphorus are seen in at least one third of the stations. Total organic carbon decreased at all stations. Dissolved oxygen concentrations increased in 50 percent of the stations.

Figure 5-1. Quintant 1 western Estuary stations

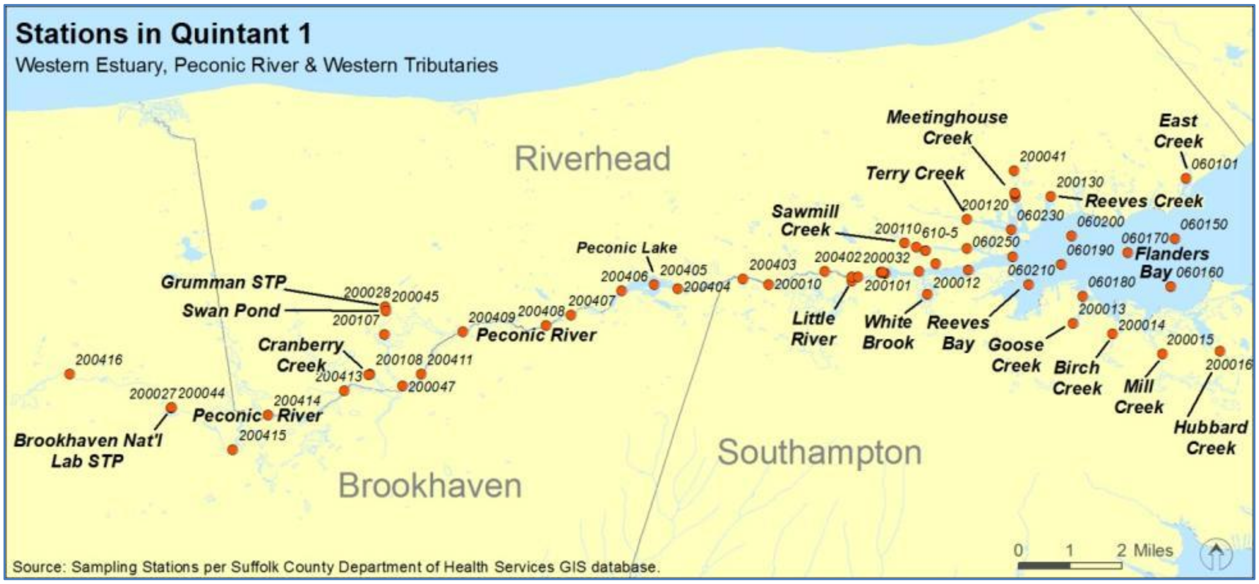


Table 5-1. Quintant 1 - western Estuary trends

Parameter	Trend	Percent of Stations
Ammonia	Significantly Decreasing	41%
	Significantly Increasing	7%
Aureococcus anophagefferens	Significantly Decreasing	50%
Chlorophyll A - Fractionated	Significantly Decreasing	40%
Chlorophyll A - Total	Significantly Decreasing	17%
Dissolved Kjeldahl Nitrogen	Significantly Decreasing	20%
	Significantly Increasing	7%
Dissolved Organic Nitrogen	Significantly Decreasing	6%
	Significantly Increasing	13%
Dissolved Oxygen	Significantly Increasing	50%
Dissolved Phosphorous	Significantly Decreasing	14%
	Significantly Increasing	14%
Fecal Coliform	Significantly Decreasing	29%
	Significantly Increasing	5%
Field Conductivity	Significantly Decreasing	46%
	Significantly Increasing	31%
Field pH	Significantly Decreasing	33%
Nitrate-Nitrite	Significantly Decreasing	32%
	Significantly Increasing	4%
Organic Nitrogen	Significantly Increasing	14%
Orthophosphate	Significantly Decreasing	72%
Temperature	Significantly Decreasing	38%
Total Coliform	Significantly Decreasing	21%
	Significantly Increasing	4%
Total Kjeldahl Nitrogen	Significantly Decreasing	29%
	Significantly Increasing	10%
Total Nitrogen	Significantly Decreasing	34%
	Significantly Increasing	10%
Total Organic Carbon	Significantly Decreasing	100%
Total Phosphorus	Significantly Decreasing	63%
	Significantly Increasing	8%

***Quintant 1 (western Estuary)** – Stable or moderately improving water quality is evident in a majority of the stations in the western estuary. Significant decreases (improvement) in ammonia, fractionated chlorophyll a, field conductivity, nitrate-nitrite, orthophosphorus, total nitrogen, and total phosphorus are seen in at least one third of the stations. Total organic carbon decreased at all stations. Dissolved oxygen concentrations increased (improved) in 50 percent of the stations.*

5.2 Quintant 2 –Central Estuary and Tributaries

Quintant 2 includes stations in the central Estuary and tributaries including areas of Great Peconic Bay, Little Peconic Bay, North Sea Harbor, and East Creek. These areas are separated from the open ocean by Shelter Island and are likely to have similar, if more subtle, responses to inputs from Peconic River drainage.

A majority of stations, 52 percent, show no significant temporal trends in water quality conditions. Approximately 37 percent show a decrease in parameter concentrations. Complete results are provided in Appendix B.

An increase in more than 15 percent of stations occurred for a number of parameters; field conductivity, nitrate-nitrite, organic nitrogen, silicates, and total Kjeldahl nitrogen. Significant decreases in ammonia, fractionated chlorophyll a, field conductivity, nitrate-nitrite, orthophosphorus, total nitrogen, and total phosphorus are seen at least one third of the stations. Dissolved oxygen concentrations increased in 50 percent of the stations.

Chlorophyll-a declined along with organic carbon and phosphorus concentrations, suggesting a decline in algal blooms over the sampling period.

As Kjeldahl nitrogen is ammonia plus dissolved organic nitrogen, these trends suggest an increase in dissolved organic nitrogen concentrations in central Flanders Bay over the entire sampling period. Other nitrogen values were unchanged.

Figure 5-2. Quintant 2 central Estuary and tributaries stations

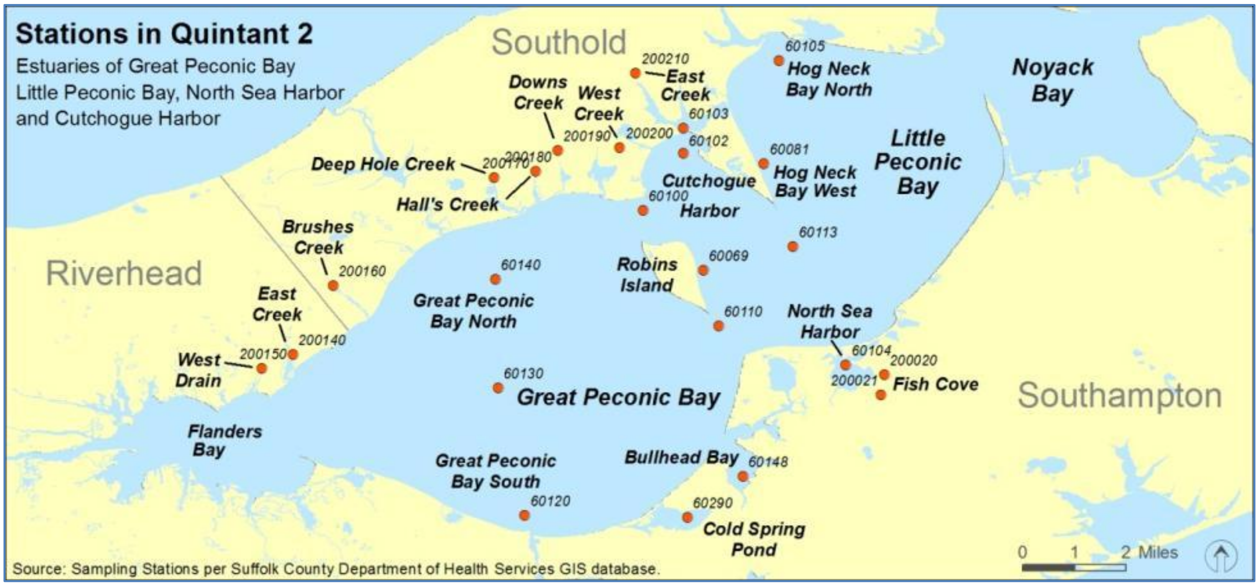


Table 5-2. Central Estuary and Tributaries Trends

Parameter	Trend	Percent of Stations
Ammonia	Significantly Decreasing	29%
	Significantly Increasing	10%
Aureococcus anophagefferens	Significantly Decreasing	100%
Chlorophyll A - Fractionated	Significantly Decreasing	100%
Chlorophyll A - Total	Significantly Decreasing	29%
	Significantly Increasing	14%
Dissolved Kjeldahl Nitrogen	Significantly Decreasing	57%
	Significantly Increasing	14%
Dissolved Organic Nitrogen	Significantly Decreasing	38%
	Significantly Increasing	13%
Dissolved Oxygen	Significantly Increasing	26%
Fecal Coliform	Significantly Decreasing	59%
Field Conductivity	Significantly Decreasing	58%
	Significantly Increasing	17%
Nitrate-Nitrite	Significantly Decreasing	29%
	Significantly Increasing	21%
Organic Nitrogen	Significantly Decreasing	43%
	Significantly Increasing	29%
Orthophosphate	Significantly Decreasing	25%
	Significantly Increasing	8%
Silicates	Significantly Increasing	50%
Temperature	Significantly Decreasing	13%
Total Coliform	Significantly Decreasing	50%
Total Kjeldahl Nitrogen	Significantly Decreasing	50%
	Significantly Increasing	25%
Total Nitrogen	Significantly Decreasing	43%
	Significantly Increasing	9%
Total Organic Carbon	Significantly Decreasing	50%
Total Phosphorus	Significantly Decreasing	60%

***Quintant 2 (central Estuary and tributaries)** – A majority of stations, 52 percent, show no significant trends in water quality. Approximately 37 percent show a decrease in parameter concentrations. An increase in more than 15 percent of stations occurred for a number of parameters; field conductivity, nitrate-nitrite, organic nitrogen, silicates, and total Kjeldahl nitrogen indicating a worsening of conditions. Significant decreases (improvements) in ammonia, fractionated chlorophyll a, field conductivity, nitrate-nitrite, orthophosphorus, total nitrogen, and total phosphorus are seen at least one third of the stations. Dissolved oxygen concentrations increased (improved) in 50 percent of the stations.*

5.3 Quintant 3 – Northeastern Estuary and Tributaries

Quintant 3 includes stations in the northeastern Estuary and tributaries. This area includes stations north of Shelter Island and may see influences from both the Peconic River and the open ocean. Approximately 43 percent of stations, the highest of all the quintants, show a decrease in parameter concentrations. Forty-nine percent of stations show no significant trends in water quality conditions. Complete results are provided in Appendix B.

Stable or moderately improving water quality is evident in a majority of the stations in Quintant 3 (Figure 5-1 and Table 5-1). While a number of parameters including nitrogen species and total suspended solids showed an increase in more than 15 percent of stations and equal or greater number of stations saw a decrease in the same parameters. Significant decreases in ammonia, fractionated chlorophyll a, field conductivity, nitrate-nitrite, orthophosphorus, and total nitrogen are seen at least one third of the stations. Improvements in dissolved Kjeldahl nitrogen, dissolved organic nitrogen, and total organic carbon was seen at approximately two thirds of the stations. Improvements in total phosphorus and fecal coliform were evident at over 80 percent of the stations.

Chlorophyll-a and organic carbon declined, suggesting a drop in the number and/or intensity of algal blooms. Phosphorus declined, a trend seen across the Estuary. Fecal and total coliform declined in Quintant 3, an indication that water quality may be more conducive to shellfish harvesting.

Figure 5-3. Quintant 3 northeastern Estuary and tributaries stations

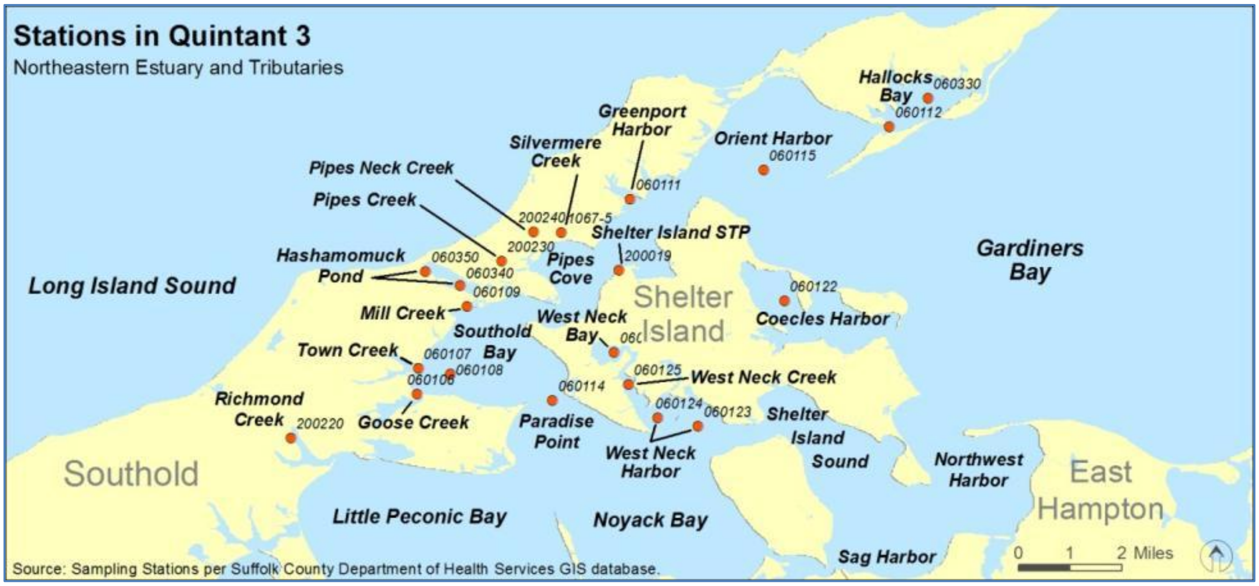


Table 5-3. Trends in Quintant 3 – Northeastern Estuary and Tributaries

Parameter	Trend	Percent of Stations
Ammonia	Significantly Decreasing	36%
Aureococcus anophagefferens	Significantly Decreasing	75%
Chlorophyll A - Fractionated	Significantly Decreasing	100%
Chlorophyll A - Total	Significantly Decreasing	31%
Dissolved Kjeldahl Nitrogen	Significantly Decreasing	67%
	Significantly Increasing	22%
Dissolved Organic Nitrogen	Significantly Decreasing	67%
	Significantly Increasing	22%
Dissolved Oxygen	Significantly Increasing	7%
Fecal Coliform	Significantly Decreasing	80%
Organic Nitrogen	Significantly Decreasing	56%
	Significantly Increasing	33%
Orthophosphate	Significantly Decreasing	11%
Silicates	Significantly Decreasing	11%
	Significantly Increasing	33%
Total Coliform	Significantly Decreasing	82%
Total Kjeldahl Nitrogen	Significantly Decreasing	50%
	Significantly Increasing	30%
Total Nitrogen	Significantly Decreasing	53%
Total Organic Carbon	Significantly Decreasing	67%
Total Phosphorus	Significantly Decreasing	83%
Total Suspended Solids	Significantly Increasing	50%

Quintant 3 (northeastern Estuary and tributaries) – *Approximately 43 percent of stations, the highest of all the quintants, show a decrease in parameter concentrations. Significant decreases in ammonia, fractionated chlorophyll a, field conductivity, nitrate-nitrite, orthophosphorus, and total nitrogen are seen at least one third of the stations. Improvements in total phosphorus and fecal coliform were evident at over 80 percent of the stations. Fecal and total coliform declined.*

5.4 Quintant 4 – Southeastern Estuary

Quintant 4 includes stations in the southeastern Estuary. This area incorporates stations south of Shelter Island and may see influences from both the Peconic River and the open ocean. A majority of stations, 54 percent, show no significant trends in water quality conditions. Approximately 40 percent show a decrease in parameter concentrations. Complete results are provided in Appendix B.

Stable or moderately improving water quality is evident in a majority of the stations in Quintant 4 (Figure 5-14 and Table 5-14).Only two parameters, dissolved organic nitrogen and silicates, showed an increase in more than 15 percent of stations. Significant decreases in ammonia, chlorophyll a, dissolved Kjeldahl nitrogen, dissolved organic nitrogen, nitrate-nitrite, fecal coliform, total coliform, organic nitrogen, total nitrogen, total organic carbon, and total phosphorus are seen at a majority of the stations. Dissolved oxygen concentrations were stable at 90 percent of the stations and increased in 10 percent of the stations.

Figure 5-4. Quintant 4 –southeastern Estuary stations

Table 5-4. Trends in Southeastern Estuary

Parameter	Trend	Percent of Stations
Aureococcus anophagefferens	Significantly Decreasing	33%
Chlorophyll A - Fractionated	Significantly Decreasing	71%
Chlorophyll A - Total	Significantly Decreasing	30%
Dissolved Kjeldahl Nitrogen	Significantly Decreasing	75%
	Significantly Increasing	13%
Dissolved Organic Nitrogen	Significantly Decreasing	67%
	Significantly Increasing	17%
Dissolved Oxygen	Significantly Increasing	10%
Fecal Coliform	Significantly Decreasing	89%
	Significantly Increasing	10%
Organic Nitrogen	Significantly Decreasing	57%
	Significantly Increasing	14%
	Significantly Increasing	43%
Total Coliform	Significantly Decreasing	78%
Total Kjeldahl Nitrogen	Significantly Decreasing	50%
	Significantly Increasing	13%
Total Nitrogen	Significantly Decreasing	64%
Total Organic Carbon	Significantly Decreasing	50%
Total Phosphorus	Significantly Decreasing	89%
	Significantly Increasing	11%
Total Suspended Solids	Significantly Decreasing	33%

***Quintant 4 (southeastern Estuary)** – A majority of stations, 54 percent, show no significant trends in water quality conditions. Approximately 40 percent of stations show a decrease in parameter concentrations. Only two parameters, dissolved organic nitrogen and silicates, showed an increase (worsening) in more than 15 percent of stations. Significant decreases (improvements) in ammonia, chlorophyll a, dissolved Kjeldahl nitrogen, dissolved organic nitrogen, nitrate-nitrite, fecal coliform, total coliform, organic nitrogen, total nitrogen, total organic carbon, and total phosphorus are seen at a majority of the stations. Dissolved oxygen concentrations were stable at 90 percent of the stations and increased (improved) in 10 percent of the stations.*

5.5 Quintant 5 – Eastern Boundary

Quintant 5 includes stations at the eastern edge of the estuary. This area, which incorporates stations east of Shelter Island, is influenced primarily from the open ocean. Stable or moderately improving water quality is evident in a majority of the stations in quintant 5 (Table 5-5 and Figure 5-5) with approximately 41 percent of stations showing no significant trends in water quality. Approximately 38 percent show a decrease in parameter concentrations. However, quintant 5 showed the highest number of stations with an increase in parameter concentrations of all the quintants. Parameter concentrations increased in approximately 22 percent of stations. Complete results are provided in Appendix B.

Dissolved Kjeldahl nitrogen, dissolved organic nitrogen, field conductivity, organic nitrogen, total Kjeldahl nitrogen, and silicates showed an increase in more than 15 percent of stations. While this might suggest that algal blooms would increase, both total and fractionated chlorophyll a concentrations decreased at 100 percent of the stations.

Significant decreases in ammonia, chlorophyll a, dissolved Kjeldahl nitrogen, dissolved organic nitrogen, nitrate-nitrite, fecal coliform, total coliform, total organic carbon, and total phosphorus are seen at a majority of the stations. Dissolved oxygen concentrations were stable at 100 percent of the stations.

Figure 5-5. Quintant 5 - eastern boundary stations

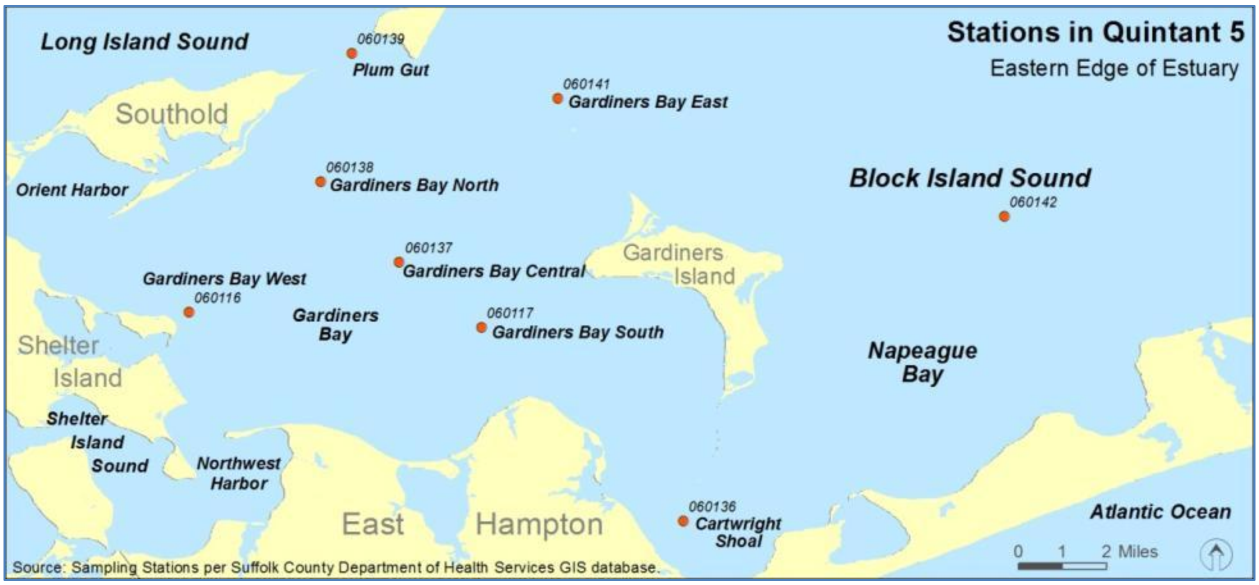


Table 5-5. Quintant 5 – eastern boundary trends

Parameter	Trend	Percent of Stations
Ammonia	Significantly Decreasing	50%
Aureococcus anophagefferens	Significantly Decreasing	100%
Chlorophyll A - Fractionated	Significantly Decreasing	100%
Chlorophyll A - Total	Significantly Decreasing	100%
Dissolved Kjeldahl Nitrogen	Significantly Increasing	100%
Dissolved Organic Nitrogen	Significantly Increasing	100%
Fecal Coliform	Significantly Decreasing	100%
Nitrate-Nitrite	Significantly Decreasing	50%
Organic Nitrogen	Significantly Increasing	100%
Silicates	Significantly Decreasing	50%
Total Coliform	Significantly Decreasing	50%
Total Kjeldahl Nitrogen	Significantly Increasing	100%
Total Organic Carbon	Significantly Decreasing	100%
Total Phosphorus	Significantly Decreasing	50%

Quintant 5 (eastern Estuary) *– Approximately 38 percent of stations show a decrease in parameter concentrations. Dissolved Kjeldahl nitrogen, dissolved organic nitrogen, field conductivity, organic nitrogen, total Kjeldahl nitrogen, and silicates increased (worsened) in more than 15 percent of stations. Total and fractionated chlorophyll a concentrations decreased (improved) at 100 percent of the stations. Significant decreases (improvements) in ammonia, chlorophyll a, dissolved Kjeldahl nitrogen, dissolved organic nitrogen, nitrate-nitrite, fecal coliform, total coliform, total organic carbon, and total phosphorus are seen at a majority of the stations. Dissolved oxygen concentrations were stable at 100 percent of the stations.*

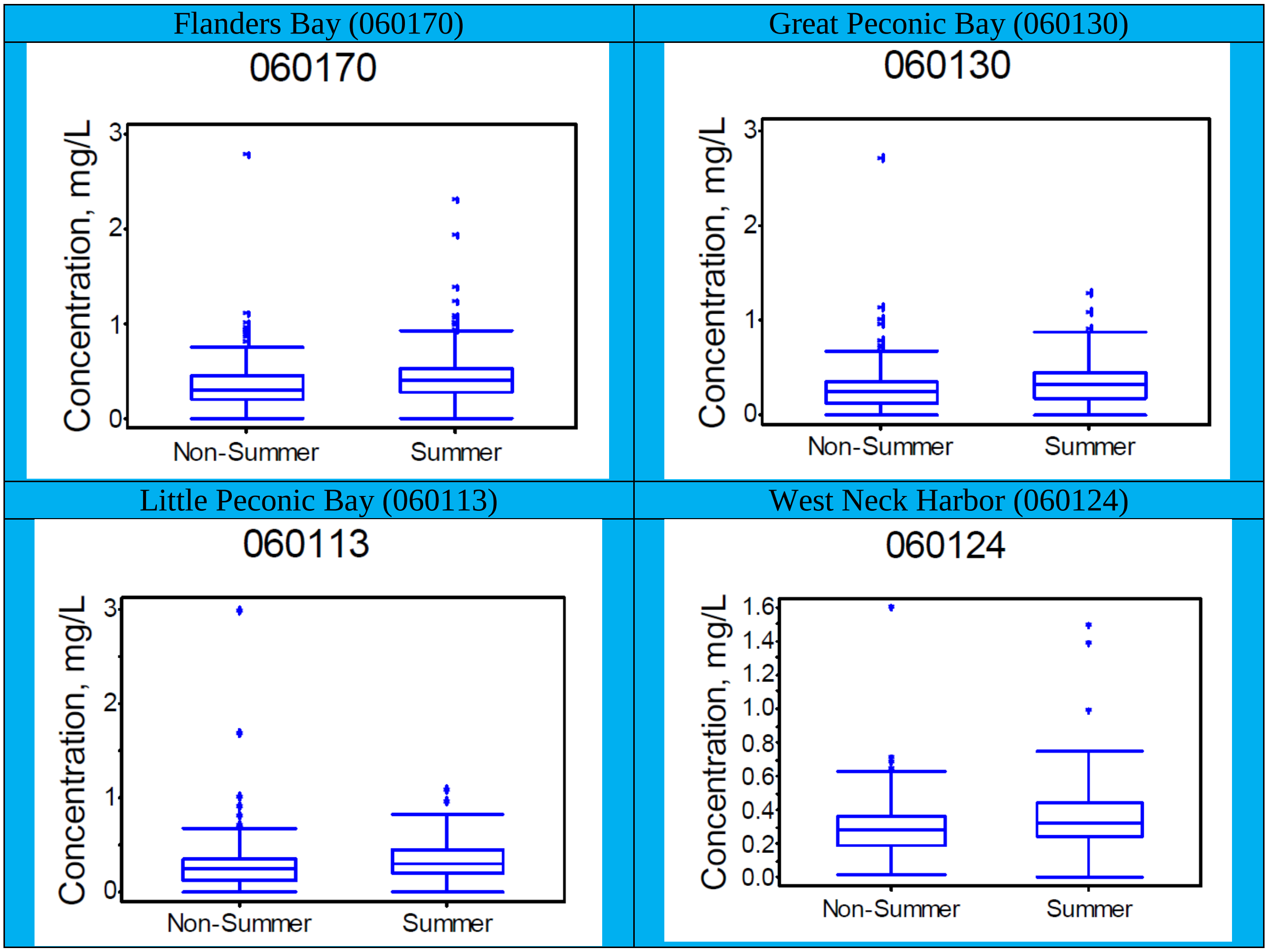
5.6 Western vs. Eastern Embayments

The trend analyses and box and whisker plots were reviewed to assess differences in water quality between embayments in the western and eastern estuary. The western estuary receives inflow from the Peconic River and numerous smaller tributaries. Land use in the western estuary tends to be more developed. The western estuary is smaller, more removed from the open ocean, and more constricted than the eastern estuary. As expected, the western estuary shows a greater influence from tributary inflow with higher nutrient concentrations, higher temperatures, and lower dissolved oxygen.

Figure 5-6 through Figure 5-9 compare these constituents for stations in the western estuary; Flanders Bay (060170) and the eastern estuary; Great Peconic Bay (060130), Little Peconic Bay (060113), and West Neck Harbor (060124).

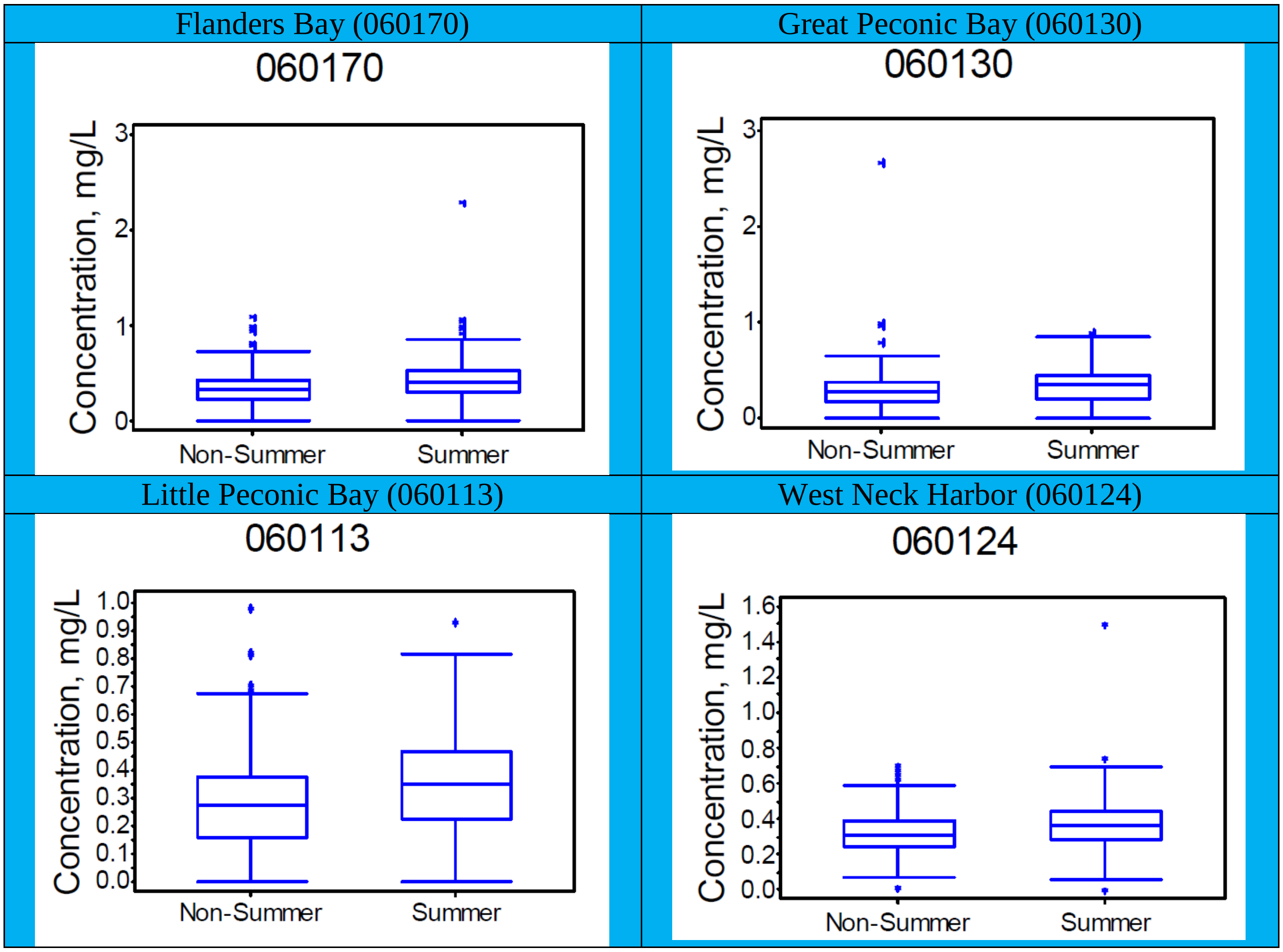
Total nitrogen is highest in Flanders Bay and decreases eastward towards the oceanic waters (Figure 5-6). Nitrogen levels are highest in the western estuary due to direct inputs from treatment plants, the duck farm, and groundwater discharge. Nitrate-nitrite concentrations are primarily driven by terrestrial sources. Organic concentrations may also be higher due to the higher nutrient loads, warmer water, and the resultant algal blooms.

Figure 5-6. Total Nitrogen in the Eastern and Western Estuary



Organic nitrogen is also highest in Flanders Bay and decreases eastward towards oceanic waters (Figure 5-7). Dissolved organic nitrogen levels are also affected by direct inputs from stormwater runoff, the duck farm, and groundwater discharge, but are more strongly influenced by the algal blooms that result from the higher nutrient inputs in the western Estuary.

Figure 5-7. Dissolved Organic Nitrogen in the Eastern and Western Estuary

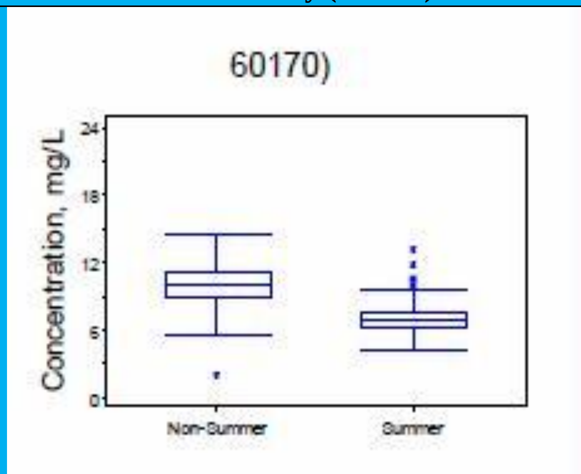


Peconic Estuary waters are warmer in the western estuary (Figure 5-7) due to the influence of warm runoff from adjacent lands, warming that occurs in the shallow bays and creeks, and reduced flushing from cooler ocean waters. Some of this warming may be counteracted by the influence of cooler groundwater discharge.

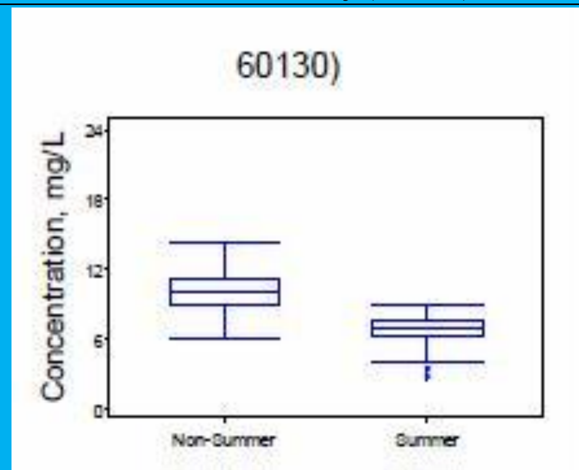
Little difference in dissolve oxygen is evident between the western and eastern Estuary as portrayed in the box and whisker plots (Figure 5-8). Dissolved oxygen concentrations would, however, be expected to be lower in the western estuary due to higher nutrient concentrations and the resultant algal blooms. Differences would be greatest during the summer when algal activity peaks.

Figure 5-8. Dissolved Oxygen in the Eastern and Western Estuary

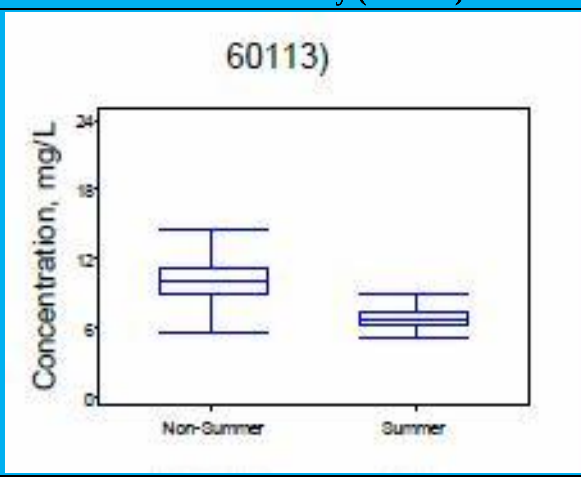
Flanders Bay (060170)



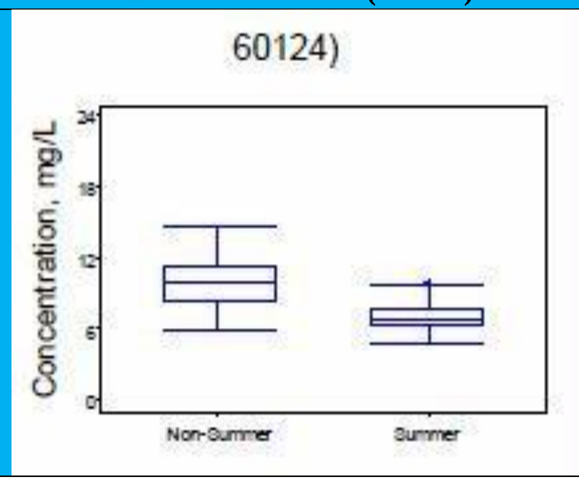
Great Peconic Bay (060130)



Little Peconic Bay (060113)



West Neck Harbor (060124)



Western vs. Eastern Embayments *– The constricted western embayments receive less exchange from the ocean and more input from high nutrient – low dissolved oxygen tributaries than the eastern embayments. Consequently, nitrogen and temperature are higher and dissolved oxygen lower in the western embayments than in the eastern embayments.*

6 CCMP Priority Management Parameters

6.1 Background

The US EPA-funded Peconic Estuary Program developed a Comprehensive Conservation and Management Plan (Peconic Estuary Program, 2001) to restore and protect the environmental quality of the Peconic Estuary. One focus was an evaluation of the physical and chemical conditions that appeared to lead to or have a direct relationship to the development of Brown Tides.

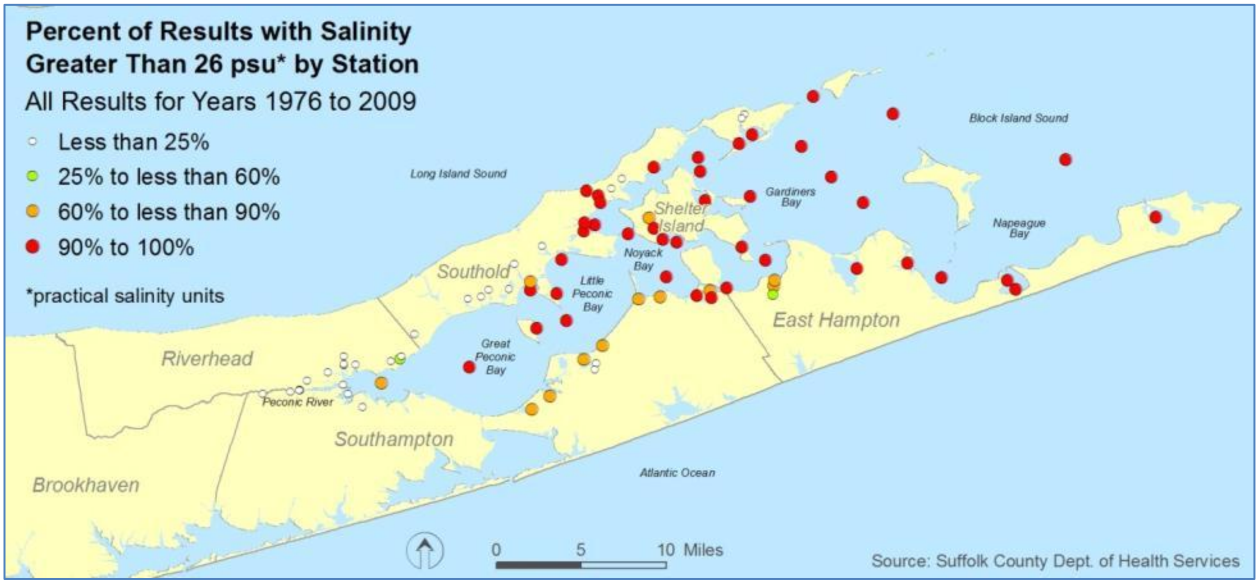
The CCMP included a nutrient management plan to control algal growth and eutrophication and to minimize the potential for Brown Tides. This plan included a set of objectives that would meet the goal of the plan. Many of the objectives were general observations or goals, but a few had measurements that could be readily quantified. These measures were:

- Salinity greater than 26 parts per thousand
- Low dissolved organic nitrogen to dissolved inorganic nitrogen ratios
- Total nitrogen less than 0.5 mg/L
- Summer nitrogen less than 0.45 mg/L

6.2 Salinity Greater than 26

Salinity data for all stations were compared to the threshold of 26 psu and the percentage of time that this level was exceeded was calculated. Figure 6-1 shows the spatial distribution of stations and their exceedance frequency. It can be seen that most stations exceeded 26 psu more than 60 percent of the time and many exceeded 26 psu 90 percent of the time. The exceptions are stations at the creek mouths or in the smaller embayments that have a proportionately greater freshwater influence.

Figure 6-1. Percent of Results where Salinity was Greater than 26psu.

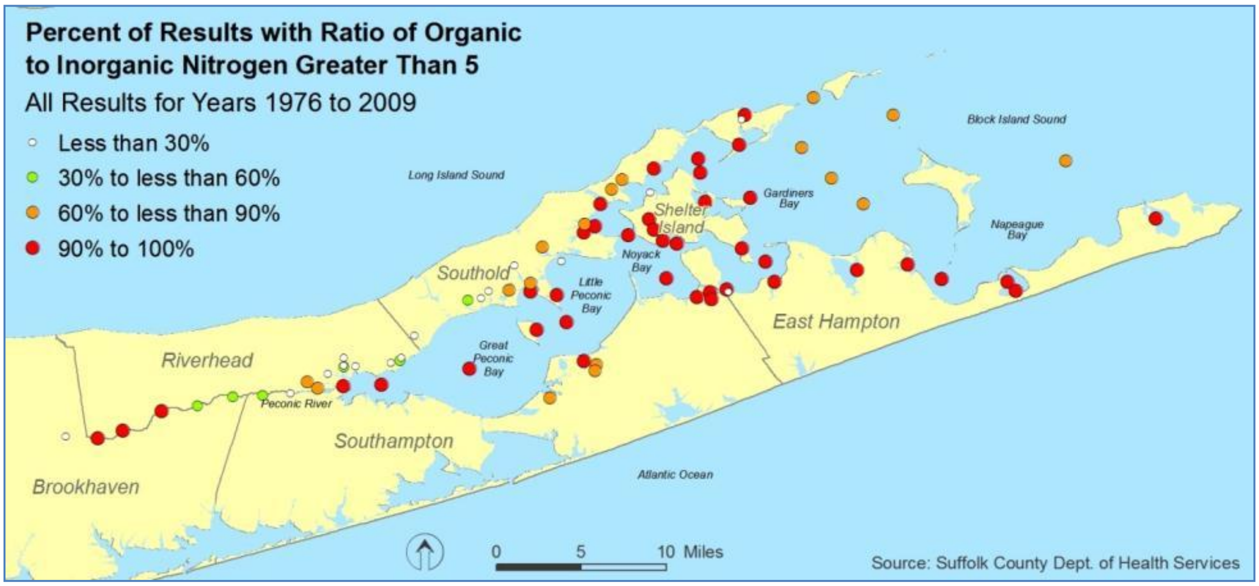


***CCMP Parameters - Salinity Greater than 26** – Most stations exceeded 26 psu more than 60 percent of the time and many exceeded 26 psu 90 percent of the time. The exceptions are stations at the creek mouths or in the smaller embayments that have a proportionately greater freshwater influence.*

6.3 High Dissolved Organic Nitrogen to Dissolved Inorganic Nitrogen Ratios

The ratio of dissolved organic nitrogen (DON) to dissolved inorganic nitrogen (DIN) has been theorized as a potentially important factor in the occurrence of Brown Tides. Data for all stations were compared to a threshold of five parts dissolved organic nitrogen to one part dissolved inorganic nitrogen and a percentage of time this level was exceeded was calculated. *A ratio of five was selected only to identify areas with higher or lower ratios and is not a value defined by studies as being a trigger level (and no trigger ration has been identified).* Figure 6-2 shows the spatial distribution of stations and their exceedance frequency. No apparent pattern is evident.

Figure 6-2. Percent of Results where Organic: Inorganic Ratio was Greater than Five

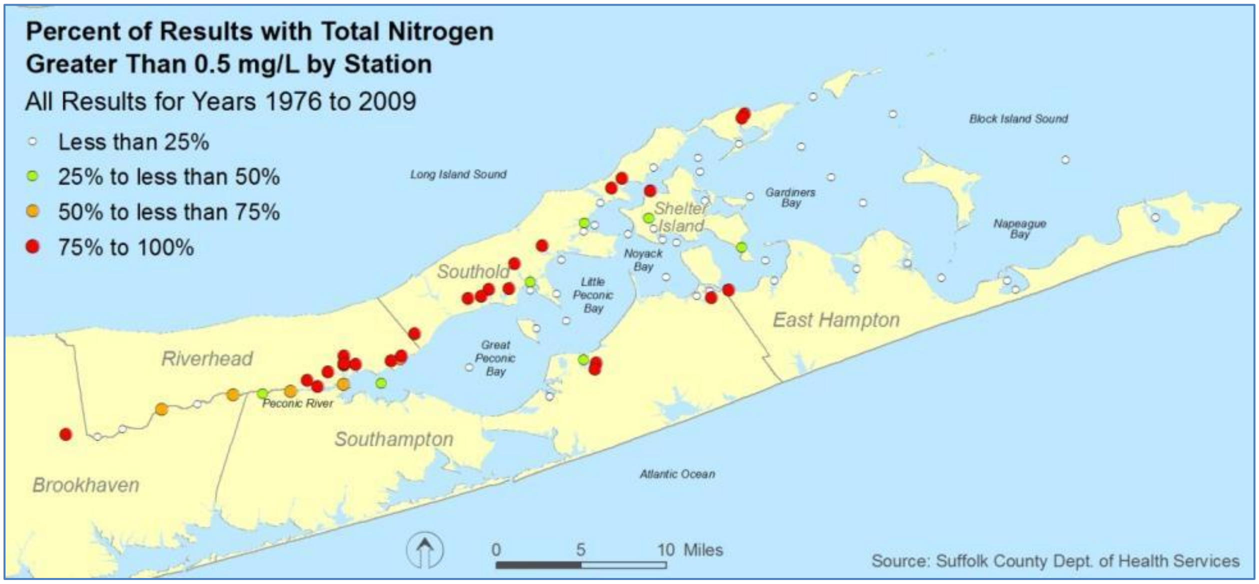


CCMP Parameters – high DON/DIN ratio *– No apparent pattern is evident.*

6.4 Non-Summer Total Nitrogen less than 0.5 mg/L

Total nitrogen data for all stations were compared to the TMDL non-summer threshold of 0.5 mg/L and the percentage of time this level was exceeded was calculated. Figure 6-1 shows the spatial distribution of stations and their exceedance frequency. The tributaries on the north side of the Estuary commonly exceeded the target level more than 90 percent of the time. The Lower Peconic River and Flanders Bay also had exceedances more than 90 percent of the time.

Figure 6-3. Percent of Results where Total Nitrogen was Greater than 0.5 mg/L

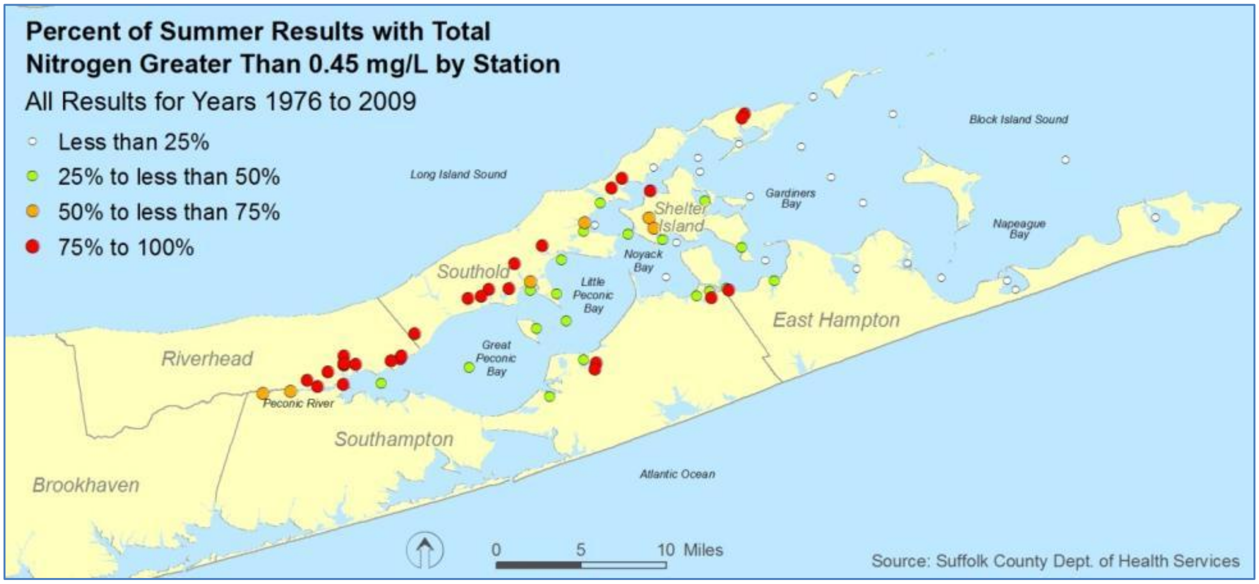


***CCMP Parameters –non-summer total nitrogen less than TMDL threshold of 0.5 mg/L** – Tributaries on the north side of the Estuary commonly exceeded the target level more than 90 percent of the time. The Lower Peconic River and Flanders Bay also have exceedances more than 90 percent of the time.*

6.5 Summer Total Nitrogen less than 0.45 mg/L

Total nitrogen data during the summer period were compared to the TMDL summer threshold of 0.45 mg/L and a percentage of time this level was exceeded was calculated. Figure 6-4 shows the spatial distribution of stations and their exceedance frequency. Similar to the year-round results (Figure 6-4), tributaries on the north side of the estuary commonly exceeded the target level more than 90 percent of the time. The Lower Peconic River and Flanders Bay also have exceedances more than 90 percent of the time.

Figure 6-4. Percent of summer results where total nitrogen was greater than 0.45 mg/L



***CCMP Priority Management Parameters – Summer Total Nitrogen less than TMDL threshold of 0.45 mg/L** - Tributaries on the north side of the estuary commonly exceeded the target level more than 90 percent of the time. The Lower Peconic River and Flanders Bay also have exceedances more than 90 percent of the time.*

6.6 Summary - CCMP Priority Management Parameters

These results demonstrate that waters on the north shores of Great Peconic Bay, Little Peconic Bay, and the areas to the north and south of Shelter Island have exceeded the indicator values. These indicators only suggest that these areas *may* have a greater potential for Brown Tide. They do not predict that Brown Tides will occur, as evidenced by the limited Brown Tide counts in recent years. A review of the trend analyses for nitrogen constituents during the years since the intense Brown Tide period (1996 – 2008) indicates that many of these areas had stable total nitrogen levels, stable or significantly decreasing dissolved organic nitrogen levels, and stable or significantly increasing dissolved inorganic nitrogen levels.

***CCMP Priority Management Parameters** – Most stations exceeded 26 psu more than 60% of the time and many exceeded 26 psu 90 % of the time. Total N exceeded 0.5 mg/L on the north side of the estuary, in the Lower Peconic River, and in Flanders Bay more than 90 % of the time. The same was true for total nitrogen >0.45 mg/L in the summer.*

7 Nitrogen Trends

7.1 Waters Included in the Nitrogen TMDLs

7.1.1 Background

Excessive nitrogen concentrations stimulate algal blooms (possibly including harmful species), which in turn leads to depressed oxygen levels and decreased water clarity. Nutrient inputs are highest and flushing poorest in the western Estuary. Nitrogen reduction in the western Estuary is a major goal of the PEP CCMP as is preservation of good water quality in the eastern Estuary. The PEP CCMP established goals of 0.45mg/l for total nitrogen (TN) in the summer season to reduce the frequency of low dissolved oxygen levels. A recommended level of 0.40 mg/l TN was established by the CCMP for shallow water to reduce the likelihood of algal blooms and thereby maintain water clarity for eelgrass management. The CCMP also suggested maintenance of TN levels in the portion of the Estuary east of Flanders Bay.

A nitrogen Total Maximum Daily Load (TMDL) was established in 2007 to reduce nitrogen loadings and help achieve dissolved oxygen standards. The TMDL was assigned to three key portions of the estuary: 1) Lower Peconic River (LPR), 2) Western Flanders Bay (WFB) and Lower Sawmill Creek and 3) Terrys Creek and Tributaries.

7.1.2 Trends in the Peconic River and its Tidal Tributaries

Water quality was stable or improved in the Lower Peconic River (LPR) as shown in Table 7-1. Many of the water quality parameters improved in White Brook (station 200012), Birch Creek (station 200014), Mill Creek (station 200015), Hubbard Creek (station 200016), and in the Peconic River at Grangebel Park (station 200017) (see Figure 7-1 for station locations). Dissolved oxygen increased from White Brook to the Peconic River headwaters. The exception to improving water quality was increasing cadmium in Mill Creek, Hubbard Creek, and near Grangebel Park.

Insufficient data was available to determine trends in the central portion of the Peconic River for stations 200013, 200403 through station 200409, the Cranberry Creek area (stations 200412 and 200413), and upstream to the headwaters area at station 200416.

Fecal and total coliform decreased in East Creek in South Jamesport (station 200210). Total nitrogen declined at station 200260, near the mouth of the Peconic River.

Figure 7-1. Peconic River stations included in the TMDL

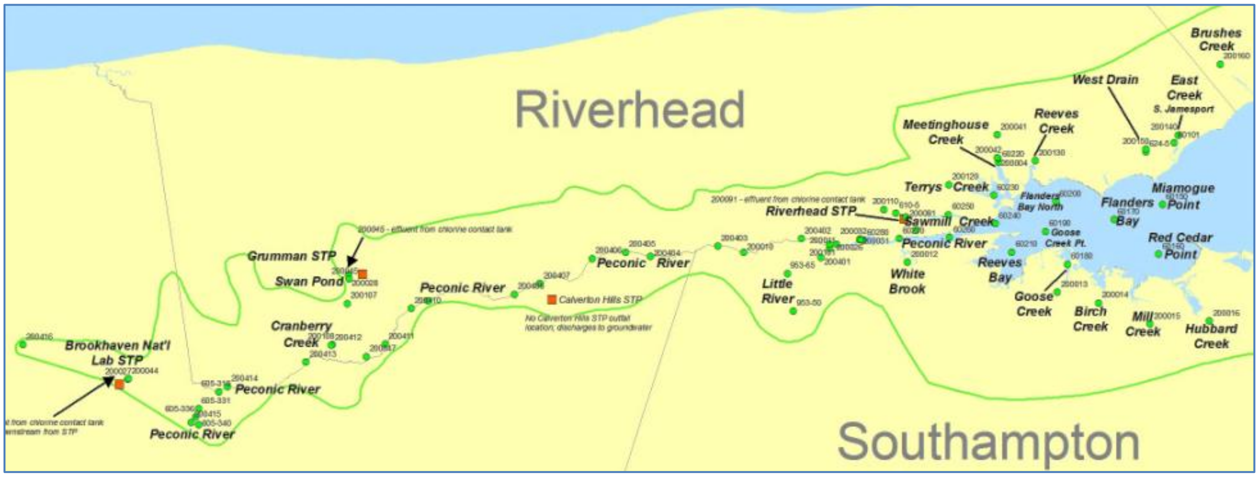


Table 7-1. Trends in Waters included in Nitrogen TMDL – Lower Peconic River

PARAMETERS	STATIONS																											
	White Brook	Goose Creek	Birch Creek	Mill Creek	Hubbard Creek	Grangebel Park	River Headwaters	Near BNL STP	Central Peconic River							Cranberry Creek area		River Headwaters			East Creek	Meetinghouse Creek		Flanders Bay N.	Narrow River N.	Peconic R. mouth
	200012	200013	200014	200015	200016	200017	200018	200044	200403	200404	200405	200406	200407	200408	200409	200412	200413	200414	200415	200416	200210	200220	200230	200240	200250	200260
Ammonia																										
Dissolved Kjeldahl Nitrogen																										
Total Kjeldahl Nitrogen																										
Nitrite																										
Nitrate																										
Nitrate & Nitrite																										
Total Nitrogen																										
Dissolved Phosphorous																										
Orthophosphate																										
Total Phosphate																										
Total Phosphorus																										
Total Organic Carbon																										
Silicates																										
Fecal Coliform																										
Total Coliform																										
Cadmium																										
Dissolved Oxygen																										
Temperature																										
Field pH																										
Field Conductivity																										
Total Suspended Solids																										

Increase improves water quality
Increase degrades water quality
Decrease improves water quality
No change
Undetermined

7.1.3 Trends in Western Flanders Bay and Sawmill Creek

Trends in Western Flanders Bay and Sawmill Creek (Figure 7-2) are depicted in Table 7-2. Water quality improved at the head of Sawmill Creek (station 200110), in particular, for nitrogen, phosphorus, and fecal coliform. Little changed at the Flanders Bay stations (060190 and 060200) other than a decline in orthophosphorus, like most of the Estuary.

Figure 7-2. Western Flanders Bay and Sawmill Creek stations included in the TMDL

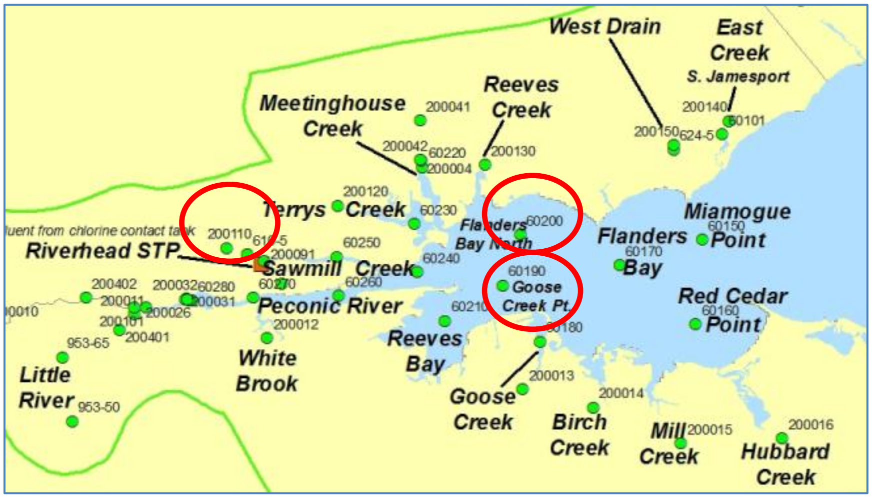


Table 7-2. Trends in Western Flanders Bay (WFB) and Sawmill Creek

PARAMETERS	STATIONS		
	Flanders Bay 060190	Flanders Bay 060200	Sawmill Creek 20110
Ammonia			
Dissolved Kjeldahl Nitrogen			
Total Kjeldahl Nitrogen			
Nitrite			
Nitrate			
Nitrate & Nitrite			
Total Nitrogen			
Dissolved Phosphorous			
Orthophosphate			
Total Phosphate			
Total Phosphorus			
Total Organic Carbon			
Chlorophyll A - Fractionated			
Chlorophyll A - Total			
Silicates			
Fecal Coliform			
Total Coliform			
Cadmium			
Dissolved Oxygen			
Temperature			
Field pH			
Field Conductivity			

Increase improves water quality
Increase degrades water quality
Decrease improves water quality
No change
Undetermined

7.1.4 Trends in Terrys Creek and Tributaries

Nitrate-nitrite increased at station 060230 (Table 7-3) at the mouth of Terrys Creek (Figure 7-3). Orthophosphate and chlorophyll-a decreased. All other parameters where sufficient data was available to evaluate trends remained the same.

Figure 7-3. Terrys Creek station included in the TMDL

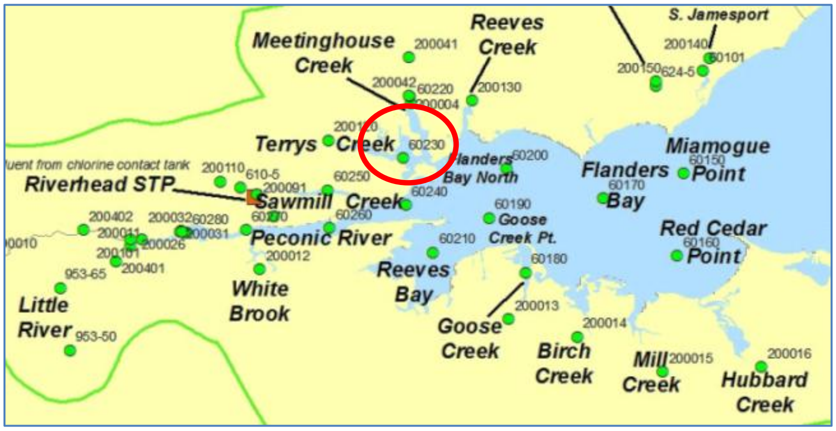


Table 7-3. Trends in Terrys Creek

PARAMETERS	STATION Mouth of Terrys Creek 060230
Ammonia	
Dissolved Kjeldahl Nitrogen	
Total Kjeldahl Nitrogen	
Nitrite	
Nitrate	
Nitrate & Nitrite	
Total Nitrogen	
Dissolved Phosphorous	
Orthophosphate	
Total Phosphate	
Total Phosphorus	
Total Organic Carbon	
Chlorophyll A - Fractionated	
Chlorophyll A - Total	
Aureococcus anophagefferens	
Silicates	
Fecal Coliform	
Total Coliform	
Cadmium	
Dissolved Oxygen	
Temperature	
Field pH	
Field Conductivity	
Total Suspended Solids	

Increase improves water quality
Increase degrades water quality
Decrease improves water quality
No change
Undetermined

***Waters Included in the Nitrogen TMDLs** – Water quality improved in the Lower Peconic River, White Brook, Birch Creek, Mill Creek, Hubbard Creek, and in the Peconic River at Grangebel Park. Little changed in Flanders Bay or in Terrys Creek.*

7.2 Point Source Nitrogen Loads

7.2.1 Wastewater Treatment Plants – Existing Conditions

Nitrogen Contribution from Wastewater Treatment Plants

There are five wastewater (sewage) treatment plants (STPs) that discharge to the Peconic Estuary: Brookhaven National Lab, Enterprise Park at Calverton, Riverhead, Sag Harbor, Shelter Island, Montauk Manor, and Rough Riders Landing. Of these, only the Riverhead and Sag Harbor plants discharge directly to surface waters. The plant at Enterprise Park at Calverton (EPCAL) discharges to McKay Lake, which eventually drains to groundwater and the Peconic River. The Greenport STP, though located within the watershed, discharges into the Long Island Sound. It does not contribute to nitrogen loading in the Peconic Estuary. Table 7-4 lists the treatment plants and their estimated nitrogen discharges.

Table 7-4. Estimated nitrogen discharges from wastewater treatment plants

Sewage Treatment Plant (S-surface water discharge, G-groundwater discharge)	Maximum SPDES Flow Rate (MGD)	Annual Nitrogen Loading (lb/yr)	Percent of Total STP Discharge
Brookhaven National Lab[1] (G)	2.300	5,840	12.7
Enterprise Park at Calverton (G)	0.078	1,705	3.7
Riverhead[2] (S)	1.300	29,930	65.3
Sag Harbor[3] (S)	0.250	6,205	13.5
Greenport	No loading to Peconic Estuary - discharges to LI Sound		
Shelter Island[2] (S)	0.053	876	1.9
Montauk Manor[2] (G)	summer - 0.030 winter - 0.006	602	1.3
Rough Riders Landing[2] (G)	Summer - 0.032 winter 0.006	654	1.4
Total		**45,812**	**100.0**

[1]Loading based on monthly averages for Years 2009-2011 from Discharge Monitoring Reports
[2]Loading based on SPDES permit limit
[3]Loading based on month averages for Years 2006-2011 from Discharge Monitoring Reports

It is important to put the nitrogen contribution of the wastewater plants into perspective. According to the nitrogen TMDL for the Peconic Estuary, the total annual nitrogen contribution of the wastewater plants to the Peconic Estuary is approximately 54,000 pounds (Table 7-5). That represents just one percent of 5.4 million pounds of nitrogen that enters the Estuary annually and just slightly more than the 47,000 pounds contributed by stormwater runoff. The atmospheric contribution is over three million pounds per year – more than half of the annual nitrogen load. Groundwater contributes 40 percent of the nitrogen. The contribution by treatment plants comprises up to two percent if the atmospheric contribution is not included (Table 7-6). When the contribution from the atmosphere is not included, the nitrogen contribution from groundwater increases to 93 percent.

Table 7-5. Estimated annual nitrogen loading to the Peconic Estuary

With Atmospheric Deposition		
Nitrogen Source	**Total Annual Load TN (lbs)**	**Percent**
Atmospheric Deposition	3,015,041	56.3%
Groundwater	2,175,031	40.6%
Creeks & Rivers	66,242	1.2%
STPs	53,689	1.0%
Stormwater	47,361	0.9%
Total	**5,357,364**	**100.0%**

Data Source: Total Maximum Daily Load for Nitrogen in the Peconic Estuary Program Study Area, Suffolk County, September 2007

Table 7-6. Estimated annual nitrogen loading to the Peconic Estuary (no atmospheric)

Without Atmospheric Deposition		
Nitrogen Source	**Total Annual Load TN (lbs)**	**Percent**
Groundwater	2,175,031	92.9%
Creeks & Rivers	66,242	2.8%
STPs	53,689	2.3%
Stormwater	47,361	2.0%
Total	**2,342,323**	**100.0%**

Data Source: Total Maximum Daily Load for Nitrogen in the Peconic Estuary Program Study Area, Suffolk County, September 2007

The critical components of the overall Estuary nitrogen budget are clearly atmospheric deposition and groundwater flow. Local authorities have limited control over atmospheric deposition, but can influence the concentration of nitrogen in groundwater through land use controls and environmental regulation (see section 7.3.1 for a discussion of groundwater nitrogen).

It is also important to consider the local impact of point sources like treatment plants. The TMDL completed for the Peconic Estuary (Suffolk County Department of Health Services, 2007) apportioned nitrogen inputs to the Lower Peconic River and its tidal tributaries (Table 7-7). The Riverhead treatment plant represents 22 percent of the nitrogen contribution to this portion of the Estuary, whereas groundwater contributes over half the nitrogen. As the Peconic River and the Little River are fed by groundwater, groundwater is actually responsible for 75 percent of the total nitrogen contribution to this portion of the Estuary. The Brookhaven National Laboratory (BNL) treatment plant is included in the groundwater contribution as it discharges at the far western edge of the watershed. Although the BNL and Riverhead treatment plants account for about a quarter of the nitrogen contribution to this portion of the Estuary, their contribution to the Estuary as a whole is a fraction of one percent.

Table 7-7. Nitrogen Loads for Lower Peconic River and Tidal Tributaries

With Atmospheric Deposition		
Nitrogen Source	**Total Annual Load TN (lbs)**	**Percent**
Atmospheric Deposition	2,590	1.2%
Groundwater	115,672	54.8%
Little River	2,181	1.0%
Peconic River	40,146	19.0%
Stormwater	3,140	1.5%
Riverhead STP	47,353	22.4%
Total	**211,082**	**100.0%**

Data Source: Total Maximum Daily Load for Nitrogen in the Peconic Estuary Program Study Area, Suffolk County, September 2007

The Riverhead wastewater treatment plant completed a major upgrade that lowered its nitrogen contribution from 35 mg/l in 1999 to under 10 mg/l in the years since tertiary treatment was completed in 2001. The Riverhead STP is responsible for approximately 65 percent of the nitrogen entering the Estuary from treatment plants, but only 1 percent of the nitrogen entering the Peconic Estuary. The Brookhaven National Laboratory (BNL) and Sag Harbor STPs contribute 13 and 14 percent respectively (Figure 7-5) of the nitrogen from STPs. The BNL plant discharges to the Peconic River and the Sag Harbor plant discharges to the bay. The other four treatment plants together contribute just over eight percent of the total nitrogen discharged by treatment plants to the Peconic Estuary.

Nitrogen from Existing Wastewater Treatment Plants *– Treatment plants contribute 1% of the 5.4 million pounds of nitrogen entering the Estuary annually, just slightly more than from stormwater runoff. The atmospheric contribution is over 3 million pounds per year – more than half the annual nitrogen load. Groundwater contributes 40 %. Treatment plant nitrogen is 2% and groundwater 93 % of the total load if the atmospheric load is not included.*

7.2.2 Wastewater Treatment Plants – Future Conditions

Riverhead - Designs are currently in progress to provide even greater reduction of nitrogen at the Riverhead plant. Those plans would reduce the plant's nitrogen discharge from 10 mg/L to 5 mg/L (the lower end of limit technology) at a cost estimated at $17,800,000 (Gannon, 2009). Prior to implementing such changes, it may be prudent to compare the benefits of such an upgrade to the benefits to be achieved by expanding the number of connections to public sewering. Sewering could replace onsite system nitrogen discharges to groundwater at approximately 45 mg/L with treated effluent at 10 mg/L nitrogen, a substantial reduction to the groundwater nitrogen that eventually reaches the Peconic Estuary.

The Town of Riverhead is in the process of revitalizing its downtown with new residential and commercial development, all of which will require a sewer plant connection. A study for the County is underway to examine the capacity of this and other selected County plants given future development plans in the districts they serve. Preliminary estimates suggest that there is insufficient capacity at the Riverhead STP to accommodate future downtown development.

Enterprise Park at Calverton (EPCAL) – Although this plant is very small (0.078 MGD), there are plans to expand it or to construct a new plant. The plans will depend on the capacity of the Riverhead plant to accept new flow and the type and intensity of development anticipated in Riverhead and EPCAL. Flow that exceeds the capacity of the Riverhead plant might be pumped to a new plant at EPCAL. Plans for the EPCAL plant have included discussion of pumping its effluent to the Long Island Sound side of the groundwater divide. The plant would then have no impact on the Peconic River or the Peconic Estuary. It would then be subject to the Long Island Sound nitrogen TMDL.

Sag Harbor – The Sag Harbor STP contributes approximately 13.5 percent of the nitrogen entering the Peconic Estuary from treatment plants (or 0.2 percent of the total nitrogen discharged to the Peconic Estuary). The sewer district includes the entire Village, though many households, including a number that are in low-lying areas, are not connected. The Village of Sag Harbor has no plans to encourage development inside the Village, nor does its zoning make that likely. Additional connections might be possible for parcels that are in environmentally sensitive areas. Its STP operates near capacity in the summer and far below capacity during the winter season, as many Village residents are seasonal.

Shelter Island – The Shelter Island STP contributes less than two percent of the nitrogen entering the Peconic Estuary from treatment plants (or less than 0.03 percent of the total nitrogen discharged to the Peconic Estuary. The private plant has a capacity of 53,000 gallons per day and services only Shelter Island Heights. Usage varies from 10,000 gpd (winter) to 40,000 gpd (summer), due to the large seasonal population. The Shelter Island STP discharges to the Shelter Island Sound.

Montauk Manor and Rough Riders Landing – These two STPs service a hotel and condominium complex, respectively. They discharge to groundwater, which likely flows to Fort Pond Bay and into the Block Island Sound. Together they represent less than three percent of the nitrogen contribution to the Peconic Estuary from STPs and only 0.04 percent of the total nitrogen contribution to the estuary.

***Future Wastewater Treatment Plant Considerations** – Upgrading the Riverhead treatment plant (STP) to reduce nitrogen discharge by 5 mg/L will cost $18 million. This expenditure should be compared to the cost of sewering additional parcels where nitrogen would be reduced by 35 mg/L. The EPCAL STP might be considered for additional Riverhead flow if expanded and upgraded. The Sag Harbor, Shelter Island, and Montauk STPs have little additional capacity.*

7.2.3 Duck Farming

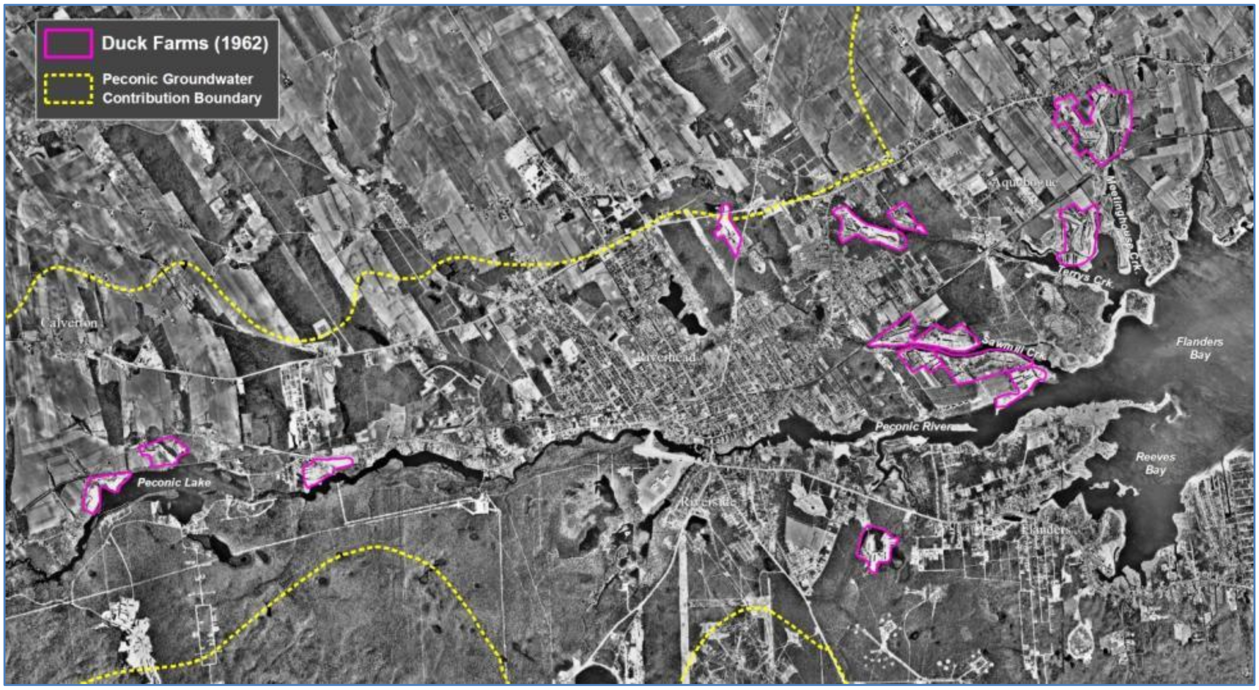
The US Army Corps of Engineers in partnership with the Suffolk County department of Planning authored a report on the history of duck farming and restoration opportunities (USACE and Suffolk County Planning, 2009). They reported that duck farming peaked in the late 1950s and early 1960s with 48 Suffolk County farms producing 7.5 million ducks. Of the 48 farms, 14 were located on tributaries to and the shoreline of Flanders Bay, the Peconic River, Meetinghouse Creek, Sawmill Creek, Reeves Creek, and Terrys Creek. Figure 7-4 shows the approximate locations of the farms in 1962 based on close examination of the historic aerial imagery provided by the Suffolk County Information Technology GIS Division.

The USACE and Suffolk County Planning study (USACE and Suffolk County Planning, 2009) cites work that calculated the total pollutant loading of those farms. Nitrogen loading was estimated at 2.5 tons of nitrogen compounds per day. Prior to passage of the Clean Water Act in 1972, most ducks were reared directly in lagoons that allowed waste to pass directly into the river or creek. After environmental regulations were enacted, the rearing areas were separated from the adjacent waterbody and settling lagoons were constructed for duck waste. Waste lagoons were constructed that then had to be emptied. The waste from the prior decades remained in the creeks and river. Waste from the lagoons was periodically removed. Where the waste was taken is not documented. Some have suggested that the duck waste was deposited on the farm property, on nearby farm fields, and in some cases directly into the creeks.

A portion of the nitrogen from duck waste deposited on farmers' fields would percolate through the soils and enter groundwater. Travel time for groundwater depends on its proximity to the estuary, varying up to 50 years or more. For most of the watershed, the travel time is no more than 20-30 years. Consequently, most of the nitrogen from the peak years of duck farming would have passed into the estuary by the 1990s. Some of that nitrogen may have entered the estuary during the peak Brown Tide years of 1985-1995 and contributed to the Brown Tide occurrences.

Duck mortality is normal in rearing operations. A mortality rate as low as 1.5 percent on a farm producing 500,000 ducks would still require the disposal of 7,500 ducks. Where these were disposed of is not known – some may have been buried on site.

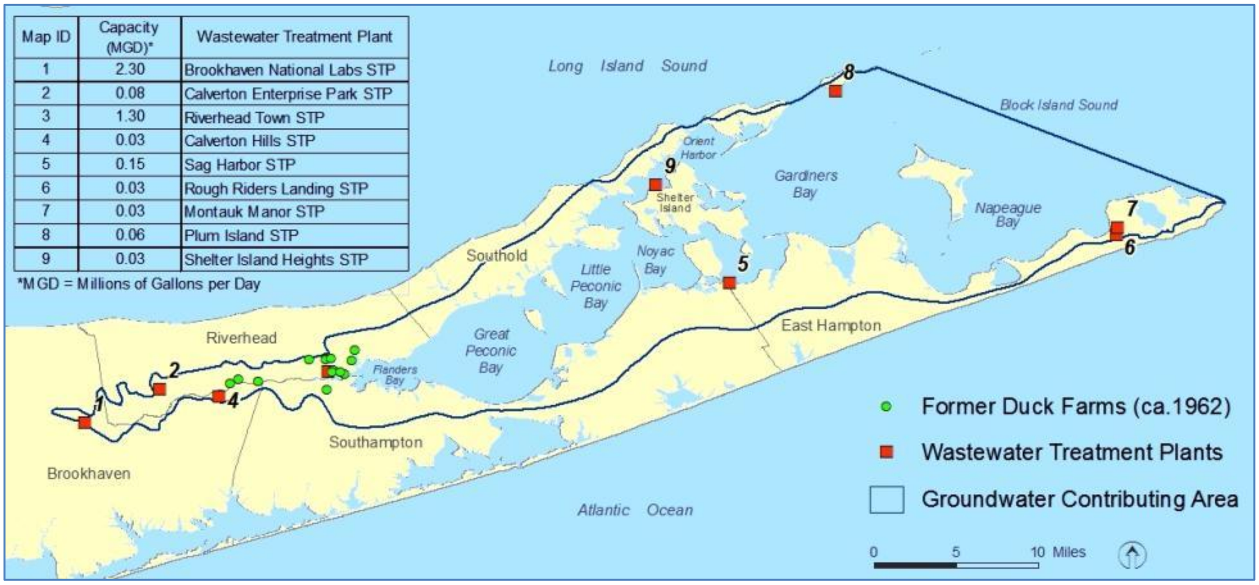
Figure 7-4. Duck farm locations in 1962



Most of the duck farms ceased operations in the mid-1980s due to a combination of factors. Compliance with environmental regulations became more difficult and costly, competition increased from mid-west farms, and development pressure increased the value of their waterfront properties. Only the Corwin family's Crescent Farm remains in Aquebogue. They installed a wastewater treatment system some years ago. According to the New York Times (Scholem, 2003), the farm was producing 1 million ducks per year in 2003. According to a Suffolk County report (Nuzzi & Waters, 1999), the Corwin duck farm was contributing 110 pounds of nitrogen per day in 1999 to Meetinghouse Creek. That value is higher than the Riverhead STP, which contributes approximately 82 pounds of nitrogen per day (Table 7-4).

The legacy of duck farming remains primarily in the sediments of the estuary's western creeks. Although some, like Meetinghouse Creek, have been dredged, others retain the consolidated waste products of millions of ducks along with organic material from years of algal blooms that resulted from the high nitrogen inputs. The legacy of duck waste in the sediments is discussed in section 9.

Figure 7-5. Point sources - wastewater treatment plants and duck farms

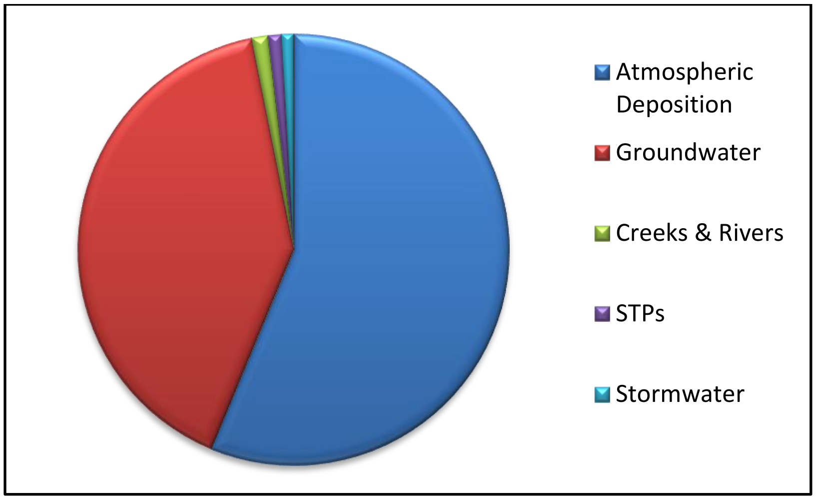


***Nitrogen from Duck Farming** – duck farming peaked in the late 1950s and early 1960s with 14 farms on tributaries to and the shores of Flanders Bay, the Peconic River, Meetinghouse Creek, Sawmill Creek, Reeves Creek, and Terrys Creek. Given groundwater travel time of 20-30 years and more, duck waste deposited on farm fields during the 1950s and 1960s would only have appeared in the Estuary in the 1980s, during the peak Brown Tide years. The last duck farm is Crescent Farm in Aquebogue, which produces 1 million ducks per year. The nitrogen load from those ducks is estimated to exceed that of the Riverhead STP.*

7.3 Non-Point Source Nitrogen Loads

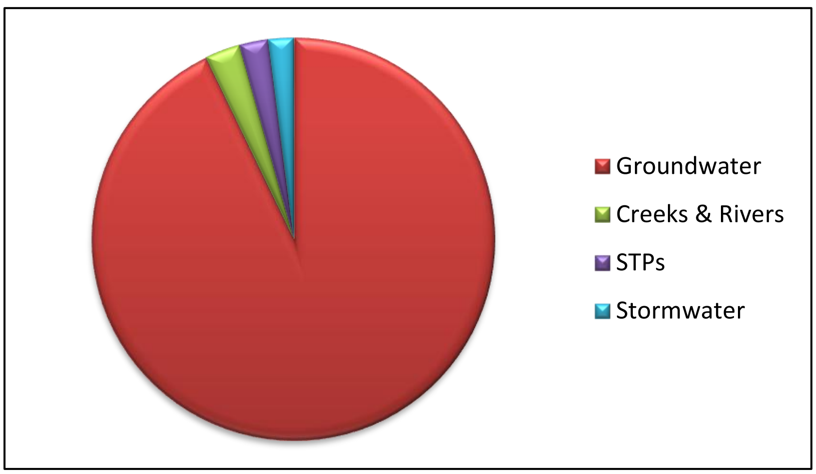
By far the largest non-point sources of nitrogen to the Peconic Estuary are atmospheric deposition and groundwater (Table 7-5, Table 7-6, and Figure 7-6), accounting for 97 percent of the nitrogen inputs according to the Peconic Estuary nitrogen TMDL (Suffolk County Department of Health Services, 2007). Atmospheric deposition accounts for 56 percent of nitrogen contributed to the Estuary and groundwater 41 percent. Groundwater constitutes 93 percent of the nitrogen input to the Estuary if atmospheric deposition is not included (Table 7-6 and Figure 7-7). Stormwater is responsible for only 0.9 percent of the nitrogen entering the Estuary or 2.0 percent if atmospheric deposition is not included.

Figure 7-6. Nitrogen contributions to the Peconic Estuary



Data Source: Total Maximum Daily Load for Nitrogen in the Peconic Estuary Program Study Area, Suffolk County, September 2007

Figure 7-7. Nitrogen contributions to the Peconic Estuary exclusive of Atmospheric Deposition



Data Source: Total Maximum Daily Load for Nitrogen in the Peconic Estuary Program Study Area, Suffolk County, September 2007

7.3.1 Atmospheric Nitrogen Sources and Trends

The greatest source of nitrogen in the Peconic Estuary is atmospheric deposition. Two data stations were available for atmospheric information. Station NY-99, located at West Point included data from 1983 through 2009. Station NY 96, located in Southold, included data from 2003-2009.

Atmospheric ammonia comes from agriculture (animal wastes and fertilizer) and from combustion in vehicles and power plants. Atmospheric ammonium deposition increased significantly from 2003 to 2009 at the Southold station, but demonstrated no significant change at the West Point station from 1983 to 2009.

Data for atmospheric nitrogen oxides (NOx) were also available. These compounds, nitric oxide and nitrogen dioxide, typically enter the atmosphere from combustion and represent primarily motor vehicle and power plant emissions. There was no significant change in NOx at the Southold station from 2003 to 2009. These compounds decreased significantly at the West Point station from 1983 to 2009.

***Atmospheric Nitrogen** – Atmospheric nitrogen represents 56 % of the total nitrogen loading to the Estuary. Ammonium deposition increased from 2003-2009 at the Southold station.*

7.3.2 Groundwater Nitrogen Sources

The vast majority of groundwater nitrogen is from two sources – onsite wastewater treatment systems and fertilizer. The fertilizer derives from both agricultural and residential use. Both sources are substantial. A study completed by Suffolk County estimated groundwater nitrogen loading (Nuzzi & Waters, 1999). At that time, the authors estimated that total groundwater nitrogen loading was 6,500 pounds per day. Of that, they estimated that 32 percent was discharged to the western estuary (Peconic River and Flanders Bay groundwater contributing area). They reported the dominant nitrogen sources as agricultural (2,700 lbs/day or 41 percent of total nitrogen loading) and residential development (40 percent of total nitrogen loading). Agricultural nitrogen loading was three times greater than that from human sanitary waste and almost double the residential nitrogen fertilizer load. Agricultural loading is also more than 30 times that of the Riverhead STP. The authors also noted that agricultural land has a per-acre total nitrogen loading rate approximately double that of residential land. The residential component included three contributors: human waste, fertilizer, and a third factor that combined animal waste, natural precipitation, and soil mineralization. The authors pointed to the utility of parsing out the human waste and fertilizer components for management purposes.

***Groundwater Nitrogen Sources** – Groundwater nitrogen loading in 1999 came from agricultural (41%) and residential (40%) sources. Agricultural loading was more than 30 times that of the Riverhead STP.*

7.3.3 Groundwater Nitrogen Trends

An examination of groundwater data was outside the scope of this study. Because groundwater nitrogen is such a key component however, USGS groundwater data was obtained, analyzed and incorporated into the project GIS. Unfortunately, the data was inadequate to determine the existence of either spatial or temporal trends.

One observation can be made, however, from the data. Two stations in the Town of Riverhead had high groundwater nitrogen concentrations throughout most of the sampling period. One (station 405634072380501) is located approximately 3,000 feet west of Meetinghouse Creek near the intersection of State Route 25A and Union Avenue. This station appears to be downgradient of several residential developments, a golf course, and considerable farming acreage. It is likely that the high nitrogen concentration at this station reflects fertilizer inputs by all three uses and onsite wastewater treatment system effluent from the residential areas. Although located near Meetinghouse Creek, groundwater is unlikely influenced by the duck farm given the fact that groundwater generally flows in a southerly or southeasterly direction toward the coastline.

The other groundwater station (405722072342001) near Herricks Lane and State Route 25A is similarly located downgradient of farms. Most of the land use upgradient of this station has been agricultural for decades. Most of the groundwater nitrogen at this station is therefore most likely from agricultural fertilizer use.

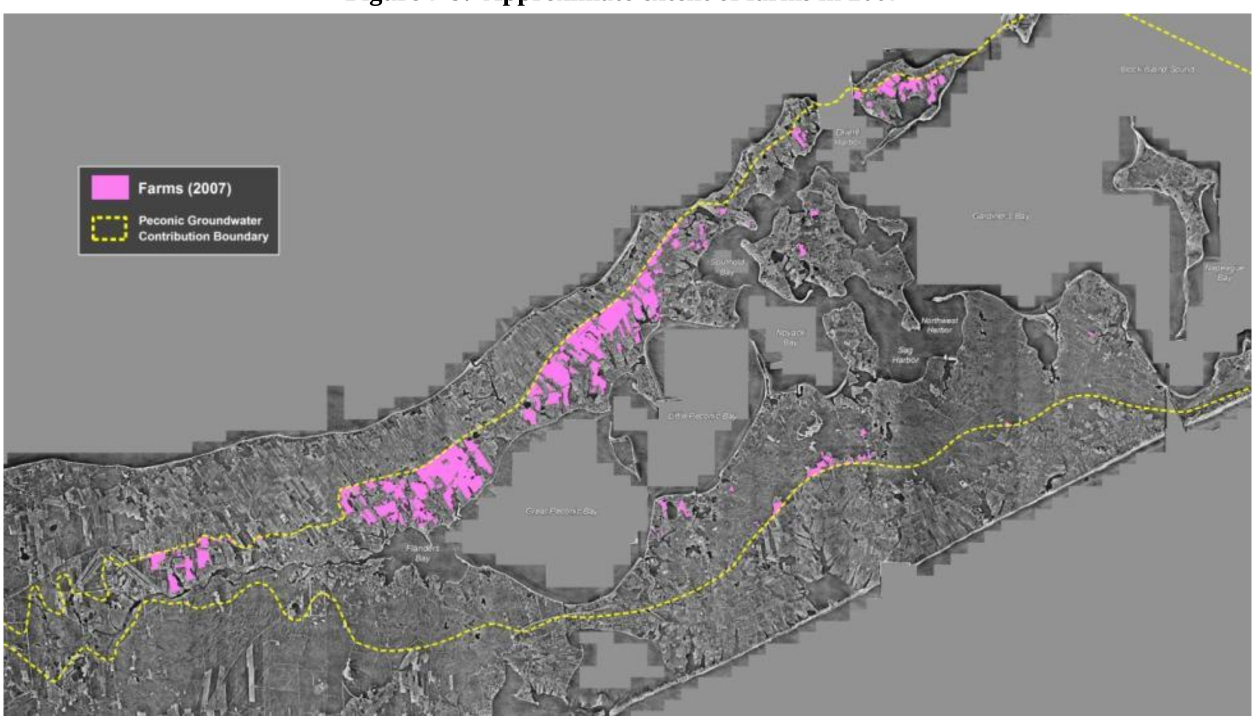
A key recommendation of this study is for the County's Office of Water Resources to expand its groundwater monitoring efforts in cooperation with the USGS and to provide the existing and future data in digital format (perhaps in a GIS). The Office of Ecology in cooperation with the Towns, and perhaps the water companies, should work with the County's Office of Water Resources and the County's groundwater modeling consultant to insure that a sufficient number of wells are in place and located properly to evaluate groundwater quality in future years. It may be appropriate to locate a series of groundwater wells equidistant from the estuary in terms of travel time (*i.e.,* located along the two-year groundwater travel-time contour) and sampled at the same elevations. The Office of Ecology could utilize the additional groundwater data to seek correlations between groundwater constituents, concentrations, and spatial and temporal trends and surface water conditions (with allowances for groundwater travel time).

Correlations may exist between groundwater nitrogen and parameters like surface water nitrogen, chlorophyll-a, and dissolved oxygen. There would likely be a time lag in the correlations equivalent to the groundwater travel time. Similarly, there may be spatial relationships between groundwater and surface water parameters, but also offset by groundwater travel time.

Land in agricultural use has declined from approximately 15,200 acres in 1962 (Figure 7-8) to 7,600 acres in 2007 (Figure 7-9), or a 50 percent decline. The use of agricultural fertilizer should have declined even more as crops have changed (*i.e.,* fertilizer-dependent potato acreage declined by over 90% and vineyard acreage, which requires far less fertilizer increased).

Figure 7-8. Approximate extent of farms in 1962

Figure 7-9. Approximate extent of farms in 2007



***Groundwater Nitrogen Trends** – Groundwater nitrogen, its types, concentrations, trends, and correlations with surface water nitrogen, chlorophyll-a, and dissolved oxygen should be investigated further. The 50% decline in agricultural acreage over the last 50 years should be reflected in groundwater quality.*

7.3.4 Stormwater Nitrogen Sources

Stormwater runoff nitrogen sources include primarily residential and agricultural fertilizers and animal waste (wild and domesticated). Only 0.9 percent of the nitrogen entering the Peconic Estuary derives from stormwater.

***Stormwater Nitrogen** – Stormwater accounts for only 0.9 % of N loading to the Estuary.*

7.4 Nitrogen Analyte Trends

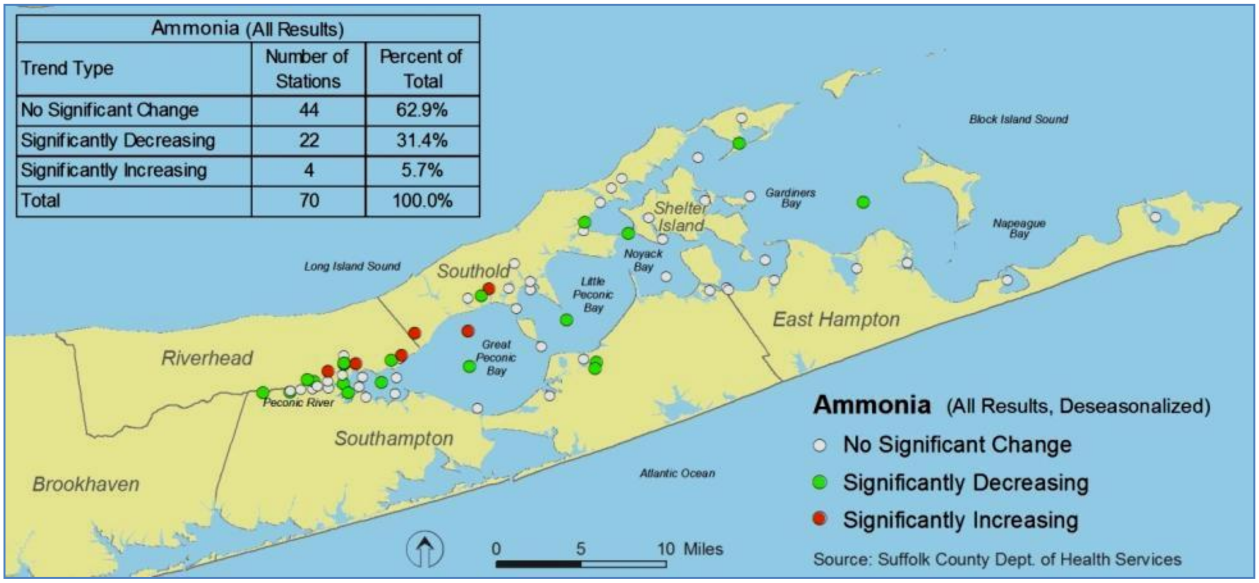
7.4.1 Ammonia Trends

Ammonia inputs to groundwater come from residential and agricultural fertilizer and onsite wastewater system effluent. Another major ammonia input is flux from microbial degradation of organic compounds in the sediments. Figure 7-10 shows trends in ammonia concentrations throughout the Estuary for all data (1976-2008). Ammonia declined in more than a quarter of the stations, with many located in western Flanders Bay and the mouth of the Peconic River. Ammonia increased in only six stations, five along the shores (or creek mouths) of the North Fork and one in Great Peconic Bay.

Table 7-8. Stations experiencing increased ammonia concentrations from 1976-2008

Station	Location
060140	Great Peconic Bay North
200120	Terry Creek
200130	Reeves Creek
200140	East Creek, South Jamesport
200190	Brushes Creek
200190	Downs Creek

Figure 7-10. Ammonia Trends



Ammonia (All Results)		
Trend Type	Number of Stations	Percent of Total
No Significant Change	44	62.9%
Significantly Decreasing	22	31.4%
Significantly Increasing	4	5.7%
Total	70	100.0%

***Ammonia Trends** – Ammonia declined in more than a quarter of stations, with many located in western Flanders Bay and the mouth of the Peconic River. Ammonia increased in only four stations, all along the shores (or creek mouths) of the North Fork.*

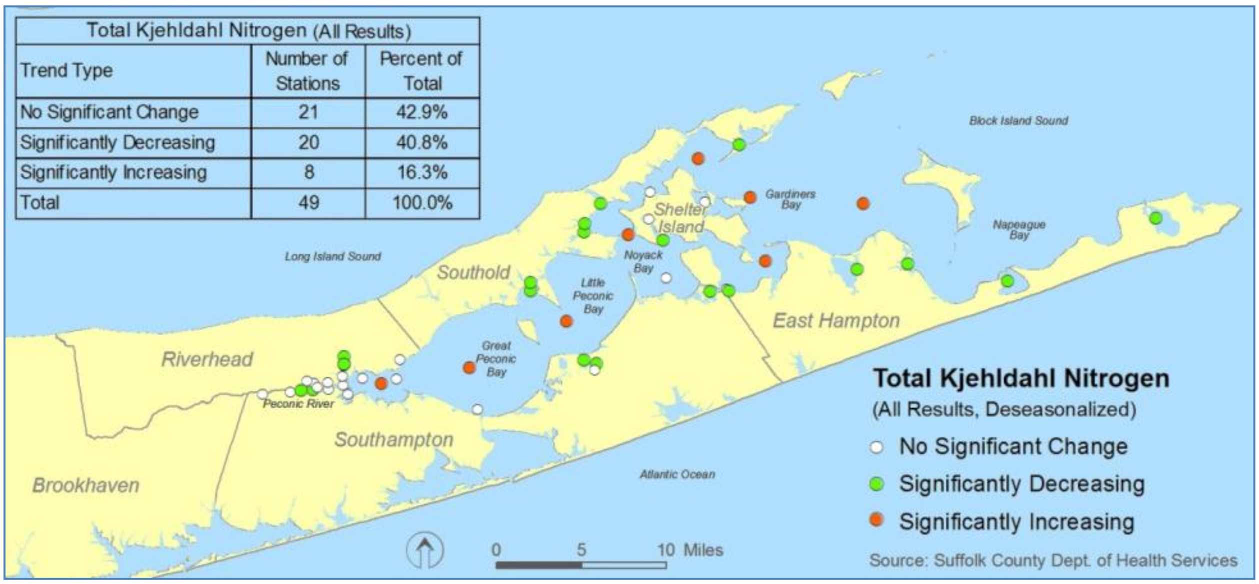
7.4.2 Kjeldahl Nitrogen Trends

Kjeldahl nitrogen is a measure of ammonia and dissolved organic nitrogen, specifically, organic proteins and their decomposition product, ammonia. Total Kjeldahl Nitrogen increased significantly in a number of the open-water central portions of the Estuary (Figure 7-11). In contrast, Total Kjeldahl Nitrogen decreased in a number of the creeks and small embayment locations. Such a pattern may be explained by improving water quality in the creeks and small embayments since the 1970s (as evidenced by declining chlorophyll-a). With the decline of algal blooms, sediment dissolved oxygen likely increased with associated improvements in the microbial community. Increased bacterial activity in these areas would have increased the degradation of organic matter and conversion of ammonia to nitrite and nitrate leading to declining Kjeldahl Nitrogen.

The increase in Kjeldahl nitrogen in the central portions of the Estuary is more difficult to explain. It may reflect a decline in sediment microbial activity due to improving water quality in the central portions of the bays. Both chlorophyll-a and total organic carbon declined in the open waters of the estuary (see Figure 14-1, Figure 14-2, Figure 14-3, Figure 15-1, and Figure 15-2) due to the presence of fewer and less intense algal blooms.

Consequently, less organic material likely reached the sediments. With less deposition of organic material, sediment microbial populations may have declined leading to less conversion of organic to inorganic nitrogen. This is supported by New York Bight and Hudson River work on the contribution of dissolved organic nitrogen from rivers to estuarine eutrophication (Seitzinger & Sanders, 1997). They found that a large portion of dissolved organic nitrogen is transported out into bays before it is degraded by bacterial populations.

Figure 7-11. Trends in Total Kjeldahl Nitrogen



***Total Kjeldahl Nitrogen Trends** – TKN increased in the open-water central portions of the Estuary and decreased in a number of the creeks and small embayments.*

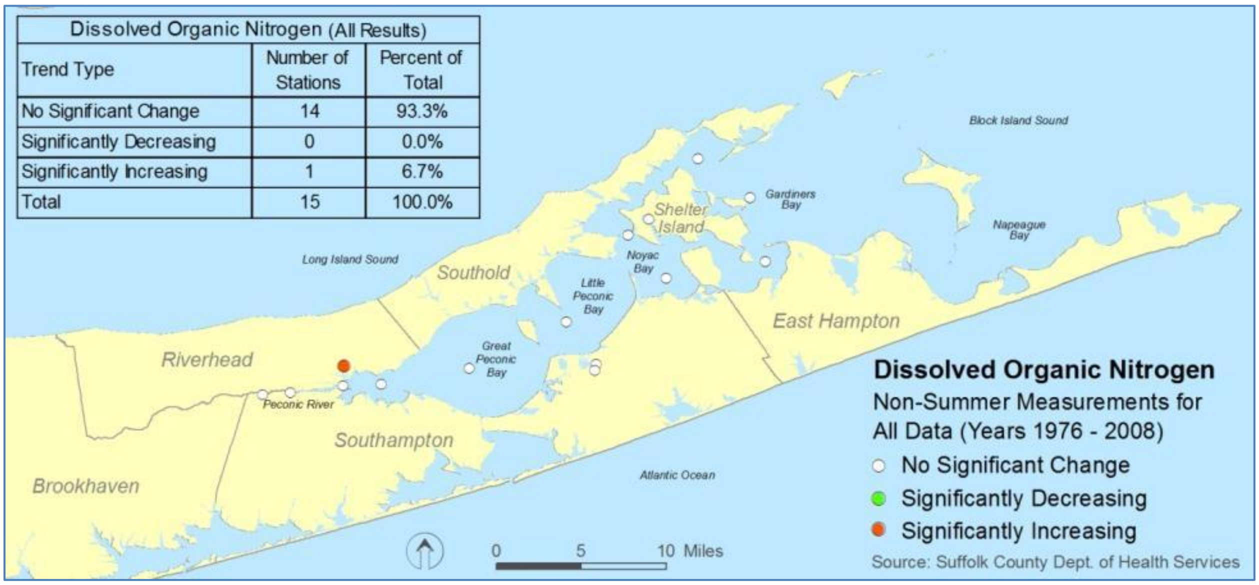
7.4.3 Dissolved Organic Nitrogen Trends

Dissolved organic nitrogen (DON) is a reflection of several potential estuarine inputs. Dissolved organic nitrogen flows into the estuary primarily from groundwater and to a lesser extent from surface water runoff (pet waste, fertilizer, and plant detrital material) and direct inputs (*i.e.*, waterfowl and leaf fall). It is incorporated into the estuarine nutrient cycle when microbial populations assimilate it into bacterial biomass and/or regenerate it as ammonia. Recent work compiling a DON budget for Narragansett Bay suggested that internal production of DON is of a similar magnitude to external inputs (Seitzinger & Sanders, 1997). Internal inputs of DON come primarily from phytoplankton. DON concentrations in the non-summer seasons, when phytoplankton abundance is minimal, reflect external DON inputs.

Dissolved organic nitrogen trends were examined for the non-summer period and the full year for the entire set of data and for the pre-Brown Tide, Brown Tide, and post-Brown Tide periods (Figure 7-12 through Figure 7-17).

Dissolved organic nitrogen for the non-summer period for 1976-2008, shows that DON showed no trend at any station except for an increase at 060220 in Meetinghouse Creek (Figure 7-12). If non-summer DON concentrations reflect primarily groundwater inputs, groundwater inputs have likely remained relatively unchanged.

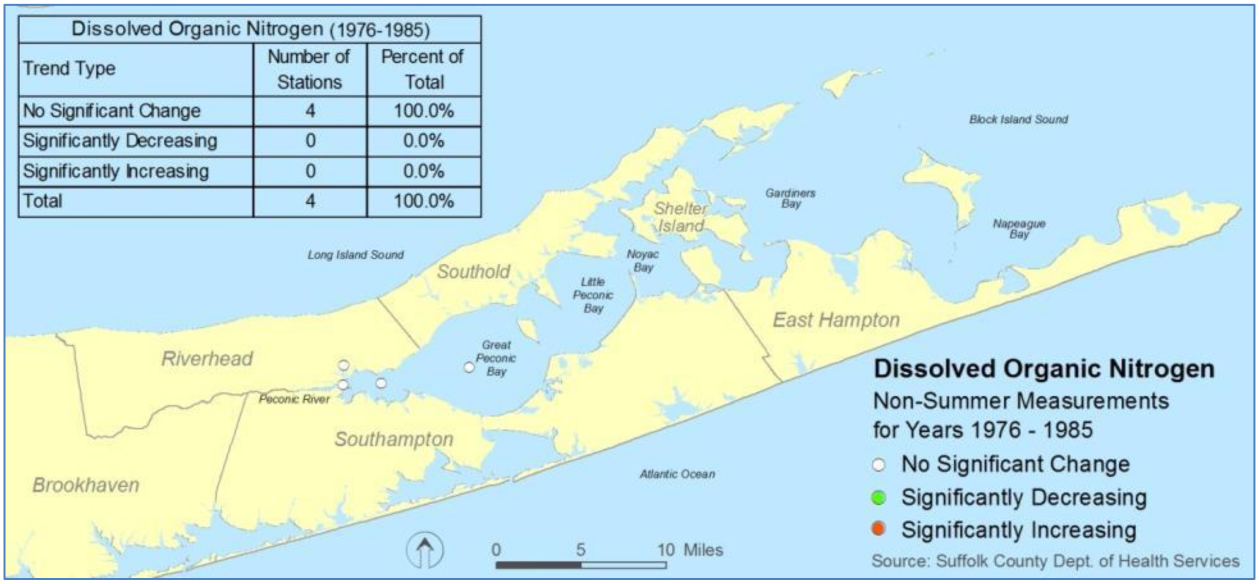
Figure 7-12. Trends in Non-Summer Dissolved Organic Nitrogen –1976-2008



There is less data available to determine significant *non-summer* DON trends for the pre-Brown Tide, Brown Tide, and post-Brown Tide years (Figure 7-14, Figure 7-15, and Figure 7-16). No trend was evident in the pre- brown Tide period for DON. Only one Shelter Island station showed a trend (increasing) for the Brown Tide years. Only the Peconic River at station 2000017 showed a significant increase in non-summer DON for the post-Brown Tide period only.

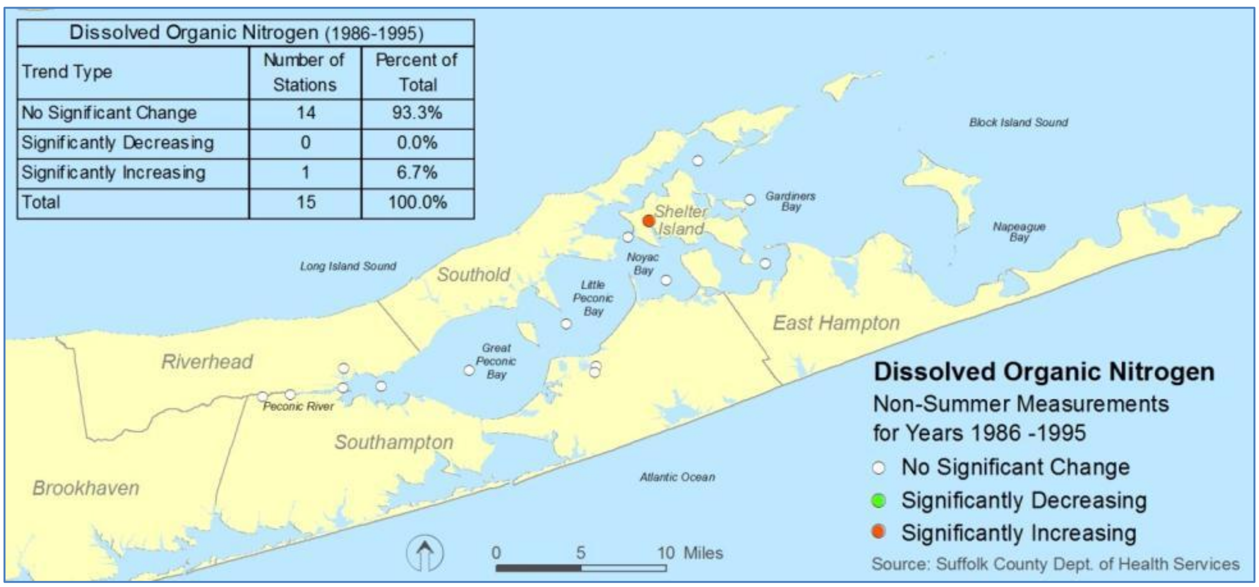
Examining trends in this manner may mask real differences in DON between periods. It is possible (see the time series plots of Figure 4-2 through Figure 4-5), that DON was relatively stable prior to the Brown Tide years, was higher during the Brown Tide years, and then returned to a concentration similar to the pre-Brown Tide years. Such a pattern would be reflected as 'No Significant Change' from 1976 to 2008 (see Figure 7-12) for the non-summer periods.

Figure 7-13. Trends in Non-Summer Dissolved Organic Nitrogen – 1976-1985



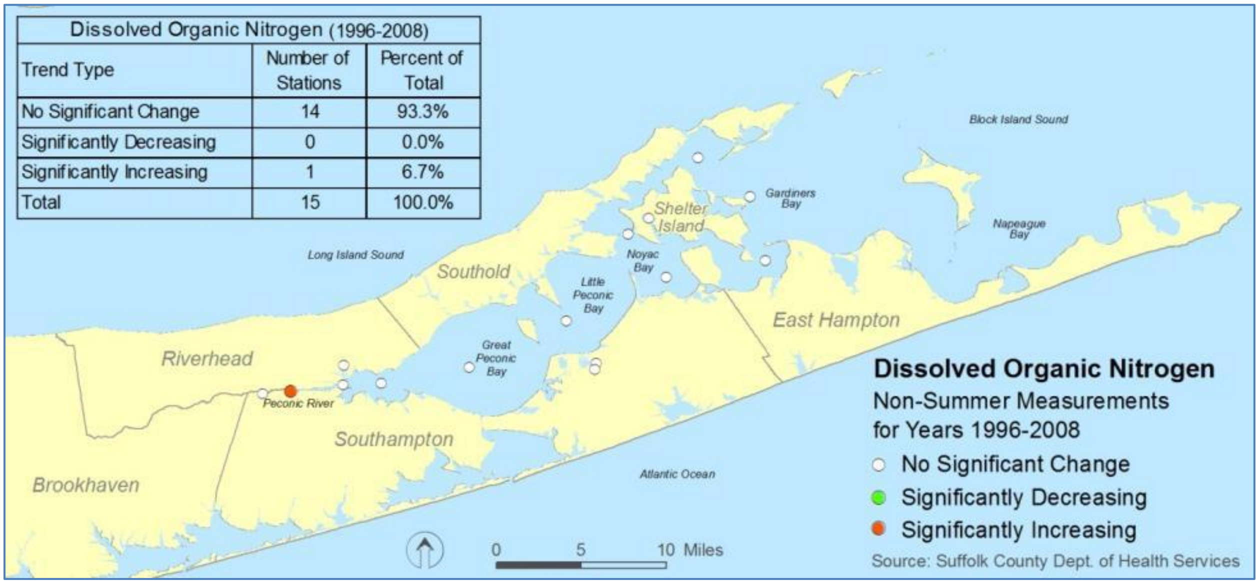
Dissolved Organic Nitrogen (1976-1985)		
Trend Type	Number of Stations	Percent of Total
No Significant Change	4	100.0%
Significantly Decreasing	0	0.0%
Significantly Increasing	0	0.0%
Total	4	100.0%

Figure 7-14. Trends in Non-Summer Dissolved Organic Nitrogen – 1986-1995



Dissolved Organic Nitrogen (1986-1995)		
Trend Type	Number of Stations	Percent of Total
No Significant Change	14	93.3%
Significantly Decreasing	0	0.0%
Significantly Increasing	1	6.7%
Total	15	100.0%

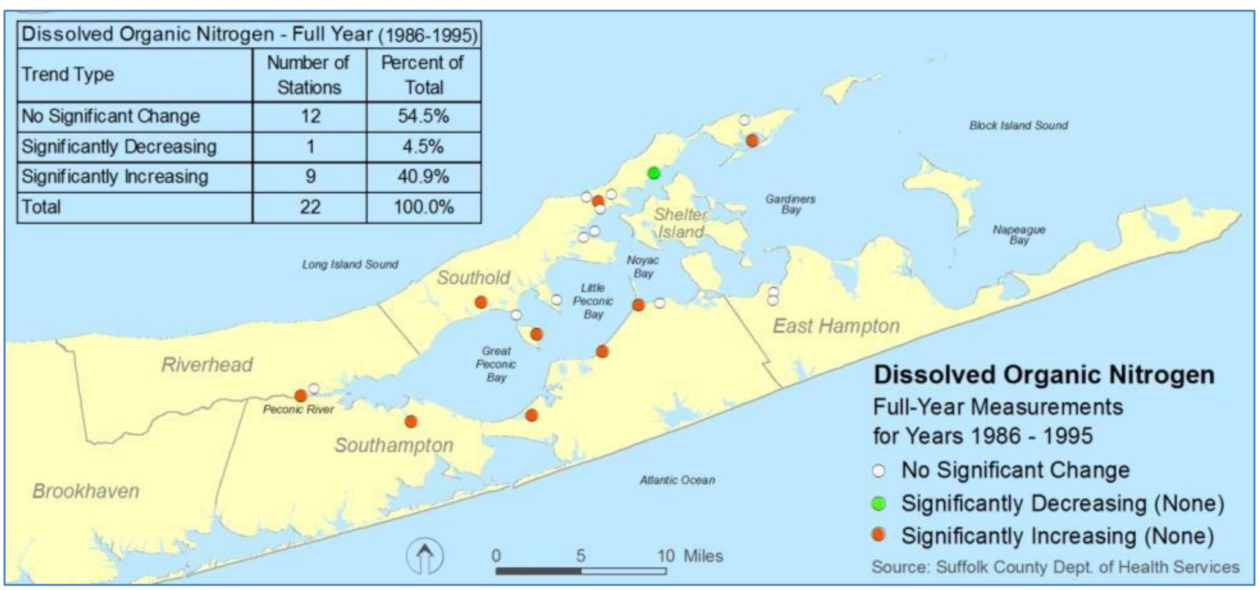
Figure 7-15. Trends in Non-Summer Dissolved Organic Nitrogen – 1996-2008



Dissolved Organic Nitrogen (1996-2008)		
Trend Type	Number of Stations	Percent of Total
No Significant Change	14	93.3%
Significantly Decreasing	0	0.0%
Significantly Increasing	1	6.7%
Total	15	100.0%

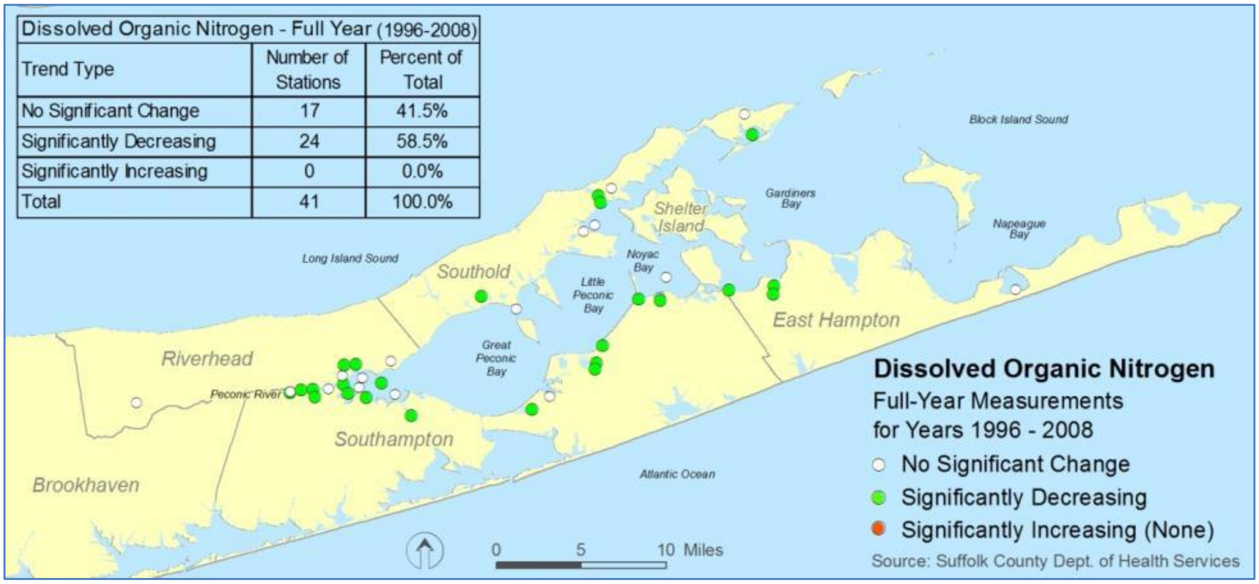
Full-year measurements of dissolved organic nitrogen show a distinct difference in the Brown Tide and post-Brown Tide periods (Figure 7-16 and Figure 7-17). Dissolved organic nitrogen increased during the Brown Tide years (1986-1995) in the creeks and tributaries of the Estuary and then decreased during the following years (1996-2008). It is unclear whether the differences were causative or instead reflect the release of DON from decaying blooms during the Brown Tide years.

Figure 7-16. Trends in Full-Year Dissolved Organic Nitrogen – 1986-1995



Dissolved Organic Nitrogen - Full Year (1986-1995)		
Trend Type	Number of Stations	Percent of Total
No Significant Change	12	54.5%
Significantly Decreasing	1	4.5%
Significantly Increasing	9	40.9%
Total	22	100.0%

Figure 7-17. Trends in Full-Year Dissolved Organic Nitrogen – 1996-2008



Dissolved Organic Nitrogen - Full Year (1996-2008)		
Trend Type	Number of Stations	Percent of Total
No Significant Change	17	41.5%
Significantly Decreasing	24	58.5%
Significantly Increasing	0	0.0%
Total	41	100.0%

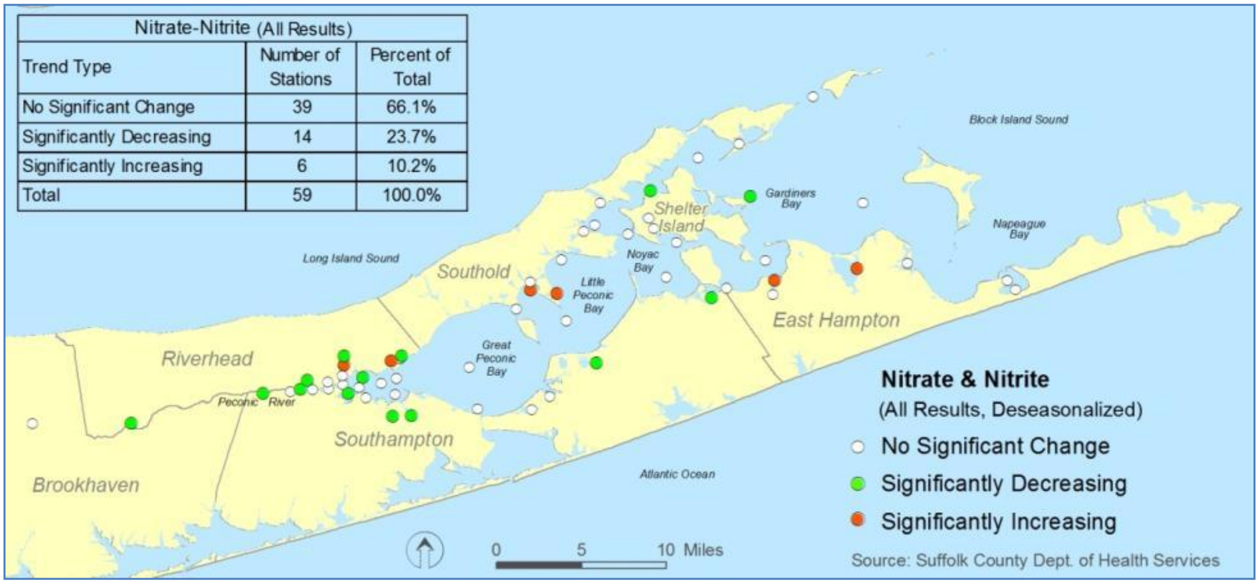
***Dissolved Organic Nitrogen Trends** – Non-summer DON showed little change at almost all stations. If non-summer DON reflects primarily groundwater input, groundwater input has therefore remained relatively unchanged. Full-year DON increased during the Brown Tide years (1986-1995) and then decreased in the following years (1996-2008).*

7.4.4 Nitrate & Nitrite Trends

Ammonia is degraded by bacteria to nitrite and nitrite to nitrate. Nitrate also comes from sources including onsite wastewater systems, residential, and agricultural fertilizer.

Nitrite and nitrate concentrations when viewed over the entire three decades of sampling increased in six stations (10 percent of stations) (Figure 7-18). Nitrite and nitrate declined in just under one quarter of the stations. Most of the declines were in the western estuary.

Figure 7-18. Nitrate & Nitrite Trends



***Nitrite-Nitrate Trends** – Nitrite and nitrate declined in just under one quarter of stations over the entire three decades and increased in only six stations (10 percent). Most declines were evident in the western Estuary.*

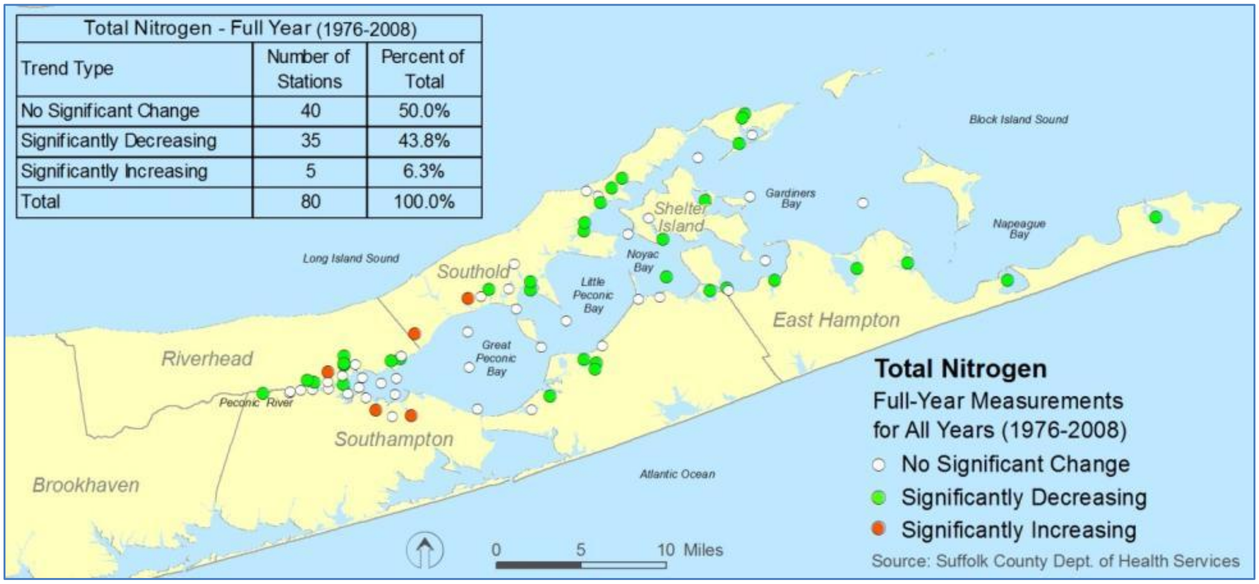
7.4.5 Total Nitrogen Trends

Total nitrogen includes all nitrogen parameters. When all the data from 1976-2008 are viewed together (Figure 7-19), it is apparent that nitrogen has declined in 44 percent of the stations (35 stations). Total nitrogen increased in only six percent (5 stations) of the stations (see Table 7-9).

Table 7-9. Stations where total nitrogen increased

Station Number	Station Location
200014	Birch Creek
200016	Hubbard Creek
200120	Terrys Creek
200160	Brushes Creek
200170	Deep Hole Creek

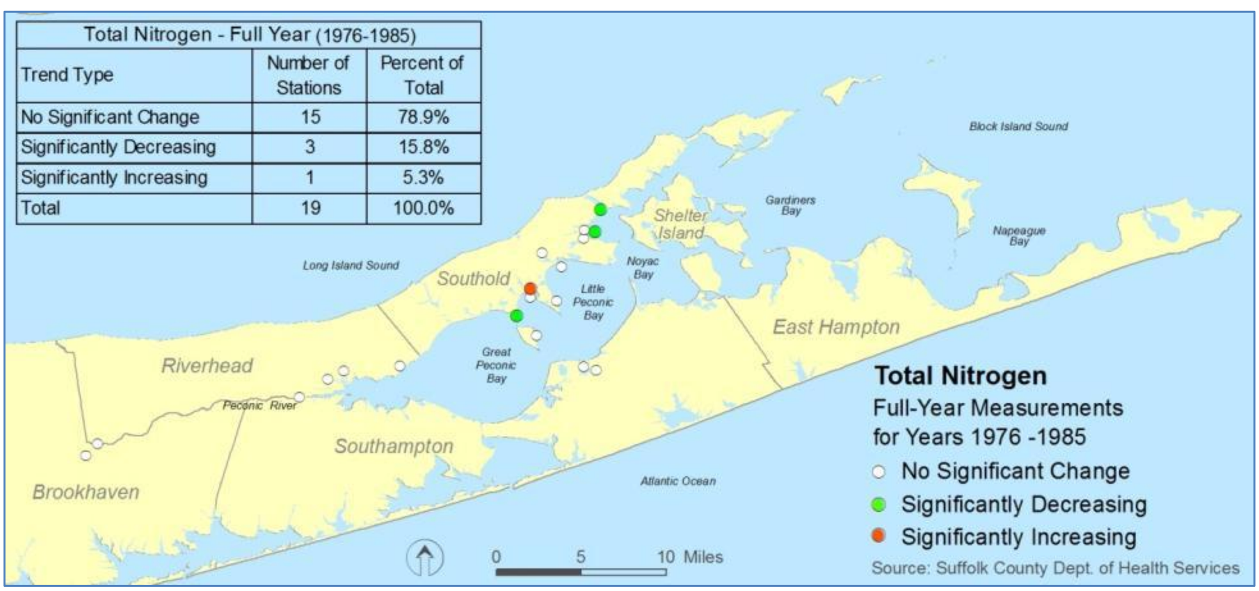
Figure 7-19. Total Nitrogen Trends – full year – 1976-2008



Total Nitrogen - Full Year (1976-2008)		
Trend Type	Number of Stations	Percent of Total
No Significant Change	40	50.0%
Significantly Decreasing	35	43.8%
Significantly Increasing	5	6.3%
Total	80	100.0%

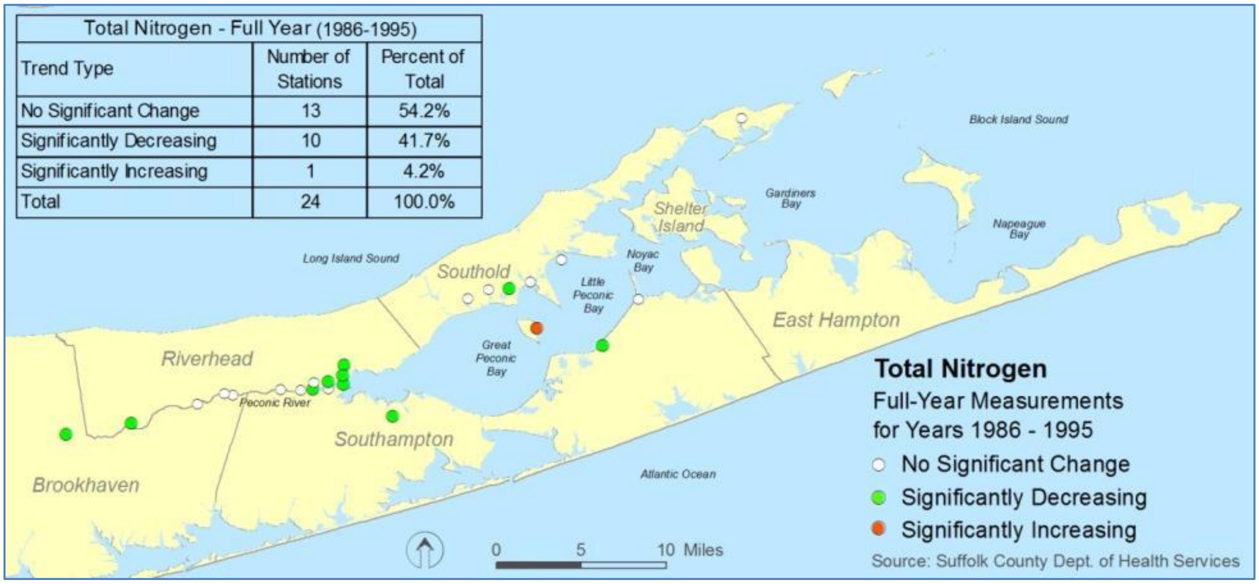
Total nitrogen (TN) is also shown for the pre-Brown Tide, Brown Tide, and post-Brown Tide periods in Figure 7-20, Figure 7-21, and Figure 7-22. The data shows that TN declined during the pre-Brown Tide period at three stations and at 10 stations during the Brown Tide years, including stations near the mouth of the Peconic River, in Meetinghouse, Terrys and Mill Creek, and at the Brookhaven National Laboratory's sewage treatment plant. Total nitrogen increased in one station just east of Robins Island during the Brown Tide years (Figure 7-21).

Figure 7-20. Total Nitrogen Trends – Full Year – 1976-1985



Total Nitrogen - Full Year (1976-1985)		
Trend Type	Number of Stations	Percent of Total
No Significant Change	15	78.9%
Significantly Decreasing	3	15.8%
Significantly Increasing	1	5.3%
Total	19	100.0%

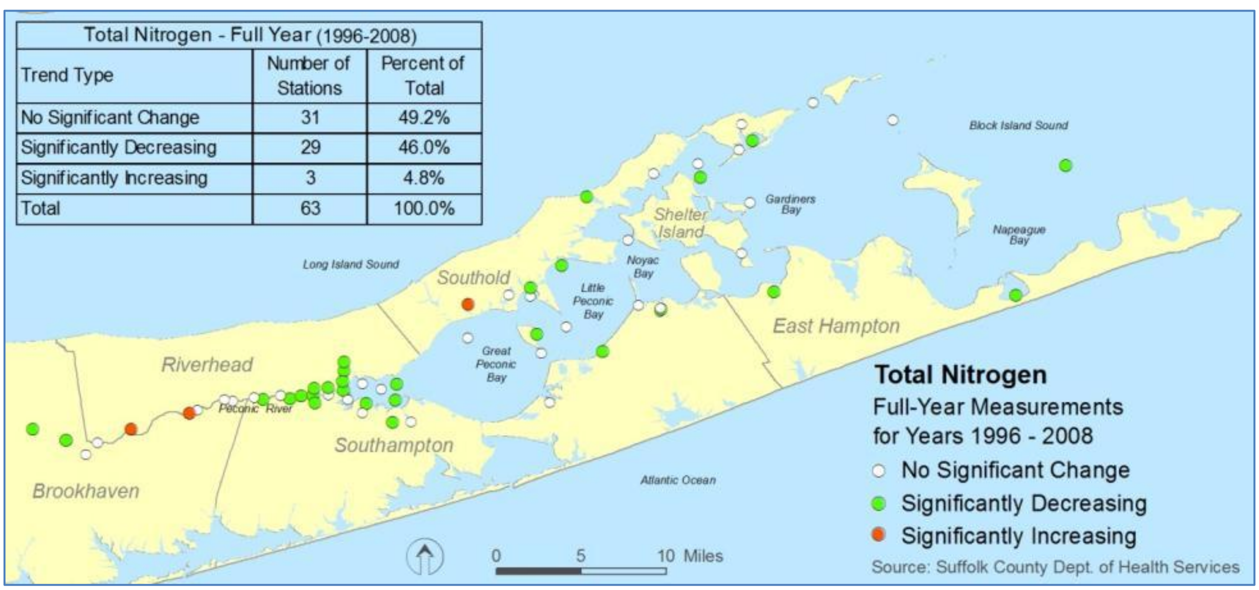
Figure 7-21. Total Nitrogen Trends – Full Year – 1986-1995



Total Nitrogen - Full Year (1986-1995)		
Trend Type	Number of Stations	Percent of Total
No Significant Change	13	54.2%
Significantly Decreasing	10	41.7%
Significantly Increasing	1	4.2%
Total	24	100.0%

Total nitrogen declined across the Estuary in the years following the Brown Tide (Figure 7-22). Total nitrogen decreased in forty-six percent of the stations (29 stations), while only three showed an increase. There was no change in almost half the stations.

Figure 7-22. Total Nitrogen Trends – Full Year – 1996-2008



Total Nitrogen - Full Year (1996-2008)		
Trend Type	Number of Stations	Percent of Total
No Significant Change	31	49.2%
Significantly Decreasing	29	46.0%
Significantly Increasing	3	4.8%
Total	63	100.0%

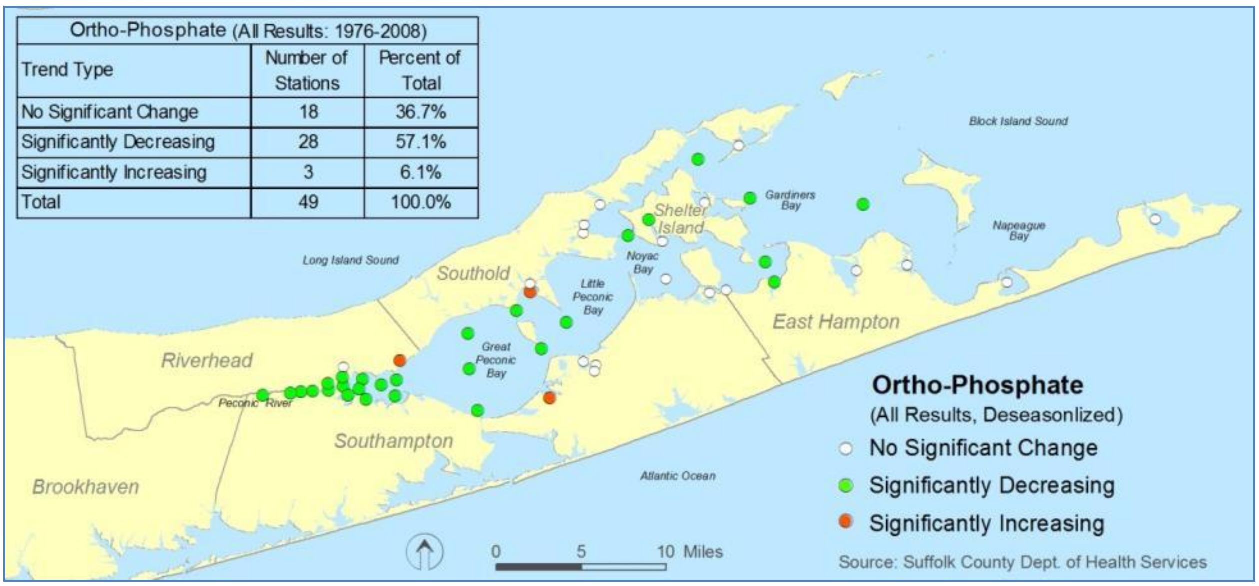
***Total Nitrogen Trends** – Total nitrogen for 1976-2008 declined in 44 percent of stations and increased in only five stations. Total nitrogen declined during and after the Brown Tide.*

8 Phosphorus Trends

Like nitrogen, annual averages for phosphorus concentrations in the Estuary are complicated by the effect of algal uptake. Samples taken during the warmer months (May – September) reflect the presence of phytoplankton. All other parameters being equal, algal concentrations increase until nutrient concentrations become limiting at which point algal populations decline. Nutrient concentrations rise following the decline of algal blooms. As nitrogen rather than phosphorus is the limiting nutrient in marine waters, phosphorus can remain elevated even during blooms, but its concentration changes with algal population densities. Orthophosphate is the form taken up by phytoplankton.

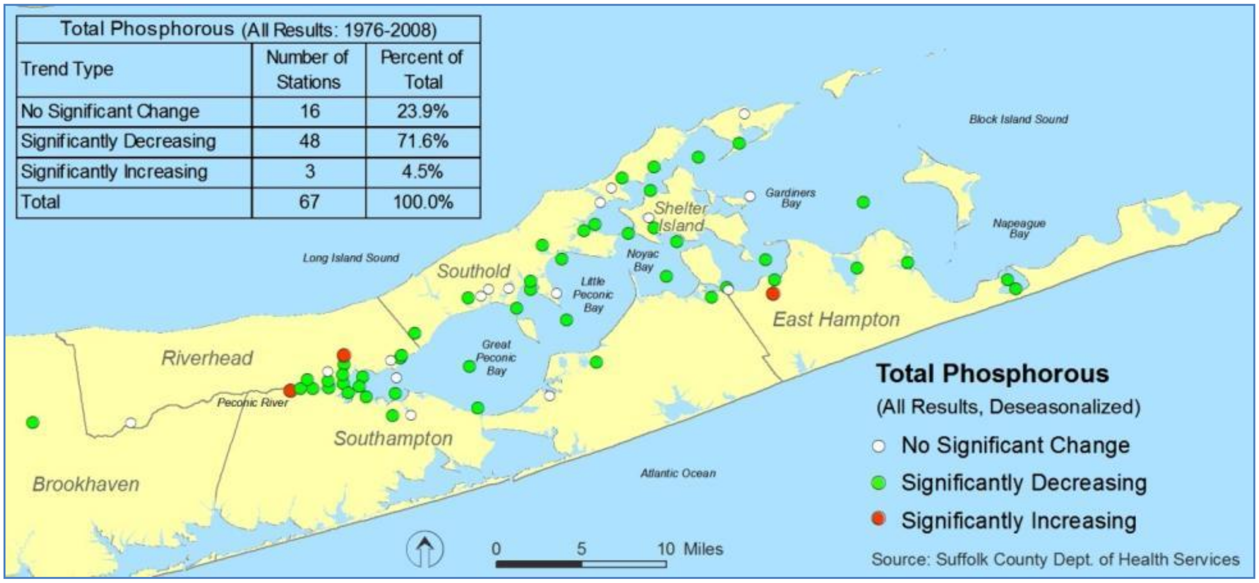
Significant declines in orthophosphate (Figure 8-1) were evidence primarily in western Flanders Bay (multiple stations), the Peconic River (multiple stations), and the Central Estuary (Quintants 1 and 2). Only three stations experienced an increase in orthophosphate. The decline in orthophosphate concentrations probably reflects 1) the reduction in agricultural acreage and the corresponding use of fertilizer, and 2) the decline in duck farming.

Figure 8-1. Trends in Orthophosphate



A substantial decline in total phosphorus was evident across the Estuary (Appendix B) with 72 percent of stations showing a significant decrease. Total phosphorus concentrations rose at only three stations (the Sag Harbor STP discharge – 200018 and stations 200004 and 200042 in Meetinghouse Creek) over the reporting period. Increasing phosphorus in Meetinghouse Creek may be related to the duck farm or could be a reflection of fertilizer use in the subwatershed.

Figure 8-2. Trends in Total Phosphorus



Total Phosphorous (All Results: 1976-2008)		
Trend Type	Number of Stations	Percent of Total
No Significant Change	16	23.9%
Significantly Decreasing	48	71.6%
Significantly Increasing	3	4.5%
Total	67	100.0%

The overall decline in phosphorus may be due to the closure by the 1980s of all but one of the 14 duck farms that operated in the Peconic Estuary watershed since the late 1960s. Duck farm effluent is high in phosphate. The decline could also be related to the elimination of phosphate from detergents during the 1990s. It could also be due to changes in land use, particularly the decline in farmed acres and the associated fertilizer use. As discussed in the Literature Review, farming acreage and types of crops have changed significantly since the mid-twentieth century, resulting in a decline in the quantity of fertilizer used by farms in the last 50 years. The travel time for groundwater to reach the Estuary is as long as 50 or more years, but most groundwater reaches the Estuary within 20-30 years. Groundwater influenced by high fertilizer loads in the 1950s and 1960s would have reached the Estuary by the 1980s and 1990s. The decline in Estuary phosphorus concentrations could therefore reflect declining groundwater concentrations from declining agricultural acreage, duck farming, and use of phosphates in laundry detergent.

Phosphorus Trends *– Total phosphorus declined substantially across the Estuary, rising only at the Sag Harbor STP discharge and in Meetinghouse Creek.*

9 Benthic Nutrient Flux

Nutrient contributions from the benthos are attributed to the internal recycling of those sediments that are enriched with organic matter. Those areas tend to be in the western portions of the estuary and in the tributary creeks where organic material accumulates from external and internal sources. The external sources can be wastewater treatment plants, stormwater flow, leaf fall, and waterfowl waste. Internal sources are primarily from the death and decay of algal blooms. Larger quantities of organic material accumulate in the 'quieter' portions of the estuary such as the creeks and embayments that are less influenced by wind and tidal currents.

Bacterial degradation of sediment organic matter converts organic compounds to inorganic compounds that are then released into the water column. As bacterial activity is temperature and oxygen dependent, most benthic nutrient flux occurs in the warmer months and only when oxygen concentrations are sufficient to support nitrifying bacteria. Researchers at the School of Marine and Atmospheric Sciences (SoMAS) at Stony Brook estimated benthic nitrogen flux for the Forge River estuary on the south shore (Aller, Gobler, & Brownawell, 2009). Although they reported substantial variability in the data, the nitrogen contribution from benthic flux was estimated to be equivalent to all other sources combined. The Forge River is, unlike the Peconic Estuary, a highly eutrophied waterbody. Some of the Peconic Estuary tributary creeks are similar to the Forge River, however, particularly those where duck farms were located. Benthic flux can be a major contributor of water column nutrients in those creeks, and especially in those that have not been dredged.

A study by Suffolk County (Waters, 2008) of creeks impacted by duck farms, however, suggested that water quality improved once nutrient loading and the associated algal blooms were substantially reduced. The study measured water column nitrogen before and after the cessation of duck farming and found that water quality improved. The improvement was likely a result of both declining land-based (duck farm) nutrient sources and declining nutrient flux from the highly enriched organic sediments. It is possible that when the introduction of new organic material to the sediments ceases or slows, so too does the bacterial degradation. Microbial activity has been shown to occur primarily in the top few centimeters of sediments. Sediment compaction, poor interstitial circulation, and inadequate sediment dissolved oxygen limit microbial activity below the first few centimeters. Thus, once the organic material has been mineralized and released back to the water column, benthic nitrogen, and phosphorus flux slows, absent new organic input. These conclusions are supported by water quality improvements in the creeks that formerly supported duck farms, but have not been dredged.

Benthic Nutrient Flux *– Bacteria degrade organic matter and release nitrogen into the water column. The internal source of organic matter is primarily algal blooms, while external sources include wastewater, stormwater, and waterfowl waste. Benthic flux from historic accumulations of organic matter, particularly former duck farms, may slow or cease as new material ceases to be added.*

10 Dissolved Oxygen Trends

10.1 Background

Nutrient enrichment in the western Estuary has driven down dissolved oxygen (DO) concentrations. Oxygen impairments led to the establishment of the nitrogen TMDL. The County has taken subsurface and near-bottom dissolved oxygen measurements at all their marine sampling stations. They also take samples to assess diurnal fluctuations from April through September at three western stations. The County deploys continuous recording sondes (*i.e.*, devices for underwater measurements; whose technical name is an acronym of Shipboard Oceanography Network Data Environment) in the western Estuary and West Neck Bay that record DO, salinity, and temperature at 15-minute intervals. Dissolved oxygen minima are the most useful form of DO data for assessing DO trends, as dissolved oxygen is highly variable with time of day, season, and algal concentrations.

10.2 Spatial and Temporal DO Trends

The sonde data provide very detailed information on dissolved oxygen patterns throughout the day. These data were compiled, statistically analyzed, and plotted. The oxygen data are best used to answer specific questions, such as the percent of time that DO is below a critical threshold during a species spawning period.

Dissolved oxygen data were also assessed in relation to the water quality standard of 5.0 mg/L. The standard has since been lowered by the NYS DEC to 4.8 mg/L. Compliance results were also evaluated using the Mann-Kendall analysis.

Figure 10-1, Figure 10-2, and Figure 10-3 demonstrate clear temporal and spatial trends in dissolved oxygen during the pre-Brown Tide, Brown Tide, and post-Brown Tide years. Although fewer samples were taken in the earlier (pre-Brown Tide) years, DO standards were not met at stations in the mouth of the Peconic River, Sawmill Creek, Meetinghouse Creek, Mill Creek, and the Riverhead STP (Figure 10-1).

Dissolved oxygen remained problematic in the same locations from 1986-1995, but far less often (Figure 10-2). More sampling was conducted during this period than the earlier period. From 1996 to 2008, many additional sampling locations were added (Figure 10-3). Dissolved oxygen concentrations improved in the lower Peconic River, Sawmill Creek, Reeves Creek, and Mill Creek. However, new sampling stations added during this period revealed numerous locations that experienced low dissolved oxygen concentrations, particularly along the north shore of the estuary.

Figure 10-1. Dissolved Oxygen - Percent Occurrences Less than 4.8 mg/L – 1976-1985

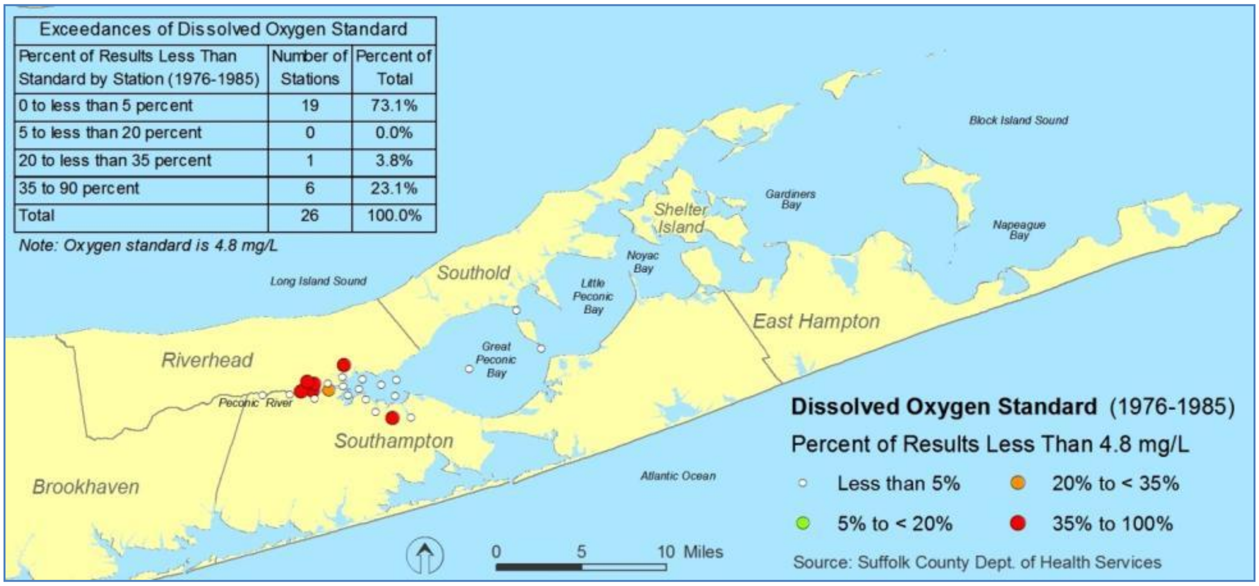


Figure 10-2. Dissolved Oxygen - Percent Occurrences Less than 4.8 mg/L – 1986-1995

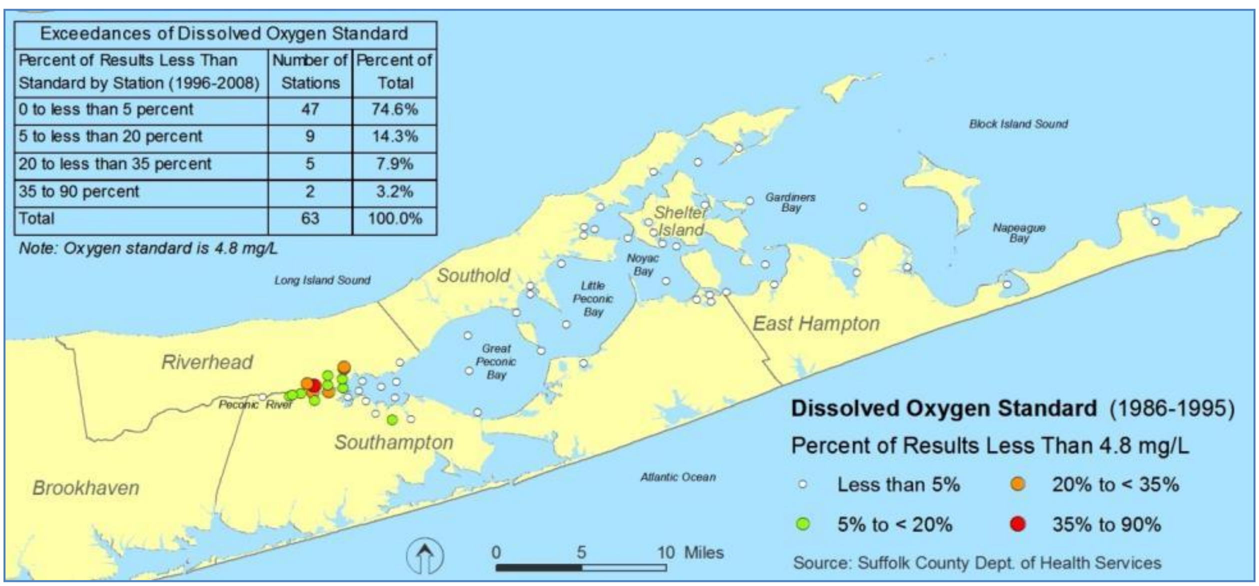
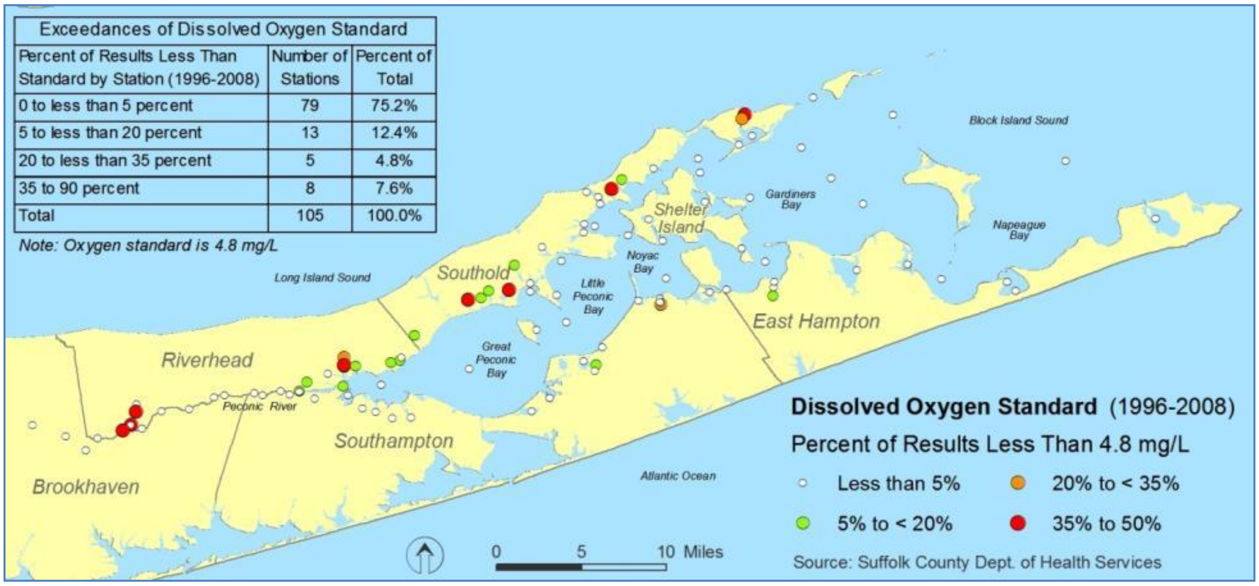


Figure 10-3. Dissolved Oxygen - Percent Occurrences Less than 4.8 mg/L – 1996-2008



Spatial and Temporal Dissolved Oxygen Trends – DO standards were not met in the pre-Brown Tide years in the mouth of the Peconic River, Sawmill Creek, Meetinghouse Creek, Reeves Creek, and Mill Creek. DO remained problematic in the same locations from 1986-1995, but far less often. Many additional sampling locations were added from 1996 to 2008. DO improved in the lower Peconic River, Sawmill Creek, Reeves Creek, and Mill Creek, but numerous locations experienced low DO particularly along the north shore of the estuary.

10.3 Trends in Dissolved Oxygen Standard Violations in 303(d) Waters

Peconic Estuary dissolved oxygen concentration are critically important to aquatic life. The State listed the Lower Peconic River and Tidal Tributaries; Western Flanders Bay and Lower Sawmill Creek; and Meetinghouse Creek, Terrys Creek and Tributaries as being impaired due to low dissolved oxygen levels. As part of this study, data for stations across the estuary were compared to a water quality standard of 5.0 mg/L (the State has since passed a standard of 4.8 mg/L for marine waters, but the TMDL uses 5.0 as the standard). Non-compliance, observations falling below this concentration, was calculated for each station. A summary of the percent of non-compliance is provided in Table 1 at the end of Appendix E. Plots of the DO concentrations and percent compliance by year are also provided in Appendix E.

A Mann-Kendall trend analysis of non-compliance was also calculated. Data was aggregated into four groups, all TMDL Station, the Lower Peconic River and Tidal Tributaries, Terry's Creek and tributaries, and Western Flanders Bay, to provide a sufficiently sized data set to perform the trend analysis. A summary of the trend results is provided in Table 10-1.

Table 10-1. Summary of Mann-Kendall Trend Evaluations for Dissolved Oxygen Compliance

Parameter	Station	Calculated Probability	Conclusion
Dissolved Oxygen	All TMDL Stations	0.334	No Significant Change
Dissolved Oxygen	Lower Peconic River and Tidal Tributaries	0.500	No Significant Change
Dissolved Oxygen	Terry's Creek and Tributaries	0.186	No Significant Change
Dissolved Oxygen	West Flanders Bay and Lower Sawmill Creek	0.625	No Significant Change

The Mann-Kendall tests do not show a statistical trend in compliance. While this may suggest stability in compliance, a number of factors can affect the analysis due the significant variability of oxygen levels. Since the trend is testing percent of compliance, improvements may not be recognized if the values are still below the standard. A review of the results in Section 10.2 suggests that compliance is improving in the 303(d) listed waters.

Compliance (100 percent) with the 5.0 mg/L level was the case in 58 of 129 stations. At another 39 stations, dissolved oxygen exceeded the standard 90 percent of the time (a common threshold). The stations with the lowest compliance rates were 060220 (Meetinghouse Creek), 060260 (Sawmill Creek), 060270 (Riverhead STP), and 060280 (Peconic River mouth). Creek stations were more likely to have low DO, although it should be noted that a number of these were based on very small datasets. In addition, these numbers span the entire period of record; trend analyses suggest that DO values have increased at many stations over time. A summary of these results for the stations included in the TMDL are provided in Table 10-2.

Trends in DO Standards Violations in Impaired Waters *– Compliance with the DO standard is improving in impaired waters: From 1976 – 2008, 58 of 129 stations complied with the standard 100% of the time. At another 39 stations, DO exceeded the standard 90% of the time (a common threshold). Stations with the lowest compliance rates were Meetinghouse Creek, Sawmill Creek, Riverhead STP, and Peconic River mouth. Trend analyses suggest that DO values have increased at many stations.*

Table 10-2. Data Used in Dissolved Oxygen Compliance Trend Evaluation

Grouping	Grouping (long)	Year	Results > 5	Results	Percent in Compliance
All TMDL	All TMDL	1974	1	1	100
All TMDL	All TMDL	1976	29	39	74
All TMDL	All TMDL	1980	3	3	100
All TMDL	All TMDL	1985	4	4	100
All TMDL	All TMDL	1986	2	3	67
All TMDL	All TMDL	1987	13	16	81
All TMDL	All TMDL	1988	35	36	97
All TMDL	All TMDL	1989	32	36	89
All TMDL	All TMDL	1990	6	6	100
All TMDL	All TMDL	1992	6	6	100
All TMDL	All TMDL	1993	6	6	100
All TMDL	All TMDL	1995	7	8	88
All TMDL	All TMDL	1996	11	11	100
All TMDL	All TMDL	1997	2	3	67
All TMDL	All TMDL	1999	52	58	90
All TMDL	All TMDL	2000	70	103	68
All TMDL	All TMDL	2001	92	127	72
All TMDL	All TMDL	2002	50	53	94
All TMDL	All TMDL	2003	47	49	96
All TMDL	All TMDL	2004	100	116	86
All TMDL	All TMDL	2005	142	154	92
All TMDL	All TMDL	2006	83	87	95
All TMDL	All TMDL	2007	74	75	99
All TMDL	All TMDL	2008	38	41	93
LPR & TT	Lower Peconic River & Tidal Tributaries	1974	1	1	100
LPR & TT	Lower Peconic River & Tidal Tributaries	1976	11	21	52
LPR & TT	Lower Peconic River & Tidal Tributaries	1980	3	3	100
LPR & TT	Lower Peconic River & Tidal Tributaries	1985	4	4	100
LPR & TT	Lower Peconic River & Tidal Tributaries	1986	2	3	67
LPR & TT	Lower Peconic River & Tidal Tributaries	1987	3	6	50
LPR & TT	Lower Peconic River & Tidal Tributaries	1988	17	18	94
LPR & TT	Lower Peconic River & Tidal Tributaries	1989	15	18	83
LPR & TT	Lower Peconic River & Tidal Tributaries	1990	6	6	100
LPR & TT	Lower Peconic River & Tidal Tributaries	1992	6	6	100
LPR & TT	Lower Peconic River & Tidal Tributaries	1993	6	6	100
LPR & TT	Lower Peconic River & Tidal Tributaries	1995	7	8	88
LPR & TT	Lower Peconic River & Tidal Tributaries	1996	11	11	100
LPR & TT	Lower Peconic River & Tidal Tributaries	1997	2	3	67
LPR & TT	Lower Peconic River & Tidal Tributaries	1999	52	58	90
LPR & TT	Lower Peconic River & Tidal Tributaries	2000	70	103	68
LPR & TT	Lower Peconic River & Tidal Tributaries	2001	92	127	72
LPR & TT	Lower Peconic River & Tidal Tributaries	2002	50	53	94
LPR & TT	Lower Peconic River & Tidal Tributaries	2003	47	49	96
LPR & TT	Lower Peconic River & Tidal Tributaries	2004	100	116	86
LPR & TT	Lower Peconic River & Tidal Tributaries	2005	142	154	92
LPR & TT	Lower Peconic River & Tidal Tributaries	2006	83	87	95
LPR & TT	Lower Peconic River & Tidal Tributaries	2007	74	75	99
LPR & TT	Lower Peconic River & Tidal Tributaries	2008	38	41	93
TC & T	Terrys Creek & Tributaries	1976	6	6	100
TC & T	Terrys Creek & Tributaries	1987	4	4	100
TC & T	Terrys Creek & Tributaries	1988	6	6	100
TC & T	Terrys Creek & Tributaries	1989	5	6	83
WFB & LS	Western Flanders Bay & Lower Sawmill Creek	1976	12	12	100
WFB & LS	Western Flanders Bay & Lower Sawmill Creek	1987	6	6	100
WFB & LS	Western Flanders Bay & Lower Sawmill Creek	1988	12	12	100
WFB & LS	Western Flanders Bay & Lower Sawmill Creek	1989	12	12	100

11 Trends from Continuous Collection of T, S, and DO

Continuous monitoring data for temperature, salinity, and dissolved oxygen were collected at four locations; Peconic River, Flanders Bay, Great Peconic Bay, and West Neck Bay as shown in Figure 11-1. The monitoring was performed using YSI sondes during the summer for the years from 2002 to 2008. Data were collected 24 hours a day every 15 minutes. These data can be used to gain a better understanding of inter-day differences and diurnal patterns. Descriptive statistics are provided in Table 11-1.

Table 11-1. Summary Statistics for Sondes Monitoring in the Peconic Estuary

Station	Count	Average	Min	Max	Std Dev
FB	8,035	5.96	2.25	11.98	1.54
PR	11,546	2.90	0.00	11.62	2.21
GPB	9,818	6.20	1.96	8.57	1.24
WNB	6,761	6.38	3.16	14.35	1.37
Total	**36,160**	**5.13**	**0.00**	**14.35**	**2.28**

Time series plots of daily means for temperature, salinity, and dissolved oxygen were also generated for each station and are provided in Appendix E. A snapshot of these data from 2005 for dissolved oxygen (DO) is provided in Figure 11-2 for review. The data represented in this figure show both spatial and temporal differences in DO between the four stations for the period portrayed. In 2005, the Peconic River experienced both the greatest summer decline in DO of the four stations and the largest range of concentrations (a symptom of eutrophication). West Neck Bay DO remained above the 5.0 mg/L regulatory standard through most of the summer. Super-saturation was also evident in West Neck Bay a likely result of a fall algal bloom.

Figure 11-1. Sondes locations

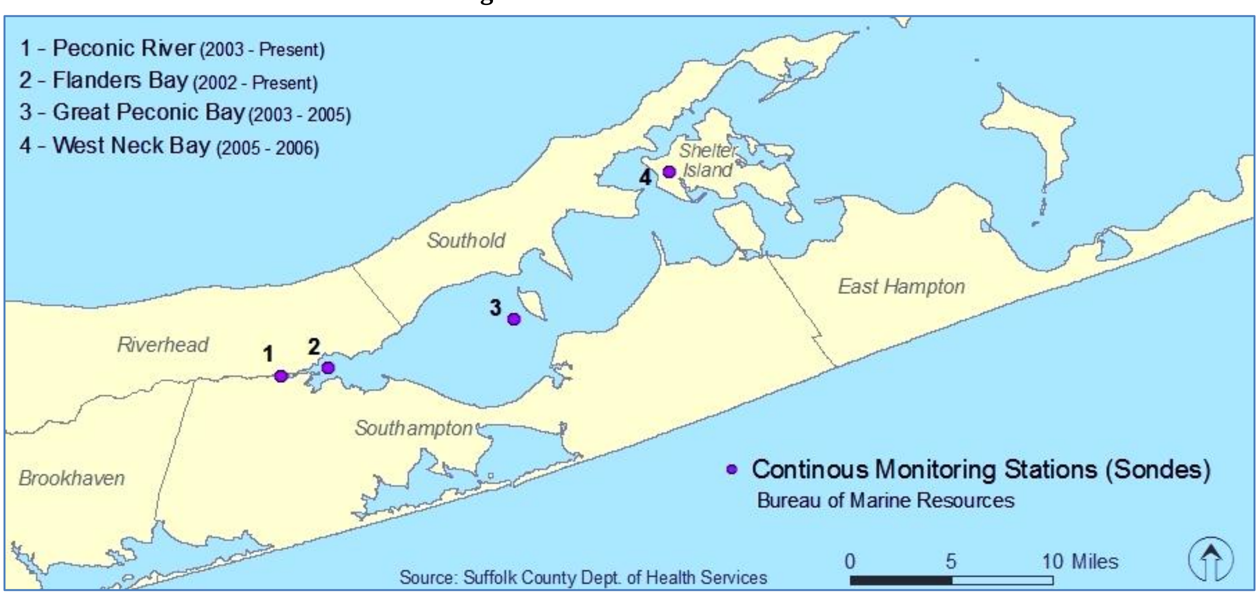
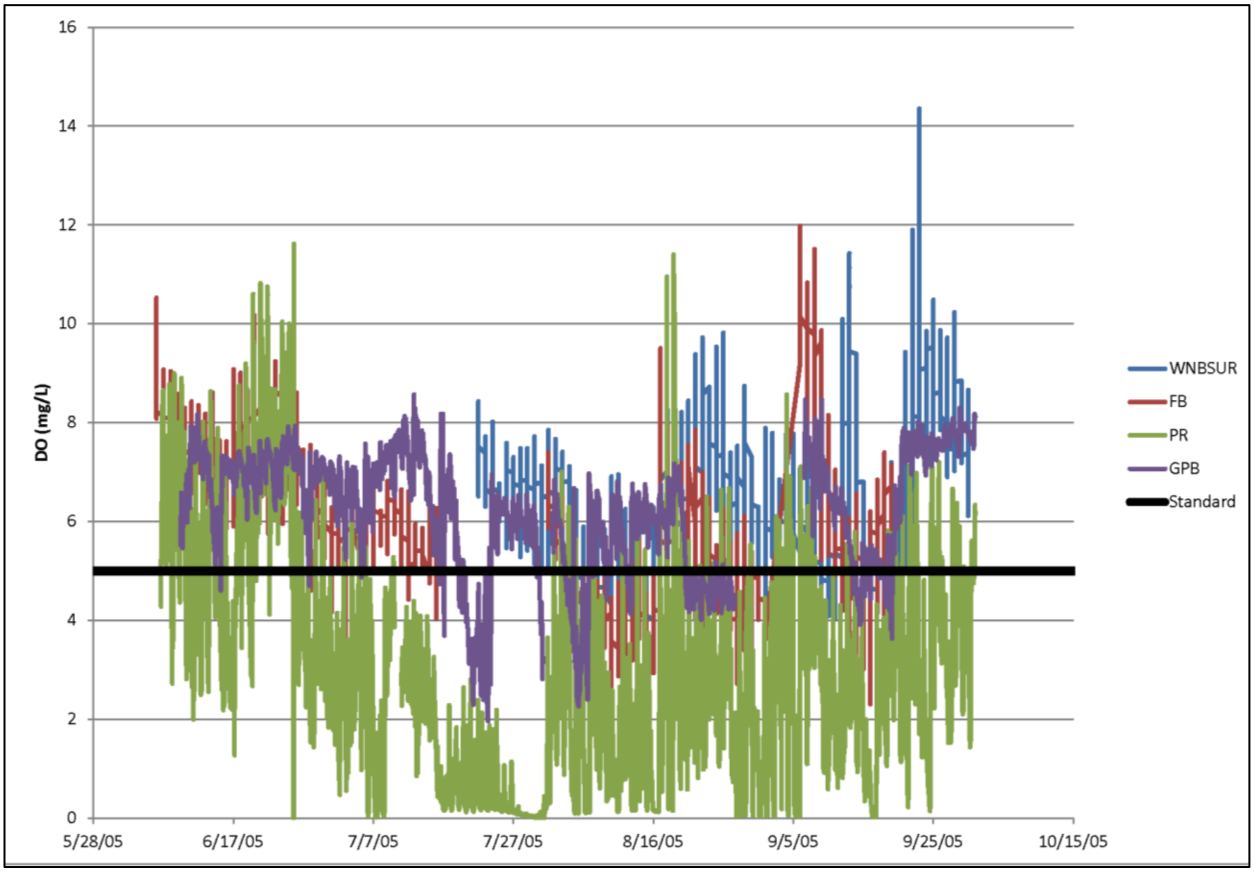


Figure 11-2. Continuous Dissolved Oxygen Data – Surface Stations



***Trends from Continuous Monitoring of T, S, DO** – Sondes were located in the Peconic River, Flanders Bay, Great Peconic Bay, and West Neck Bay. In 2005, the Peconic River experienced the greatest summer decline in dissolved oxygen (DO) of the four stations and the largest range of concentrations (a symptom of eutrophication). West Neck Bay DO remained above the 5.0 mg/L regulatory standard through most of the summer. Super-saturation was evident in West Neck Bay, likely a result of a fall algal bloom.*

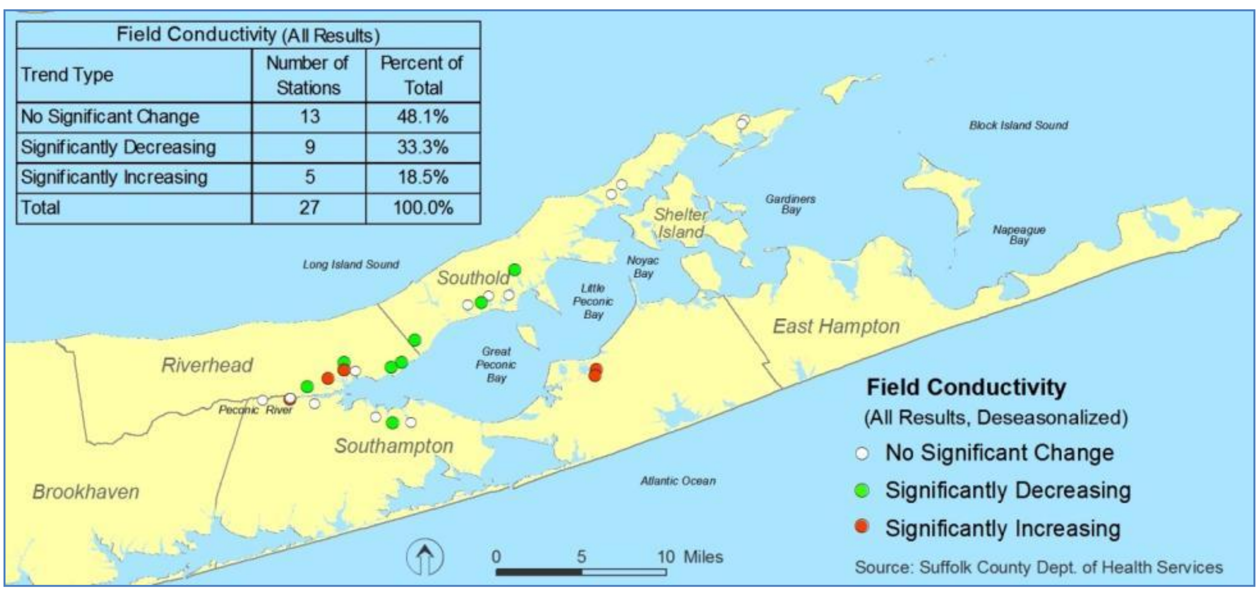
12 Conductivity Trends

Conductivity is affected by the presence of inorganic dissolved solids such as chloride, nitrate, sulfate, and phosphate anions (ions that carry a negative charge) or sodium, magnesium, calcium, iron, and aluminum cations (ions that carry a positive charge). Conductivity increases in the presence of road salt runoff and high nutrient concentrations.

Conductivity was measured in the heads of a number of the creeks and in the Peconic River. Nine stations out of 27 (one third) showed a significant decrease in conductivity (Figure 12-1). Declining conductivity may be due to a decrease in stormwater runoff in those areas. It could also reflect an increase in groundwater flow. Earlier developments used private wells from the shallow Upper Glacial aquifer, whereas in recent years, drinking water and residential irrigation comes from public water derived from the deeper Magothy Aquifer. The addition of public water to shallow groundwater through onsite system effluent and infiltration of irrigation water could contribute to greater groundwater flow and conductivity.

Conductivity increased significantly in five of the stations; Little River, two stations in Fish Cove, Terrys Creek, and Meetinghouse Creek. These changes may reflect increasing nutrient flow into these locations.

Figure 12-1. Conductivity trends



Field Conductivity (All Results)		
Trend Type	Number of Stations	Percent of Total
No Significant Change	13	48.1%
Significantly Decreasing	9	33.3%
Significantly Increasing	5	18.5%
Total	27	100.0%

Conductivity Trends *–Conductivity declined in 9 stations (33 percent), primarily in the heads of a number of north shore creeks. Lower conductivity may reflect improved stormwater management or increasing groundwater flow, possibly a result of greater public water use. Conductivity increased in five stations possibly reflecting increasing nutrient flow; Little River, two in Fish Cove, Terrys Creek, and Meetinghouse Creek.*

13 Pathogen Trends

The NYSDEC has water quality standards for shellfish harvesting and bathing beaches. As Peconic Estuary beaches generally have excellent water quality, pathogens are primarily a concern for shellfishing. The Peconic Estuary program (PEP) Comprehensive Conservation Management Program (CCMP) set a goal of maintaining lands currently open to shellfishing and ultimately opening those that are now closed. The County collects total and fecal coliform samples at all sites. The CCMP includes a pathogen TMDL for 20 of the 25 waterbodies on the State 303d list of impaired waters.

Coliform bacteria include a number of genera that originate in feces (*e.g. Escherichia*) as well as genera that are not of fecal origin (*e.g. Enterobacter*, *Klebsiella*, *Citrobacter*). The test for coliform bacteria is used as an indicator of possible fecal contamination. Fecal contamination can indicate that other and more virulent bacteria and viruses could be present.

The total coliform test measures the presence of bacteria that are found in the soil, in water that has been influenced by surface water, and in human or animal waste. The fecal coliform test measures the presence of coliform bacteria that are present in the gut and feces of warm-blooded animals. The fecal coliform test is therefore a more specific test for the presence of animal or human waste than total coliform. Fecal coliform contamination comes from stormwater runoff, groundwater contaminated by onsite wastewater treatment system effluent, and directly from waterfowl feces. Stormwater runoff includes non-domesticated (wild) animal waste, pet feces, and livestock feces (primarily ducks and horses in the Peconic Estuary watershed).

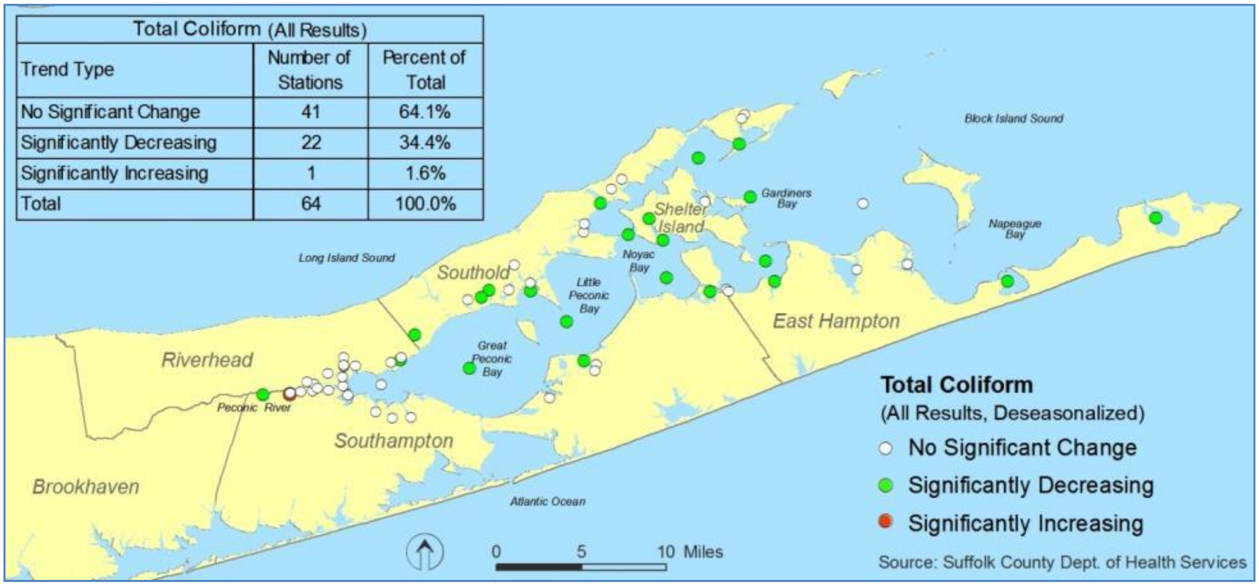
An ongoing study for Suffolk County (Suffolk County Department of Health Services, 2011) concluded that although the contribution from geese to fecal coliform loading is less than previously estimated. The contribution from all waterfowl (ducks, swan, and geese) is the same order of magnitude as and potentially greater than that from pet waste.

Onsite wastewater systems within the groundwater travel zone of 70-80 days contribute coliform bacteria to the Estuary. In most cases, these systems are located on parcels that are adjacent to or across the street from the surface water. Stormwater runoff washes the waste products of domesticated and wild animals onto the streets and into the pipes that discharge into the Estuary.

13.1 Total Coliform

Total coliform declined across the Estuary (Figure 13-1). Of 64 stations, 22 showed significantly decreasing values (34 percent), 41 were unchanged (64 percent), and only one significantly increased. Even some of the creeks showed improvement, notably Brushes Creek (200160), Downs Creek (200190), and Hall’s Creek (200180). The exception to the general decline was the station in the Little River (200011) which exhibited a significant increase in total coliform over the data collection period.

Figure 13-1. Total coliform trends



Total Coliform (All Results)		
Trend Type	Number of Stations	Percent of Total
No Significant Change	41	64.1%
Significantly Decreasing	22	34.4%
Significantly Increasing	1	1.6%
Total	64	100.0%

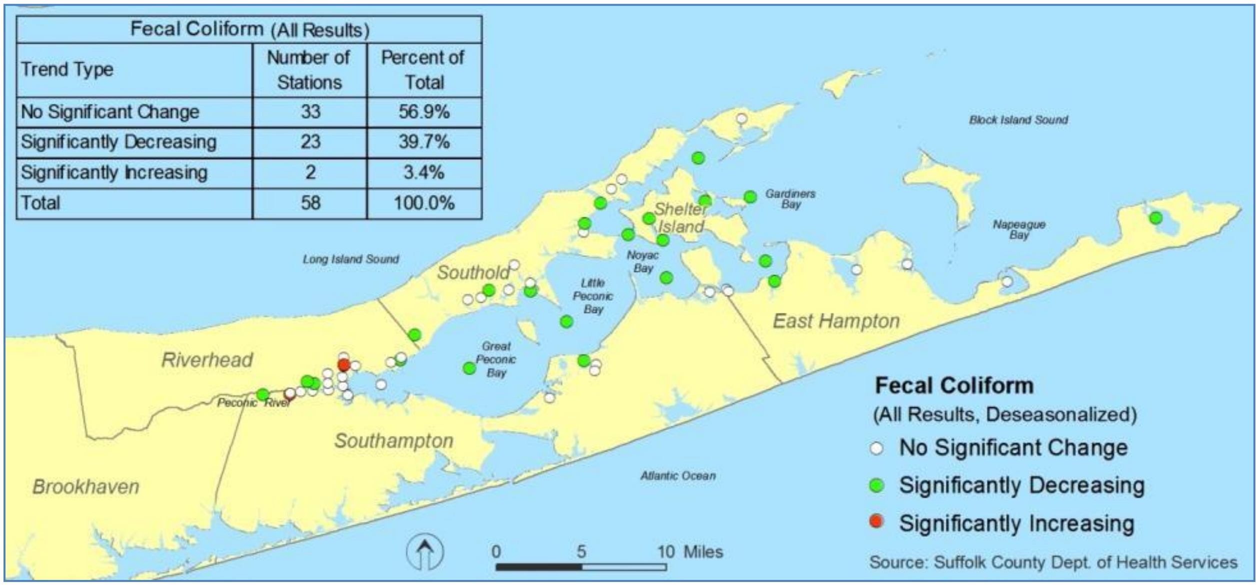
The decline in total coliform is not likely related to changes in onsite wastewater systems as the number of these along the coastline has increased with new development. It is also not likely related to the decline in duck farming, as coliform in those creeks has not changed.

Stormwater improvements implemented since the 1970's have almost certainly contributed to the decline in coliform concentrations. Public awareness of the need to protect estuarine water quality has certainly increased since the 1970s. This has translated into a big improvement in the number of people that pick up their pets' waste - from near zero to an estimated 50 percent of pet owners (Swann, 1999). Recreational boaters have been able to use pumpout stations and vessels and since 2002 have been prohibited from discharging waste into the Estuary, a 'no-discharge zone.'

13.2 Fecal Coliform

Fecal coliform declined in 23 (40 percent) of 58 stations (Figure 13-2). Only Little River (200011) and Meetinghouse Creek (200042) exhibited increases in fecal coliform.

Figure 13-2. Fecal coliform trends



Fecal Coliform (All Results)		
Trend Type	Number of Stations	Percent of Total
No Significant Change	33	56.9%
Significantly Decreasing	23	39.7%
Significantly Increasing	2	3.4%
Total	58	100.0%

Coliform Trends *– Total and fecal coliform declined in 39 and 40 percent of stations, respectively. Conductivity decreased in many stations with declining coliform, suggesting improved stormwater management.*

14 Organic Carbon Trends

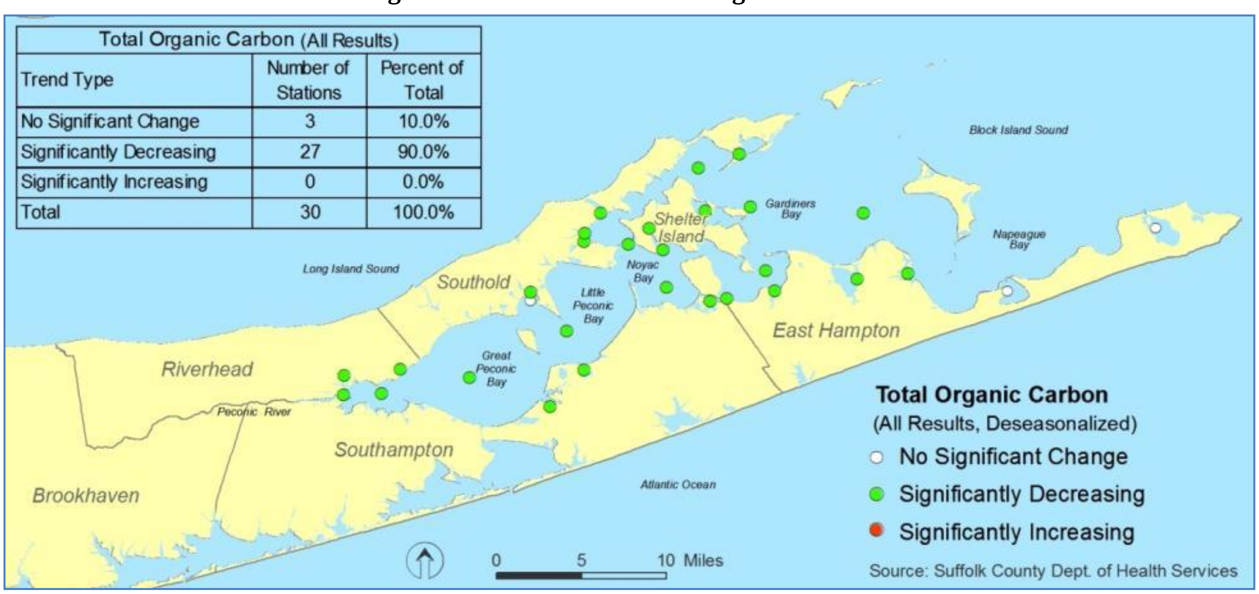
Total organic carbon (TOC) in aquatic environments comes primarily from decaying organic matter and the release of metabolic compounds from living organisms. The New Jersey / New York Harbor Estuary Program considers TOC less than two percent to be good, 2-5 percent to be fair, and greater than five percent to be poor. Average concentrations tended to be above 2 mg/L for embayments west of Little Peconic Bay.

Particulate organic carbon represents only about one percent of TOC, the rest of the organic carbon is dissolved (Sharp, 1973). Early research cited by Sharp indicated that of the particulate organic carbon, in near surface waters, about 10 to more than 50 percent of the particulate organic matter is living, the remainder is detritus. Clearly, the percentage increases substantially during algal blooms.

The vast majority of TOC is dissolved (*i.e.* <0.45 or 0.22μm) and comes from natural and anthropogenic sources. Natural sources include re-suspension of organic material from the sediments and from the activity of microorganisms (release of polypeptides and polysaccharides). Anthropogenic sources include wastewater effluent and stormwater runoff. Much of the TOC is metabolized by heterotrophic bacteria into simpler compounds.

Total organic carbon declined across much of the Estuary (Figure 14-1). In general, a decline in TOC is regarded as a sign that water quality has improved. No stations showed a significant increase in TOC, whereas in 27 of 30 stations (90 percent), TOC declined significantly. Meetinghouse Creek (station 200220), one of the more problematic creeks, showed a decline in TOC.

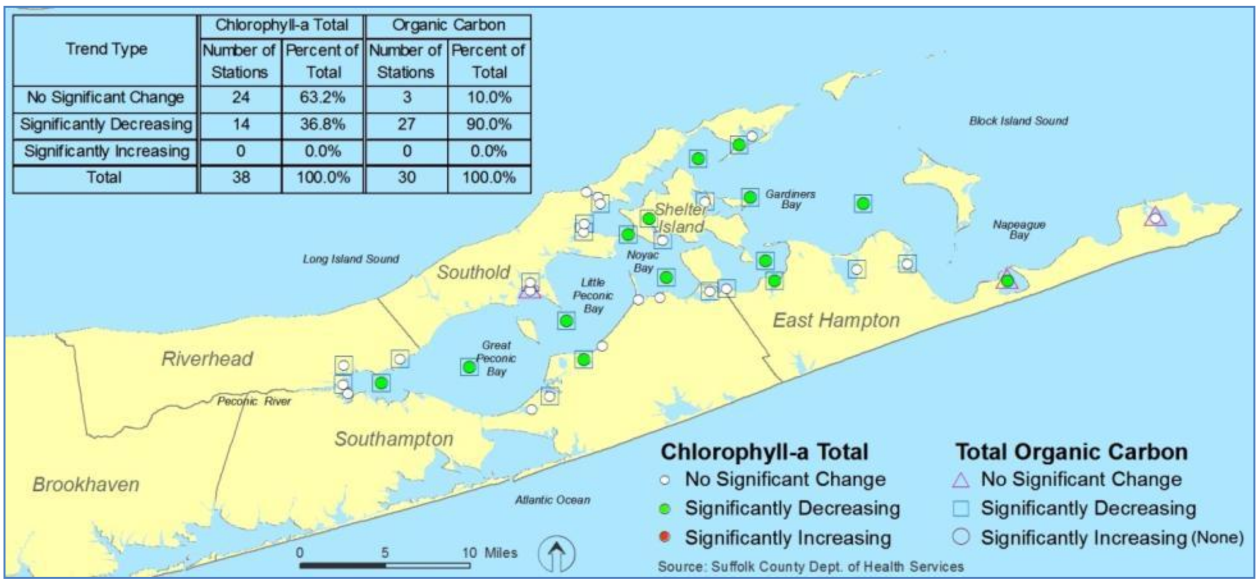
Figure 14-1. Trends in Total Organic Carbon



In most cases, the concentration of TOC is a reflection of phytoplankton activity. Algal blooms die and the sink to the bottom where sediment bacteria break down the cells and metabolize their contents. That process releases TOC into the water column. Thus, one would expect that as algal production declines, so too would TOC. In fact, trends in chlorophyll-a (see section 15, below) are very similar to those of TOC (see Figure 14-2 and Figure 14-3).

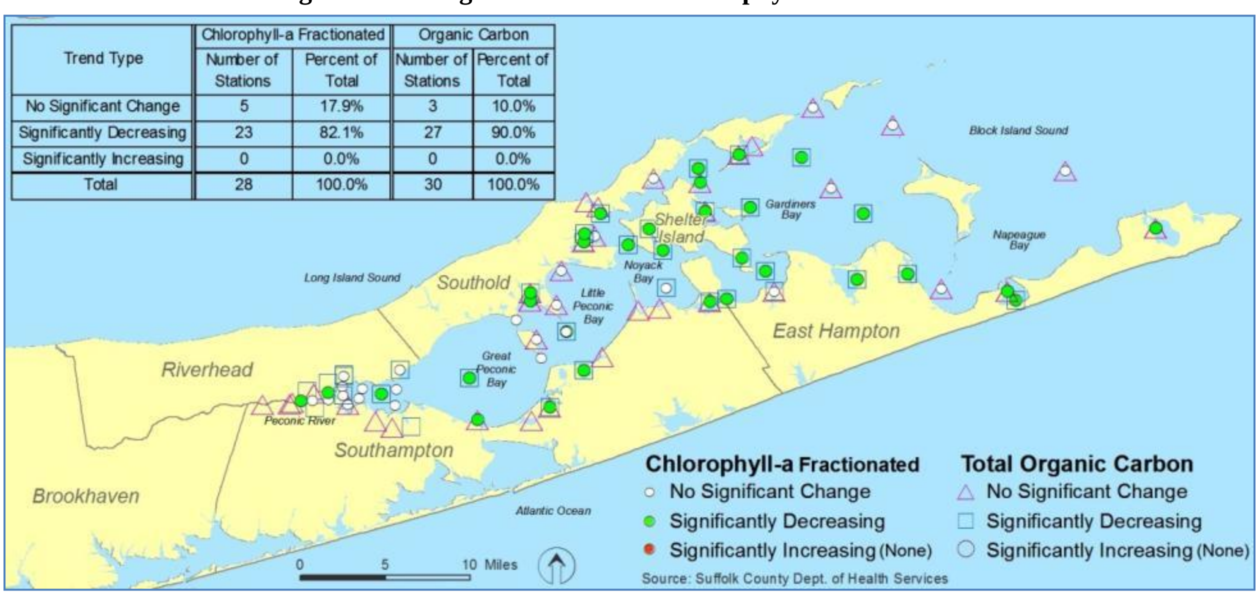
The other influences on organic carbon were improvements to the Riverhead wastewater treatment plant effluent (from plant upgrades) and the closure of most of the duck farms in the 1980s.

Figure 14-2. Organic carbon and Chlorophyll-a - Total



Trend Type	Chlorophyll-a Total		Organic Carbon	
	Number of Stations	Percent of Total	Number of Stations	Percent of Total
No Significant Change	24	63.2%	3	10.0%
Significantly Decreasing	14	36.8%	27	90.0%
Significantly Increasing	0	0.0%	0	0.0%
Total	38	100.0%	30	100.0%

Figure 14-3. Organic carbon and Chlorophyll-a Fractionated



Trend Type	Chlorophyll-a Fractionated		Organic Carbon	
	Number of Stations	Percent of Total	Number of Stations	Percent of Total
No Significant Change	5	17.9%	3	10.0%
Significantly Decreasing	23	82.1%	27	90.0%
Significantly Increasing	0	0.0%	0	0.0%
Total	28	100.0%	30	100.0%

Total Organic Carbon Trends *– Total organic carbon, made up of particulate and dissolved organic carbon, declined across much of the Estuary. Trends in chlorophyll-a are similar to those of TOC, suggesting the decline is evidence of reduced algal bloom intensity/frequency. Improvements to the Riverhead STP and the closure of all but one duck farm in the 1980s may also be responsible for the decline.*

15 Chlorophyll-a Trends

Chlorophyll-a measurements are a proxy for phytoplankton concentrations. All phytoplankton species have chlorophyll-a pigments, though their concentration varies widely with species, growth stage, season, and more. Nonetheless, chlorophyll-a is a reasonably good measure of temporal and spatial changes in algal activity. Total chlorophyll-a values include all species. Fractionated chlorophyll-a is a measure of the pigment in those species that pass through a 10µm filter, thus representing only small nanoplankton.

Of the 38 stations where sufficient total chlorophyll-a measurements were available (Figure 15-1), values were unchanged for 24 stations (63 percent), declined for 14 stations (37 percent), and increased at none of the stations. The fact that none of the stations showed an increase in chlorophyll-a and a third actually declined is a significant result. If chlorophyll-a is reflective of estuarine health, then an overall improvement has occurred. It is particularly significant to see that total chlorophyll-a declined at the mouth of the Peconic River and in western Flanders Bay, locations that experienced the greatest water quality impairments in the past.

Of the 28 stations where fractionated chlorophyll-a was measured, 5 remained unchanged (18 percent), 23 decreased (82 percent), and none increased (Figure 15-2). This data confirms that the concentrations of small nanoplankton (including the Brown Tide) have declined across the Estuary over the 30-year period. According to research cited in a Suffolk County study of the history of duck farming, phytoplankton species shifted from a mixed community of larger forms such as diatoms (~5µm) to a unialgal community dominated by smaller forms (1-4µm) or chlorophytes during the peak years of duck farming in the 1960s (USACE and Suffolk County Planning, 2009).

If the overall decline in chlorophyll-a reflects a decline in algal production in the Estuary, then one might expect a corresponding decline in one or more of the nitrogen parameters. This is, however, not the case – most of the nitrogen parameters show a mix of trends - stations where nitrogen compounds increased, decreased, and remained unchanged (see section 0).

The data are confounded, however, by the very high phytoplankton densities that were typical of the Brown Tide years (two to three orders of magnitude greater than 'normal' cell densities). The overall decline in chlorophyll-a is driven by the disappearance of those blooms.

Figure 15-1. Trends in Chlorophyll-a Total

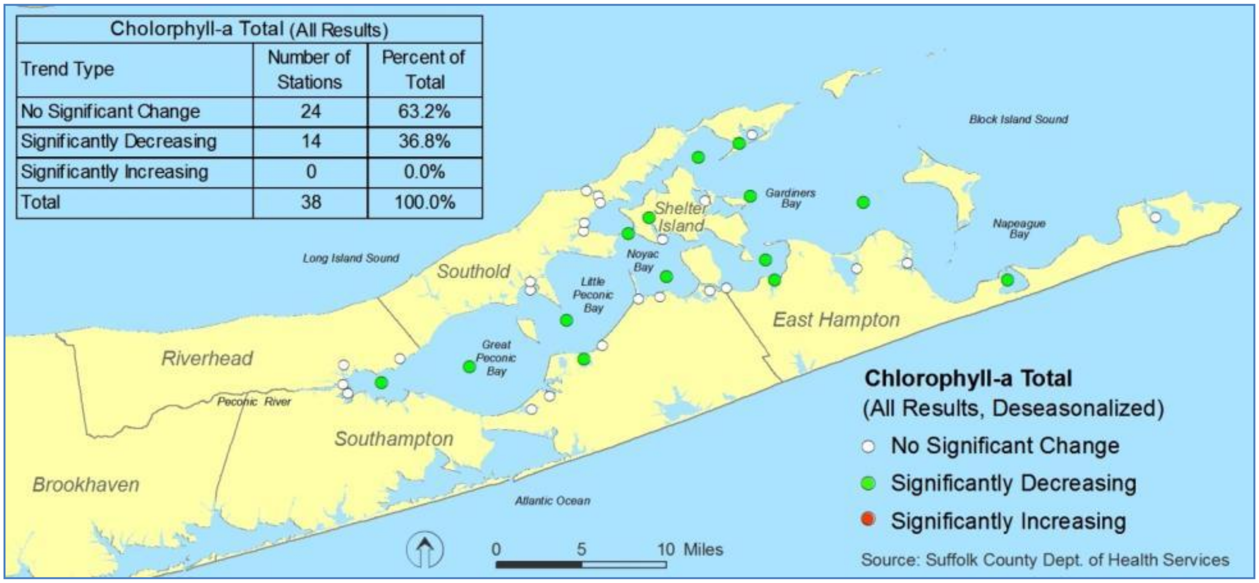
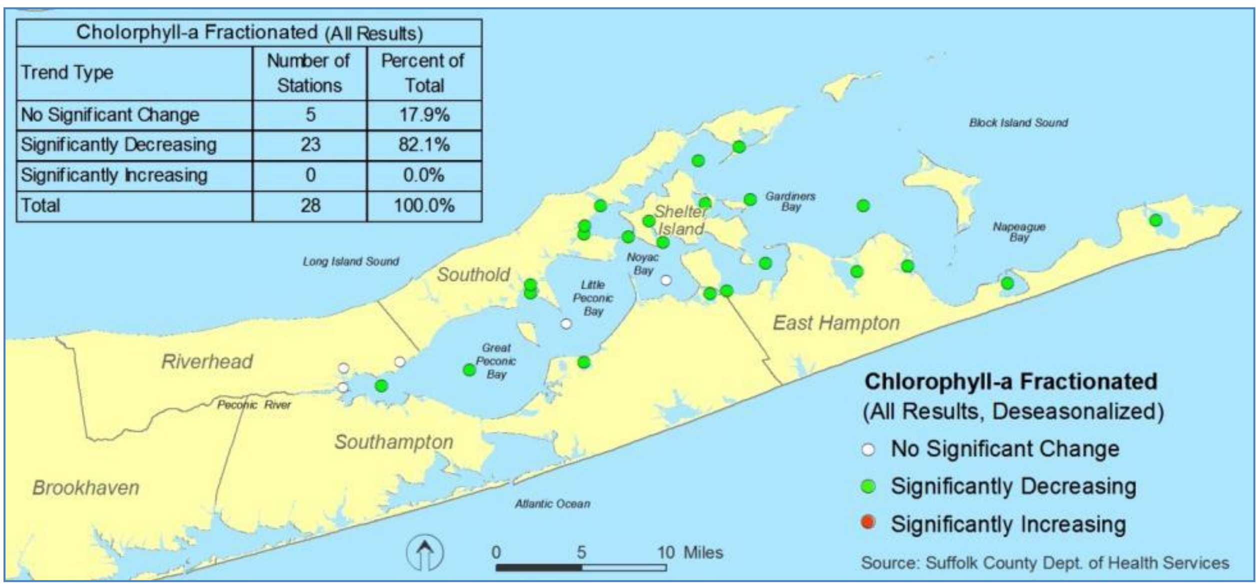


Figure 15-2. Trends in Chlorophyll-a Fractionated



Chlorophyll-a Trends *– Chlorophyll-a declined in 37 percent of stations and 63 percent were unchanged. Nanoplankton declined in 82 percent of stations. Results reflect declining Brown Tide cell counts and improving water quality.*

16 Metals and Organic Compound Trends

16.1 Metals

Metals such as cadmium, copper and lead typically enter waterbodies due to runoff from adjacent land. These metals are most mobile when they accumulate on impervious surfaces from vehicle exhaust, brake linings, and tire and engine wear. Cadmium was selected as a surrogate for evaluating trends in metals.

Cadmium showed the highest percentage of significantly increasing trends for all parameters at twenty percent. Trace metal pollutants can travel to estuaries from urban runoff.

Trace Metal Trends *– Cadmium was used as a surrogate for evaluating trends in trace metals. It increased 20 percent. Its source is unknown, though trace metals are usually a component of stormwater runoff.*

16.2 Organic Compounds

Organic compounds such as benzene, benzo (a) pyrene, and phenathrene are chemicals that may have negative human and wildlife health effects. These compounds are produced for direct use as gas additives or solvents, are used in the production of other compounds such as plastics and phenols, and are created through burning fossil fuels.

The monitoring data for the Peconic estuary were reviewed to assess compliance with relevant water quality standards. Measurements for these organic compounds were below the detection limit 100 percent of the time for all stations.

Organic Compound Trends *–Concentrations of organic compounds like certain PAHs were below the detection limit 100 percent of the time for all stations.*

16.3 Herbicides and Pesticides

Toxins include inorganic (primarily metals) and organic compounds. The County has found an increasing number of pesticides and herbicides in North Fork streams including compounds such as Alachlor, Aldicarb, Dinoseb, Imidacloprid, Metolachlor, Metalaxl, Ronstar, Siazine, and Terbacil. Volatile organic compounds (VOCs) have included TCA, THM, Freon, methylene chloride, toluene, and MTBE.

Personal care product (PCP) and pharmaceutical contamination of groundwater have received recent attention. The County recorded some detections in Peconic Estuary streams.

The monitoring data for the Peconic Estuary were reviewed to assess compliance with water quality standards. The standards, however, are for drinking water and do not necessarily reflect potential effects on marine organisms. The US EPA has an extensive ecological toxicity database (ECOTOX) that provides toxicity information for thousands of chemical compounds and for hundreds of aquatic organisms at different life stages and under a variety of environmental conditions. County data is useful for examining potential impacts on specific organisms. The discussion below is only relative to drinking water standards.

Concentrations of alachlor and aldicarb were below the detection limit and water quality standard 100 percent of the time at all stations. The remaining constituents were detected in some samples with the highest detection being metalaxl, a fungicide, at 9.9 percent of the time. There currently is no surface water standard for this compound. A review of results for other herbicides and pesticides show that while these compounds may be detected, values are generally well below drinking water standards. For example, Simazine, an herbicide that does have a water quality standard, was detected in 0.7 percent of samples but was above the water quality standard only 0.3 percent of the time. All of the detects occurred in the period between 2001 and 2004.

Herbicides and Pesticides *– Concentrations of alachlor and aldicarb were below the detection limit and drinking water standard 100 % of the time at all stations. The remaining constituents were detected in some samples with the highest detection being metalaxl, a fungicide, at 9.9 percent of the time. Other herbicides and pesticides were detected but generally at well below drinking water standards.*

17 Correlation Analysis

Pearson and (nonparametric) Spearman correlation coefficients (based on ranks of the data) were calculated for annual averages of selected constituents. The correlation coefficients measure the strength of a linear relationship between two data sets, that is, how much association exists between an increase or decrease in the concentration of one parameter and the concentration of another parameter. These correlation coefficients range from -1 to 1. A zero value would indicate no observed correlation, whereas more negative or positive values indicate increasing correlation, either inverse or direct, respectively.

A correlation analysis was performed to determine the correlation between nitrogen components, algal populations, and organic carbon. The correlations tests and the results of the Pearsons tests are provided in Table 17-1.

Table 17-1. Pearson's Tests of Correlation for Nitrogen, Chlorophyll-a, and Dissolved Oxygen

Variable 1	Variable 2	Pearson Coefficient	Pearson Probability	Pearson Significance
Annual average DON	Annual average Chlorophyll-a - Total	-0.069	0.792	NS
Annual average DON	Annual average Chlorophyll-a - Total	-0.069	0.792	NS
Non-summer average DON	Annual average Chlorophyll-a - Total	-0.215	0.424	NS
Non-summer average TN	Annual average Chlorophyll-a - Total	0.109	0.630	NS
Annual average DON	Annual average DO	-0.062	0.785	NS
Non-summer average TN	Annual average DO	0.004	0.983	NS
Annual average DON	Annual average Total Organic Carbon	-0.073	0.788	NS
Non-summer average TN	Annual average Total Organic Carbon	-0.238	0.326	NS
Annual average DON	Annual average Chlorophyll-a - Fractionated	-0.327	0.217	NS
Non-summer average DON	Annual average Chlorophyll-a - Fractionated	-0.413	0.112	NS

Results did not show any strong correlation for any of the combinations. While nitrogen is well documented as the limiting factor for algal growth in marine systems, this could not be clearly substantiated with this analysis. This may be due to the lag-time associated with elevated nitrogen levels and resulting algal blooms, the delayed impact due to changes in groundwater concentrations, the interplay of rainfall, groundwater recharge, and algal blooms, or changes in the ratio of dissolved organic to inorganic nitrogen levels in the estuary. A much more focused correlation analysis, taking into account spatial and temporal variations would likely result in a more definitive conclusions. Literature studies for the connections between nutrients and algal blooms should be relied on as the primary source of information.

18 Meeting the Goals of the CCMP

An important objective of this study is to determine if the goals of the Peconic Estuary Program CCMP pertaining to water quality have been adequately met. Relevant water quality goals are reproduced in the sections below and a determination made as to whether the goals have been adequately met.

18.1 Brown Tide

The following CCMP goals pertain to Brown Tide:

- *Determine the chemical, physical and biological factors responsible for producing, sustaining and ending blooms of the Brown Tide organism, Aureococcus anophagefferens.*
- *Determine what management actions can be undertaken to prevent or, if that is not possible, to mitigate the effects of recurrent Brown Tide blooms on the ecosystem and economy of the Peconics.*

The literature review compiled as part of this effort details the extensive studies related to the causes of Brown Tide. The ratio of dissolved organic to dissolved inorganic nitrogen was identified as one of the strongest influences on Brown Tide occurrence. Salinity, total nitrogen, and summer nitrogen were also identified as potential factors.

Brown tide frequency and intensity have decreased since the early 1990s suggesting that conditions driving the blooms have changed. As a definitive cause of the blooms has not been identified, it is unclear what management efforts, if any, may have led to a decline in the blooms. A review of monitoring data suggests that areas on the north side of the estuary and around Shelter Island still have high nitrogen concentrations and high ratios of dissolved organic to dissolved inorganic nitrogen. These areas may be more likely to see Brown Tide blooms if other conditions are also supportive.

Meeting the Goals of the CCMP - Brown Tide - *Brown tide frequency and intensity declined since the early 1990s suggesting that conditions driving the blooms have changed. As no definitive cause of the blooms or their decline has been determined, it is unclear what management actions would be most likely to reduce the likelihood of future blooms.*

18.2 Nutrients

The following CCMP goals pertain to nutrients:

- *No net increase in western estuary. Immediately prevent net increases in nitrogen loading to the surface waters of the western estuary (Peconic River and Flanders Bay) to prevent worsening of current dissolved oxygen (DO) stresses in the marine surface waters of the area.*

- *Long-term reductions in western estuary. Develop and implement a long-term nitrogen load reduction strategy to the western estuary, to optimize surface water conditions for dissolved oxygen, with ancillary consideration of potential benefits to submerged aquatic vegetation (especially eelgrass) habitat.*
- *Eelgrass habitat optimization in shallow water. Maintain and, where cost-effective, improve conditions with respect to nitrogen (and related chlorophyll-a, light extinction, and possibly other parameters) in shallow waters (less than three meters) to optimize eelgrass habitat.*
- *Water quality preservation in eastern waters. Implement a "water quality preservation" policy in eastern estuary waters (east of Flanders Bay) to prevent degradation which could adversely impact the high quality of those surface waters.*
- *Subwatershed management. Focus on characterization of peripheral creeks and embayments and management of their subwatersheds; optimize surface water quality in these areas, which are often highly productive but poorly flushed and subject to environmental stresses.*
- *Load allocation in the entire watershed. Develop and implement a load allocation strategy for point and nonpoint sources in the entire estuary, which accomplishes the above objectives.*

Trend analyses have shown that nutrient levels have been stable or decreased in many parts of the estuary. Comparisons of box and whisker plots for pre- and post-CCMP nutrient levels show a clear decrease in many of the stations since the CCMP was implemented. A few locations, however, have shown increases in constituents such as ammonia and nitrate-nitrites. Continued watershed management should focus on these constituents, especially along the north side of the estuary and near Shelter Island where conditions are amenable to Brown Tides.

Long-term reductions in nutrient concentrations will be best achieved through improved land use management. The vast majority of nitrogen entering the Estuary comes from groundwater and not point sources. Nitrogen enters groundwater from onsite wastewater treatment systems (OWTS) and fertilizer applications (agricultural and residential).

The largest non-point sources of nitrogen to the Peconic Estuary are atmospheric deposition and groundwater (Table 7-5, Table 7-6, and Figure 7-6), accounting for 97 percent of the nitrogen inputs according to the Peconic Estuary nitrogen TMDL (Suffolk County Department of Health Services, 2007). Atmospheric deposition accounts for 56 percent of nitrogen contributed to the Estuary and groundwater 41 percent. Groundwater constitutes 93 percent of the nitrogen input to the Estuary if atmospheric deposition is not considered (Table 7-6 and Figure 7-7). Stormwater is responsible for only 0.9 percent of the nitrogen entering the Estuary or 2.0 percent if atmospheric deposition is not included.

Land use should be an important focus of future Peconic Estuary efforts. Though management of atmospheric deposition is beyond the jurisdiction of local authorities, the County and towns can influence the quality of groundwater through land use management. The conclusions reached by the County in 1999 (Nuzzi & Waters, 1999) are still valid. The authors reported that the dominant nitrogen sources as agricultural (2,700 lbs/day or 41 percent of total nitrogen loading) and residential development (40 percent of total nitrogen loading). Agricultural loading was three times greater than human sanitary waste and almost double the residential nitrogen fertilizer load. The authors also noted that agricultural land has a per-acre total nitrogen loading rate approximately double that of residential land. The residential component included three contributors: human waste, fertilizer, and a third factor that combined animal waste, natural precipitation, and soil mineralization. The authors pointed to the utility of parsing out the human waste and fertilizer components for management purposes.

Future Peconic Estuary management efforts may be best focused on ways to reduce nitrogen inputs to groundwater. For example, agricultural loading is more than 30 times that of the Riverhead wastewater treatment plant. Efforts and capital funding may be better spent on finding crops or varieties that require less fertilizer than on further nitrogen reductions by the Riverhead wastewater treatment plant. In fact, agriculture has already changed because of market forces. There are now more vineyards (which require far less fertilizer than row crops) and less potato farms (which require large nitrogen inputs). Unfortunately, changes in land use are reflected slowly in groundwater discharges to the Estuary, as its travel time to the Estuary is up to 25 years or more.

The County should consider focusing on new residential sewering or alternative on-site wastewater treatment systems that reduce nitrogen output further than traditional cesspool and septic systems, rather than on further wastewater treatment plant (STP) upgrades. The Riverhead wastewater treatment plant completed a major upgrade that lowered its nitrogen contribution from 35 mg/l in 1999 to under 10 mg/l in the years since tertiary treatment was completed in 2001. The Riverhead STP is responsible for only two percent of the nitrogen entering the Peconic Estuary (exclusive of atmospheric deposition), whereas residential nitrogen loading represents almost 40 percent of the nitrogen to the Estuary. Sewering can reduce nitrogen concentrations from 45 to 10 mg/L, while further treatment plant upgrades costing approximately $20 million will reduce nitrogen from 10 to 5 mg/L. As groundwater nitrogen from all OWTS inside the contributing area ultimately reaches the Estuary, sewering of at least all hamlet centers should be a priority for consideration.

As 25 to 50 years of historic nitrogen will continue to flow to the Estuary via groundwater, other mitigation measures might also be considered by the County. Technologies exist to stimulate *in situ* microbial denitrification of groundwater. These methods include permeable reactive barriers and injection of compounds to create conditions conducive to bacterial denitrification. Such technologies should be investigated for use in creeks and small embayments with high nutrient loadings.

Meeting the Goals of the CCMP - Nutrients *- Nutrient levels show a clear decline in many areas of the Estuary since the CCMP was implemented and have been stable in other areas. Long-term nutrient reductions are best achieved through improved land use management. Exclusive of atmospheric deposition, the vast majority of nitrogen entering the Estuary is from groundwater (93%). Management of nitrogen loading to the groundwater that flows to the Estuary is a priority. A focus on nitrogen loading from sources other than the STPs may be most fruitful. Agricultural and septic system nitrogen loading are the two largest contributors. Sewering can reduce nitrogen concentrations from 45 to 10 mg/L, while further treatment plant upgrades costing $18 million will reduce nitrogen from 10 to 5 mg/L. As groundwater nitrogen from all onsite systems inside the contributing area reaches the Estuary, sewering of at least all hamlet centers should be a priority consideration. As 25 to 50 years of historic nitrogen will continue to flow to the Estuary via groundwater, other mitigation measures should be considered. Technologies to stimulate in situ microbial denitrification in groundwater include permeable reactive barriers and bio-augmentation. Such technologies should be examined first for embayments with high nutrient loadings.*

18.3 Habitat & Living Resources

The following CCMP goals pertain to habitat and living resources:

- *Preserve and enhance the integrity of the ecosystems and natural resources present in the study area so that optimal quantity and quality of fish and wildlife habitat and diversity of species can be assured and conservation and wise management of the consumable, renewable natural resources of the estuary are promoted and enhanced.*
- *Protect and enhance biogeographical areas within the Peconic watershed with concentrations of high quality spawning, breeding, feeding, and wintering or seasonal habitat for shellfish, finfish, waterfowl, shorebirds, anadromous fish, and rare plant, animal, and natural communities.*
- *Protect and enhance the ecosystems and the diversity of ecological communities and habitat complexes throughout the system, particularly tidal wetlands, eelgrass meadows, and beaches and dunes by preventing or minimizing loss, degradation, and fragmentation and by maintaining and restoring natural processes essential to the health of the estuary and its watershed.*
- *Restore degraded habitats to maintain or increase native species and community diversity, provide connectivity of natural areas, and expand existing natural areas.*
- *Foster recreational and commercial uses of the Peconic Estuary that are sustainable and compatible with protection of biodiversity.*

- *Protect and enhance species which are endangered, threatened, or of special concern throughout the system by mitigating stresses to these species and ensuring essential habitats crucial for their survival.*
- *Promote coordination and cooperation among Federal, state, and local governments and stakeholders to maximize protection, stewardship, and restoration of the Peconic Estuary.*
- *Develop and carry out an estuary-wide research, monitoring, and assessment program to guide and evaluate management decisions concerning the estuary and to ensure management and policy decisions are based on the best available information.*

Water quality improvements in the Peconic Estuary over the past 30 years have likely generated habitat improvements for aquatic organisms. Nitrogen reductions in particular have led to lower chlorophyll-a concentrations, an indication that algal blooms have declined. Declining algal blooms can lead to improved water clarity with consequent improvements to eelgrass habitat. Less intense and fewer blooms leads to higher DO concentrations, which benefits benthic and pelagic organisms. Reduced algal activity can also substantially reduce the accumulation of organic material. As less organic matter accumulates in the sediments, sediment oxygen concentrations can rise as microbial degradation declines. Less re-mineralization also follows with less nutrient release to the water column.

Meeting the Goals of the CCMP – Habitat and Living Resources *– Nitrogen reductions have reduced algal blooms and chlorophyll-a concentrations. Fewer and less intense algal blooms improve water clarity, which is important to eelgrass survival. A decrease in algal blooms leads to higher DO concentrations, which benefits benthic and pelagic organisms. Reduced algal activity also reduces the accumulation of organic material in the water column and in the sediments, leading to a decrease in benthic oxygen demand as microbial degradation declines. Less re-mineralization also follows with less nutrient release to the water column. Future groundwater nitrogen reductions will further protect marine habitat.*

18.4 Pathogens

The following CCMP goals pertain to pathogens:

- *To minimize health risks due to human consumption of shellfish.*
- *To promote, to the maximum practicable extent, the social and economic benefits which have been associated with the Peconic Estuary system.*
- *To maintain the current status of certified (seasonally and year-round) shellfish beds and re-open uncertified beds by eliminating or reducing pathogen (indicator) inputs to the Peconic Estuary System.*
- *To minimize the closure of bathing beaches in the Peconic Estuary while adequately protecting human health.*

Pathogen levels have shown a significant decrease at approximately one third of the monitoring stations with significant trends. This indicates that efforts have been successful in reducing sources of bacteria to the Peconic Estuary. Pathogen reductions can make it possible to expand areas that are certified for shellfish harvesting. Pathogen reductions are likely tied to fewer duck farms, improved stormwater management by area municipalities and public education on the need to clean up after pets.

Meeting the Goals of the CCMP – Pathogens – *Pathogen levels declined significantly at one third of stations. Efforts since the CCMP successfully reduced bacterial loading to the Estuary. Pathogen reductions make it possible to expand areas certified for shellfish harvesting. Pathogen reductions are likely tied to fewer duck farms, improved stormwater management by area municipalities and public education on the need to clean up after pets.*

18.5 Toxics

The following CCMP goals pertain to toxics:

- *Measure the levels of toxics in the environment to discern trends in environmental quality and to determine the effectiveness of management programs.*
- *Minimize human health risks due to the consumption of shellfish, finfish, and drinking water.*
- *Protect and improve water and sediment quality to ensure a healthy and diverse marine community.*
- *Eliminate where possible, and minimize where practicable, the introduction of toxic substances to the environment, through regulatory and non-regulatory means.*
- *Where toxic contamination has occurred, ensure clean-ups occur quickly, and according to the most appropriate and stringent environmental standards.*

Toxics such as organic compounds, pesticides, and herbicides are rarely detected in the Peconic Estuary. Some measurements have identified these constituents and in recent years, a few have exceeded water quality standards. Concerns have been raised that personal care products and pharmaceuticals are increasingly found in wastewater and drinking water. Pesticide use may have declined over the years with the decline in farming acreage, but the number of pesticides found in groundwater has increased. All these compounds should be monitored, particularly in groundwater.

Meeting the Goals of the CCMP – Toxins – *Toxics such as organic compounds, pesticides, and herbicides are rarely detected in the Peconic Estuary. Pesticide use may have declined with farming acreage, but the number of pesticides found in groundwater has increased.*

18.6 Post-CCMP Management

The following CCMP goals pertain to post-CCMP management:

- *Create a stable and effective management structure for CCMP implementation.*
- *Ensure widespread public agency participation/representation and use existing authorities to the maximum extent possible.*
- *Develop and implement an integrated long-term monitoring plan for water quality and habitats/living resources issues with a coordinated data management strategy.*
- *Track the progress of CCMP implementation (commitments, outcomes, and environmental effects), providing routine reporting and allowing for refining of management approaches*.

As land use has a disproportionately large impact on Peconic Estuary water quality, participation in post-CCMP water quality management by the County and East End town planning departments is recommended. Continued tracking and research into harmful algal blooms is recommended even as overall algal densities and Brown Tide have declined. Red tides continue to occur, adversely affecting the health of the estuary. More extensive groundwater sampling and analyses (see section below) will help land use planners manage the impacts of agriculture and residential development and help elected officials make decisions on wastewater collection and treatment. The County's water quality monitoring program is a critical part of post-CCMP management and must be continued, even if its work effort is slightly redirected (see following section). A regional approach to managing the Peconic Estuary contributing area continues to be the best way to apportion limited resources to the most appropriate and beneficial land use management decisions and infrastructure improvements.

***Post- CCMP Management** – Participation in post-CCMP water quality management by the County and East End town planning departments is recommended. Continued tracking and research into harmful algal blooms, particularly red tides, is important. More extensive groundwater sampling and analyses will help land use planners manage the impacts of agriculture and residential development and help elected officials make decisions on wastewater collection and treatment. The County should continue its critically important monitoring program, but optimize its efforts as described elsewhere.*

19 Program Recommendations

19.1 The Value of the Water Quality Monitoring Program

Suffolk County is known on Long Island, in the region, and elsewhere for its north fork and south fork communities and especially for access to the Peconic Estuary where boating, fishing, swimming, and beach activities attract over a million tourists each year. Good water quality is a key attraction not only for the tourists, but for the residents as well. It is vitally important to recreational and commercial fishermen that the Peconic Estuary support a healthy fishery. The boating and fishing industries support large numbers of direct and indirect jobs for at least eight months of the year and generate significant tax revenue for local municipalities. Fishing and boating rely on clean water.

The Peconic Estuary also supports a growing shellfish aquaculture industry, with 100,000 acres potentially available for cultivation. Good water quality is required not only to grow the bivalves, but also to market them successfully. The value of the clams, oysters, and scallops that can be grown on these leases runs into the millions of dollars (Anderson & Spatz, 1997). The industry also generates jobs for growers and various support industries. Good water quality is also important to the real estate industry. Waterfront and other area homes are most valuable when they have access to an attractive, clean, and high quality waterbody like the Peconic.

Continuous and long-term monitoring with 'boots on the water' is critical to recognizing and responding quickly to water quality concerns. Water quality and resource issues uncovered by the County's program have generated millions of dollars of academic research by local scientists and advanced our understanding of the Peconic Estuary. It also generated important connections between the regulatory, academic, environmental, and for-profit communities in their common desire to preserve and protect the natural resources of the Estuary.

Impacts to groundwater and ultimately to surfaces waters will occur as land use continues to change in the Peconic Estuary watershed. Data collection must be expanded to better understand the impacts of land use on groundwater and ultimately on surface water. As groundwater travels slowly to the Estuary, there is time to investigate potentially adverse environmental conditions and to formulate a plan to reduce those impacts. The County Health Department's Division of Environmental Quality should expand its groundwater monitoring effort. The Office of Ecology is the appropriate entity to utilize this data to interpret the effects of groundwater on Peconic Estuary water quality. It should continue to collect surface water data with the modifications recommended herein and continue to serve as a source of high quality data and analysis for the PEP's coalition of researchers, planners, advocacy groups, business interests, and decision makers to plot the best course for the future of the Peconic Estuary.

***Value of the Water Quality Monitoring Program** – Continuous and long-term monitoring with 'boots on the water' is critical to recognizing and responding quickly to water quality concerns. The Office of Water Resources should expand its groundwater monitoring efforts with the Office of Ecology providing data analysis and interpretation relative to Peconic Estuary water quality. The Office of Ecology is uniquely qualified to continue the sampling and analysis needed to protect the aquatic resources that contribute millions of dollars to the County's economy.*

19.2 Redirect Estuarine Sampling Effort

Water quality monitoring in the Peconic Estuary has been extensive. Information is available from 130 stations. Over 300 parameters have been monitored at various stations over time. The data from this effort provides an excellent basis for evaluation of trends and correlations. Data collection, however, is time consuming and resource intensive. Three types of information; evaluation of trend data, comparison of box and whisker plots, and input from the Bureau of Marine Resources were used to determine whether conditions were stable over time and if adjacent stations had similar enough data to consider eliminating one of them. This evaluation helped identify stations for which continued monitoring may not be needed as little additional temporal or spatial information would be collected from continued sampling.

This data analysis makes clear that some of the stations have changed little over the past 30 years. Some of these 'stable' stations could be dropped from the sampling program. The concentration of analytes at some adjacent stations has been similar enough to consider dropping one or more of them. Parameters at other stations are still changing – many of these should continue to be monitored. Water quality in portions of the Estuary is still impaired – stations there should continue to be monitored.

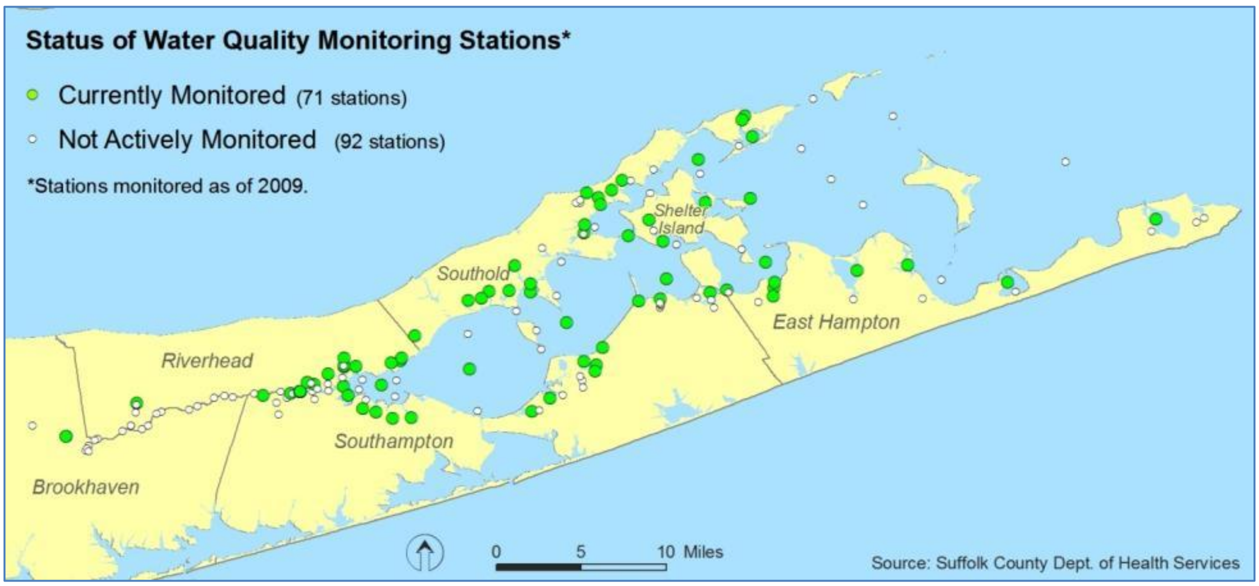
Initial recommendations for future sampling were reviewed with the SCDHS Office of Ecology. Considerations for future monitoring were reviewed by Robert 'Mac' Waters, past Supervisor of the Bureau of Marine Resources and Peconic Estuary Program Quality Assurance Officer for the water quality monitoring program. Mr. Waters is very familiar with the sampling and analysis history of each station and the overall health of the Peconic Estuary for the past many years. Detailed station recommendations are found in Appendix F and form the basis for the discussions below.

19.2.2 Sampling Recommendations

Tables found in Appendix F list stations (marine and stream) that have been sampled by the County with the sampling frequency. The tables show those stations where the County discontinued sampling and those stations where sampling should be continued or resumed. The tables include the column 'Rationale for Continued Sampling' for some of the stations.

It is clear from the data that the County's sampling effort changed after 1996 when the sampling frequency declined substantially in some stations and other new stations were added. This change was made to track Brown Tide occurrences, though ironically, the algal blooms declined the same year the sampling changes were made. Currently active and inactive monitoring stations are shown Figure 19-1.

Figure 19-1. Active and Inactive Monitoring Locations



With the subsidence of the Brown Tide, it is time to change the sampling strategy from extensive back to intensive. Elimination of the monitoring effort is recommended for 10 marine stations and 16 stream stations; continuation of monitoring for 28 marine stations and 17 stream stations, and resumption of monitoring for six marine stations (Table 19-1). Figure 19-3 shows all stations recommended for discontinuation, continuation, and resumption. Sampling frequency should be increased at the stations recommended for future monitoring.

Table 19-1. Recommended Monitoring Station Changes

Station Action	Number Marine/ Estuarine Stations	Number Point/ Stream Stations	Totals
Continue	28	17	**45**
Discontinue*	10	16	**26**
Resume	6	0	**6**

19.2.3 Discontinue Sampling of Some Stable Stations

Many stations were discontinued over the years. A majority of the remaining stations provide unique information due to the highly variable conditions in the estuary (*e.g.*, depth, proximity to point sources, and influence from tributaries). Currently active stations and those that are no longer actively monitored are shown in Figure 19-1. Not all of the previously monitored stations shown in Figure 19-1 are included in the chart found in Appendix F (163 vs. 138).

Trend analyses were performed for the full set of stations and a subset of parameters. The trend analysis results were reviewed to identify locations where trends have shown no significant change over the period of record. Stations with no more than four undetermined, significantly increasing, or significantly decreasing results were identified and considered ‘stable.’ Some of these ‘stable’ stations could be considered for discontinuation because past data suggests that future monitoring will not provide additional insight into conditions at this location. The full set of stable and unstable stations are listed in Table 19-2. Eight stations had insufficient data to make a determination.

Of the ‘stable’ stations, about half had inconclusive or downward trend results. Of the remaining ‘stable’ stations, all had only one increasing parameter – nitrate in five cases, ammonia at one. Ammonia increased at station 60104 (North Sea Harbor). Only nitrate increased at the following ‘stable’ stations: 060210 (Reeves Bay), 060220 (Meetinghouse Creek), 200013 (Goose Creek), 200180 (Downs Creek), 200240 (Pipes Neck Creek), and 200250 (Narrow River North). The County might consider discontinuing sampling of the some of the ‘stable’ stations (marine: 06290, 060310, and 060320 and stream: 200044, 200230, and 200240).

Table 19-2. 'Stable,' 'Non-Stable,' and Undetermined Stations

Non-Stable Location	Unstable Station #
Acabonac Harbor	
Brushes Creek	200160
Coecles Harbor	060122
Cutchogue Harbor	060102
Downs Creek	200190
East Creek (Cutchogue)	060103
East Creek (South Jamesport)	060101
Fish Cove	200020
Flanders Bay	060170
Gardiner's Bay West	060116
Goose Creek	060106
Great Peconic Bay	060130
Lake Montauk	060135
Little Peconic Bay	060113
Meetinghouse Creek	060220
Meetinghouse Creek	200004
Meetinghouse Creek	200041
Mill Creek (Hashamomuck Pond)	060109
Napeague Harbor	060134
North Sea Harbor	060104
Northwest Creek - Mouth	060131
Northwest harbor	060118
Noyac Bay	060121
Orient Harbor	060115
Paradise Point	060114
Peconic River	200010
Peconic River Mouth	060240
Reeves Bay	060210
Sag Harbor	060126
Sag Harbor Cove	060127
Sawmill Creek	200110
Three Mile Harbor	060132
Town Creek	060107
West Neck Bay	060119
West Neck Harbor	060124

Stable Location	Stable Station #
	200014
Bullhead Bay	060148
Cold Spring Pond	060290
Deep Hole Creek	200170
East Creek, Cutchogue	200210
East Creek, South Jamesport	200140
Fish Cove	200021
Hallocks Bay	060330
Hall's Creek	200180
Hashamomuck Pond 1	060340
Hashamomuck Pond 2	060350
Hubbard Creek	200016
Mill Creek	060320
Mill Creek	200015
Narrow River North	200250
Narrow River South	200260
Noyac Creek	060310
Peconic River	200017
Pipes Creek	200230
Pipes Neck Creek	200240
Reeves Creek	200130
Riverhead STP	200009
Terry Creek	200120
West Creek	200200
West Drain, S. Jamesport	200150
Wooley Pond	060300
Northwest Creek - Head	060370
Riverhead Aquarium	200032

Undetermined Location	Station #
Brookhaven NatÆl Lab STP	200027
Goose Creek, Flanders	200013
Grumman STP	200028
Peconic River	200044
Riverhead Aquarium	200026
Northwest Creek	060360
Peconic River	200030
Riverhead Aquarium	200031

Figure 19-2. Stable and non-Stable Monitoring Locations

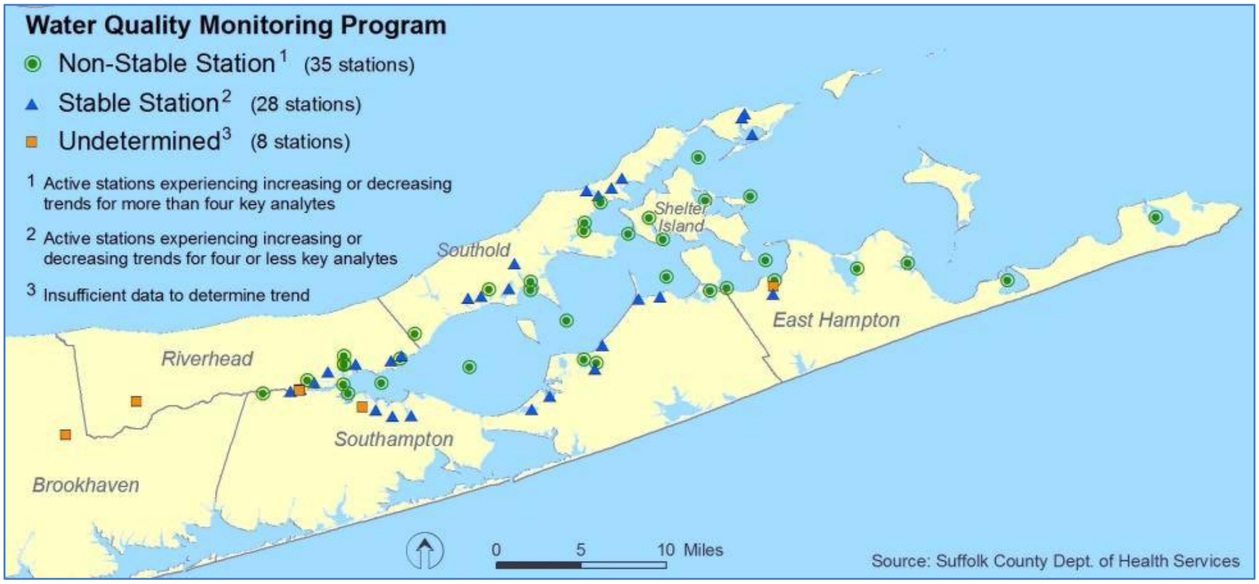


Figure 19-3 shows all stations recommended for discontinuation, continuation, and resumption. The following sections discuss the recommended sampling effort for different portions of the Estuary including the central open water locations, small bays and harbors, creeks and ponds, and the Peconic River.

***Eliminate Some Stable Stations** – The County should discontinue sampling at selected stable stations: marine: 06290, 060310, 060320 and stream: 200044, 200230, and 200240.*

Figure 19-3. Stations recommended for sampling discontinuance, continuance, and resunption

19.2.4 Continue or Resume Sampling of Central Open Water Stations

Samples taken in the portion of the Peconic Estuary east of Shelter Island have good water quality that has changed little. The number of these stations sampled can be reduced. Sampling should continue (or resume) in the "main stem' of the estuary (*i.e.*, center of Flanders Bay, Great Peconic Bay, Little Peconic Bay, Gardiner's Bay West, and Gardiner's Bay Central – see Table 19-3 and Figure 19-3). These 'main stem' stations have had good water quality and can function as 'reference stations.'

Plum Gut and Block Island Sound stations can be dropped as they represent substantial ocean water input. Open water stations can be discontinued in North and South Gardiner's Bay; north, south, and east of Robins Island, in north and south Great Peconic Bay (Table 19-3 and Figure 19-3). Flanders Bay should continue to be monitored to track improving water quality.

Table 19-3. Open Water Station Recommendations

Discontinue Sampling (east to west)	
060142	Block Island Sound
060141	Gardiner's Bay East
060139	Plum Gut
060117	Gardiner's Bay South
060138	Gardiner's Bay North
060069	Robins Island East
060110	Robins Island South
060100	Robins Island North
060120	Great Peconic Bay South
060140	Great Peconic Bay North

Continue/Resume Sampling (east to west)	
060137	Gardiners Bay Central
060116	Gardiners Bay West
060114	Paradise Point
060113	Little Peconic Bay
060130	Great Peconic Bay
060170	Flanders Bay

Continue Sampling 'Main Stem' Stations and Discontinue Other Open Water Stations – *Sampling should continue or resume in the six central open water stations for reference purposes. Ten other open water locations should be discontinued including: Block Island Sound, Plum Gut, Gardiner's Bay East, South, North; Robins Island East, South, North; Great Peconic Bay South and North.*

19.2.5 Continue Sampling Enclosed or Isolated Small Bays and Harbors

Harbor water quality is a reflection of stormwater and most significantly, creek and groundwater inputs. Sampling of the creeks generates more valuable information than sampling of the small bays and harbors into which they discharge. Consequently, sampling at many of the small bays, harbors, and creek mouths could be discontinued (Table 19-4, Figure 19-3).

Some smaller, more enclosed bays and harbors should continue to be monitored because they experience limited open water exchange (*e.g.* North Sea Harbor, Three Mile Harbor, and Bullhead Bay). Other bays and harbors, though more open, should also continue to be sampled as there are no nearby stations (*e.g.* Northwest Harbor, Orient Harbor). Table 19-4 includes all bay and harbor stations recommendations.

Table 19-4. Small Bay and Harbor Station Recommendations

Discontinue Sampling (east to west)	
390-5	Oyster Pond Creek
385-5	Oyster Pond Creek West
375-5	Osborne Brook
060145	Napeague Harbor
060136	Cartwright Shoal
060112	Hallocks Bay
060143	Majors Harbor
060144	Cornelius Point
060128	Sag Harbor Cove
060129	Upper Sag Harbor Cove
060124	West Neck Harbor
060125	West Neck Creek
060108	Southold Bay
060105	Hog Neck Bay North
060081	Hog Neck Bay West
060102	Cutchogue Harbor
060150	Miamogue Point
060160	Red Cedar Point
060180	Goose Creek Flanders
060190	Goose Creek Point
060200	Flanders Bay North

Continue/Resume Sampling (east to west)	
060135	Lake Montauk
060134	Napeague Harbor
060133	Accabonac Harbor
060132	Three Mile Harbor
060118	Northwest Harbor
060126	Sag Harbor
060127	Sag Harbor Cove
060330	Hallocks Bay
060115	Orient Harbor
060111	Greenport Harbor
060122	Coecles Harbor
060119	West Neck Bay
060121	Noyac Bay
060104	North Sea Harbor
060148	Bullhead Bay
060240	Peconic River
060210	Reeves Bay
060230	Terrys Creek

Continue Sampling Enclosed or Isolated Small Bays and Harbors *– Sampling should continue in the small bays and harbors (18) with limited open water exchange and those that are isolated from other stations. Many others (21) can be discontinued (many of these have not been sampled for some time).*

19.2.6 Continue Sampling of Selected Creeks and Ponds

The County conducted a very extensive sampling program across a large number of Peconic Estuary tributary creeks. In order to shift to a more intensive program, where sampling is more frequent, sampling at many of the smaller and less impaired creeks and ponds should be discontinued (Table 19-5, Figure 19-3). (Note that many of the stations where the recommendation is to discontinue sampling have not been sampled for many years).

A greater number of creeks in the western estuary continue to experience poor water quality and should be sampled. Sampling of creek mouths at ebb tide can be substituted for sampling of the creek heads, as long as sampling is conducted at ebb tide. Much of the ebb tide sampling could be done from shore, making it possible for some staff to travel from creek to creek by car.

In several cases, creek and pond stations recommended for discontinuance discharge into harbors where sampling should continue (*e.g.* Northwest Creeks, Big Fresh Pond, Fish Cove, Little Sebonac Creek, Hashamomuck Pond). Sampling could be resumed in these creeks or ponds if water quality is found to decline downstream. Sampling at the wastewater treatment plants (Sag Harbor, Shelter Island, and Riverhead) can be discontinued as these plants are sampled regularly by the NYS DEC.

Sampling in Hashamomuck Pond can be discontinued as long as sampling continues on ebb tides at station 60109. Similarly, sampling at the head of East Creek (200210) can be discontinued as long as sampling continues at station 060103 at the mouth of the Creek at ebb tide.

***Continue Sampling of Selected Creeks and Ponds* –** *Sampling should be discontinued in 30 creek and pond stations and continued in 24 creek and pond stations (many of these have not been sampled for some time).*

Table 19-5. Creek and Pond Recommendations

Discontinue Sampling (east to west)	
350-5	Little Northwest Creek
200250	Narrow River North
060360	Northwest Creek
060370	Northwest Creek
989-5	Ligonee Brook
200230	Pipes Creek
200240	Pipes Neck Creek
1067-5	Silvermere Creek
200018	Sag Harbor STP
200019	Shelter Island STP
060310	Noyac Creek
060340	Hashamomuck Pond
060350	Hashamomuck Pond
200022	Mill Creek (Trout Pond)
200023	Mill Creek (Trout Pond)
200024	Mill Creek (Trout Pond)
200025	Mill Creek (Trout Pond)
060300	Wooley Pond
200220	Richmond Creek
200210	East Creek (Cutchogue)
200200	West Creek
200020	Fish Cove
200021	Fish Cove
977-5	Little Sebonac Creek
60290	Cold Spring Pond
200150	West Drain
200004	Meetinghouse Creek
200091	Riverhead Scavenger Plant
610-5	Sawmill Creek
200092	Riverhead STP

Continue/Resume Sampling (east to west)	
200260	Narrow River South
060131	Northwest Creek
060109	Mill Creek (HP)
060106	Goose Creek
060107	Town Creek
060320	Mill Creek (Trout Pond)
060103	East Creek (Cutchogue)
200190	Downs Creek
200180	Halls Creek
200170	Deep Hole Creek
200160	Brushes Creek
200140	East Creek
060101	East Creek
200016	Hubbard Creek
200015	Mill Creek
200014	Birch Creek
200013	Goose Creek
200130	Reeves Creek
200041	Meetinghouse Creek
200004	Meetinghouse Creek
200120	Terrys Creek
060250	Sawmill Creek
200110	Sawmill Creek
200009	Riverhead STP

19.2.7 Reduce Sampling Effort in the Peconic River

Sampling of the Peconic River is important for the continued protection of water quality. The major nitrogen inputs to the River are the treatment plants and agricultural fertilizer (via groundwater). Agricultural pesticides also enter the River via groundwater. Industrial land uses, particularly in the southern half of EPCAL could also affect Peconic River via groundwater.

As the County's overall Peconic Estuary sampling effort should be refocused to increase sampling intensity, it is necessary to reduce the number of stations monitored (Table 19-6, Figure 19-3). Station 200010 in the Peconic River has been sampled for many years and will be important for data continuity. The station is far enough west to be relatively representative of upstream water quality. Sampling of the remaining upstream and tributary stations to the west can be discontinued. Additional sampling could be resumed should results from station 200010 reveal declining water quality or pollutant concentrations of concern. Sampling at the wastewater treatment plants (Brookhaven National Laboratory and EPCAL (Grumman) can be discontinued as these plants are sampled by the NYS DEC.

Sampling of three stations at the mouth of the River (060260, 060270, and 060280) should be resumed. Data from these stations will reflect the inputs of the Riverhead STP and aquarium and will be important to the implementation of the nitrogen TMDL.

Reduce Sampling Effort in the Peconic River *– Discontinue sampling in the Peconic River west of station 200010, as upstream water quality issues will be evident at this station. Resume sampling in the mouth of the River.*

Table 19-6. Peconic River and Tributaries Recommendations

Discontinue Sampling (east to west)	
200030	Peconic River
200031	Riverhead Aquarium
200032	Riverhead Aquarium
200011	Little River
200012	White Brook
200101	Peconic River
200402	Peconic River
200403	Peconic River
200404	Peconic River
200405	Peconic River
200406	Peconic River
200407	Peconic River
200408	Peconic River
200409	Peconic River
200410	Peconic River
200411	Peconic River
200047	Peconic River
200412	Peconic River
200413	Peconic River
200106	Peconic River
200107	Peconic River
200108	Peconic River
200045	Peconic River
200028	Grumman STP
200044	Peconic River
200027	Brookhaven STP
200416	Peconic River
605-310	Peconic River
605-331	Peconic River
605-336	Peconic River
605-415	Peconic River
605-340	Peconic River

Continue/Resume Sampling (east to west)	
060260	Peconic River
060270	Peconic River
060280	Peconic River
200026	Riverhead Aquarium
200017	Peconic River
200010	Peconic River

19.2.8 Other Sampling Recommendations

Monitoring should be continued in both the summer and non-summer periods. It is important to sample in the colder months when there is less influence from algal uptake and sediment flux and water quality is more a reflection of other factors, in particular groundwater inputs.

With 26 current monitoring stations recommended for discontinuance (and 6 for monitoring resumption), sampling of the remaining stations can become more frequent. More frequent data collection will enhance the statistical relevance of trends analysis.

Many creek and pond stations were recommended for discontinuance because water quality could be measured at stations located at their mouths if sampled on ebb tides. It is important to be sure that all these stations are sampled when pond or creek water is flowing out into the Estuary.

Analyses of organics and pesticides show that the vast majority of measurements were below the detection limit. A few exceedances of applicable standards have occurred and are likely to occur in the future as urbanization continues. The County should continue to monitor organics, metals, pesticides, and herbicides on a quarterly basis, but should do so only at selected 'representative' stations. If the frequency of detections or absolute value of a particular measurement increases, a return to a more extensive monitoring program could be implemented.

***Other Sampling Recommendations** – Continue monitoring during the winter months when there is less influence from algal uptake and sediment flux and water quality reflects other factors like groundwater inputs. Sample the mouths of creek and pond stations at ebb tides. Continue monitoring for organics, pesticides, and metals.*

19.2.9 Suspend Continuous Monitoring Effort

Continuous water quality monitoring by the YSI sondes has limited use in assessing long-term trends. Sonde deployment and data collection also requires considerable dedication of Program resources that might be better utilized elsewhere. The YSI sondes are most useful for specific and time-limited studies by the County or by outside researchers. Temporary suspension of sonde deployment is recommended.

***Suspend Continuous Monitoring Effort** – Dedicate the YSI sondes for time-limited special project use by the County or other researchers.*

19.3 Broaden the Focus to Include Land Use Impacts on Groundwater

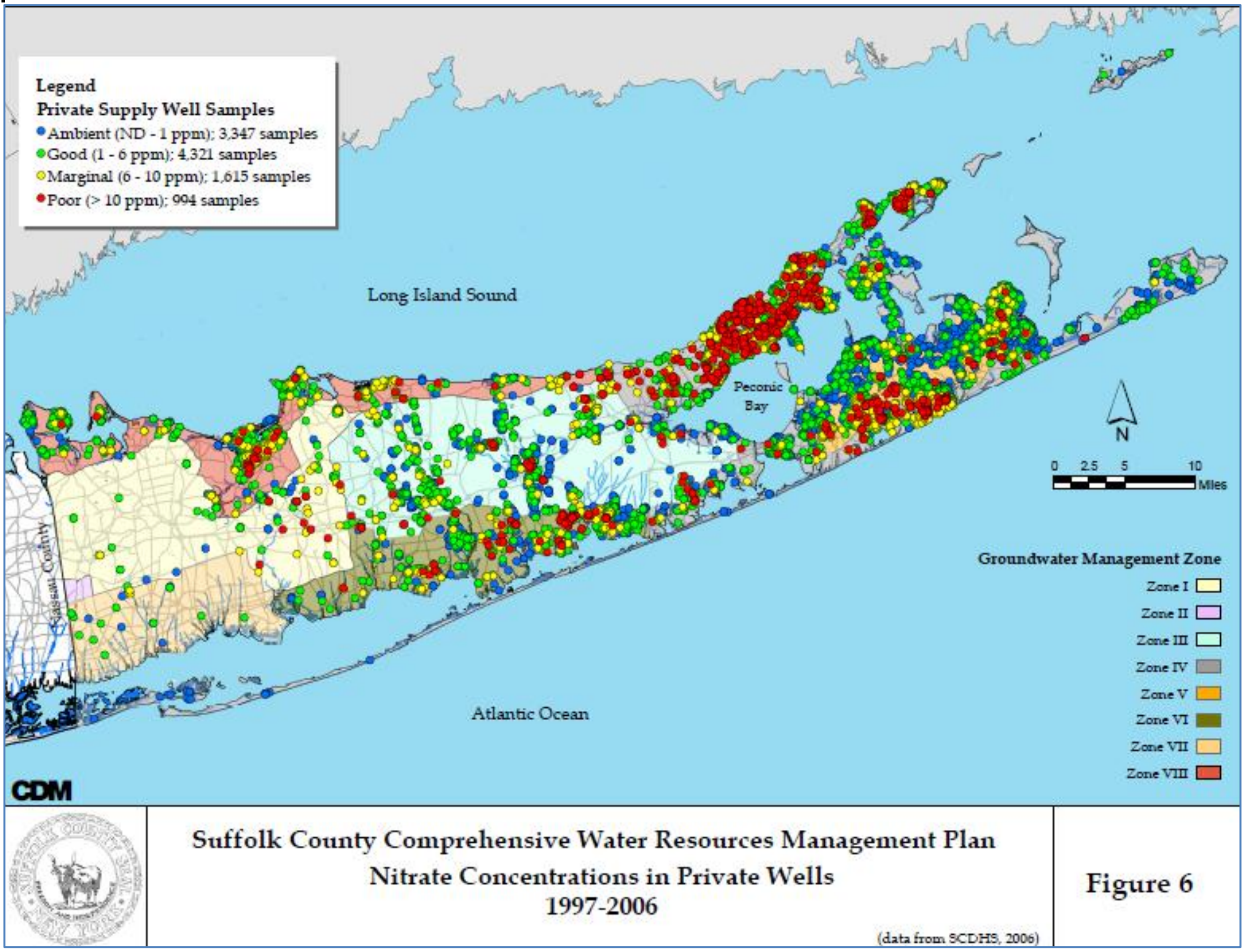
The surface waters of the Peconic have been extensively monitored. The data makes it possible to characterize water quality spatially and temporally. A continuation of the post-CCMP water quality management effort should be a primary focus of the program. Tracking bloom occurrences and supporting research into harmful algal blooms, particularly red tides, with reliable data is recommended.

Groundwater quality, in contrast, is poorly characterized. This is a critical data gap since groundwater is a large source of nutrients and a variety of potential contaminants to the Estuary. An increased focus on land use and its impact on the Estuary through groundwater are important as nutrient reductions are best achieved through improved land use management. Exclusive of atmospheric deposition, the vast majority of nitrogen entering the Estuary is from groundwater (93 percent). Management of nitrogen loading to the groundwater that flows to the Estuary should be a priority. The Suffolk County Comprehensive Water Resources Management Plan (CDM, 2008) found high (>10 mg/L) concentrations of nitrate in the private wells of the north fork (Figure 19-4). That nitrogen is flowing to the Long Island Sound and Peconic Estuary.

A focus on nitrogen loading from sources other than the STPs may be most fruitful. Agricultural and septic system nitrogen loading are the two largest contributors. Sewering can reduce nitrogen concentrations from 45 to 10 mg/L or lower with advanced systems, while further treatment plant upgrades to the Riverhead STP for $18 million will reduce nitrogen loading to the Estuary only marginally. Better management of residential and especially agricultural fertilizer use should also be a priority.

As groundwater nitrogen from all onsite systems inside the contributing area reaches the Estuary, sewering of hamlet centers and onsite system management should be priorities. The program should work closely with County and town planning departments to identify priority areas for sewering as well as onsite system management. Expansion of the County's groundwater sampling and analyses program will help land use planners manage the impacts of agriculture and residential development and help elected officials make decisions on wastewater management. Greater information on groundwater constituents would also increase the feasibility of conducting groundwater pollutant mitigation. Mitigation will be needed to reduce the 25-50 years of historic nitrogen that will continue to flow to the Estuary via groundwater.

Figure 19-4. Nitrate concentrations in private wells on Long Island



The Office of Ecology has been collecting valuable surface water data for over 30 years. The Office of Water Resources, another agency of the SCDHS Division of Environmental Quality, has been collecting groundwater data. The greatest contribution to Estuary water quality, other than atmospheric deposition, is groundwater. For that reason, the Office of Water Resources should expand its groundwater monitoring efforts and digitize past and current data for use in GIS and groundwater models. The network of groundwater monitoring stations should be expanded in consultation with the County's groundwater modeling consultant and others with expertise in this area including the Soil and Water Conservation Service, the local office of the USGS, area water companies, and university researchers. A series of stations should be located perpendicular to the direction of groundwater flow for each of the major embayments and creeks. Additional work is recommended that examines groundwater inputs to the creeks and embayments similar to the study conducted by the USGS (Schubert, 1999). A better understanding of groundwater flow dynamics is needed particularly with respect to nutrient and other contaminant dynamics.

The Office of Ecology is the appropriate entity to interpret the significance of past and new groundwater information relative to Peconic Estuary water quality. The Office of Ecology should also coordinate its efforts with related initiatives such as the Agricultural Stewardship Program of the PEP operated by Cornell Cooperative Extension. The program focuses on the agricultural lands that surround the impaired waterbodies identified in the Peconic Estuary TMDL. The program seeks to reduce non-point source nitrogen loading by fifty percent from agriculture land uses. Another initiative underway by Cornell Cooperative Extension's Marine program is the measurement of groundwater flow into the Peconic Estuary. Understanding the volume of this flow as well as its constituents is critically important to the future health of the Estuary.

Broaden the Focus to Include Interpretation of Expanded Groundwater Monitoring – *Work with the Office of Water Resources to expand the network of groundwater monitoring wells inside the Peconic Estuary contributing area with an emphasis on areas upgradient of impaired creeks and embayments. Provide groundwater data interpretation relative to Peconic Estuary water quality. Work with County and Town planning departments to prioritize areas for sewering and onsite system management. Support the efforts of others to reduce agricultural nitrogen inputs to groundwater.*

19.4 Prepare for Climate Change

Climate change has been identified by numerous state and federal agencies as an issue that must be considered in all long-range plans. Climate change can affect the Peconic Estuary and its contributing area from increasing precipitation, rising sea level, increasing water temperature, more frequent storms, and elevated atmospheric carbon dioxide. Each of these climate change factors has one or more primary and secondary effects on the waterbodies of the Estuary, the groundwater that feeds the system, and the land in the contributing area that ultimately affects the Estuary through runoff and groundwater flow.

A study of 'Climate Change Sentinels' was conducted for the Long Island Sound (Long Island Sound Study, 2009). Much of the following information was adapted from a matrix of the sentinels produced for that study. The study included 35 sentinels that the authors grouped into the following four categories: Water Quality/Quantity, Pelagic/Benthic Systems and Associate Species, Fisheries, and Coastal Habitats. The study distinguished between climate change 'indicators' and 'core' parameters that are measured in most large estuaries including the Peconic Estuary: The County should be sure that data on the core parameters related to climate change continue to be collected (Table 19-7).

Table 19-7. Climate Change Core Parameters

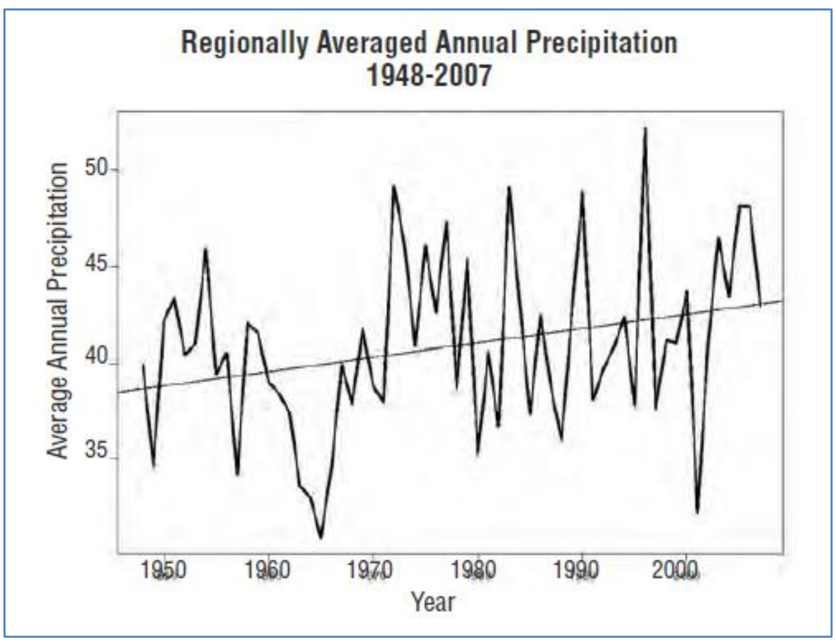
Collected by County	Collected by Others
▪ pH ▪ Temperature ▪ Salinity	▪ Wind speed and direction ▪ Precipitation ▪ Relative humidity ▪ Groundwater elevation ▪ Streamflow (Peconic River) ▪ Sea level

***Monitor Climate Change Sentinels** – The County should record the climate change parameters identified by the LISS that are considered the 'core parameters' including those it currently measures: pH, temperature, and salinity, and those collected by others: precipitation, stream flow (Peconic River), sea level, wind speed and direction, and relative humidity.*

19.4.1 Increasing Precipitation

Precipitation in the Northeast has increased in the past 70 years (Spierre & Wake, 2010) nearly three quarters of an inch per decade (Figure 19-5), plus or minus a little more than a quarter inch.

Figure 19-5. Time series of regionally averaged annual precipitation



From (Spierre & Wake, 2010)

The time series also shows the period in the mid-1960s that had extremely low annual precipitation totals – the New England Drought – which the authors identified as "*the most severe and widespread drought to affect the northeastern United States since European settlement*." The study looked at the frequency of extreme rainfall events. It found positive trends in one-year recurrence intervals (less time between events) at 187 (85 percent) of the New England stations. Interestingly, the largest trend in one-year recurrence intervals was found at Mineola, which had an increase of 2.54 events per decade. In other words, 12.7 additional one-year rainfall events occurred at Mineola over the study period (for this aspect of the report) of 50 years.

Increased precipitation leads to increased runoff, which affects Peconic Estuary water quality by carrying additional atmospheric and stormwater nitrogen into surface water. Runoff changes have been mitigated to some degree by improvements in stormwater management. Increased precipitation may also influence groundwater elevations. The County should continue to measure precipitation and should determine whether long-term changes in precipitation have affected the Estuary.

Investigate the Impact of Increased Precipitation *– The County should determine if there is a relationship between precipitation trends, sea level, groundwater elevations, and pollutant concentrations in groundwater and in the Estuary.*

19.4.2 Rising Sea Level

The NYS DEC established a Sea Level Rise Task Force in 2007 to study the potential for sea level rise and its impact on the coastal and other tidally-influenced areas of New York. According to the DEC, sea level has risen more quickly in the 20th century than in the prior two centuries because ocean waters warmed and expanded and greater volumes of melt-water have reached the ocean from mountain glaciers and polar ice caps. The DEC reports (Table 19-8) "*conservative projections expect the seas will rise by 7 to 23 inches by 2100, but do not account for rapid melt of land-based ice.*" Recent observations find rapid ice melt could lead to a rise in global mean sea level of three feet or more. Sea level rise can drown coastal wetlands and flood mudflats and can accelerate coastal erosion.

Table 19-8. Sea Level Rise in Inches

Lower Hudson Valley & Long Island	2020s	2050s	2080s
Sea level rise	2-5	7-12	12-23
Sea level rise with rapid ice-melt scenario	5-10	19-29	41-55

Note: Data from ClimAid Integrated Assessment for Effective Climate-change Adaptation Strategies in New York State

***Investigate the Impact of Sea level Rise** – The County should track the work of others on the impacts of sea level rise on coastal environments and monitor the impacts of sea level rise on Peconic Estuary tidal wetlands.*

19.4.3 Increasing Water Temperature

According to a recent study, the western Atlantic ocean has risen approximately 0.8 degrees centigrade since 1900 (Saenger, Cohen, Oppo, Halley, & Carilli, 2009). The authors suggested that much of the warming since 1900 was driven by anthropogenic forcing. More locally, researchers at the University of Connecticut found that southern New England seas have been warming since the 1960s and that there have been more extended periods when temperatures have exceeded 20 degrees centigrade in the Sound since the 1990s (Howell, Benway, Giannini, Mckown, Burgess, & Hayden, 2005).

Climate change has led to increasing water temperature in many of the world's waterbodies including the Long Island Sound. The data for Peconic Estuary water temperature trends, however, are inconclusive. The Estuary may be subject to greater groundwater flow due to increased precipitation and greater use of public water from deeper aquifers and discharged via wastewater and irrigation to shallow groundwater and then the Estuary.

If cooler groundwater flow has increased, it could have moderated surface water temperatures. Perhaps the temperature of the Estuary reflects a greater influence of groundwater rather than oceanic water. Ocean circulation and the activity of the Gulf Stream can also influence Peconic Estuary water temperature. The County should continue to monitor Estuary water temperature for its potential effects on species distribution, growth and reproduction (particularly for those that rare at the limit of their range), the frequency, timing, and intensity of algal blooms, and other temperature driven phenomena.

***Continue to Monitor Water Temperature** – The County should continue to monitor Peconic Estuary water temperature for its potential effects on species distribution, growth and reproduction (particularly for those that rare at the limit of their range), the frequency, timing, and intensity of algal blooms, and other temperature driven phenomena.*

19.4.4 More Frequent Storms

The 'Climate Change Sentinels' study suggested that storm events have become more frequent and more intense in the past 50 years and this trend will continue and perhaps even escalate in future years as the rate of climate change increases. The U.S. Global

Change Research Program (U.S. Global Change Research Program, 2009) observed that many forms of extreme weather events, such as heat waves and regional droughts, have become more frequent and intense during the past 40 to 50 years. They found that there are more weather extremes in recent decades, such as more unusually hot days and nights, fewer unusually cold days and nights, and fewer frost days. Some regions of the US are experiencing more severe droughts. They observed that the power and frequency of Atlantic hurricanes increased in recent decades, cold-season storm tracks are shifting northward, and the strongest storms are becoming stronger. The report predicts severe flooding due to sea-level rise and heavy downpours that will occur more frequently. These events could increase the contaminant load carried by stormwater along with the erosion and coastal wetland damage caused by wind and wave action. Large storm events may have adverse impacts on coastal environments and will require planning by local villages, towns, and private land owners. The County's presence on the water through its monitoring program will enable it to report to the PEP on natural systems that may be vulnerable to more frequent storm events.

19.4.5 Elevated Atmospheric Carbon Dioxide

The increase in atmospheric carbon dioxide concentration is well documented. Increased atmospheric carbon dioxide leads directly to ocean acidification. Ocean acidity has increased by approximately 30 percent (SCOR Biological Observatories Workshop, 2009) in the past several centuries, with most of the change occurring more recently. The most obvious consequence is a reduction in seawater calcite and aragonite concentrations, two forms of calcium carbonate that are formed by shelled marine organisms such as commercially-important oysters, mussels, and clams. The paper cited other researchers who documented reduced calcification rates in the presence of elevated carbon dioxide levels. They also reported, however, that the growth rates of some seagrasses and nitrogen-fixing cyanobacteria might be enhanced by elevated carbon dioxide. No action is recommended relative to CO_2, as it is a parameter driven by forces outside the control of the County.

19.5 Expand Data Availability

Data should be made available on the web for all interested parties to utilize through an on-line mapping utility and search engine. A potential utility for providing water quality data is the existing Suffolk County on-line mapping utility, or Suffolk iMap. With an appropriate search engine, water quality data should be made accessible through specific queries according to type of analyte, location (*e.g.*, within a given water body) and time period. Raw data should also be made available for download. Reports, including tables and charts, could be made available for each station and water body. A model for such a utility is the National Water Information System (NWIS), which is maintained by the United States Geological Survey (http://maps.waterdata.usgs.gov/mapper/). This on-line mapping utility provides water resources information for data collected in all 50 states and territories.

19.6 Prepare Annual Report on Water Quality Trends

The County's data collection efforts over the past 30 plus years have been valuable to a wide variety of research, environmental, and commercial interests. The information generated each year would be of even greater use if it were collected, summarized, and described in an annual report. The annual Peconic Estuary Water Quality Assessment should not only document the data collected, but should note changes that might be evident from the previous year(s). Changes may or may not reflect a trend, but are usually significant and require some explanation.

An annual report would be of great value to resource managers, scientists, land use planners, and officials from the communities of the Peconic Estuary watershed. The annual Peconic Estuary Water Quality Assessment should be made available on the County's website. The annual report by the Bureau of Marine Resources (BMR) should also contain information on research that involves the BMR and the research of others as relates to the health of the Peconic Estuary.

Prepare Annual Report *– The Bureau of Marine Resources should prepare an annual Peconic Estuary Water Quality Assessment, noting changes from prior years, new and ongoing research. The report should be posted on the County's website.*

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APPENDICES

Appendix A. Summary Statistical Data

Appendix B. Trend Summaries

Appendix C. Compiled Box and Whisker Plots

Appendix D. Box and Whisker Plots for Monthly and Seasonal DO and Organic N

Appendix E. Peconic River Time Series

Appendix F. Sampling Recommendations Details