Memorandum

To: *Veronica King*

From: *CDM Smith/HDR|HydroQual*

Date: *November 15, 2012, revised December 31, 2012*

Subject: *Task 3.1 Endpoint for the Forge River Nitrogen TMDL*

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Introduction

The Forge River, which discharges to the northwest portion of Moriches Bay, is approximately 3.0 miles in length and is relatively shallow with most areas less than 6 feet deep (Figures 1 and 2). The river has a small tidal range of about 2 feet near the head end of the estuary. Similar to other Long Island streams, the Forge River is reported to derive the majority of its freshwater baseflow from groundwater. The Forge River suffers from poor water quality due to cultural eutrophication related to excessive nutrient loading coupled with weak flushing characteristics (Forge River Watershed Management Plan, Town of Brookhaven, 2012). The nutrient loading sources include duck farms (recently closed), septic systems and stormwater runoff (Forge River Watershed Management Plan, Town of Brookhaven, 2012). There are no direct wastewater treatment plant point sources to the river, although there are three small treatment plants that discharge to groundwater within the Forge River watershed. Nitrogen loading to the Forge River is relatively high compared to other estuaries around the world. Evidence of the degree of cultural eutrophication in the Forge River and the areas immediately adjacent to the Forge River in Moriches Bay can be found in the high levels of micro-phytoplankton biomass, often exceeding 100 µg/L chlorophyll-a during the summer months (Gobler, personal communication); the presence of the macro-algae, *Ulva lactuca*; and the occurrence of hypoxia and anoxia in the bottom waters of the river during the summer months. The occurrence of hypoxia and anoxia has resulted in the Forge River and its tributaries being placed on the current New York State Department of Environmental Conservation (NYSDEC) 303(d) list of impaired water bodies.

The New York State 303(d) list includes Water Index Numbers (MW7.2a) AO-MB-168a thru 175, which are tidal tributaries to West Moriches Bay (1701-0312) including the upper Forge River, as

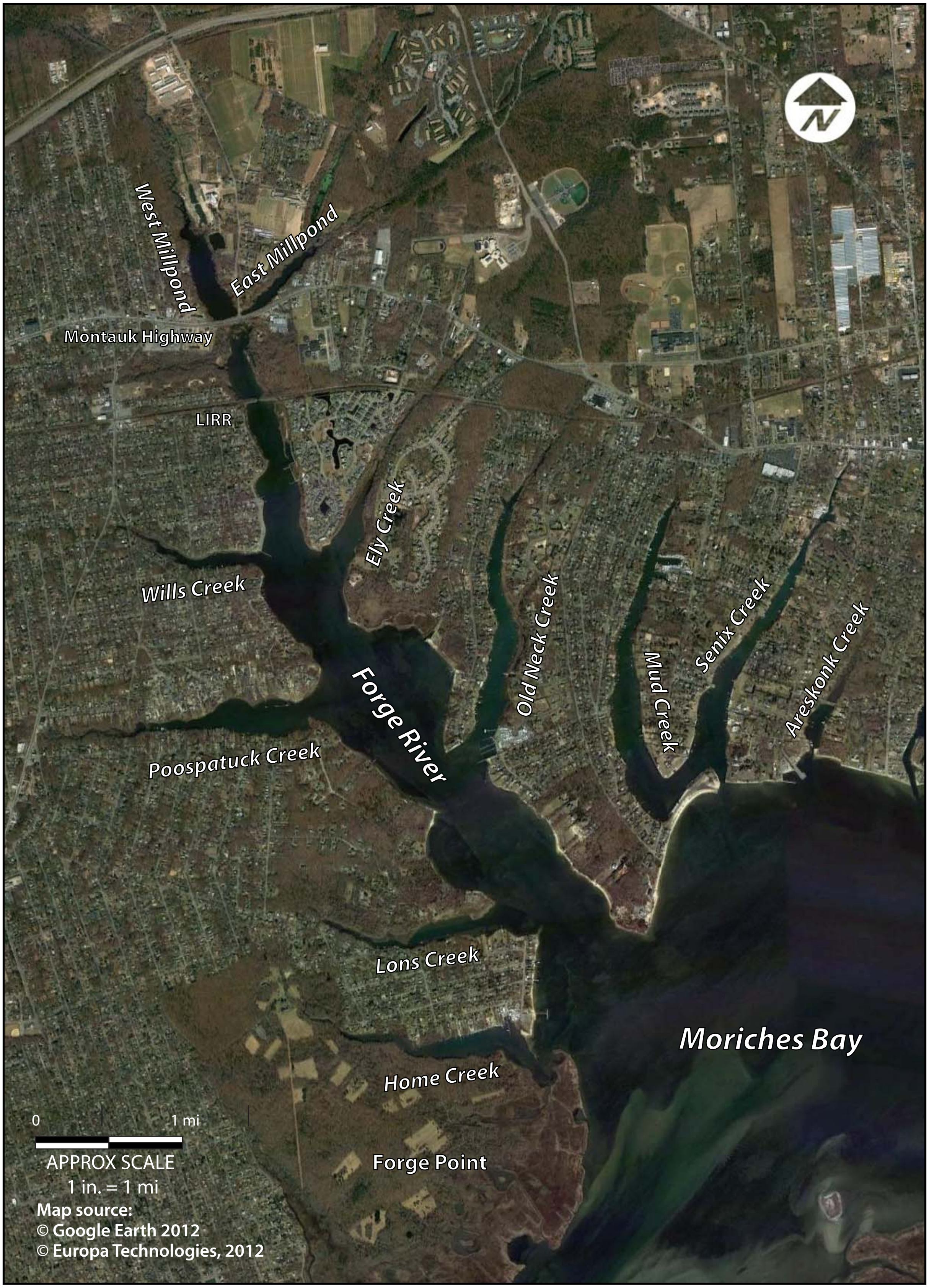


Figure 1. Forge River Study Area.

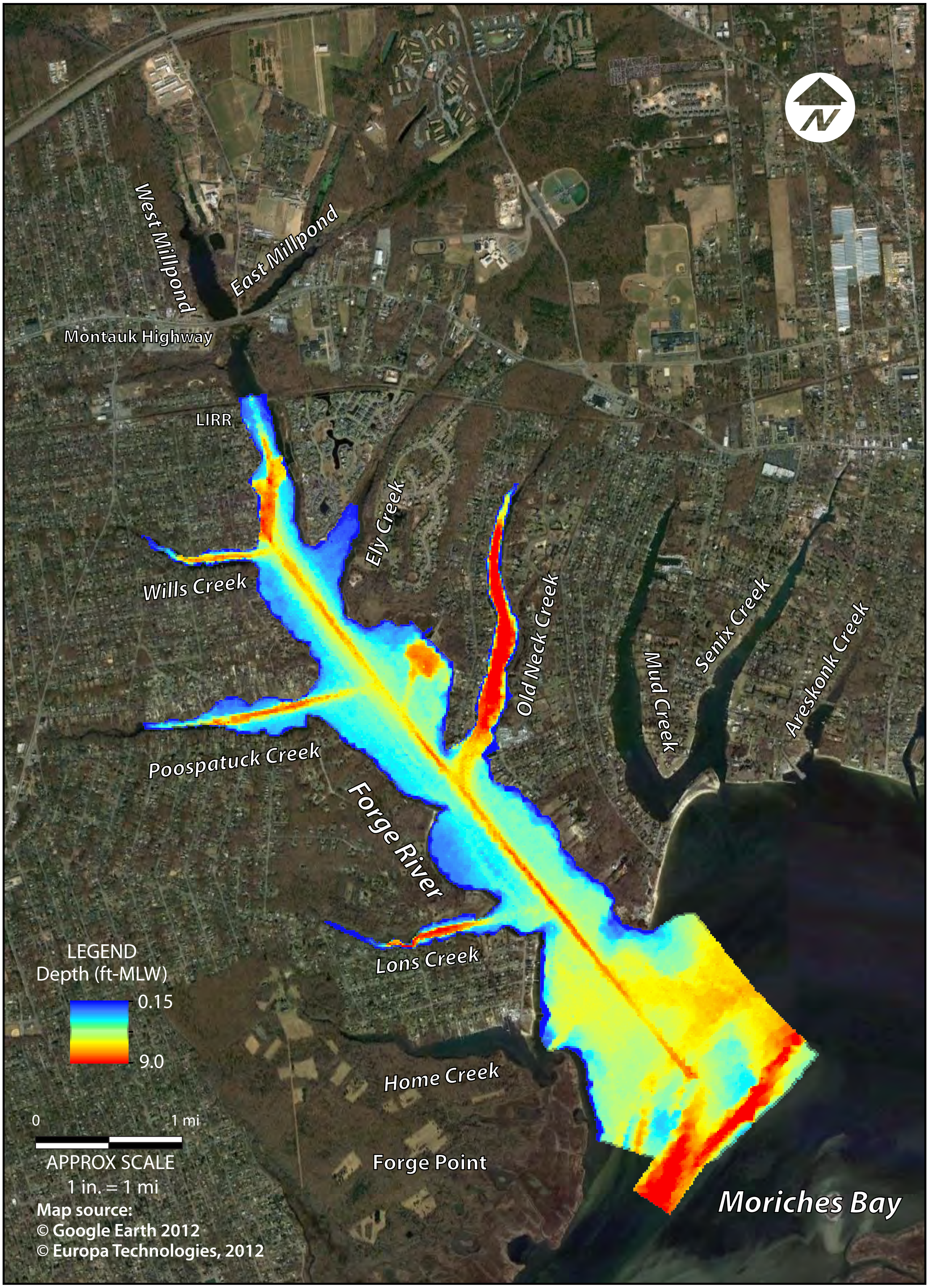


Figure 2. Forge River Bathymetry.

shown by Figure 3, which depicts the Forge River, its tidal tributaries, and their classifications and pollutants of concern. The 303(d) list identifies pathogens, nitrogen, and D.O./Oxygen Demand as the pollutants of concern. The inclusion of the Forge River and its tidal tributaries on the 303(d) list has prompted the development of a Total Maximum Daily Load (TMDL) for nitrogen. The Town of Brookhaven has assumed the leadership role in developing the nitrogen TMDL.

A modeling approach using hydrodynamic and receiving water quality models of the river will be used to develop scientifically based nutrient allocations for the nutrient loading sources to meet the requirements of the TMDL. One of the key initial steps in developing the TMDL is determination of the TMDL endpoint(s). It is desirable to choose an endpoint that has a causal link to the water quality impairment that must be resolved. The TMDL endpoint for the Forge River TMDL is documented in this Technical Memorandum.

Water Quality Standards

The upper Forge River is classified as class SC by the NYSDEC (6 NYCRR Part 920.4). *"The best usage of Class SC waters is fishing"* (6 NYCRR Part 701.12). *"These waters shall be suitable for fish, shellfish, and wildlife propagation and survival. The water quality shall be suitable for primary and secondary contact recreation, although other factors may limit the use for these purposes."*

The NYSDEC includes the following standards related to class SC waters, including the Forge River, in order to protect these best uses.

Nutrients

The narrative ambient water quality standards for nutrients, defines the limits for this nutrient as "*None in amounts that will result in growths of algae, weeds and slimes that will impair the waters for their best usages.*"

Under the authority of the Clean Water Act, Section 304a, the United States Environmental Protection Agency (USEPA) is advancing an initiative to establish regional nutrient criteria, in accordance with the National Nutrient Criteria Program. USEPA has published a Nutrient Criteria Technical Guidance Manual for Estuarine and Coastal Waters (2001b) to assist states to "establish water quality criteria and standards under the Clean Water Act (CWA) to protect aquatic life from acute and chronic effects of nutrient over-enrichment."

In response to the USEPA initiative, NYSDEC is deriving state-specific criteria based on New York State waters; these criteria will be established to identify nutrient levels that will protect the best designated uses of local waters. Work to establish and adopt total nitrogen criteria for estuaries is underway; however, NYSDEC currently anticipates that draft criteria will not be released to the public until 2015, and that they will not be adopted until 2016. The NYSDEC approach recognizes that appropriate response factors and links to the regulated waters' designated uses must also be considered.

Figure 2
Forge River Segments and Impairments

Dissolved Oxygen (DO)

For DO, chronic and acute standards apply. Chronic standards address the long term impacts of the impairment, in this case, low DO levels. The chronic standards protect the "propagation" requirement of the regulation. Acute standards address the short term impacts of the impairment, which protects the adult organism "survival" requirement of the regulation. The NYSDEC standards are based primarily on the EPA guidance for the Virginian Province (EPA, 2000).

Chronic: *"Shall not be less than a daily average of 4.8 mg/L."*

Acute: "*Shall not be less than 3.0 mg/L at any time."*

The chronic standard does provide some relief for short-term exceedances of the standard, which protects larval organism survival:

"The DO concentration may fall below 4.8 mg/L for a limited number of days as defined by the formula:

$$DO_i = \frac{13.0}{2.80 + 1.84e^{-0.1t}}$$

Where DO_i = DO concentration between 3.0-4.8 mg/L and t_i = time in days. This equation is applied by dividing the range of 3.0-4.8 mg/L into a number of equal intervals. DO_i is the lower bound of each interval (i) and t_i is the allowable number of days that the DO concentration can be within that interval. The actual number of days that the measured DO concentration falls within each interval (i) is divided by the allowable number of days that the DO can fall within interval (t_i). The sum of the quotients of all intervals (i…n) cannot exceed 1.0:"

$$\sum_{t=1}^{n} \frac{t_i(actual)}{t_i(allowed)} < 1.0$$

NYSDEC TOGS 1.1.6 (NYSDEC 2008) provides some guidance as to the number of DO intervals and the time period over which this equation is applied. A DO interval of 0.1 mg/L (18 intervals) and moving 66-day period are recommended to assess compliance. The 66-day period is based on the EPA guidance document, and represents the early life stage of an organism when the organism is most vulnerable to low DO concentrations. Other DO intervals could be chosen, but it is recommended that approval be obtained from NYSDEC before proceeding on a different path. The interpretation of the DO criteria can be confusing, so the TOGS provides a useful reference for understanding how the criteria are applied.

The Relationship between DO and Nutrients

A water body that is exposed to the atmosphere will contain dissolved oxygen. When the DO concentration in the water is in equilibrium with the concentration in the atmosphere, the water has reached the saturation level of oxygen. This saturation level/equilibrium condition is dependent on atmospheric pressure, salinity and water temperature. Less oxygen can be dissolved in water as pressure decreases, or as salinity and/or temperature increase. Thus, in temperate climates, during the winter months, water can hold more oxygen, and the DO saturation concentration is higher than during the summer.

In an estuary setting, the concentration of dissolved oxygen is also affected by physical, biological and chemical processes. As oxygen levels within the estuary change, the exchange between the water and atmosphere changes as the system seeks to establish a new equilibrium. If the concentration of DO in the estuary is lower than the saturation concentration, oxygen from the atmosphere will enter the surface layer of the water column until the saturation concentration is achieved.

Photosynthesis by aquatic plants and algae is another source of oxygen within an estuary. If the photosynthetic process produces more oxygen than the saturation concentration, the water column is super-saturated and there is a net exchange of oxygen from the water column to the atmosphere over time.

A third source of oxygen is the input of oxygen rich waters from freshwater inputs or tidal exchange.

Losses or sinks of oxygen within an estuary include respiration of aquatic plants and algae, the oxidation of carbon to carbon dioxide (also known as the oxidation of BOD), the nitrification of ammonia to nitrite and nitrate, the oxidation of hydrogen sulfide, and sediment oxygen demand. These processes are also affected by temperature, such that higher rates occur as the temperature increases. When the oxygen concentration falls below the saturation concentration, a dissolved oxygen deficit results.

As a result of the combination of lower DO saturation levels and higher rates of oxygen utilization during periods with higher temperatures, low levels of oxygen are most often observed during the summer. Additionally, temperature stratification can occur during the summer months when warmer surface water overlies cooler, denser water. This temperature stratification magnifies the salinity stratification that occurs in estuaries when fresher surface water overlies denser more saline water. The combination of temperature and salinity stratification results in overall density stratification that inhibits mixing between the surface and bottom waters. When this stratification occurs, oxygen atmospheric oxygen that aerates the surface layer cannot mix down to the deeper water to replenish DO that has been used to satisfy sediment oxygen demand and other processes.

Since most aquatic organisms require oxygen, sources and sinks of oxygen are balanced in a healthy ecosystem to sustain adequate oxygen levels to allow organisms to survive and propagate. One way in which an ecosystem can become unbalanced is through the addition of excess nutrients that impact the growth of aquatic plants and algae, and the levels of dissolved oxygen in the water column.

Algae are an important part of the ecosystem and are the foundation of the food web. Algae require adequate temperature, light levels, nutrient levels and time for growth. At the proper levels, nutrients stimulate algal growth at a level in balance within the ecosystem. In particular, nitrogen (N) and phosphorus (P) are the major nutrients used by algae. The Redfield ratio (Redfield, 1934) describes the approximate composition of algae and the relative requirements of nitrogen and phosphorus for algal biomass. On a mass basis the ratio is:

41.0 Carbon : 7.2 Nitrogen : 1.0 Phosphorus

Based on this ratio, algae require 7.2 times more nitrogen than phosphorus for growth. It should be noted that this is an idealized ratio and algae can vary from this ratio. When nitrogen and phosphorus occur in a water body in a ratio that is different than the Redfield ratio algae can deplete one nutrient before the other, which limits the ability of the algae to continue to grow. The nutrient that limits algal growth is said to be the limiting nutrient. Under the right conditions, high nutrient levels lead to excessive algal growth (algal blooms), and nutrient limitation may not occur, but light limitation or insufficient residence time might limit algal growth. Highly nutrient enriched water bodies are classified as eutrophic.

The oxygen balance changes when excessive algal growth occurs. During the day, with sufficient sunlight, algae can produce enough oxygen to super-saturate the water column. During the night, photosynthesis and oxygen production stop and algal respiration uses oxygen. When algae die, their carbon biomass is oxidized in the water column or settles to the sediment and undergoes diagenesis, which creates a sediment oxygen demand (SOD). When the loss rate of oxygen is greater than oxygen replacement by mixing with oxygen rich surface waters, the bottom water can become hypoxic (DO < 3 mg/L) or anoxic (DO = 0 mg/L) leading to mortality of aquatic organisms. Large diurnal swings in DO levels that can result from algal photosynthesis and respiration also stress organisms. To control excessive algal growth the sources of nitrogen and phosphorus must be reduced. Usually, the objective is to reduce the load of the limiting (or potentially limiting) nutrient. In most cases, nitrogen is the limiting nutrient in estuaries, but there are cases when phosphorus is the limiting nutrient, or nitrogen and phosphorus are co-limiting.

Finding a nutrient level that will sustain the required levels of oxygen in estuaries is challenging due to the time component of the relationship between nutrients and DO, as well as the timing of the other factors that affect DO concentrations. While nutrients can directly affect DO concentrations (e.g., nitrification), the majority of the impact of nutrients on DO concentrations is indirect. Nutrients impact the growth of algae and aquatic plants, which in turn affects DO concentrations. Thus, there is not always a direct cause and effect relationship between a particular nutrient level and dissolved oxygen levels. For example, high nitrogen concentrations might exist in a location where there is not sufficient residence time for algae to grow to a level that results in a DO impairment. In another case, nitrogen levels could cause an algal bloom during the spring when the temperatures are cool and the DO levels are high. However, after the bloom the algal biomass settles to the sediment, and later exerts a sediment oxygen demand during the summer when temperatures are warmer and DO concentrations are lower.

Evaluation of the impacts of nutrients on estuary water quality is particularly complex. The impacts of tides and density stratification due to differing temperatures and salinities within the estuary complicate the DO balance. This is why a time-variable eutrophication modeling framework has been proposed to evaluate the effect of nutrient loading on dissolved oxygen for the Forge River estuary. The model can track the time-variable effects of various factors affecting DO including nutrients, carbon inputs, nitrification, SOD, temperature, density stratification, and tidal flushing. In this way, a cause and effect relationship can be developed between the nutrient loading and the dissolved oxygen concentrations.

Existing Water Quality Conditions

Water quality samples are collected on a routine basis (approximately monthly) by the Suffolk County Department of Health Services (SCDHS) at the stations shown in Figure 4. In addition to the discrete sampling, data sondes have been placed in the river, from time to time, to record continuous data. Available water quality data in the upper Forge River indicate that nutrient and DO water quality standards are not being met. Figure 5 presents data collected during July 2008 from a data sonde placed at the Waterways Condominium pier, which is located on the east side of the River, roughly 1.9 miles upstream from the mouth of the river (SCDHS, 2011). These data are instructive for showing how the DO concentration varies over a short period and the relationship of DO to other measurements. The figure depicts water depth, temperature, salinity, DO and chlorophyll-a data collected at 15 minute intervals during a one week period. The data show a tidal range of approximately 1.5 to 2.0 feet, temperature variation of approximately 5°C, and salinity variation of approximately 8 psu during this period. The DO does not vary with the same periodicity as the tide, so tidal flushing does not account for the changes observed in the DO concentrations. Temperature changes do not explain the changes to DO either, as the temperature variation does not correspond to the observed variation in DO concentration. The salinity changes that are observed during this period occur on a longer time scale than the tides. An increase in salinity during the 14^{th} and 15^{th} corresponds to a period of lower DO and chlorophyll-a. However, in general the tides and changes in temperature and salinity do not explain the observed changes observed in DO.

The DO data in Figure 5 indicate there are periods when the measured DO concentrations are below the water quality standards (illustrated by the red lines on the figure) and also periods when the DO concentration represents super-saturated conditions (as indicated by the blue line). While there are several factors that can cause low DO levels, large swings in DO over the day are typically indicative of excessive plant/algal growth. DO concentrations tend to increase during the day when the sources of oxygen (algal photosynthesis and atmospheric reaeration) are greater than the sinks of oxygen (algal respiration, sediment oxygen demand (SOD), carbon oxidation and nitrification). During the night when the absence of sunlight halts algal photosynthesis, the oxygen sinks are greater than the sources and the DO concentrations decrease. The chlorophyll-a data in the bottom panel of Figure 5 indicate that there were high chlorophyll-a concentrations during this period, which supports the theory that algae are strongly influencing the observed changes in DO concentrations. These high chlorophyll levels indicate there is a high nutrient loading to the river, which is the ultimate cause of the observed low DO concentrations.

Station FRG007 is located just north of the data sonde location. Figure 6 presents DO, salinity, total nitrogen (TN), total phosphorus (TP), and chl-a data from station FRG007 on a longer time-scale, 2005-2011. This figure shows there is some year to year variability in water quality. Despite

Figure 4. SCDHS Water Quality Monitoring Sampling Stations.

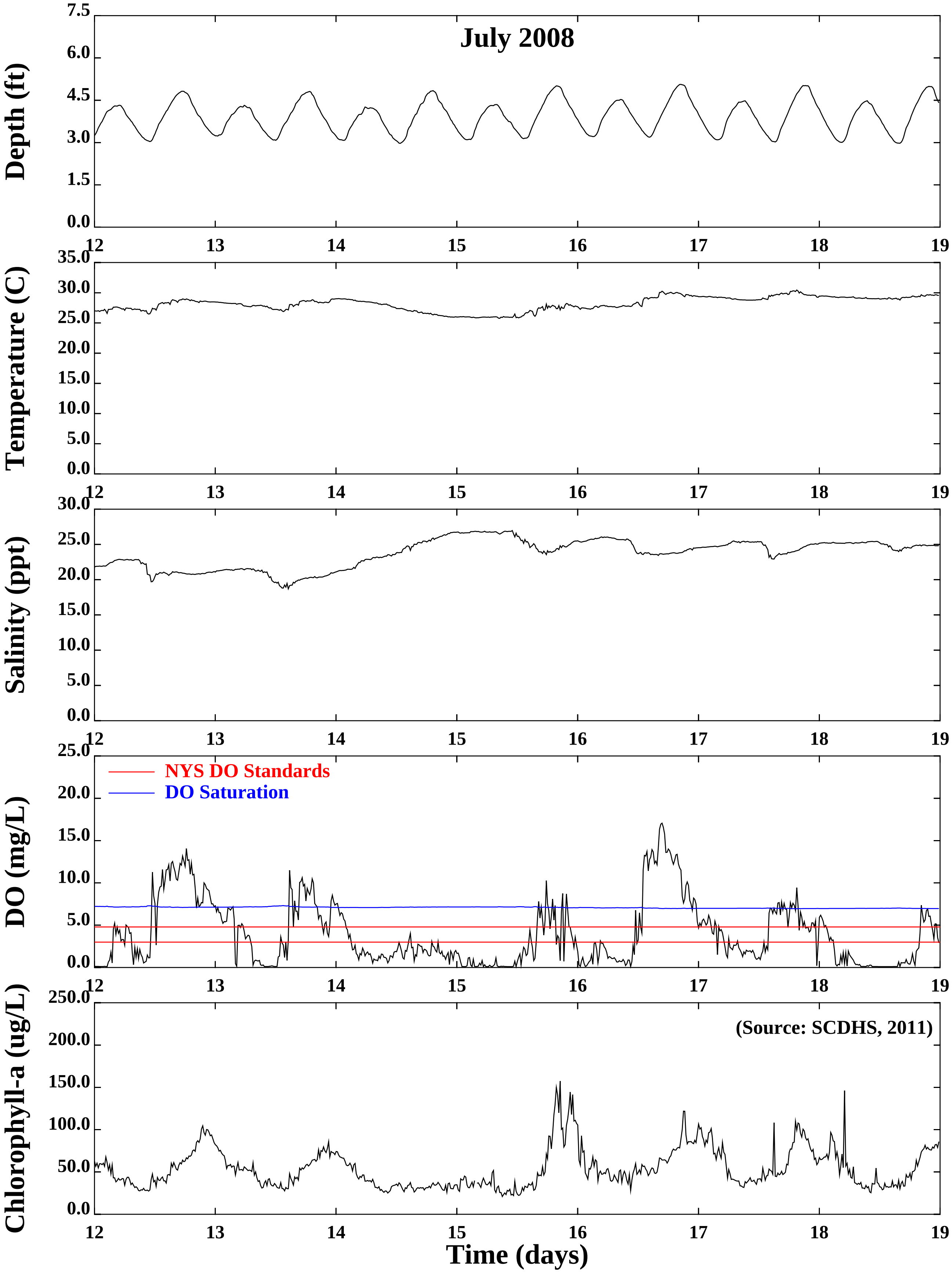


Figure 5 - Waterways Condominium Pier Data Sonde Measurements - July 2008

consistently high nutrient levels, there are some years when the DO levels are not quite as low or the period of low DO is shorter. The same variability exists for chl-a concentrations. This suggests that there are other factors in addition to nutrients that control DO and chlorophyll-a levels in the Forge River.

Figure 7 presents some additional data collected at station FRG007: DO deficit, salinity stratification, temperature stratification, the total nitrogen (TN) to total phosphorus (TP) ratio and the dissolved inorganic nitrogen (DIN) to dissolved inorganic phosphorus (DIP) ratio. The data indicate that the greatest difference between the DO saturation concentration and the DO concentration (DO deficit) occurs during the summer and there is year to year variability. The difference between the bottom and surface salinity (salinity stratification) can be fairly large, approaching 20 psu. There does not seem to be a consistent seasonal pattern in the salinity stratification. The temperature stratification is relatively minor with the majority of the difference between surface and bottom temperatures less than 2 °C. The TN to TP ratio is generally less than 7.2 indicating that in this location, nitrogen is the potentially limiting nutrient for algal growth, but because the concentrations are much higher than the concentration that limits algal growth, nitrogen does not actually limit algal growth. Since algae only use dissolved inorganic nutrient for growth, the DIN (NH_3+NO_2+NO_3) to DIP (PO_4) ratio is also presented. It is generally the case that nitrogen potentially limits algal growth in estuarine settings, but there are occasions when phosphorus could potentially be the limiting nutrient for algal growth at this station.

Data from station FRG009, located south of Ely Creek, is presented in Figure 8. Low DO concentrations are still observed in this location, although concentrations are slightly higher than at station FRG007. Here there is less of a freshwater signal as the salinity levels are higher. TN and TP concentrations are much lower at this location and are less variable. However, the chl-a levels measured here are just as high as measured at station FRG007. Additional data from station FRG009 is presented in Figure 9. Station FRG009, near the center of the river, differs from station FRG007, near the head end of the river, in that there is less salinity stratification, greater temperature stratification and the nitrogen to phosphorus ratios show that potential phosphorus limitation occurs more often.

At station FRG013, near the mouth of the Forge River (Figure 10), the water quality is relatively good. DO concentrations rarely decline to less than 4.8 mg/L. Salinity is higher than at the other Forge River stations while nutrient and chl-a concentrations are lower. Figure 11 shows that there is less DO deficit, salinity stratification and temperature stratification at this location than the other areas of the Forge River. Similar to station FRG009, station FRG013 shows that both nitrogen and phosphorus can be potentially limiting to algal growth.

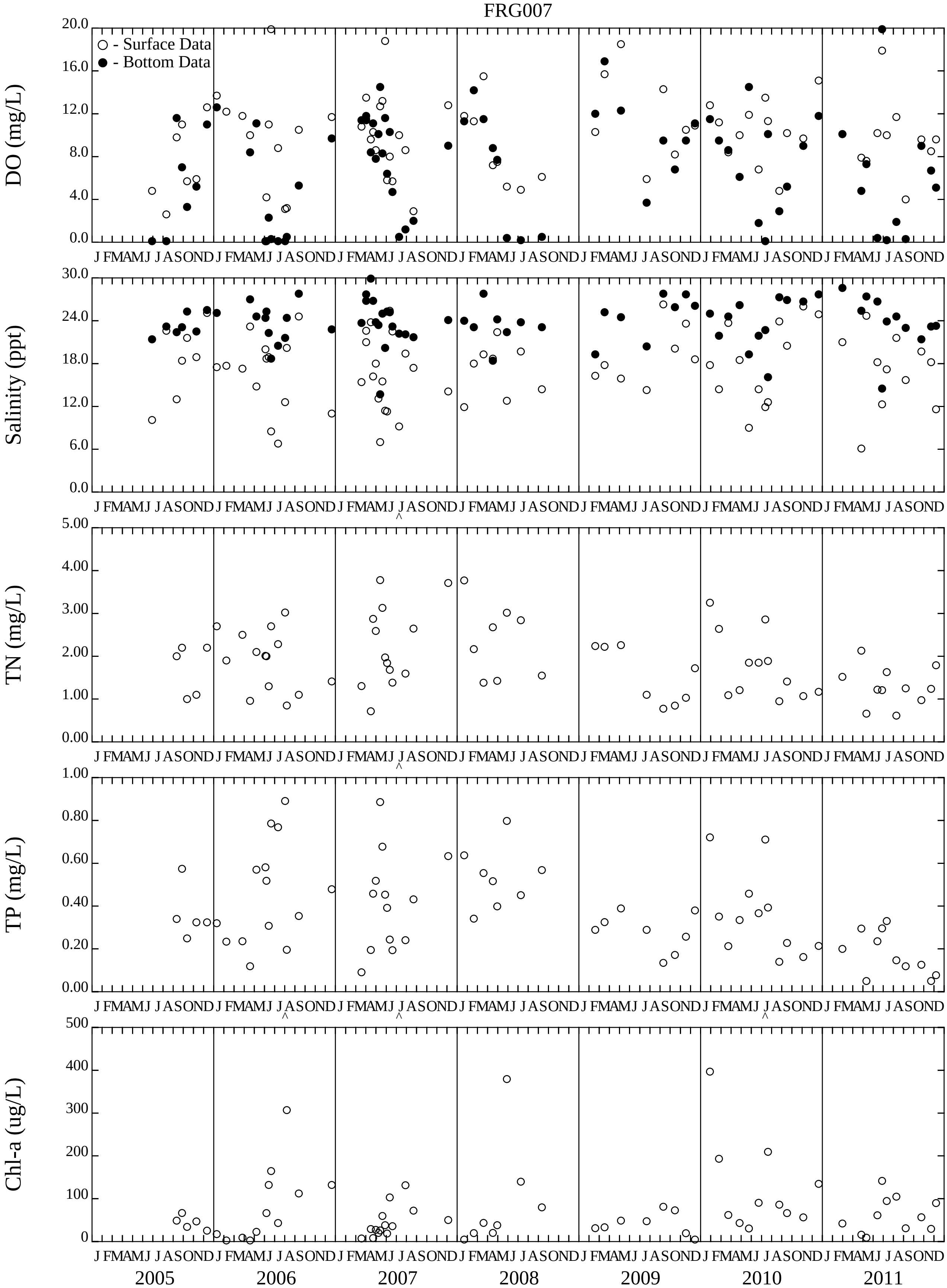


Figure 6. DO, Salinity, TN, TP, and Chl-a Data (2005-2011) - Station FRG007

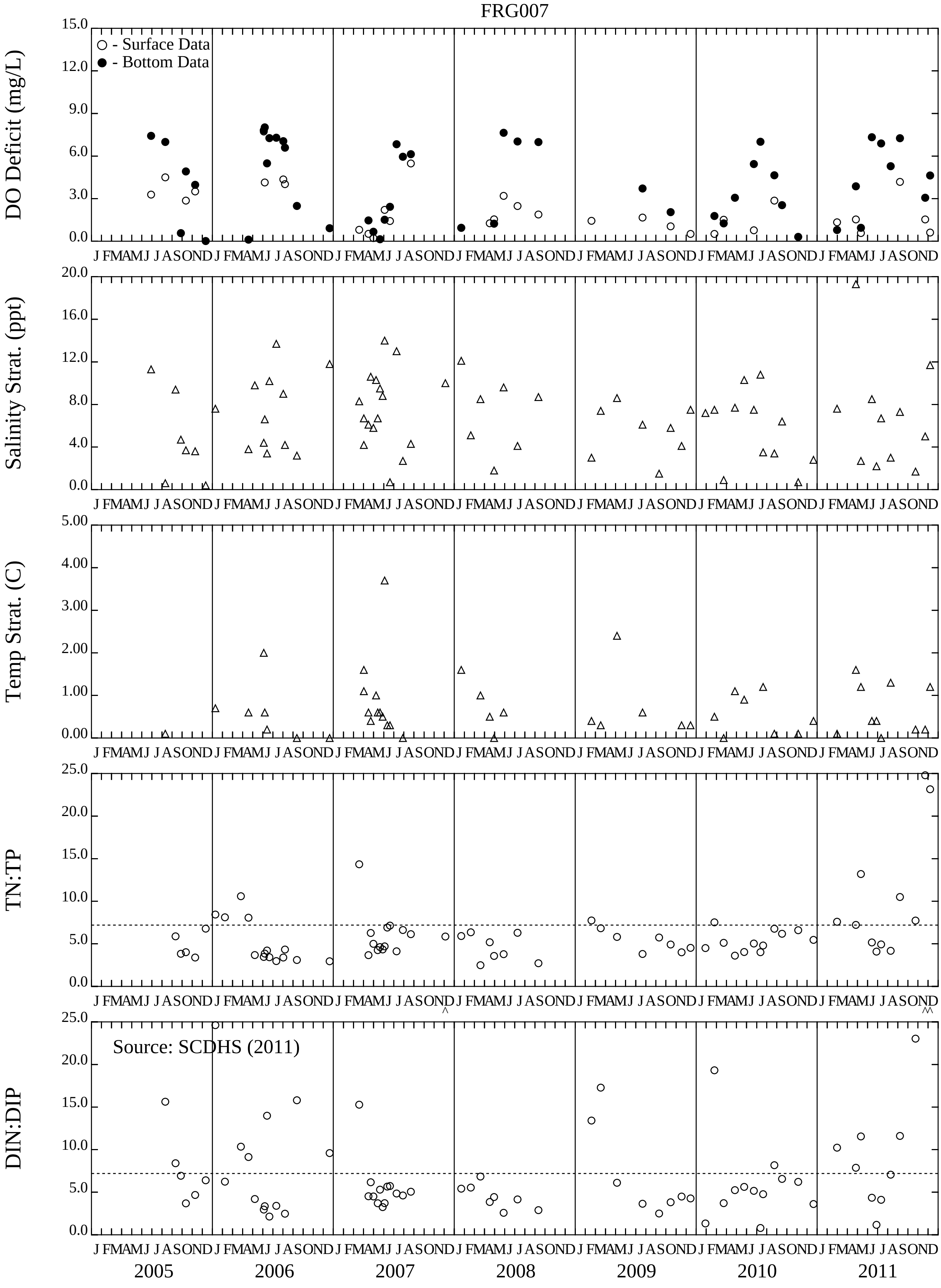


Figure 7. DO Deficit, Salinity Stratification, Temperature Stratification, TN:TP, and DIN:DIP Data (2005-2011) - Station FRG007

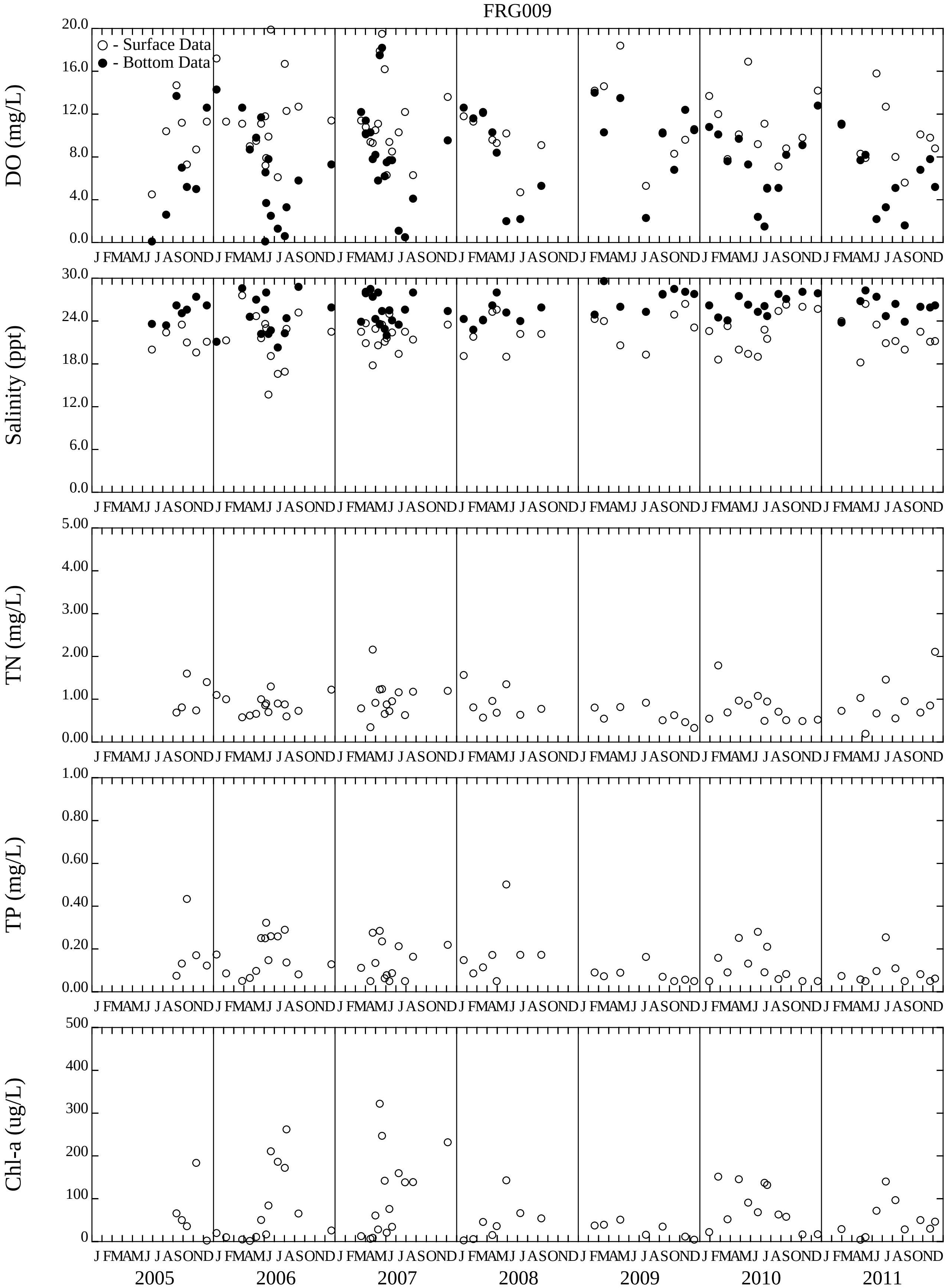


Figure 8. DO, Salinity, TN, TP, and Chl-a Data (2005-2011) - Station FRG009

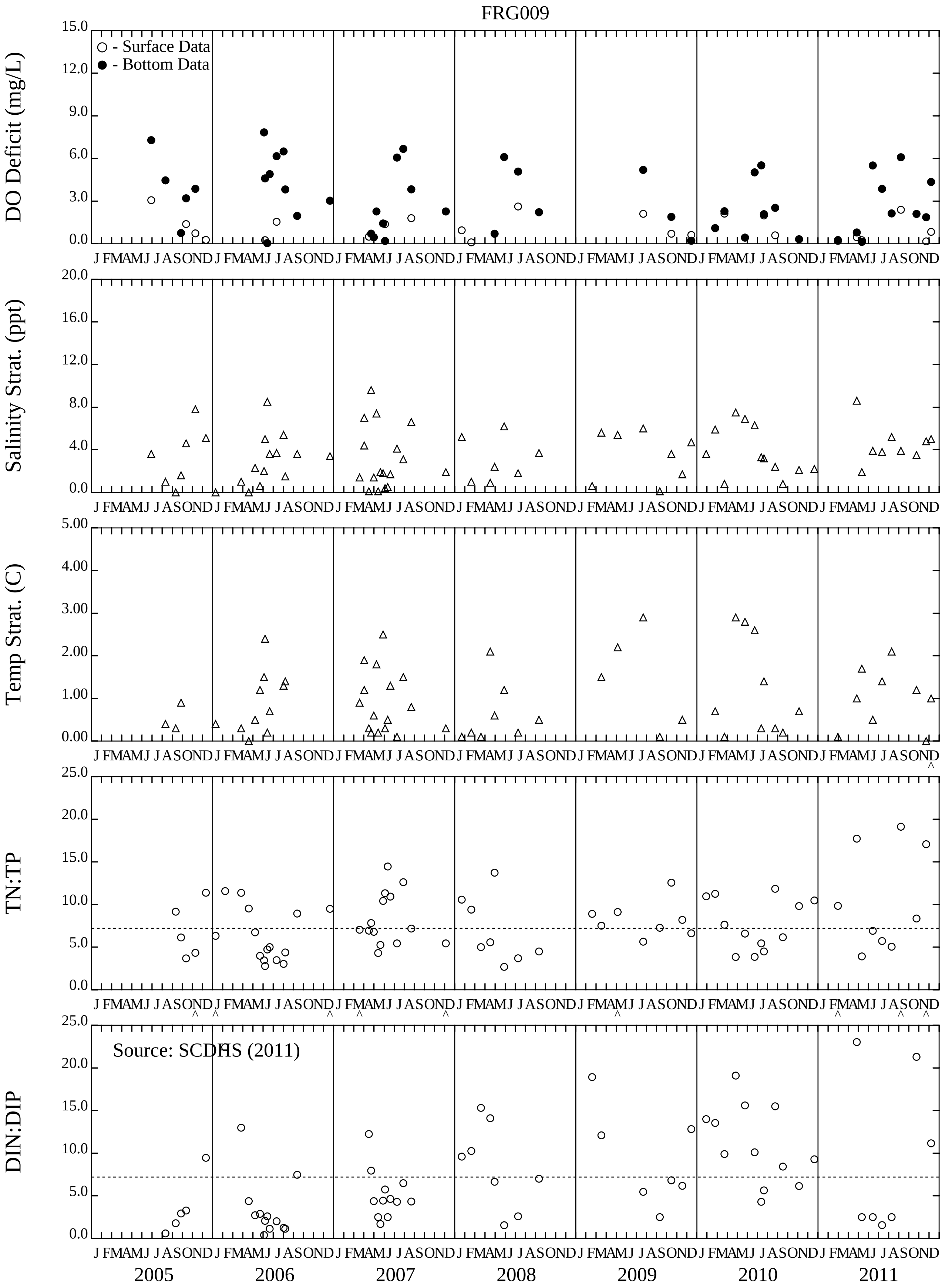


Figure 9. DO Deficit, Salinity Stratification, Temperature Stratification, TN:TP, and DIN:DIP Data (2005-2011) - Station FRG009

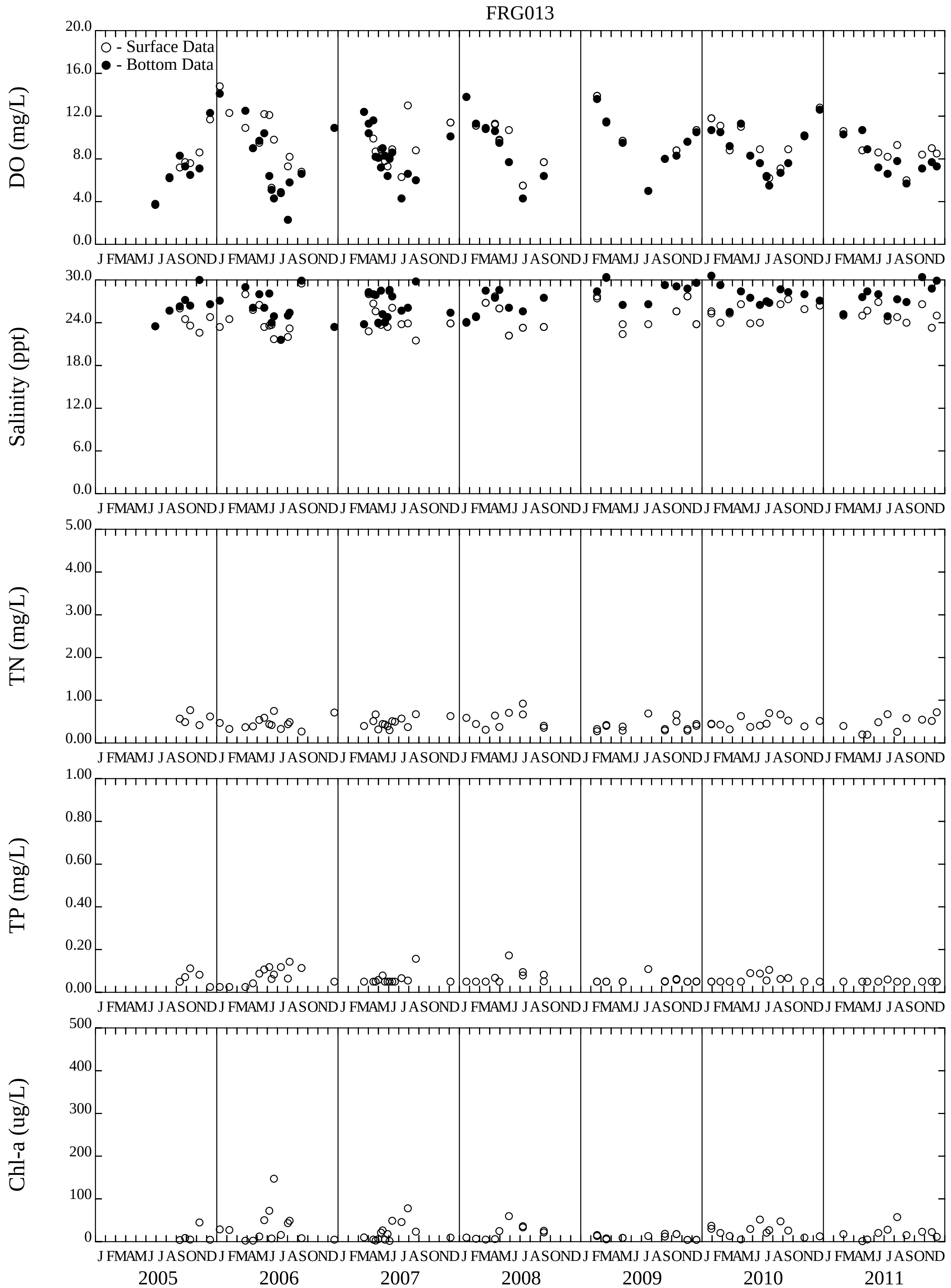


Figure 10. DO, Salinity, TN, TP, and Chl-a Data (2005-2011) - Station FRG013

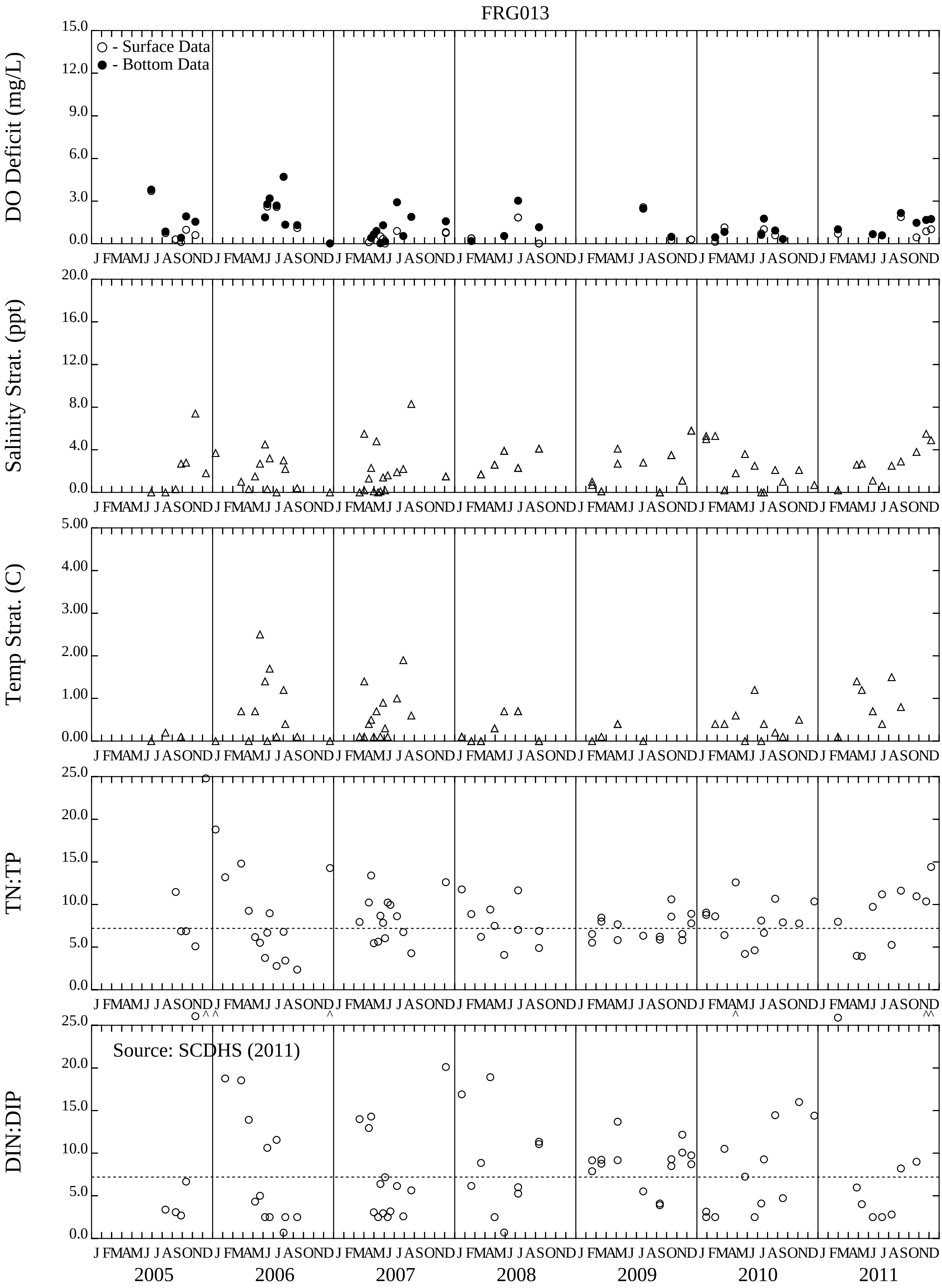


Figure 11. DO Deficit, Salinity Stratification, Temperature Stratification, TN:TP, and DIN:DIP Data (2005-2011) - Station FRG013

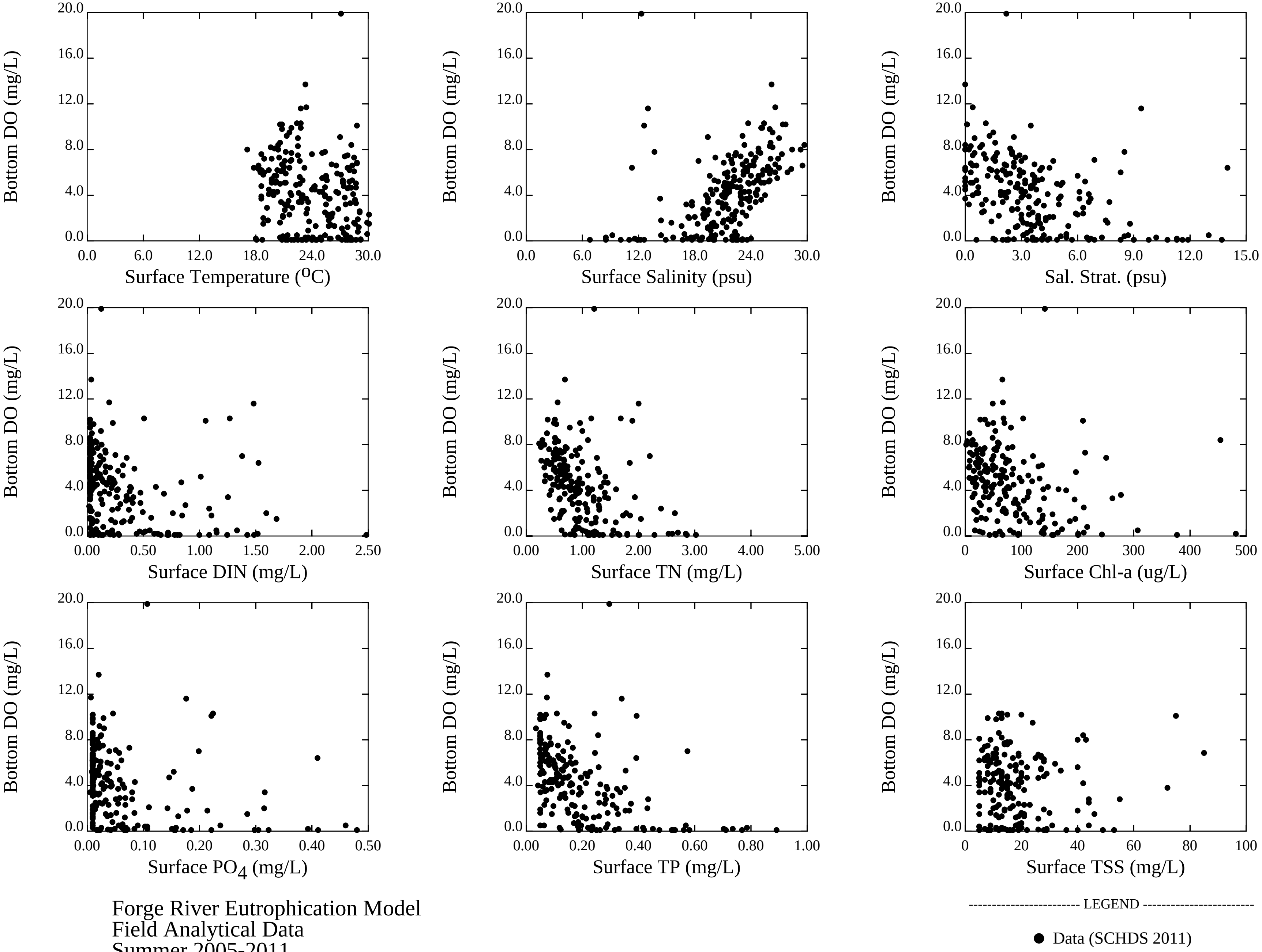
The patterns that develop from the data collected at these three stations are that DO and salinity levels increase from the head end to the mouth of the river. Nutrients and chlorophyll-a decrease from the head end toward the mouth. Potential phosphorus limitation is more likely in the lower half of the river. These patterns are related to the location of nitrogen and phosphorus sources to the river as well as the river's flushing characteristics. To assess the correlation between DO and various parameters, summer data from FRG stations 7, 1, 2, 9, 11, 12, and 13 (along the length of the Forge River) were plotted against DO concentrations.

Figure 12 presents DO data plotted against several parameters. Some general patterns emerge, but there is a great deal of scatter present in the data. Since only DO, temperature, and salinity are measured at both surface and bottom levels, bottom DO is plotted against the surface measurement on the x-axis, with the exception of salinity stratification, which is the difference between the bottom and surface salinity. No correlation between bottom DO and surface temperature was observed. Bottom DO is somewhat correlated to salinity as higher DO tends to occur when the salinity is higher. While DO saturation levels are lower at high salinity, nutrients enter the system via freshwater inputs and lower salinity is generally related to higher vertical density stratification. This is somewhat confirmed with the inverse correlation between DO and salinity stratification. DO also shows a weak inverse correlation to both total nitrogen and total phosphorus. As expected, the data confirms that summer bottom DO concentrations tend to be higher when the nutrient concentrations are lower.

To assess the correlations from another perspective, the bottom DO concentrations were binned into 0.5 mg/L increments and averaged. The binned averages plus the ranges of the DO bins are presented in Figure 13. Trends in the averages are more apparent than in the individual data points. However, correlation does not provide causation, and there is a fairly large range in most of the bins. The confounding factors include dilution from tidal flushing and the time component of the relationships between nutrients, algae and DO. High nutrient concentrations will not instantaneously cause low DO concentrations. High nutrient concentrations can result in algal growth, death, and settlement to the sediment and where they can exert a sediment oxygen demand (SOD), which reduces DO levels. Since no one nutrient concentration will result in compliance with the DO water quality standards, a modeling approach that accounts for the time-variable nature of all of the factors affecting DO will be used to assess nutrient loads to the Forge River.

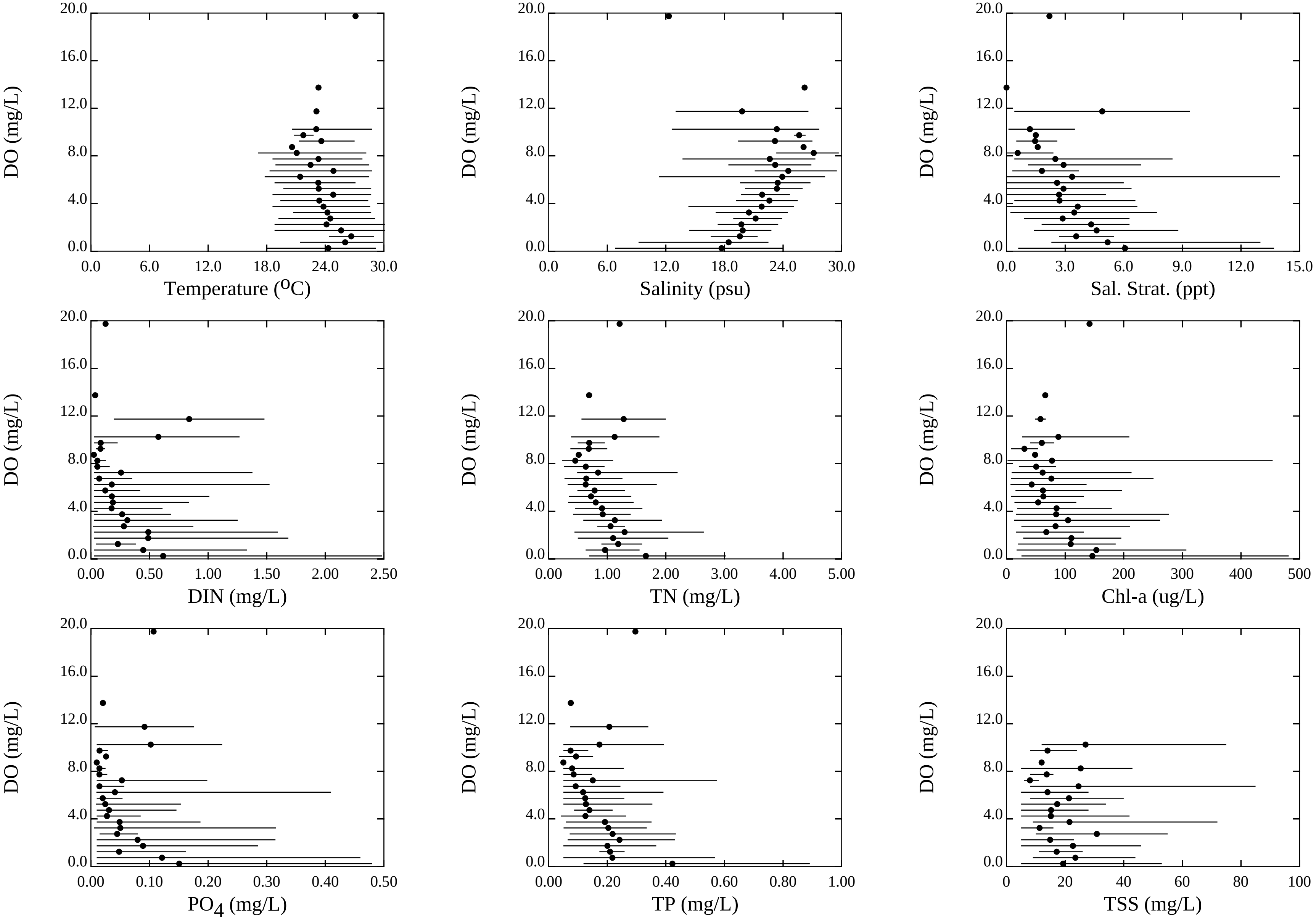
Initial Review of Nutrient Source Data

A review of the water quality data indicates that the upper Forge River tends to be potentially nitrogen limited and the lower portion of the river has the potential for either nitrogen or phosphorus to be the limiting nutrient. Figure 14 presents TN to TP ratios at water quality stations that provide information about the loading of nutrients to the river (note the scale changes on the y-axis). At the northern end of the system, north of West Mill Pond, the Forge River freshwater data at Station 020 have a TN to TP ratio of approximately 10:1 indicating the potential for slightly phosphorus limited to co-limited conditions. Freshwater systems are typically phosphorus limited. After the contribution of the duck farm load to the West Mill Pond (Station 015), the flow entering the tidal portion of the Forge River is potentially nitrogen limited with a low TN to TP ratio. Duck



Forge River Eutrophication Model
Field Analytical Data
Summer 2005-2011
Station 7, 1, 2, 9, 11, 12, 13

Figure 12. DO Correlation Analysis



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● Data (SCDHS 2011)

Forge River Eutrophication Model
Field Analytical Data
Summer 2005-2011
Station 7, 1, 2, 9, 11, 12, 13

Figure 13. Binned Correlation Analysis

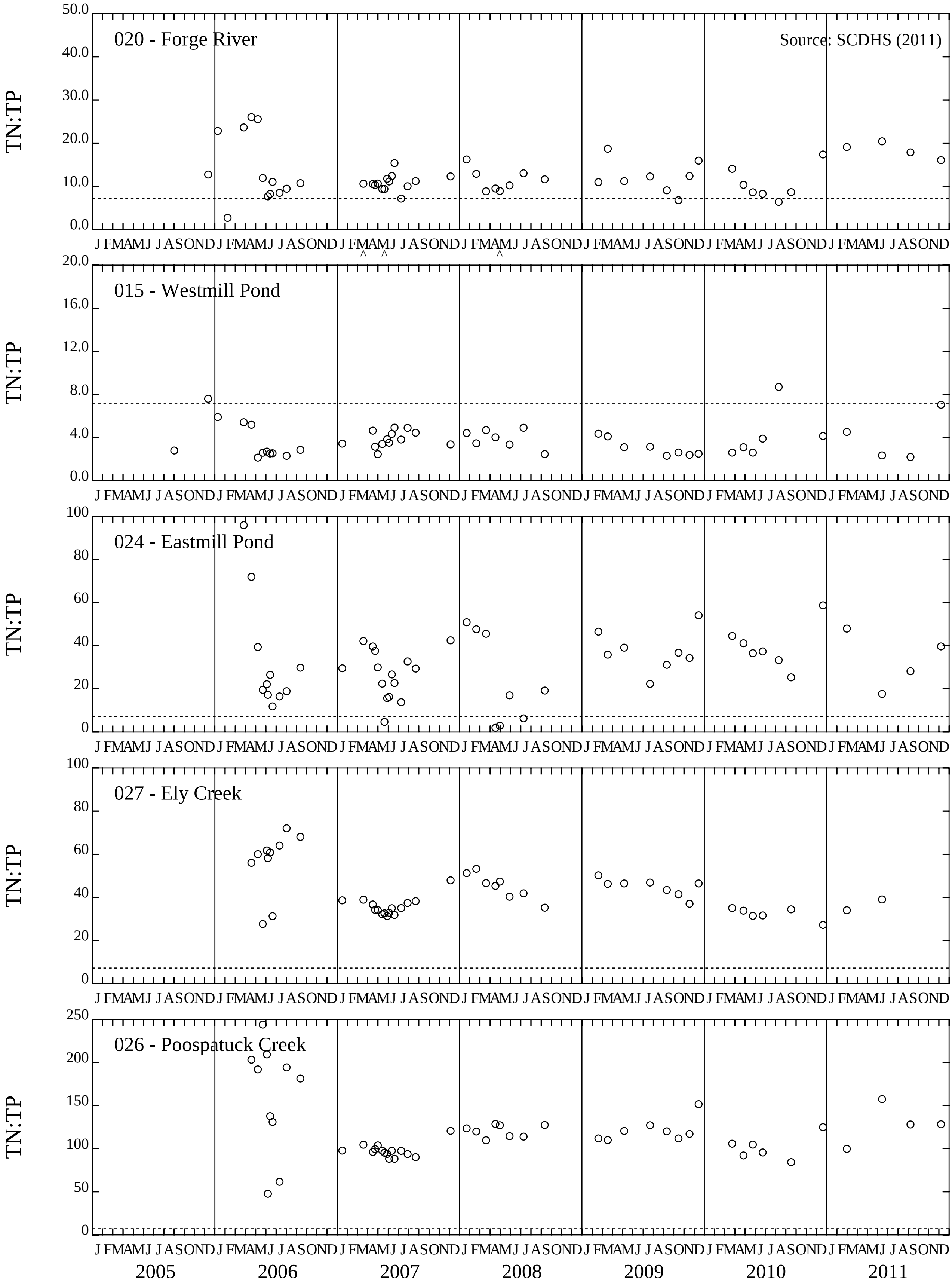

Figure 14. TN:TP for Several Nutrient Sources

waste has a low N to P ratio. Flow from East Mill Pond (Station 024) that enters the tidal portion of the Forge River is generally potentially phosphorus limited with a high TN to TP ratio. Both Ely Creek (Station 027) and Poospatuck Creek (Station 026) also have high TN to TP ratios indicating they are potentially phosphorus limited. These creeks are fed by groundwater, and nitrogen tends to be more mobile than phosphorus in groundwater.

Based on these data, the duck farm is the major contributor of TP to the Forge River. Since the duck farm has been closed, there is the potential for phosphorus to become the potentially limiting nutrient in the river. The bottom sediments of the Forge River likely have a large supply of phosphorus, which can be released when the overlying DO concentrations are low, and it may take a long time for the supply to be exhausted. When the 2012 water quality data is released, it will be reviewed to see if the potential for a nitrogen limited system in the upper Forge River is shifting to a potentially phosphorus limited system.

Task 3B includes the quantification of the loads to the river and the question of phosphorus limitation can be examined further in the technical memorandum for that task. The time variable water quality model developed and calibrated as Task 3C will be used to assess the impacts of both nitrogen and phosphorus, as well as other factors that affect dissolved oxygen levels including carbon oxidation, density stratification and residence time. The calibrated model will be used to evaluate the impacts of the cessation of nutrient addition from the duck farm discharge and the impacts of the continued contribution of nutrients from the sediments, from groundwater and stormwater discharges and from the bay boundary upon dissolved oxygen levels in the Forge River.

TMDL Endpoint

The studies performed in support of the Forge River Watershed Management Plan have documented that:

- The observed "hypoxic and anoxic conditions are inhospitable to aquatic life" and
- The "severe dissolved oxygen depletion in the Forge River is primarily due to algal blooms fed by exceptionally high nitrogen"

This is consistent with the USEPA (2001b, Nutrient Criteria Technical Guidance Manual, Estuarine and Coastal Marine Waters) guidance that dissolved oxygen is an initial response variable to over-enrichment of nutrients (typically nitrogen in estuarine settings) when hypoxia is observed. As previously noted, no numeric nitrogen criteria currently exist.

Due to the demonstrated linkages among increased nutrient loading, hypoxia and aquatic life, it is anticipated that reduction in nutrient loading to the Forge River will result in achievement of DO standards so that the best usage of the SC waters can also be achieved. Other factors that potentially affect DO and algal productivity, including detention time, available light and water clarity will also be considered as part of the modeling assessment that will be implemented for the project.

This TMDL endpoint was discussed at the Forge River TMDL Project Scoping Meeting, and achievement of the DO standard at all times throughout the Forge River was confirmed as an appropriate endpoint for this nitrogen TMDL. In addition, DO levels have been directly linked to aquatic organism health, and the concentrations that are suitable for fish and shellfish propagation and survival (EPA, 2000) are reflected in the water quality standards. Achievement of these DO standards in the Forge River is anticipated to support fish, shellfish and wildlife propagation and survival in the Forge River. On the other hand, there is no specific nutrient concentration that impairs water quality. Nutrients, at levels that are not excessive, are desirable because they stimulate the algal growth that forms the basis of the aquatic food chain. At high concentrations, nutrients can stimulate excessive algal growth that can lead to high chlorophyll-a levels, reduced water clarity and low dissolved oxygen concentrations. Nitrogen and phosphorus levels along with other factors such as detention time, available light and water clarity influence whether nutrient loading may impair water quality (EPA, 2001).

The goal of the Forge River nitrogen TMDL is to identify the conditions that will enable the Forge River and its tidal tributaries to consistently achieve the NYSDEC DO standards. These conditions will include nutrient load reductions, but may also include bathymetric changes to improve tidal flushing. Because compliance with the existing DO water quality standards varies both seasonally and spatially, the applicability of seasonal and spatially varying nutrient loading rates for the TMDL will be assessed.

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