USEPA REGION 2
NY/NJ HARBOR ESTUARY PROGRAM

NARRATIVE DESCRIPTION OF HISTORICAL DISSOLVED OXYGEN IMPROVEMENTS IN NY/NJ HARBOR RELATED TO PREVIOUS NUTRIENT REDUCTION ACTIVITIES

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CONTENTS

INTRODUCTION

Improvements in dissolved oxygen concentrations in the NY/NJ Harbor have been on-going for a number of years, independent of a TMDL for nitrogen and carbon loadings. Both historical improvements in dissolved oxygen and the management actions producing those improvements are described herein for the NY/NJ Harbor Estuary.

1.0 DISSOLVED OXYGEN IMPROVEMENTS

Previous dissolved oxygen improvements throughout the NY/NJ Harbor have been documented by several on-going long-term monitoring programs. These programs include:

- New York City Department of Environmental Protection (NYCDEP) Harbor Survey
- New Jersey Harbor Dischargers Group (NJHDG) Monitoring
- Meadowlands Environmental Research Institute (MERI) Seasonal Monitoring (formerly known as Hackensack Meadowlands Development Commission Seasonal Monitoring)

In addition, a previous program operated by the Interstate Sanitation Commission (now Interstate Environmental Commission) measured dissolved oxygen with continuous monitors deployed at up to eight Harbor locations during 1973 to 1980.

Each of these programs is described below. Also described are the measured trends in dissolved oxygen.

1.1 NYCDEP Harbor Survey

The City of New York has been collecting water quality data in New York Harbor since 1909. Data collection has been the responsibility of the NYCDEP Marine Sciences Section (MSS) for the past 22 years. The Survey currently consists of 62 stations; 35 stations located throughout the open waters of the Harbor, and more than 27 stations located in smaller tributaries within the City which vary from year to year. 20 water quality parameters are now measured.

Dating back to 1909, the Metropolitan Sewerage Commission was responsible for dissolved oxygen monitoring. In an August 1912 Report of the Metropolitan Sewerage Commission (available at www.openlibrary.org), *Present Sanitary Condition of New York Harbor and the Degree of Cleanness Which Is Necessary and Sufficient for the Water*, dissolved oxygen measurements for summers 1909 and 1911 are reported as a percentage of saturation. 2,670 analyses for dissolved oxygen were conducted: 800 in 1909 and the remainder in 1911. 1911 was a worse year than 1909. In 1911, dry summer weather dissolved oxygen was 64%-89% of saturation at the Narrows, 51%-64% of saturation at the mouth of the Hudson, and 50%-64% at the mouth of the East River. In 1909, dry summer weather dissolved oxygen was 60%-80% of saturation in Newark Bay; 0%-40% of saturation for the Passaic River; and the oxygen in the Arthur Kill was generally half gone.

Since 1909, the City reports that Harbor water quality has improved dramatically (see http://www.nyc.gov/html/dep/html/news/hwqs.shtml). Summer average dissolved oxygen levels in both surface and bottom waters of the Inner Harbor have increased from less than 4 mg/L in the mid-1970s to above 5 mg/L beginning in the early 1990s (NYCDEP, 2002). In addition, summer average bottom water dissolved oxygen levels have increased from long-term (1920-1960) averages of 2 mg/L (range from 1 to 4 mg/L) to near 5 mg/L in the mid- to late-1990s (Brosnan and O'Shea, 1996a).

The *2008 New York Harbor Water Quality Report* includes presentations of dissolved oxygen trends from 1986 to 2008 for major Harbor areas including the Inner Harbor and Lower New York Bay/Raritan Bay. These presentations are included here as Attachment 1 and are described below.

1.1.1 Inner Harbor

The Inner Harbor includes the Hudson River from the NYC-Westchester County line, through the Battery to the Verrazano Narrows; the Lower East River to the Battery; and the Kill van Kull and Arthur Kill. Results from 13 Harbor Survey stations in these waters were combined as June-September averages for the trend reporting purposes shown in Attachment 1. Average June-September near surface dissolved oxygen values in the Inner Harbor have been on the rise since the late 1980's as shown in Attachment 1. Similarly, June-September average near bottom dissolved oxygen has increased from near 3 mg/L in 1970 to 6.6 mg/L in 2008. The June-September averages show an increase between 0.4 and 1.3 mg/L for each decade.

The City also reports that there is very little inter-annual chlorophyll-a variability in the Inner Harbor. June-September chlorophyll-a averages were fairly constant since 2000. Chlorophyll-a is an indicator of phytoplankton biomass. In marine waters, phytoplankton use of the available nitrogen often causes dissolved oxygen depletion. The constant chlorophyll-a levels in the Inner Harbor suggest that nitrogen management in these waters was not likely to be largely responsible for the increasing dissolved oxygen trend.

Despite the sustained increasing trend in June-September average dissolved oxygen in the Inner Harbor, water quality standards are not yet fully attained. For example, during June–September 2008, dissolved oxygen measurements were below 4 mg/L once at Mt. St. Vincent in the Hudson River near the Westchester County line and three times at Tottenville in the Arthur Kill near the confluence with Raritan Bay.

1.1.2 Lower New York Bay/Raritan Bay

There are five Harbor Survey monitoring stations located between Coney Island in Brooklyn; Staten Island, New York; Middlesex and Monmouth Counties in New Jersey; and Sandy Hook. These five stations represent the Lower New York Bay and Raritan Bay. Since 1970 June-September average dissolved oxygen concentrations have increased 2.6 mg/L, from 5.2 to 7.8 mg/L, for bottom waters as shown in Attachment 1. In 2008, however, discrete measurements included five readings within the 4.1 to 4.9 mg/L range. Average June-September chlorophyll-a measurements peaked in 1995 around 30 ug/L and have declined since to June-September 2008 average levels of 10 ug/L.

1.2 NJHDG Monitoring

In 2003, NJHDG began a long-term water quality monitoring program for the waters in the New Jersey portion of the NY/NJ Harbor Estuary. Thirty-three locations are monitored weekly from May to September and twice per month from October through April. While most stations are sampled at mid-depth, deep-water sites are sampled at two discrete depths (1 meter below the surface and meter above the bottom substrate). Displays of dissolved oxygen results for the years 2004 through 2008 of dissolved oxygen compliance with standards have been prepared by NJHDG (see www.pvsc.org, 2008 Water Quality Report) and are included here as Attachment 2.

The display in Attachment 2 documents year to year variation in dissolved oxygen concentrations across the 5 years considered. In general, dissolved oxygen levels were better in 2006 and 2007 than in 2004, 2005, or 2008 in terms of standards attainment.

1.3 MERI Seasonal Monitoring

The New Jersey Meadowlands Commission has monitored water quality in the Hackensack River since 1993. Four times each year (spring, summer, winter, and fall), samples are collected at 5 sites on the Hackensack River and at 9 sites tributary to the Hackensack River.

In 2005, MERI prepared an analysis of the dissolved oxygen monitoring data collected between 1993 and 2005 (see http://meri.njmeadowlands.gov/scientific/dissolved_oxygen.html). The MERI analysis pooled the data from the 5 Hackensack River stations from all four seasons to calculate River-wide, across-season, averaged dissolved oxygen concentrations. MERI reports an increasing trend in Hackensack River-wide, across-season, annual average dissolved oxygen concentrations between 1993 and 2005. The increasing trend is reported by MERI as a slope of 20% when averaged dissolved oxygen concentration is plotted vs. year of measurement. Over 12 years, the trend predicts an increase in averaged dissolved oxygen of 2.3 mg/L.

The MERI trend analysis is include here in Attachment 3. There are clear outlying averaged dissolved oxygen measurements from the MERI trend analysis. Further, inspection of discrete data collected seasonally at the 5 individual MERI Hackensack River stations shows relatively little change in dissolved oxygen at individual stations between 1998 and 2010 as shown in the Attachment 3 displays downloaded from the Vista Data Vision program available on the MERI website. One exception is perhaps seasonal station 5, South Hackensack River, for which dissolved oxygen minima have been increasing between 2006 and 2010. Station minima for the years 1998 to 2010 range between 0.9 and 2.4 mg/L. The downloaded graphics are included in Attachment 3.

The graphics in Attachment 3 also include displays of the seasonal measurements of BOD and nitrogen at the five Hackensack River stations. Largely, these measurements are not suggestive of declining nutrient concentrations. Seasonal station 5, South Hackensack River, shows somewhat of a decline in seasonal ammonia nitrogen concentrations with increases in nitrate nitrogen concentrations from 1998 through 2010.

1.4 Interstate Sanitation Commission Continuous Monitoring

A discontinued program operated by the Interstate Sanitation Commission (now Interstate Environmental Commission) measured dissolved oxygen with continuous remote monitors deployed at up to eight Harbor locations during 1973 to 1980. The stations of greatest interest for current TMDL efforts in HEP waters include: the Arthur Kill near the confluence with the Rahway River (also near a Consolidated Edison Generating Station); the Raritan River at the Victory Bridge near Perth Amboy, NJ; the Arthur Kill near the Outerbridge Crossing in Staten Island, NY; the Narrows at the Southern end of the Upper Bay near Fort Wadsworth in Staten Island, NY; the Kill van Kull near U.S. Gypsum Company on Staten Island, NY; and the Hudson River above the NYC line near the Consolidated Edison Generating Station in Yonkers, NY.

The remote monitors included both monitors owned by the Interstate Sanitation Commission and monitors leased from EPA. Water was pumped to the monitoring units from five feet below the water surface. Readings were taken hourly (i.e., 24 readings per day). Once an hour, each remote unit telemetered data to a central receiver at the Commission’s office. This data set is very valuable in terms of its high frequency nature. A modern version of such a time intensive and continuous data set would be useful for assessing compliance with today’s dissolved oxygen standards which involve 24-hr averaged dissolved oxygen. Graphs are available for several of the stations which show monthly minima, monthly maxima, and monthly averages for the period of record. Dotted lines are used on the graphs to identify months for which ten days or less of data were collected. These graphs are included in Attachment 4.

For the Arthur Kill near the confluence with the Rahway River location, measured dissolved oxygen monthly minima did not show improvement from 1974 to 1980. The same is essentially true for the Kill van Kull near U.S. Gypsum. Monthly minima in the Kill van Kull were essentially the same for 1973 to 1977 with some small improvements from 1978 to 1980. For the Raritan River near the Victory Bridge, monthly minima were more severe in 1973 and 1974 than in 1975 to 1977. Unfortunately, the data record at this location doesn't go beyond 1977. There is a similar finding at the Narrows. The worst monthly minima occurred in 1974 with some improvement in monthly minima for 1975 to 1978. The Narrows data record ended in 1978.

While the graphs presented in Attachment 4 are useful for assessing trends at a given station as described above for a limited temporal window, they are also collectively important for illustrating that dissolved oxygen minima in NY/NJ Harbor were frequently measured at or near 0 mg/L, anoxia. That doesn't happen as often today as evidenced by information presented in Attachments 1 to 3. The diagrams in all the attachments taken together evidence that Harbor dissolved oxygen has improved since the 1970s. It is unlikely that the statement, ". . . . during the summer months District waters are grossly deficient in dissolved oxygen.", from page 2 of the 1977 Report of the Interstate Sanitation Commission, would be made today regarding the Harbor. Page 1 of the 1981 Report of the Interstate Sanitation Commission states that "compared to seven years ago, area waters are greatly improved, particularly with respect to the presence of dissolved oxygen." Page 2 of the 1982 Report of the Interstate Sanitation Commission reads, "A comparison of 1982 and 1977 dissolved oxygen data, during the critical summer months, showed a significant improvement in water quality over the past five years."

2.0 MANAGEMENT ACTIONS PRODUCING DISSOLVED OXYGEN IMPROVEMENTS

Infrastructure improvements and the capture and treatment of virtually all dry-weather sewage are the primary reasons for water quality improvement in the NY/NJ Harbor over the past century. (see http://www.nyc.gov/html/dep/html/news/hwqs.shtml) The history of these improvements is presented below.

2.1 Historical Problem Development

For more than 300 years, NY/NJ Harbor and the New York metropolitan area have been the center of urban development, transportation, manufacturing, and commerce. As a result New York City and the metropolitan area have undergone rapid population growth. Associated with this population growth have been the problems of waste water disposal and water pollution. The issues of waste disposal and water pollution were first noted in lower Manhattan during the time of the early European settlement. The first efforts to remedy these problems began in 1696 with the construction of a sewer and wastewater collection system. Additional sewer systems were constructed in lower and central Manhattan between 1830 and 1870. While the sewer systems helped address the issue of waste disposal, they did not address the issue of water pollution, since the Harbor received untreated wastewater from the sewers. According to Soper 1930, as early as

1914, the Metropolitan Sewerage Commission had a plan to discharge sewage from the lower East River and Jamaica Bay from an ocean island. By the 1920s New York City discharged approximately 600 mgd of raw sewage into the Harbor (Brosnan and O'Shea 1996b). In addition, the Harbor also received raw sewage from New Jersey communities. These pollutant discharges had a deleterious effect on water quality and the natural resources of NY/NJ Harbor.

The waters of NY/NJ Harbor once supported a large and diverse community of fish, shellfish, and shorebirds. However, these resources began to decline as a result of pollution and habitat loss. Most notable was the loss of a commercially-viable oyster industry. In the 1800s oyster beds were harvested in Raritan Bay, the Kill Van Kull, Jamaica Bay, Newark Bay, and the Shrewsbury River. Seed beds and habitat were disrupted by dredging, disposal of dredge spoils, construction materials, and cellar dirt. Bacterial contamination also resulted in the closure of many oyster beds by the early 1920s (Franz, 1982). Commercial fish landings also appear to have suffered from long-term pollution and habitat loss. Combined landings of important estuarine and anadromous species such as shad, alewife, striped bass, sturgeon, American oyster, hard clam, and bay scallop have declined 90 percent over the past century (McHugh et al., 1990).

2.2 History of Regulatory Actions, Facility Construction, and Management

The passage of the Clean Water Act in 1972 was an important milestone for the protection of the NY/NJ Harbor and other waterways throughout the United States. Highlights of the history of regulatory actions, facility construction, and management activities in the NY/NJ Harbor are presented in the context of before and after the Clean Water Act.

2.2.1 Regulatory Actions, Facility Construction, and Management Before the Clean Water Act

Legislative and regulatory efforts to quantify, control, and reduce pollutant inputs into NY/NJ Harbor have been taking place for almost a century. The first of these efforts took place in 1906, with the New York State legislature directing the City of New York to form the Metropolitan Sewerage Commission of New York. The Commission was charged with the dual tasks of investigating the extent of water pollution in the Harbor and formulating a plan to improve sanitary conditions in the City. Besides initiating routine water pollution surveys in 1909 (which represent the longest historical record in the United States), the Commission recommended upgrades in wastewater treatment, including construction of new wastewater treatment facilities. Construction of the first of these modern treatment facilities began in 1935 at Coney Island. Three additional facilities, which discharged to the East River, entered into construction in 1938. Other communities within the region also constructed modern treatment plants at that time.

They included the Passaic Valley (New Jersey) and the Yonkers (New York) primary wastewater treatment plants in 1924 and 1933, respectively.

In 1936, the Interstate Sanitation Commission was formed by a compact between the States of New York and New Jersey for the abatement of existing water pollution and the control of future water pollution in the tidal waters of the New York Metropolitan area.

Federal funding for water pollution control was provided via the Federal Water Pollution Control Act and its amendments in 1948 and 1956. Beginning in 1956, the Construction Grants Program provided municipalities with funding for the construction of wastewater treatment facilities. With the passage of the 1965 Federal Water Pollution Control Act, federal funding was also provided for technical assistance in monitoring and analysis in support of water quality management issues.

Between the late 1950's and early 1970's, initial efforts to numerically model water quality in NY/NJ Harbor were undertaken by Donald O'Connor (1962, 1966) and O'Connor and Mancini (1972). The resulting numerical model was used to make projections of expected changes in dissolved oxygen levels in the Upper Bay, the North River, and the East River resulting from various load reductions in BOD discharges from the Passaic Valley (New Jersey), Newtown Creek, and the yet to be constructed North River water pollution control facilities (WPCPs). The authors concluded that regional planning and wastewater treatment was required in order to achieve water quality goals for NY/NJ Harbor.

2.2.2 Regulatory Actions, Facility Construction, and Management After the Clean Water Act

With the passage of the 1972 Clean Water Act (CWA), the Construction Grants Program continued funding for construction of municipal WPCPs. According to the 1973 Report of the Interstate Sanitation Commission, some examples of construction projects from 1973 include: the Rahway Valley Sewerage Authority plant in Middlesex County NJ was upgraded from primary treatment to secondary treatment at a cost of $16,000,000 and the Yonkers plant in Westchester County NY was being upgraded from primary treatment to secondary treatment at an estimated cost of $55,000,000 (the 1974 report notes the cost at $100 million).

The 1972 CWA also provided funding to conduct regional analysis of pollutant inputs and pollutant load reductions required to address water quality problems. These area-wide studies were known as 208 studies. O'Connor and Mueller (1984) reported on the area-wide 208 study conducted for NY/NJ Harbor sponsored by the U.S. Environmental Protection Agency (USEPA) and administered by the New York City Department of Water Resources. The NYC 208 study was initiated in 1975 to assess the seasonal impact of continuous (domestic and industrial sources) and intermittent discharges, the latter including combined sewer overflows (CSOs) and separately-sewered stormwater sources.

With the advent of (at the time) modern computers and newer mathematical modeling techniques, the earlier analytical solution models of the Harbor were replaced with a higher spatial resolution finite-difference model of the Harbor. While the importance of density-driven circulation and vertical stratification in the Harbor had previously been recognized, early Harbor models did not address this physical phenomenon. However, the advent of the NYC 208 model, which included vertical segmentation in the Hudson River and Upper Bay portions of the Harbor, provided a first attempt to consider the effects of density-driven circulation and vertical stratification on water quality and, in particular, dissolved oxygen.

The calibrated/validated NYC 208 model was used to develop a loading component analysis of the DO-deficit in the NY/NJ Harbor. The NYC 208 study loading component analysis indicated that the NY and NJ WPCPs and untreated municipal sewage were responsible for approximately 55% of the maximum DO-deficit at that time. The remaining deficit was divided between SOD (approximately 15%) and other sources (30%). The model had indicated that if an 85% removal of BOD at the WPCPs could be achieved, the New York State Department of Environmental Conservation (NYSDEC) standard for dissolved oxygen (never less than 5 mg/L) could be achieved. The NYC 208 model represented one of the first cases of the application of a credible, density-driven estuarine model to project water quality response to the control of continuous and intermittent wastewater sources.

Driven by the regulatory controls of the 1972 CWA, and supported by model projections developed during the NYC 208 study, New York City and New Jersey communities began to upgrade WPCPs to full secondary treatment in the 1970s and 1980s. For example, as reported by the 1977 report of the Interstate Sanitation Commission, work was essentially completed on the upgrading and expansion of the former Middlesex County Utilities Authority primary plant in Middlesex County, NJ. The then new 120 MGD secondary treatment Middlesex County plant was scheduled to go on line in November 1977. In October 1981, as reported in the 1981 Report of the Interstate Sanitation Commission, the Passaic Valley Sewerage Commissioners placed their then new secondary waste treatment system into operation. Completion of the North River WPCP in 1986 ended the discharge of 170 mgd of raw sewage to the Hudson River from Manhattan. The discharge of 40 mgd of raw sewage to the lower East River from Brooklyn was eliminated with the construction of the Red Hook WPCP in 1987.

One of the key findings of the NYC 208 study was the deleterious impact on water quality of the discharge of CSOs in a number of New York City tributaries (e.g., Flushing Creek and Flushing Bay and Newtown Creek in the East River, and Paerdegat Basin, Thruston Basin, and Fresh Creek in Jamaica Bay, etc.). However, with New York City's fiscal crisis of the mid- to late-1970s, efforts to correct these problems were deferred in favor of eliminating the discharge of raw sewerage to the waters of the Harbor.

In 1982, a Water Quality Steering Committee formed. The Committee was formed to determine whether any excess assimilative capacity existed in the Harbor based on the then applicable dissolved oxygen standards. The Committee's purpose was to provide a basis for EPA and the States of NY and NJ to evaluate applications for permit modifications under Section 301(h) of the Clean Water Act.

In 1984, the National Estuary Program (NEP) was established. Since 1988, the NY/NJ Harbor NEP has been receiving funding coordinated through EPA Region 2. The NY/NJ Harbor Estuary Program (HEP) developed and continues to update a Comprehensive Conservation and Management Plan (CCMP) for NY/NJ Harbor which sets targets and goals for the management of the Harbor.

With the recovery of New York City from its earlier financial problems, work proceeded on completing upgrades to full secondary treatment at 13 of the City's 14 WPCPs. This work was completed in 1993 and ensured that the wastewater collected in the total sewered area of the City of about 2,000 square miles would be provided with treatment before being discharged to the Harbor. Work then began on the fourteenth NYC facility not yet operating at secondary treatment in 1993, the Newtown Creek WPCP.

As a result of the completion of the secondary treatment upgrade of the 14 NYC WPCPs, the NYC discharge of raw sewage to the Harbor had been reduced from 1,070 mgd in 1936 to less than 1 mgd by 1993 (Brosnan and O'Shea, 1996b). Associated with this reduction in raw sewage discharge and upgrades in treatment at all of the NJ and NY Harbor WPCPs, the loading of BOD to Harbor waters decreased almost three-fold from the highest levels observed in the mid-sixties (Suskowski, 1990). All of these upgrades in wastewater capture and treatment have resulted in significant improvements in water quality throughout the Harbor as described in Section 1.1.

However, water quality, in particular dissolved oxygen, had not improved everywhere within the Harbor. For example, the urban tributaries and embayments of the East River (the Bronx River, Flushing Bay, Newtown Creek, etc.) and Jamaica Bay (Paerdegat Basin, Fresh Creek, Hendrix Creek, Shellbank Basin, etc.) continued to demonstrate poor water quality and often failed to meet NYSDEC water quality standards for dissolved oxygen. These problems appeared to be related to episodic pollutants inputs from wet weather combined sewer overflows. NYCDEP provided funding during the mid- to late 1990s to develop facility plans for abating CSO discharges (Apicella et al, 1988, Apicella et al. 1993, Apicella et al., 1996, Apicella, 2001, HydroQual, 1990, 1991).

In addition, water quality problems continued in the western portion of Long Island Sound and the Grassy Bay section of Jamaica Bay. In particular these waterbodies failed to meet NYSDEC water quality standards for dissolved oxygen. However, nutrient enrichment, and not simply anthropogenic inputs of organic carbon, appeared to be the more important factor contributing to the contravention of the dissolved oxygen standards. In order to investigate the relationship between nutrient inputs, primary production, and dissolved oxygen in these waterbodies, more comprehensive modeling frameworks were developed. The first of these mathematical models, LIS 3.0, was developed for the USEPA Long Island Sound Study Office (HydroQual, 1996). The LIS 3.0 model was used by the States of New York and Connecticut to conduct a nitrogen

TMDL, in order to improve dissolved oxygen standards attainment for the Sound (NYSDEC and CTDEP, 2000).

The LIS3.0 model set the stage for the development of the System Wide Eutrophication Model (SWEM), beginning in the early 1990s. SWEM is currently being applied by the USEPA Region 2 NY/NJ Harbor Estuary Program (HEP) and the States of NY and NJ to develop nitrogen and carbon TMDL plans for improved Harbor dissolved oxygen standards attainment, particularly in the Hackensack, Passaic, Raritan, and Hudson Rivers; the Newark, Raritan, and Upper Bays; and the Arthur Kill.

In November 2000, EPA issued the final guidance document, *Ambient Aquatic Life Water Quality Criteria for Dissolved Oxygen (Saltwater): Cape Cod to Cape Hatteras*. The federally endorsed dissolved oxygen criteria are exposure duration based and consider 24-hr averages for the protection of juvenile and adult survival of marine organisms, larval recruitment of marine organisms, and growth of marine organisms. The 2000 marine dissolved oxygen criteria represented a significant difference from the "never less than" dissolved oxygen standards in effect in the Harbor at that time and still in effect in significant portions of the NY/NJ Harbor today. The current nitrogen and carbon TMDL efforts in NY/NJ Harbor are attempting to maximize Harbor compliance with the federal criteria.

Engineering studies and capital improvement projects supporting the maintenance and upkeep at all of the Harbor's WPCPs have been and continue to be a continuous major effort in the region. Costs of individual engineering studies and capital improvement projects are now often in the multi-millions of dollars range. Cost for these engineering studies and capital improvement projects ongoing simultaneously throughout the Harbor in any given year now total in the multi-billions of dollars range. The annual reports of the Interstate Environmental Commission (former Sanitation Commission) serve as a good source of documentation for the engineering studies and capital improvement projects.

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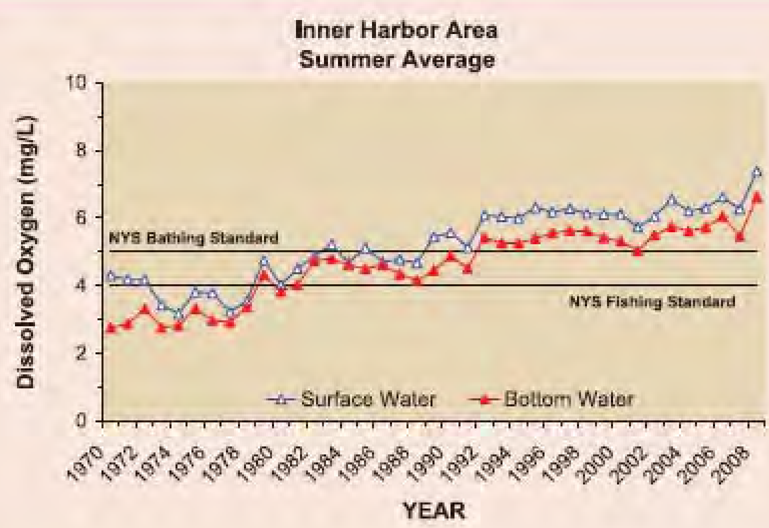
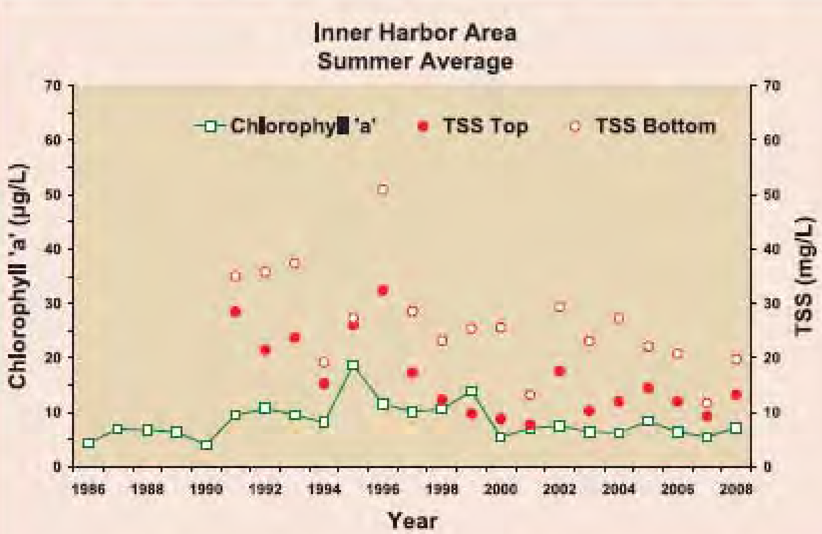
ATTACHMENT 1

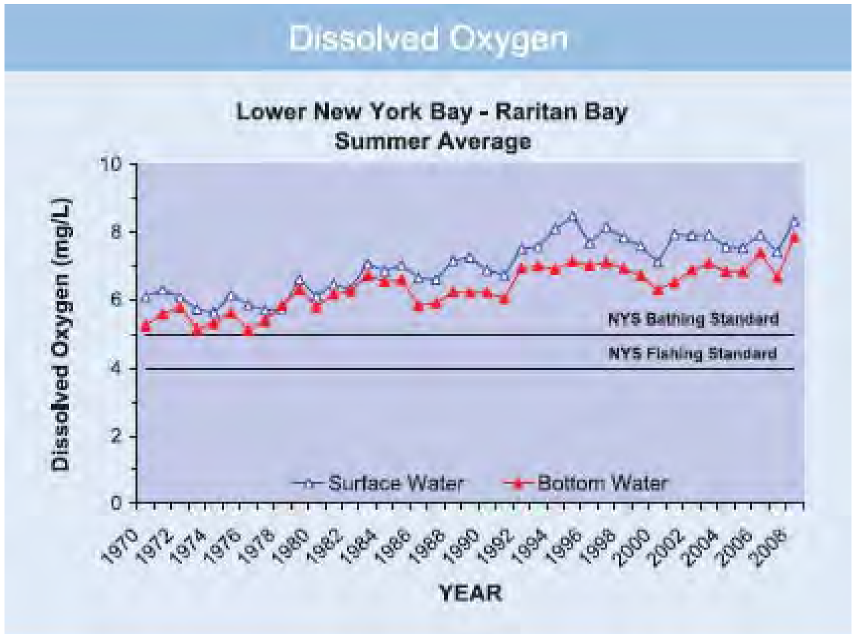
NYCDEP HARBOR SURVEY DATA DISPLAYS

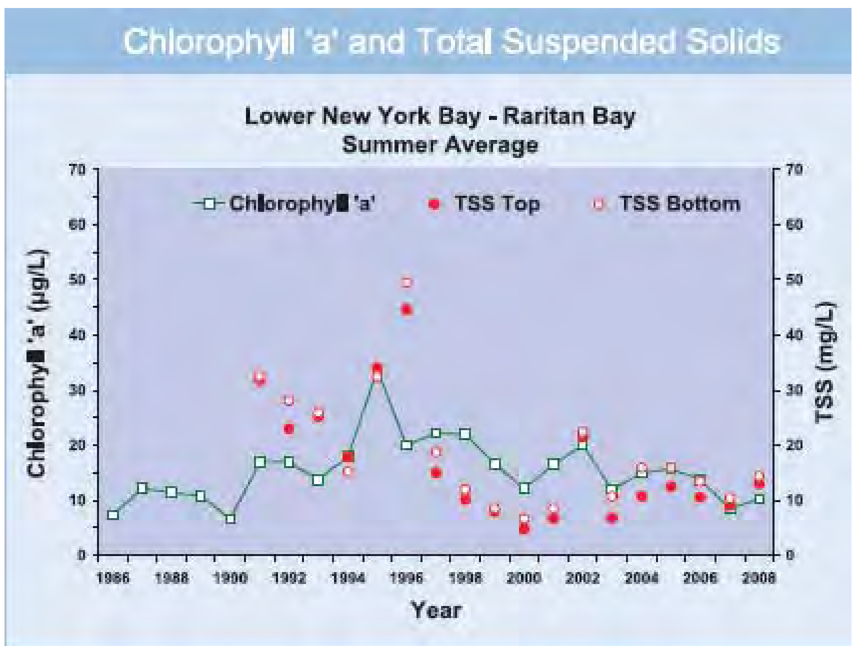
Dissolved Oxygen



Chlorophyll 'a' and Total Suspended Solids




Dissolved Oxygen
Lower New York Bay - Raritan Bay
Summer Average
Dissolved Oxygen (mg/L)
NYS Bathing Standard
NYS Fishing Standard
Surface Water
Bottom Water
YEAR


Chlorophyll 'a' and Total Suspended Solids
Lower New York Bay - Raritan Bay
Summer Average
Chlorophyll 'a'
TSS Top
TSS Bottom
Chlorophyll 'a' (µg/L)
TSS (mg/L)
Year

ATTACHMENT 2

NJHDG DATA DISPLAYS

Figure 18. % DO samples below Standards—Passaic River

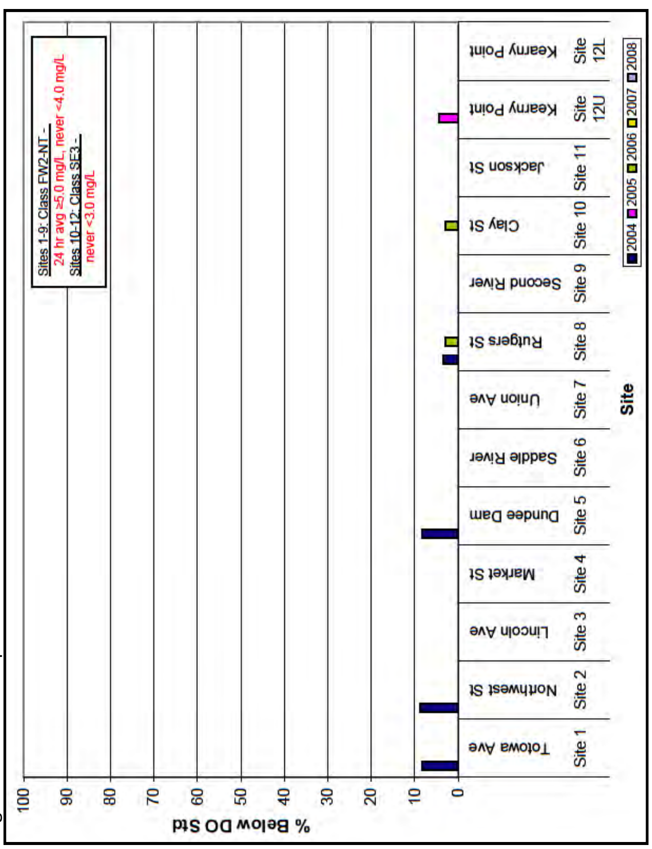


Figure 19. % DO samples below Standards—Hackensack & Hudson Rivers

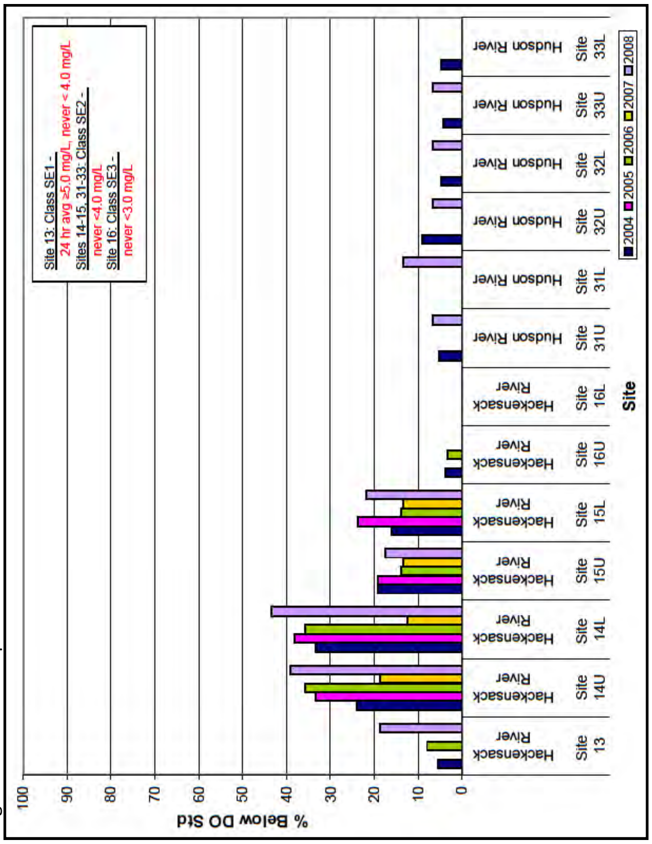


Figure 20. % DO samples below Standards—Newark Bay & Arthur Kill

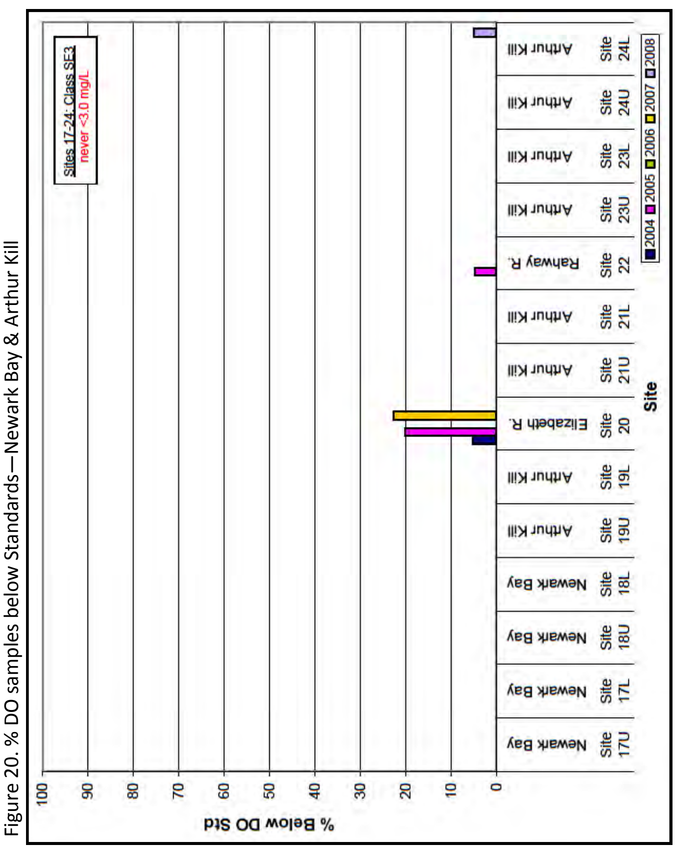
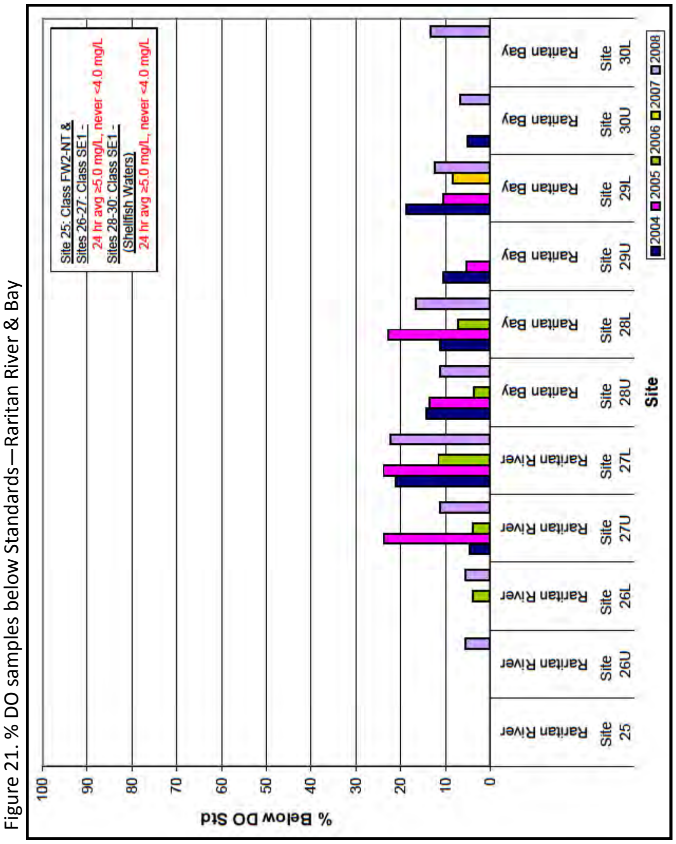


Figure 21. % DO samples below Standards—Raritan River & Bay



Note: Site 13—No DO measurements in summer 2005 due to equipment problems
Site 1—bridge closed for construction Jul 2007-Mar 2009—No data for summer 2008

ATTACHMENT 3

MERI DATA DISPLAYS

The scientific arm of the **New Jersey Meadowlands Commission**.

Seasonal Water Quality Monitoring Program

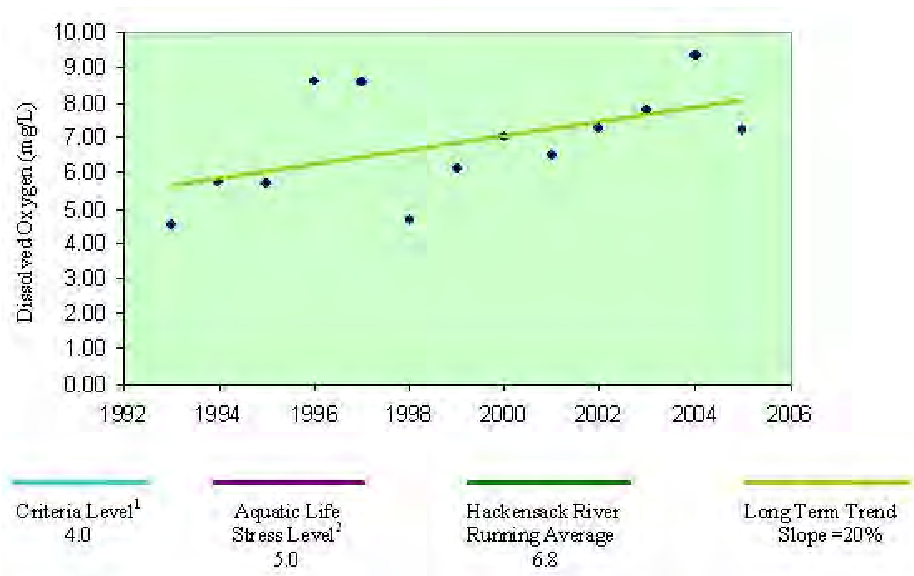
Participants: MERI

The New Jersey Meadowlands Commission has monitored the quality of water within the Meadowlands District since 1993. Four times each year (spring, summer, fall and winter) samples are collected at 14 sites on the Hackensack River and its tributaries. Analyses are conducted in the Meadowlands Environmental Research Institute laboratory, certified by the state of New Jersey. These efforts provide a general assessment of overall water quality in the Meadowlands, identify any large-scale, long-term trends in water quality, and detect any acute water quality problems.

NJMC-MERI Seasonal Water Quality Monitoring Data

Thirteen year (1993-2005) dissolved oxygen trend in the Hackensack River
Historical USGS Chlorophyll data 1993-1994

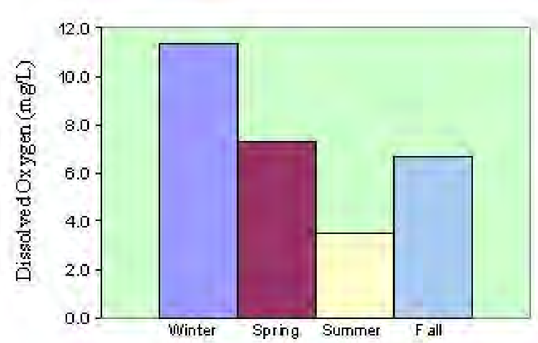
Thirteen year (1993-2005) dissolved oxygen trend in the Hackensack River



Dissolved Oxygen in the Hackensack River: 2005 Update

The Meadowlands Environmental Research Institute has completed its monitoring of the surface water of the Hackensack River for 2005. All five sites were sampled once during each season. An additional data point representing the 2005 yearly average is depicted in the chart above.

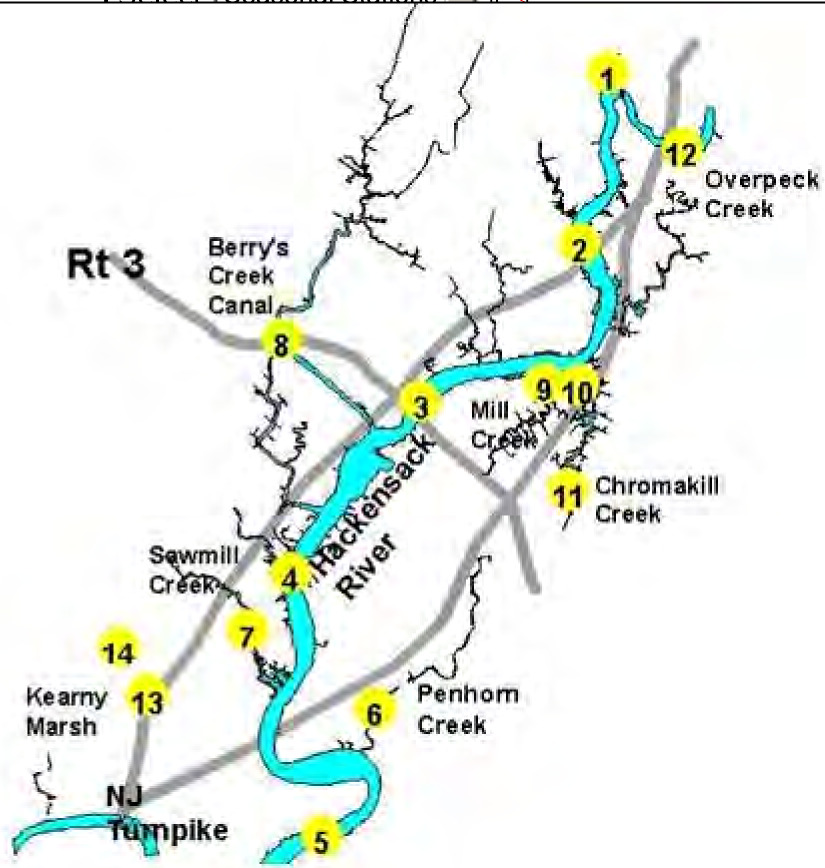
The average concentration for 2005 was 5% below the prior year's average. The long term trend for dissolved oxygen continues to be positive. The value of 7.2 for 2005 was above the running average, which continues to be well above criteria and stress levels. As in 1993 and 1998, an extremely dry summer was encountered, diminishing DO levels. As in prior years, oxygen rebounded with the resumption of normal precipitation in the fall.



Notes:
1 NJDEP criteria SE-2 (NJAC 7:9B) allows for secondary contact recreation and maintenance, migration and propagation of biota.
2 Ambient Aquatic Life Water Quality Criteria for Dissolved Oxygen, USEPA, November 2000.

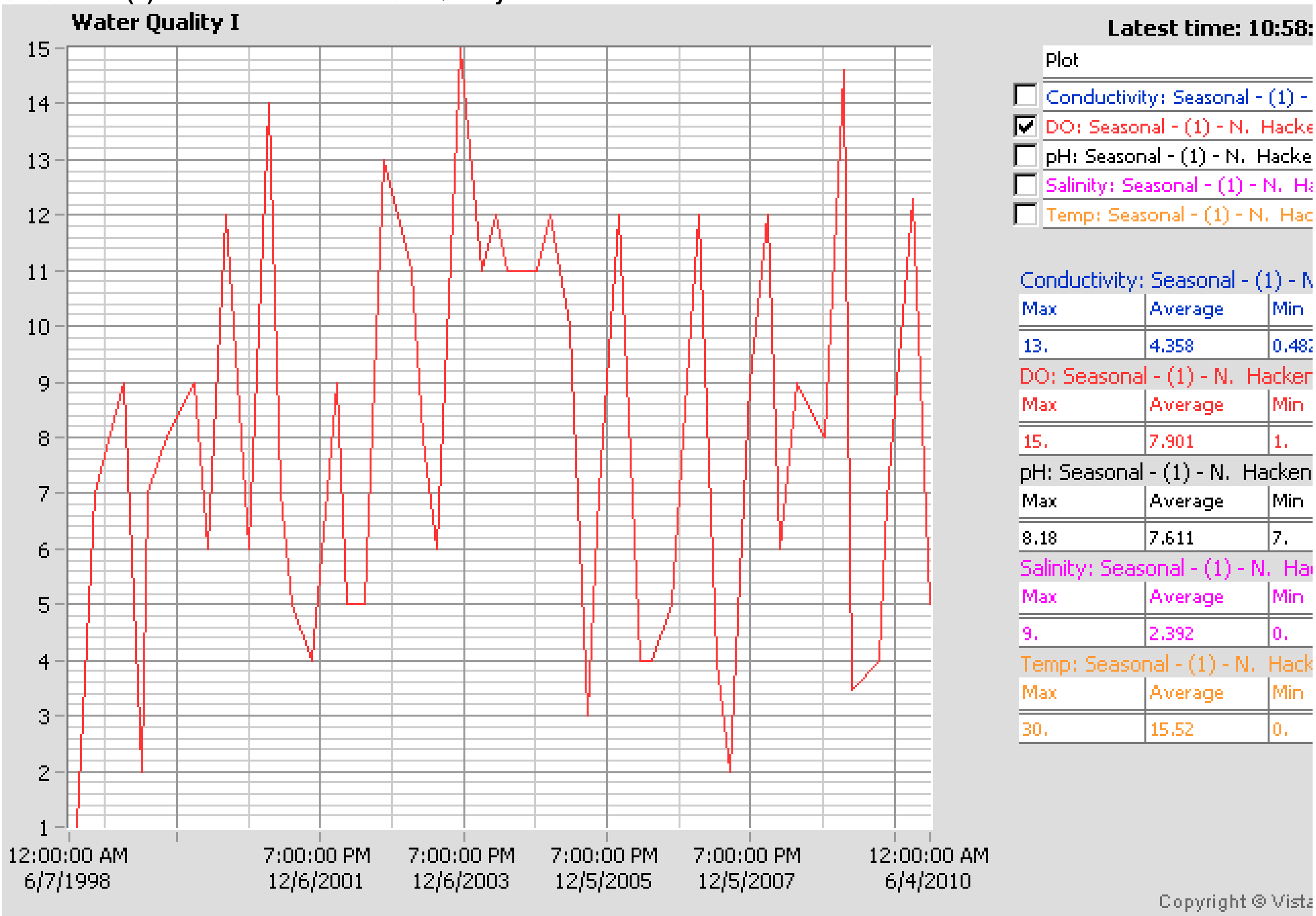
Locaton of EMS Stations & Seasonal Water Quality Stations: Seasonal Stations

Select Seasonal Stations

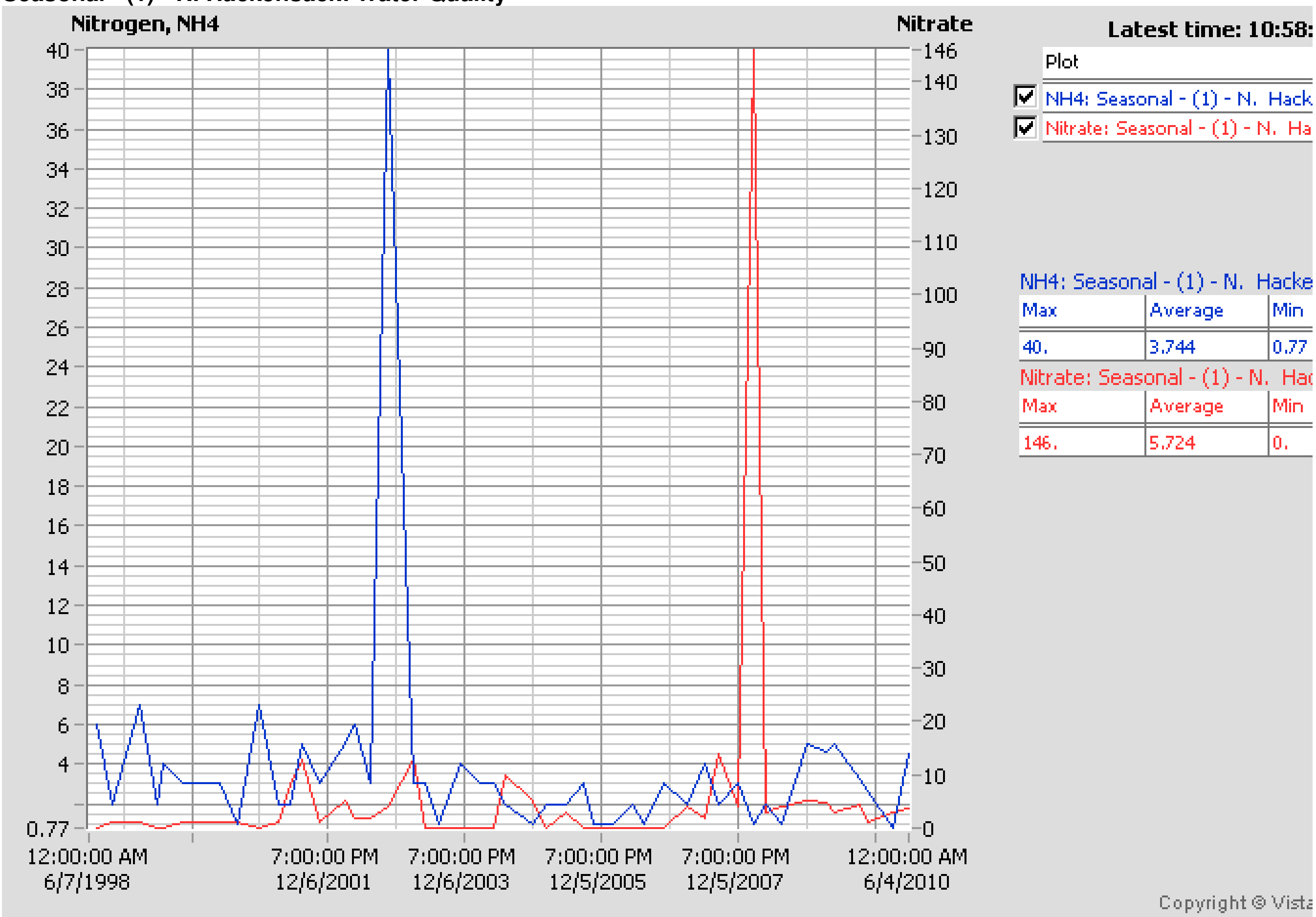


Last Reload Time: 13:53:31

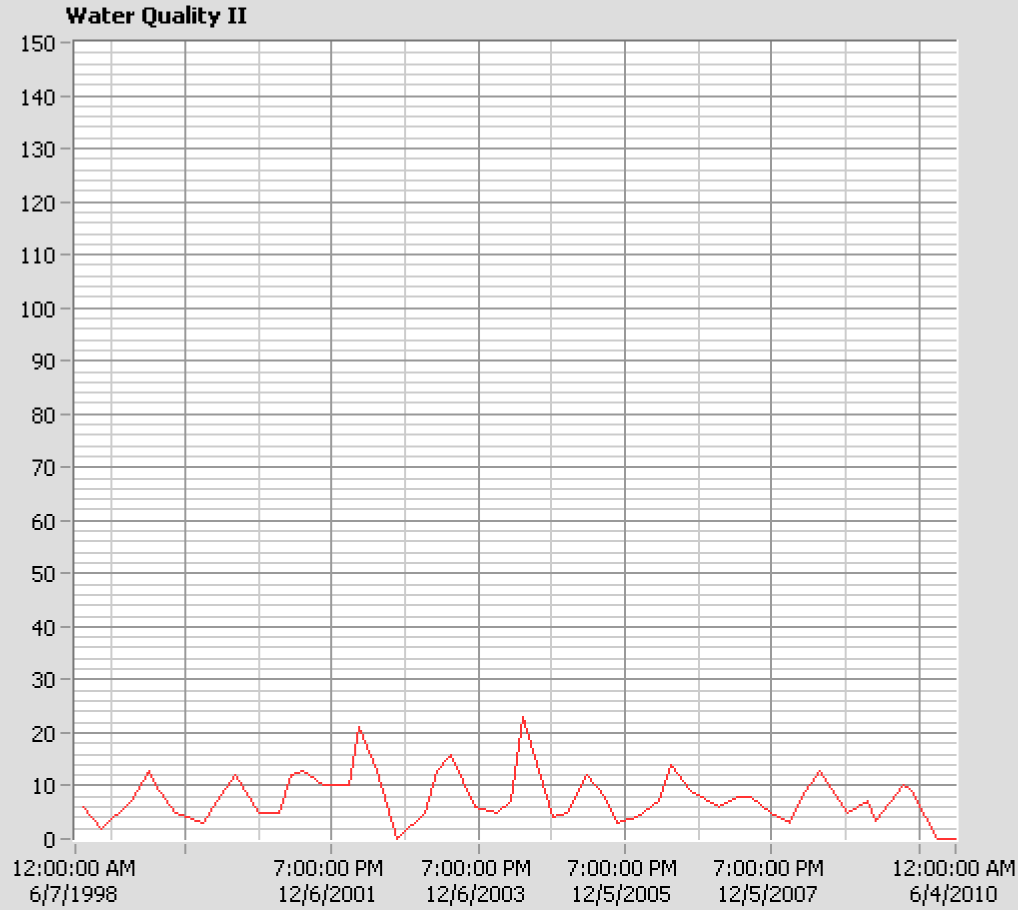
Seasonal - (1) - N. Hackensack: Water Quality



Seasonal - (1) - N. Hackensack: Water Quality



Seasonal - (1) - N. Hackensack: Water Quality



Latest time: 10:58:

Plot
Alkilinity: Seasonal - (1) - N. H
BOD: Seasonal - (1) - N. Hack
Turbidity: Seasonal - (1) - N.
TSS: Seasonal - (1) - N. Hack

Alkilinity: Seasonal - (1) - N. Ha

Max	Average	Min
0.	0	0.

BOD: Seasonal - (1) - N. Hacke

Max	Average	Min
23.	7.931	0.

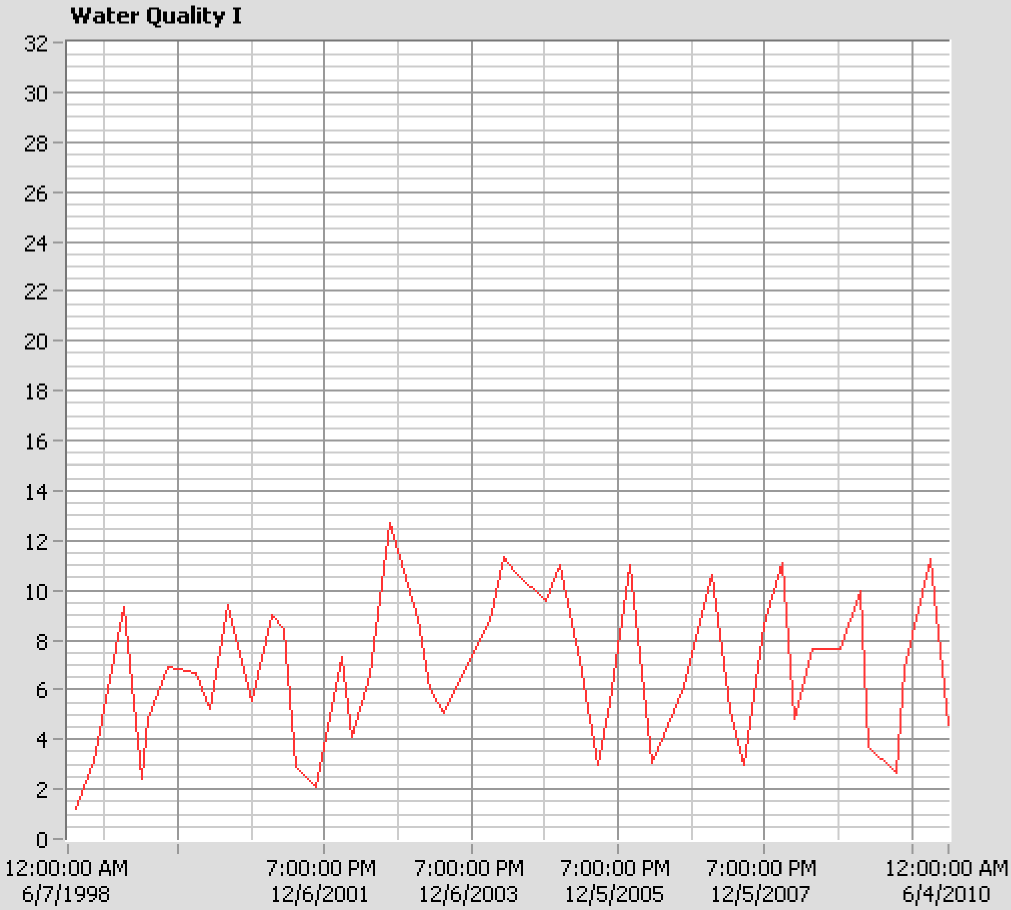
Turbidity: Seasonal - (1) - N. H

Max	Average	Min
407.	28.92	0.

TSS: Seasonal - (1) - N. Hacke

Max	Average	Min
129.	31.72	2.

Seasonal - (2) - Turnpike HR: Water Quality



Conductivity: Seasonal - (2) - T

Max	Average	Min
16.	6.003	0.86

DO: Seasonal - (2) - Turnpike H

Max	Average	Min
12.7	6.74	1.2

pH: Seasonal - (2) - Turnpike HI

Max	Average	Min
8.35	7.495	6.38

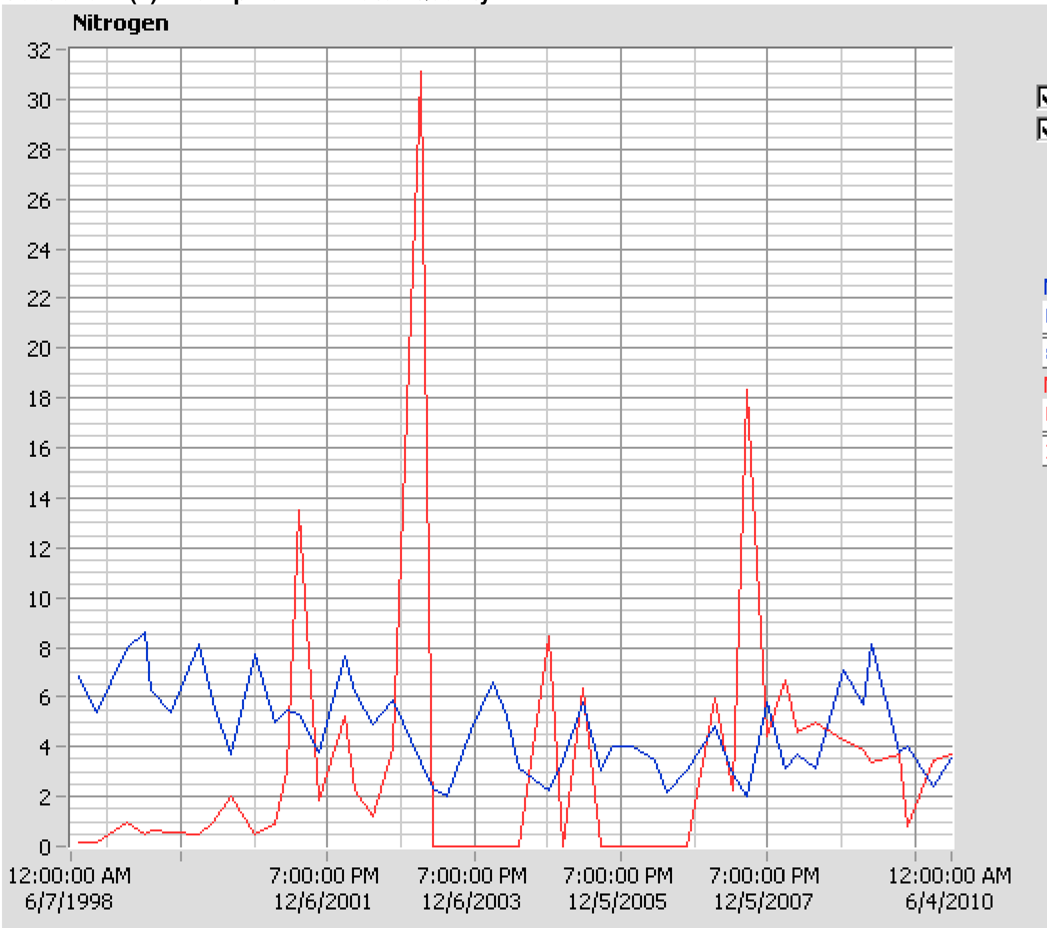
Salinity: Seasonal - (2) - Turnpil

Max	Average	Min
9.36	3.466	0.45

Temp: Seasonal - (2) - Turnpike

Max	Average	Min
29.1	15.73	0.

Seasonal - (2) - Turnpike HR: Water Quality



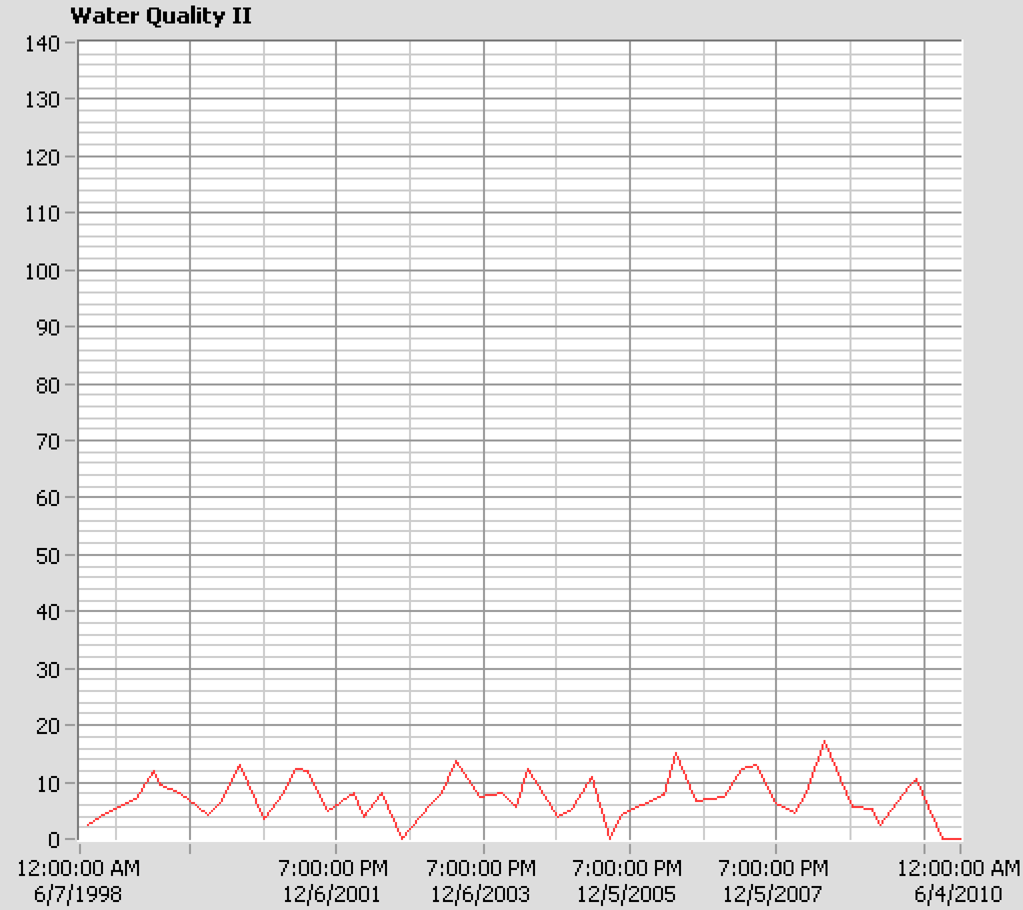
NH4: Seasonal - (2) - Turnpike I

Max	Average	Min
8.6	4.77	2.02

Nitrate: Seasonal - (2) - Turnpik

Max	Average	Min
31.1	3.225	0.

Seasonal - (2) - Turnpike HR: Water Quality



Latest time: 10:46:

Plot
Alkalinity: Seasonal - (2) - Tur
BOD: Seasonal - (2) - Turnpik
TSS: Seasonal - (2) - Turnpike
Turbidity: Seasonal - (2) - Tur

Alkalinity: Seasonal - (2) - Turn

Max	Average	Min
0.	0	0.

BOD: Seasonal - (2) - Turnpike

Max	Average	Min
17.3	7.339	0.

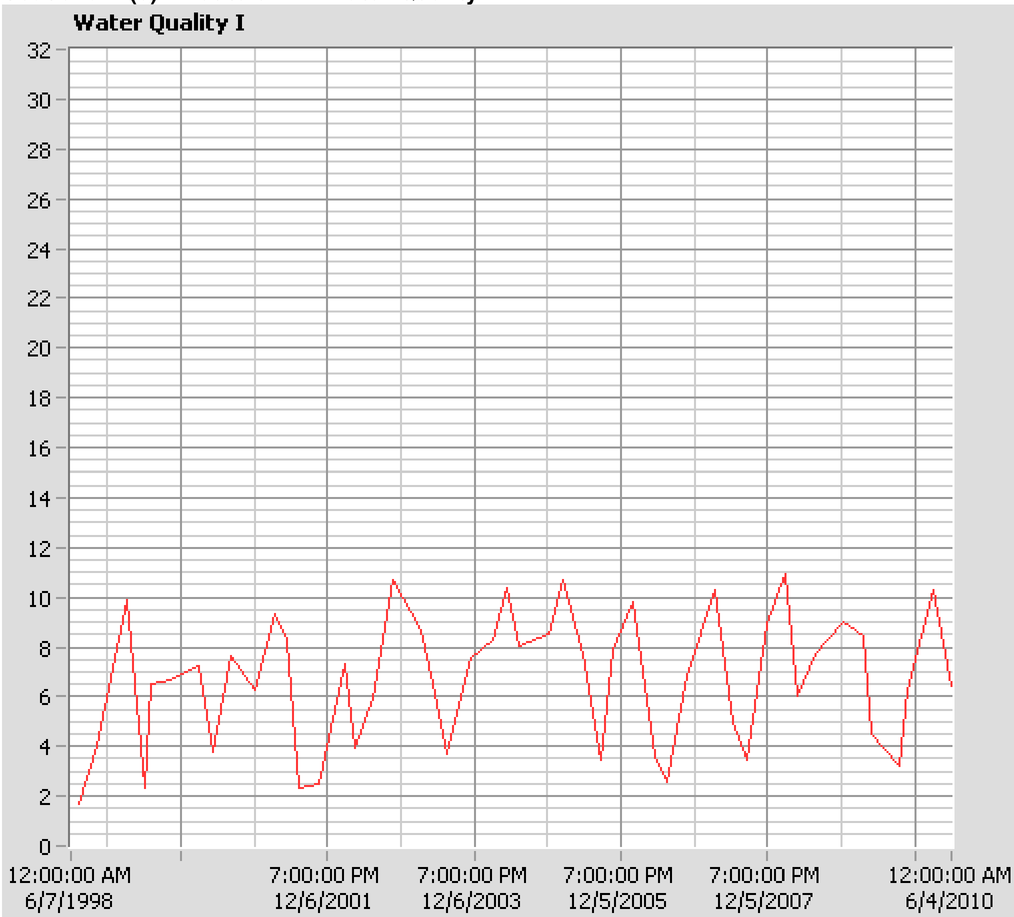
TSS: Seasonal - (2) - Turnpike H

Max	Average	Min
135.	23.31	1.2

Turbidity: Seasonal - (2) - Turn

Max	Average	Min
38.3	14.94	0.

Seasonal - (3) - Route 3 HR: Water Quality



Latest time: 10:32:

Plot
☐ Conductivity: Seasonal - (3) -
☑ DO: Seasonal - (3) - Route 3 H
☐ pH: Seasonal - (3) - Route 3 H
☐ Salinity: Seasonal - (3) - Route
☐ Temp: Seasonal - (3) - Route 3

Conductivity: Seasonal - (3) - R

Max	Average	Min
22.1	9.295	2.93

DO: Seasonal - (3) - Route 3 HF

Max	Average	Min
10.9	6.683	1.7

pH: Seasonal - (3) - Route 3 HF

Max	Average	Min
8.22	7.48	6.17

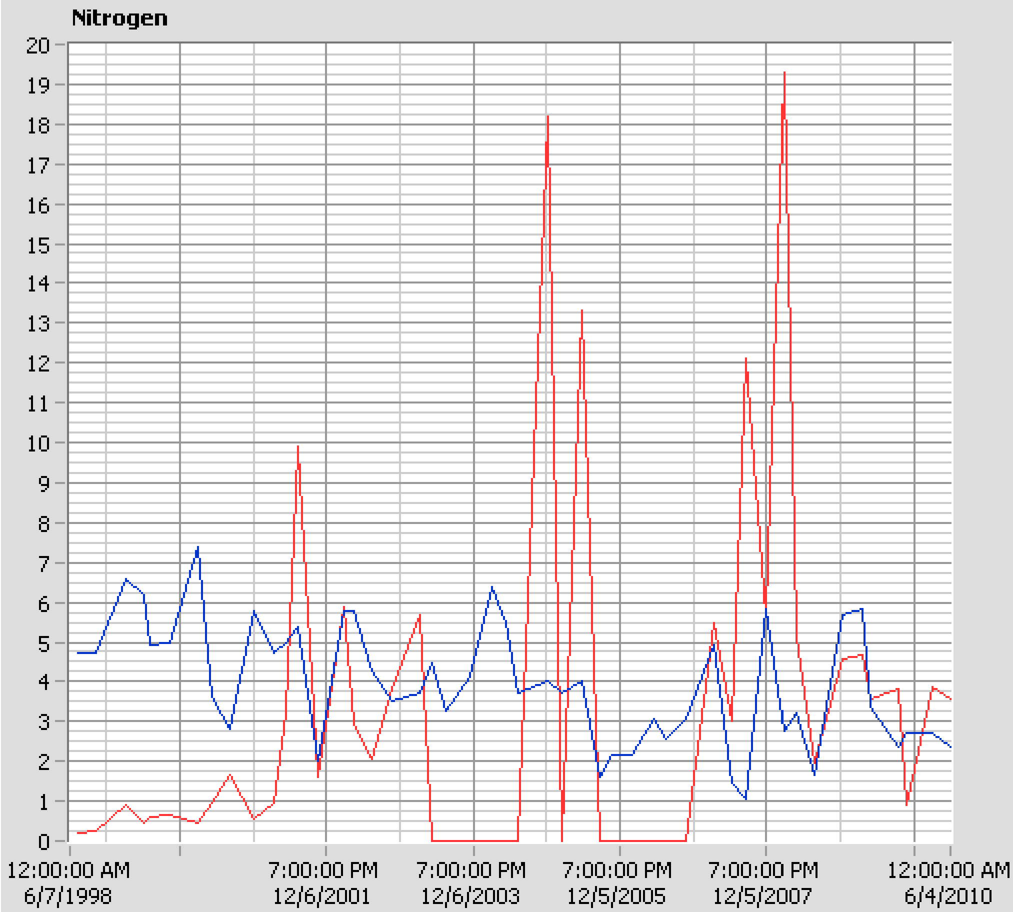
Salinity: Seasonal - (3) - Route

Max	Average	Min
13.2	5.445	1.59

Temp: Seasonal - (3) - Route 3

Max	Average	Min
29.3	15.72	0.

Seasonal - (3) - Route 3 HR: Water Quality



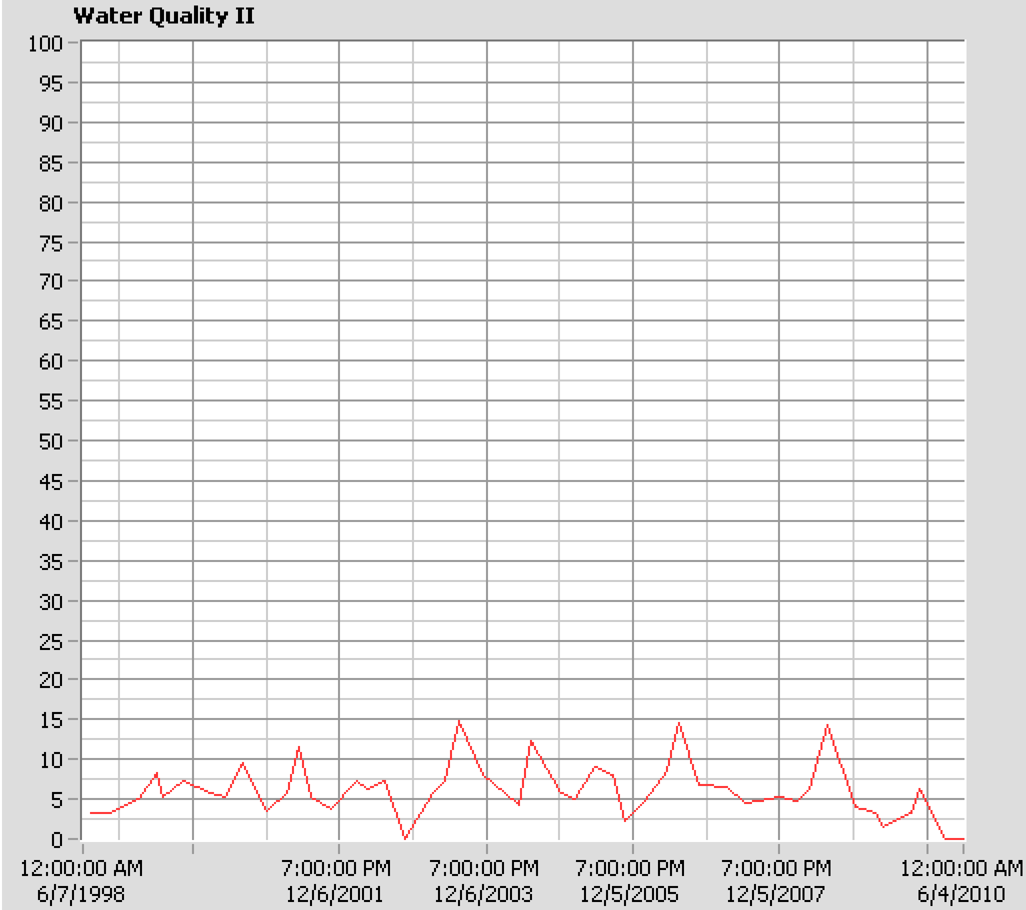
NH4: Seasonal - (3) - Route 3 H

Max	Average	Min
7.4	3.963	1.06

Nitrate: Seasonal - (3) - Route

Max	Average	Min
19.3	3.172	0.

Seasonal - (3) - Route 3 HR: Water Quality



Latest time: 10:32:

Plot
☐ Alkalinity: Seasonal - (3) - Rou
☑ BOD: Seasonal - (3) - Route 3
☐ TSS: Seasonal - (3) - Route 3 H
☐ Turbidity: Seasonal - (3) - Rou

Alkalinity: Seasonal - (3) - Rout

Max	Average	Min
0.	0	0.

BOD: Seasonal - (3) - Route 3 H

Max	Average	Min
14.75	5.962	0.

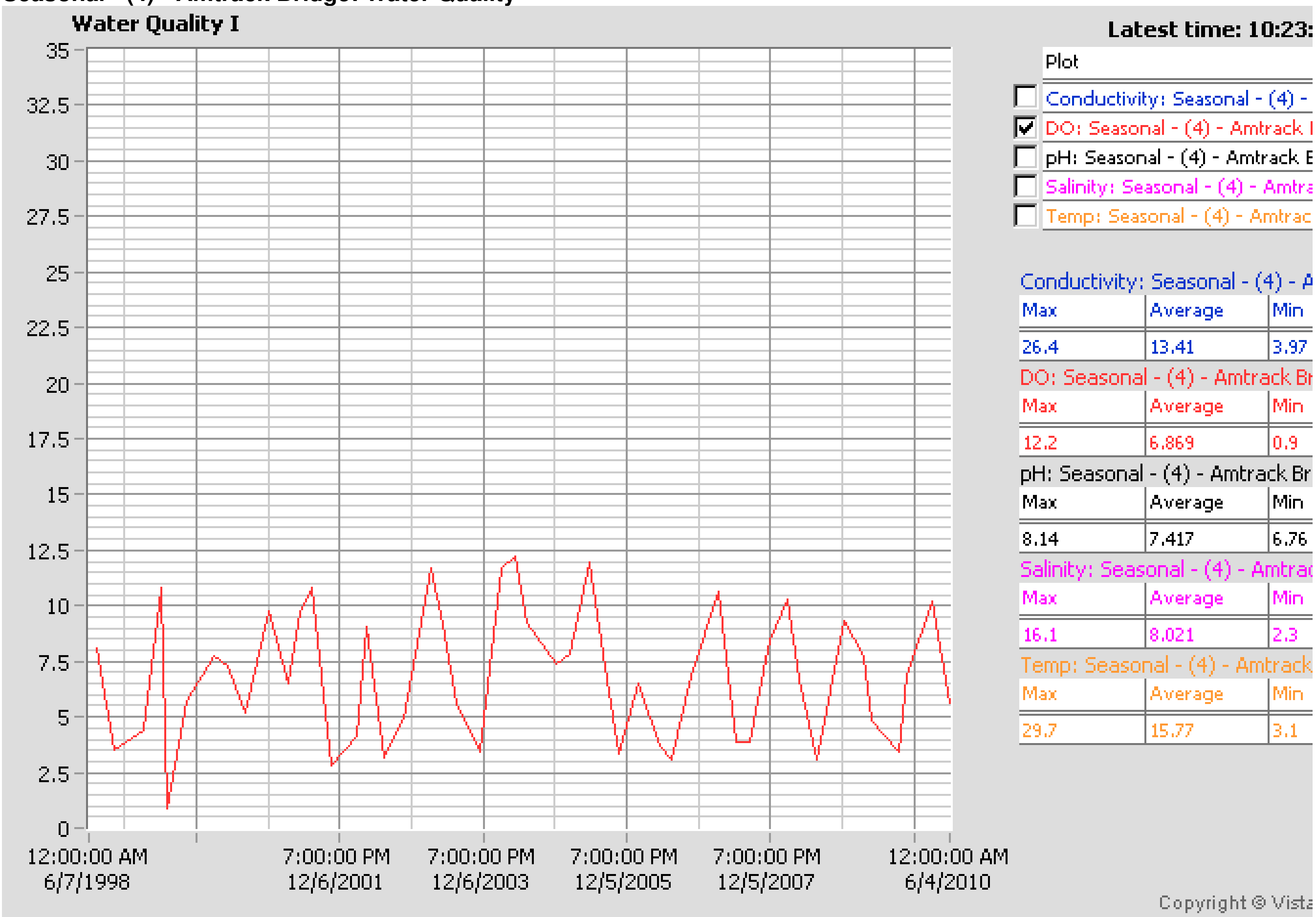
TSS: Seasonal - (3) - Route 3 H

Max	Average	Min
95.	20	1.3

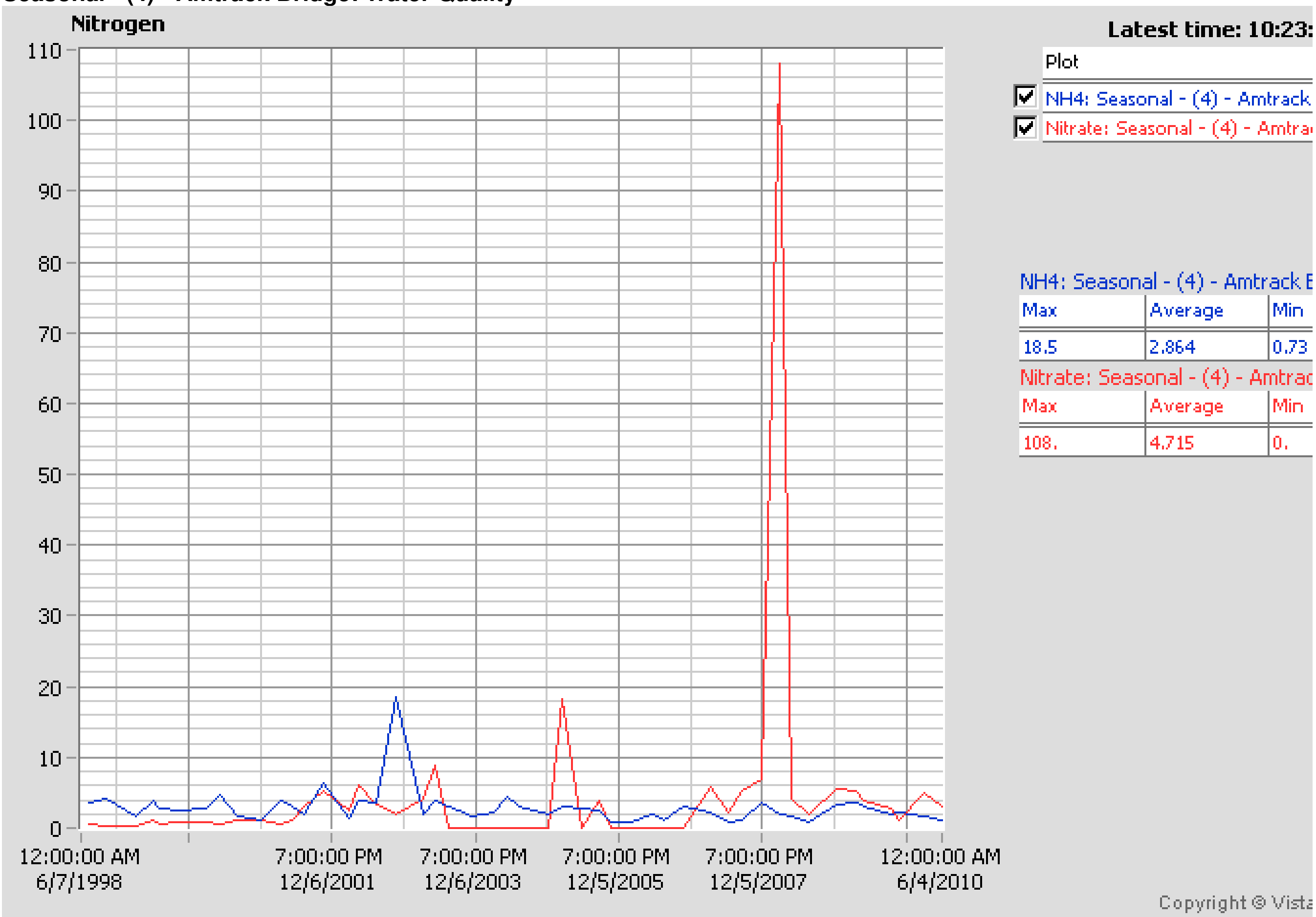
Turbidity: Seasonal - (3) - Rout

Max	Average	Min
54.3	12.66	0.

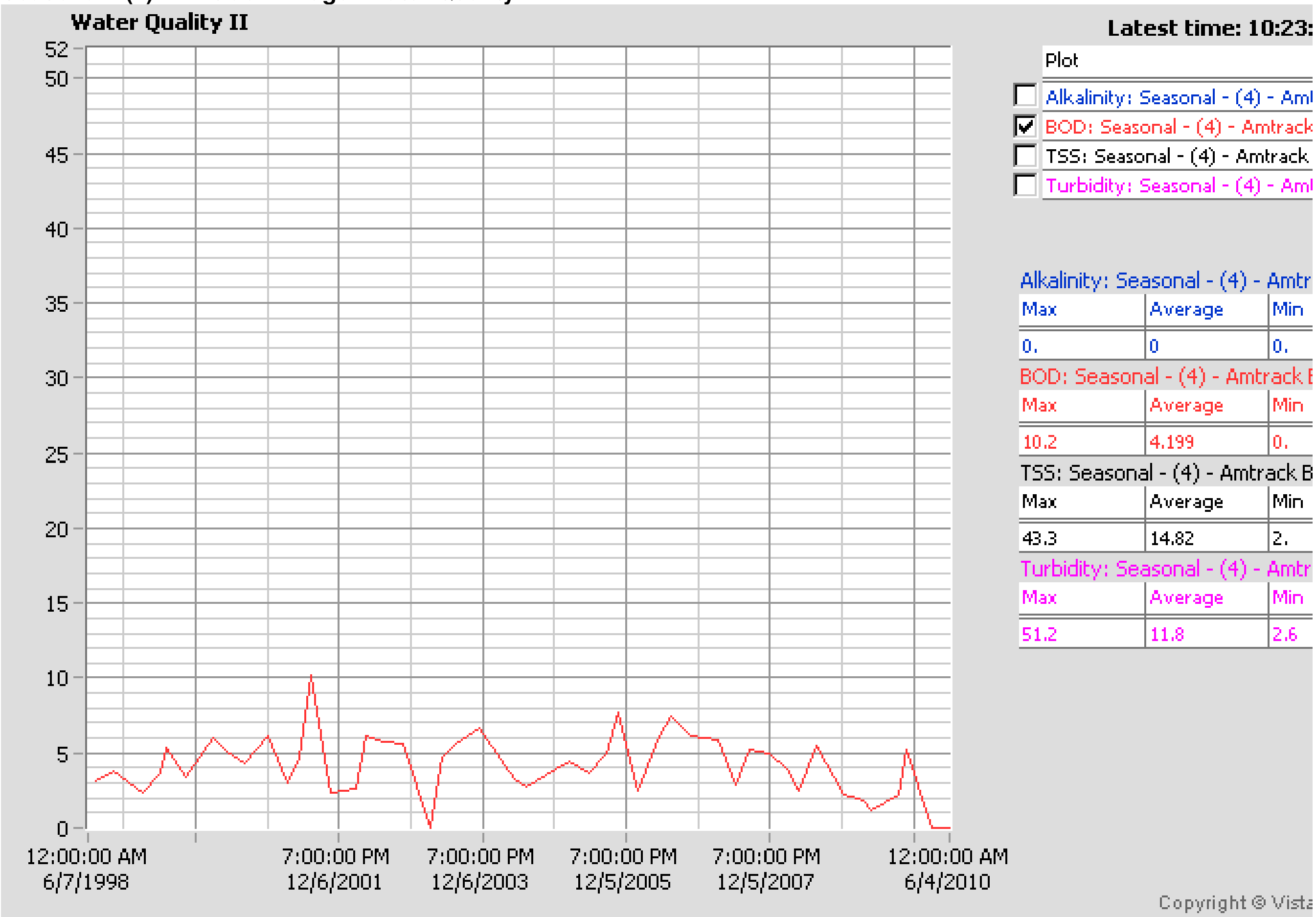
Seasonal - (4) - Amtrack Bridge: Water Quality



Seasonal - (4) - Amtrack Bridge: Water Quality



Seasonal - (4) - Amtrack Bridge: Water Quality



Alkalinity: Seasonal - (4) - Amtr

Max	Average	Min
0.	0	0.

BOD: Seasonal - (4) - Amtrack E

Max	Average	Min
10.2	4.199	0.

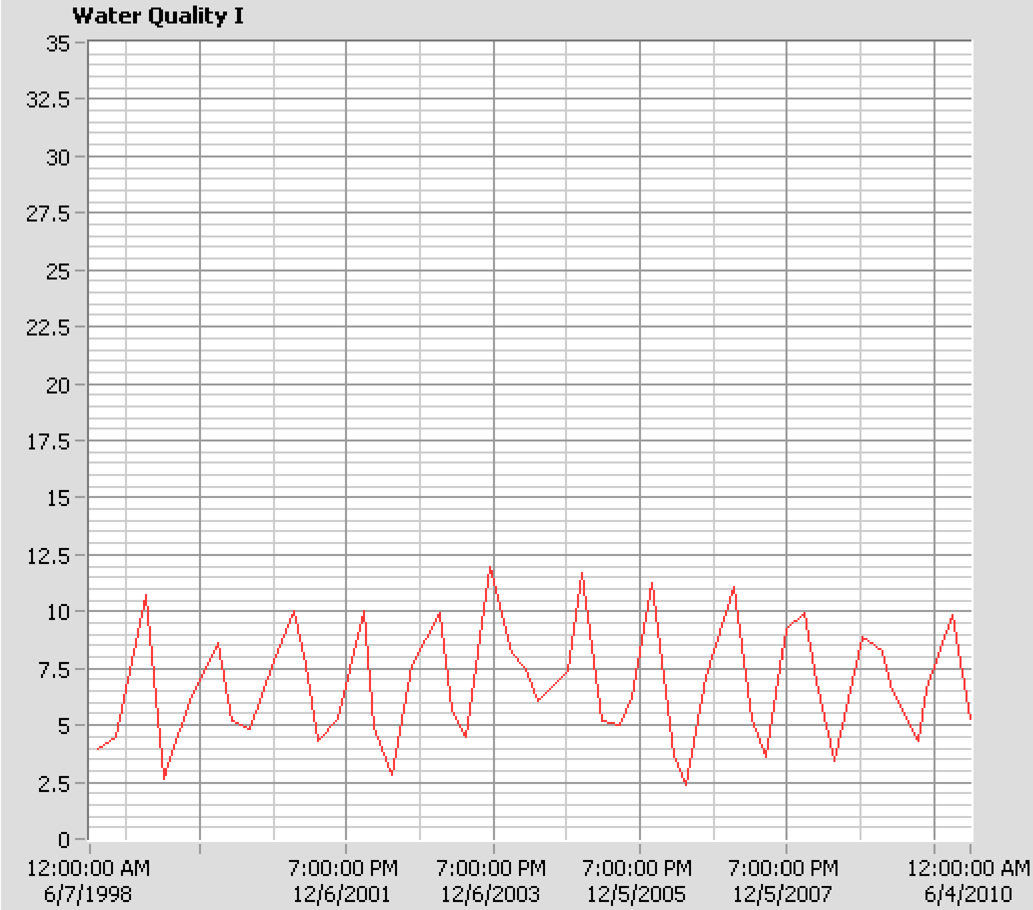
TSS: Seasonal - (4) - Amtrack B

Max	Average	Min
43.3	14.82	2.

Turbidity: Seasonal - (4) - Amtr

Max	Average	Min
51.2	11.8	2.6

Seasonal - (5) - S. Hackensack: Water Quality



Latest time: 10:04:

Plot
Conductivity: Seasonal - (5) -
DO: Seasonal - (5) - S. Hacker
pH: Seasonal - (5) - S. Hacker
Salinity: Seasonal - (5) - S. Ha
Temp: Seasonal - (5) - S. Hack

Conductivity: Seasonal - (5) - S

Max	Average	Min
33.8	19.42	10.56

DO: Seasonal - (5) - S. Hackens

Max	Average	Min
11.92	6.74	2.4

pH: Seasonal - (5) - S. Hackens

Max	Average	Min
7.85	7.291	6.53

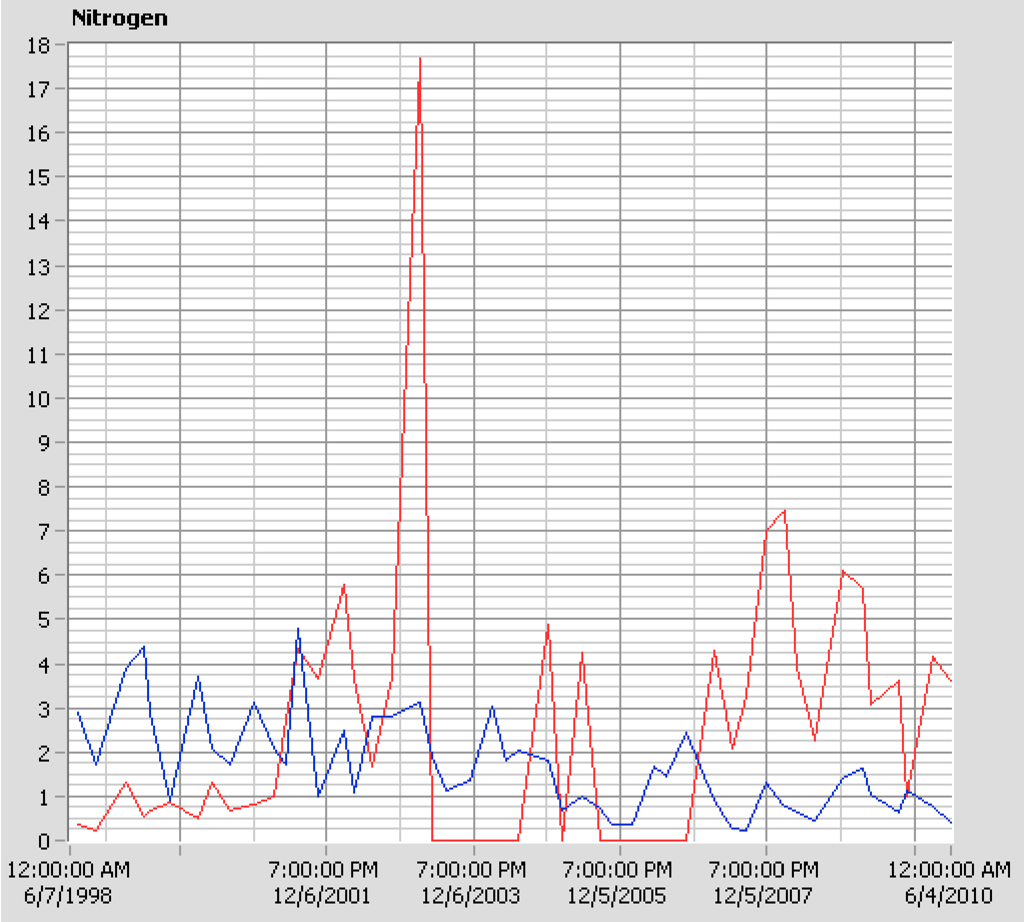
Salinity: Seasonal - (5) - S. Hac

Max	Average	Min
21.2	12.04	5.969

Temp: Seasonal - (5) - S. Hacke

Max	Average	Min
30.6	16.15	0.

Seasonal - (5) - S. Hackensack: Water Quality



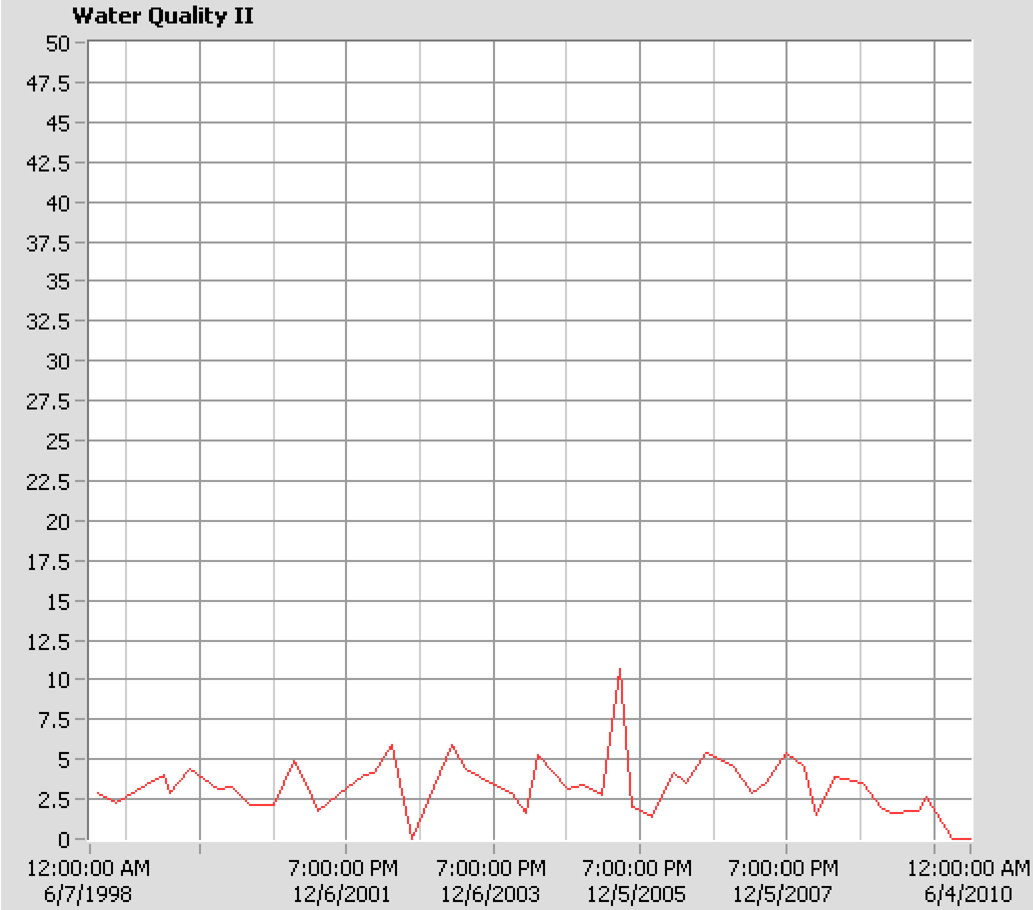
NH4: Seasonal - (5) - S. Hacken

Max	Average	Min
4.8	1.718	0.22

Nitrate: Seasonal - (5) - S. Hacl

Max	Average	Min
17.7	2.466	0.

Seasonal - (5) - S. Hackensack: Water Quality



Latest time: 10:04:

	Plot
☐	Alkalinity: Seasonal - (5) - S. H
☑	BOD: Seasonal - (5) - S. Hack
☐	TSS: Seasonal - (5) - S. Hacke
☐	Turbidity: Seasonal - (5) - S. H

Alkalinity: Seasonal - (5) - S. Ha

Max	Average	Min
0.	0	0.

BOD: Seasonal - (5) - S. Hacke

Max	Average	Min
10.7	3.323	0.

TSS: Seasonal - (5) - S. Hacken

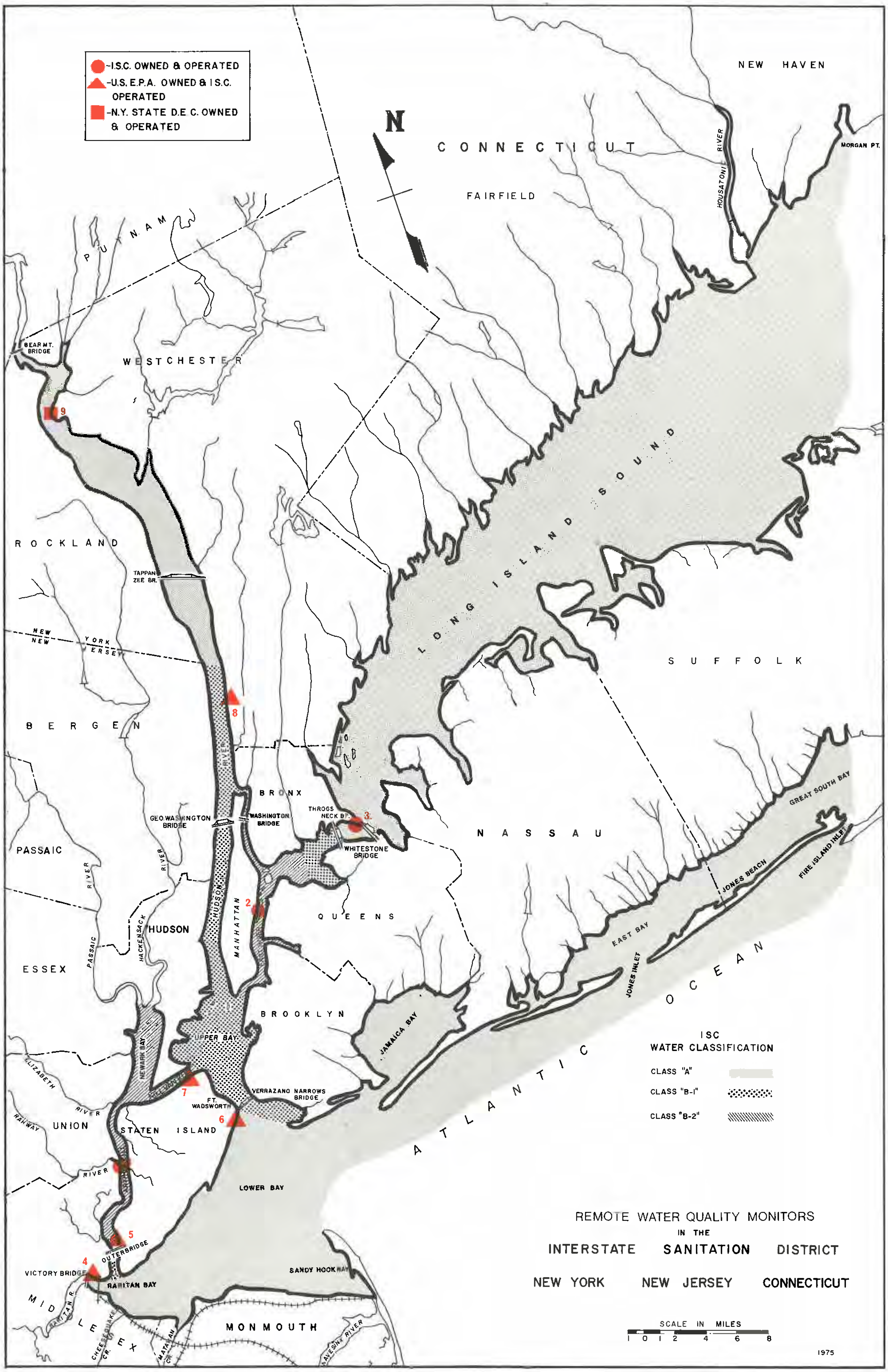
Max	Average	Min
46.	14.44	1.2

Turbidity: Seasonal - (5) - S. Ha

Max	Average	Min
41.3	10.27	0.

ATTACHMENT 4

INTERSTATE SANITATION DISSOLVED OXYGEN FROM REMOTE SENSORS DISPLAYS



-I.S.C. OWNED & OPERATED
-U.S. E.P.A. OWNED & I.S.C. OPERATED
-N.Y. STATE D.E.C. OWNED & OPERATED
N
CONNECTICUT
FAIRFIELD
NEW HAVEN
HOUSATONIC RIVER
MORGAN PT.
PUTNAM
WESTCHESTER
BEAR MT. BRIDGE
ROCKLAND
TAPPAN ZEE BR.
NEW YORK
NEW JERSEY
LONG ISLAND SOUND
SUFFOLK
BERGEN
HUDSON RIVER
BRONX
GEO. WASHINGTON BRIDGE
WASHINGTON BRIDGE
THROGS NECK BR.
WHITESTONE BRIDGE
NASSAU
PASSAIC
PASSAIC RIVER
HACKENSACK RIVER
HUDSON
MANHATTAN
QUEENS
ESSEX
BROOKLYN
UPPER BAY
NEWARK BAY
ELIZABETH RIVER
RAHWAY
UNION
STATEN ISLAND
FT. WADSWORTH
VERRAZANO NARROWS BRIDGE
JAMAICA BAY
EAST BAY
JONES INLET
JONES BEACH
GREAT SOUTH BAY
FIRE ISLAND INLET
ATLANTIC OCEAN
LOWER BAY
OUTERBRIDGE
VICTORY BRIDGE
RARITAN BAY
SANDY HOOK BAY
MIDDLESEX
RARITAN R.
CHEESEQUAKE CR.
MATAWAN CR.
MONMOUTH
NAVESINK RIVER
1
2
3
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9
ISC WATER CLASSIFICATION
CLASS "A"
CLASS "B-I"
CLASS "B-2"
REMOTE WATER QUALITY MONITORS
IN THE
INTERSTATE SANITATION DISTRICT
NEW YORK NEW JERSEY CONNECTICUT
SCALE IN MILES
1 0 1 2 4 6 8
1975

REMOTE AUTOMATIC WATER QUALITY MONITORING STATIONS IN THE INTERSTATE SANITATION DISTRICT

INTERSTATE SANITATION COMMISSION OWNED AND OPERATED

1. Arthur Kill - Consolidated Edison Arthur Kill Generating Station, Staten Island, New York

2. East River - Consolidated Edison Ravenswood Generating Station, Long Island City, New York

3. East River - Throgs Neck Bridge, Fort Schuyler, Bronx, New York

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY OWNED AND INTERSTATE SANITATION COMMISSION OPERATED

4. Raritan River - Victory Bridge, Perth Amboy, New Jersey

5. Arthur Kill - Outerbridge Crossing, Staten Island, New York

6. The Narrows - Fort Wadsworth, Staten Island, New York

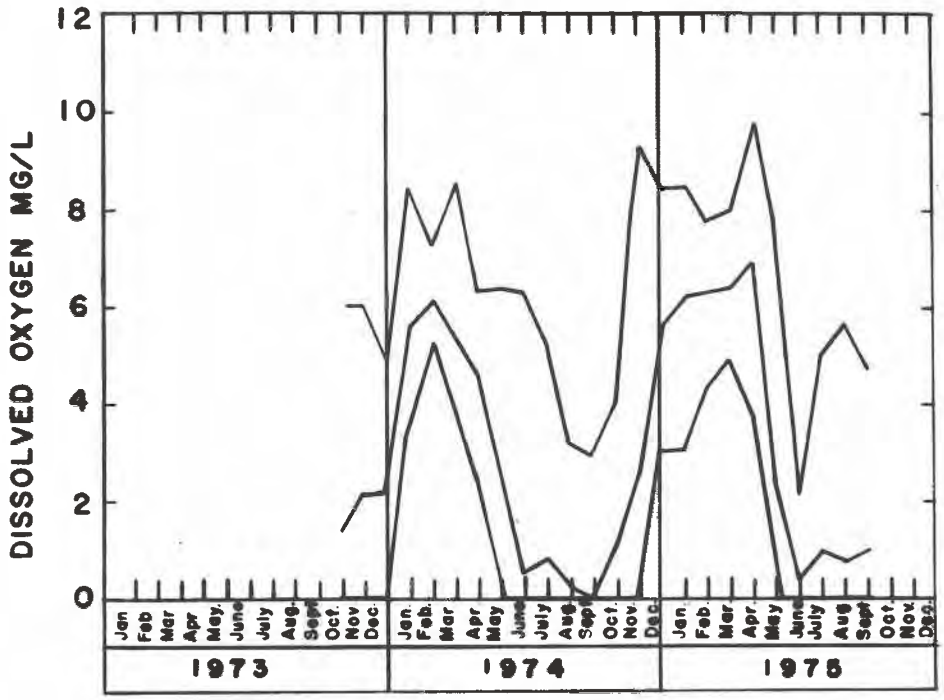
7. Kill Van Kull - U.S. Gypsum Company, Staten Island, New York

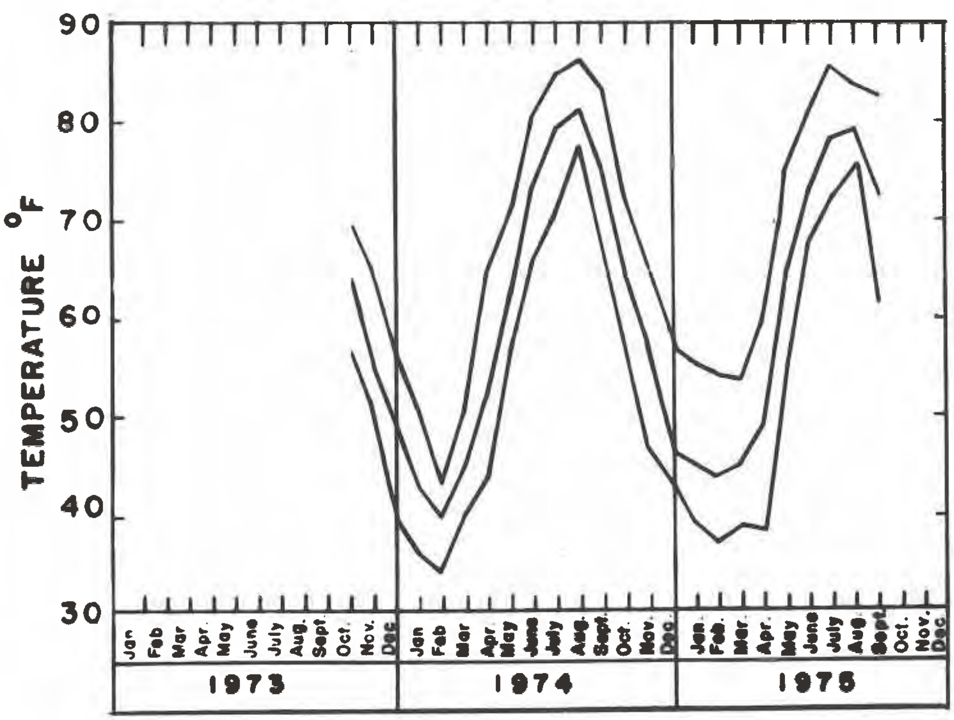
8. Hudson River - Consolidated Edison Glenwood Generating Station, Yonkers, New York

NEW YORK STATE DEPARTMENT OF ENVIRONMENTAL CONSERVATION OWNED AND OPERATED

9. Hudson River - Verplanck, New York

ARTHUR KILL-CON ED.
station no. 1



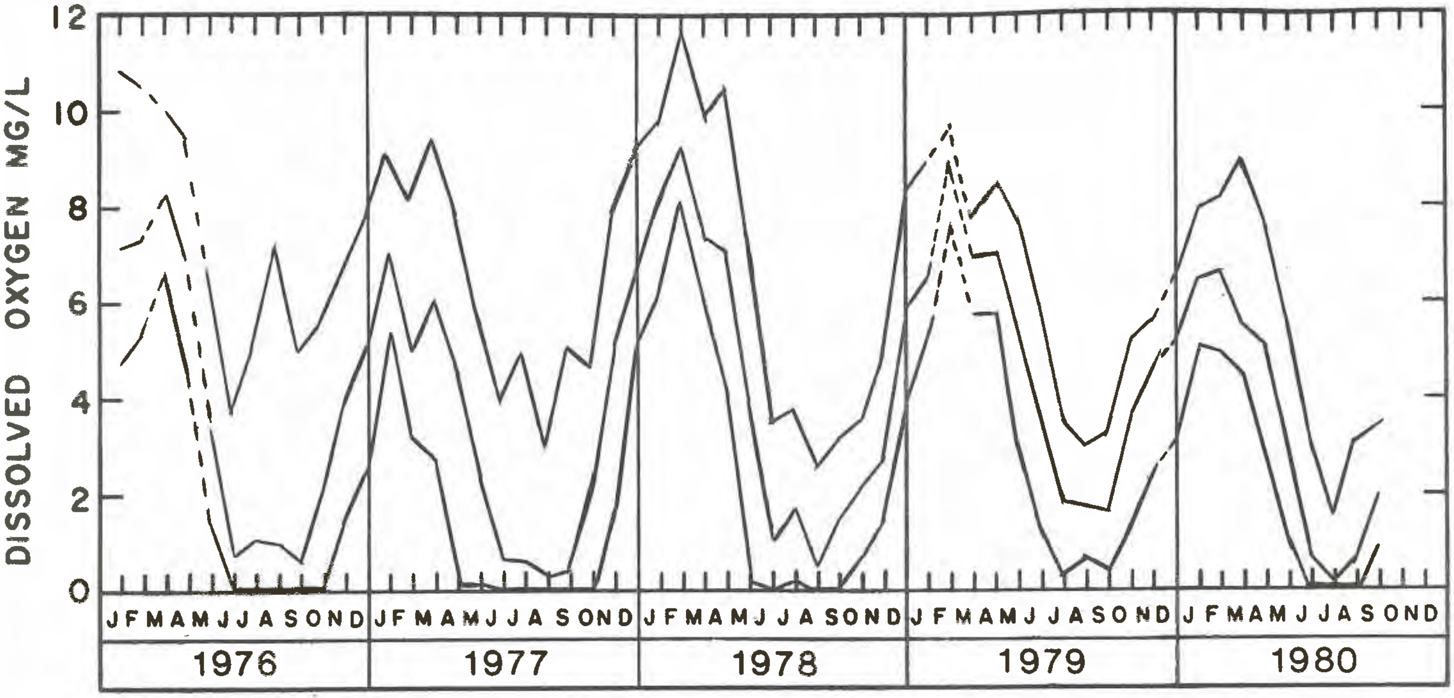


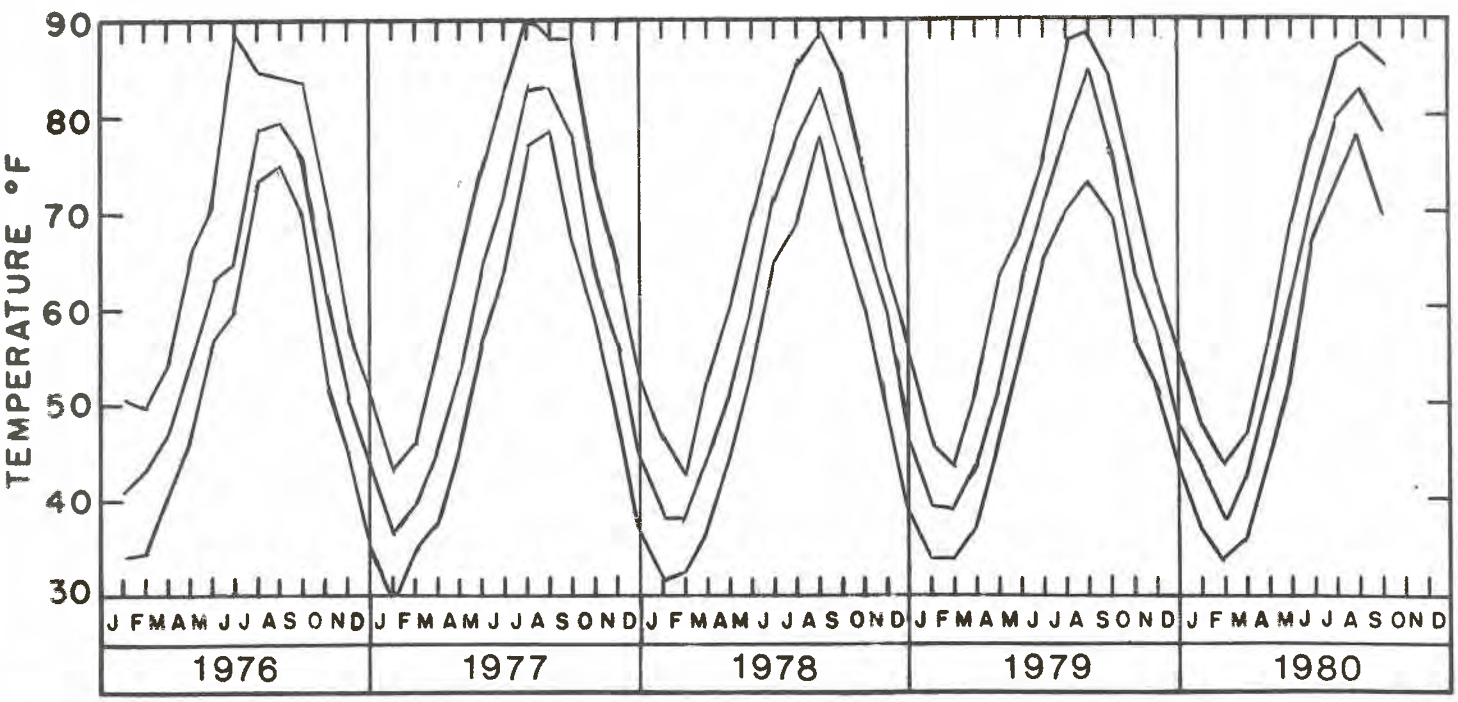
TOP LINE: MAXIMUM MONTHLY VALUE

CENTER LINE: AVERAGE OF THE DAILY AVERAGE VALUES

BOTTOM LINE: MINIMUM MONTHLY VALUE

ARTHUR KILL — CON ED. (station no. 1)



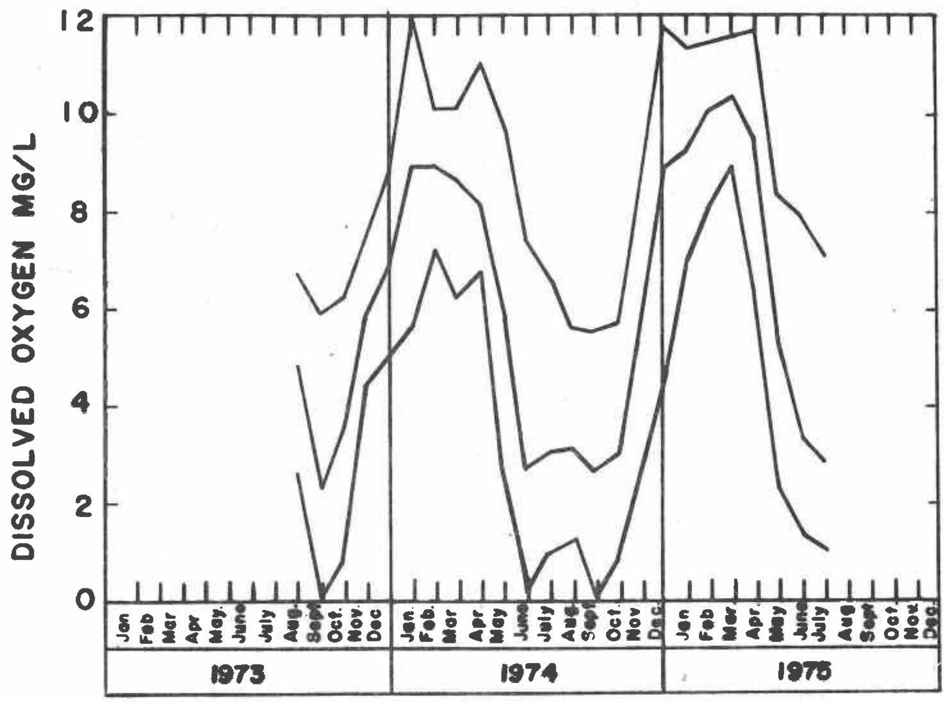


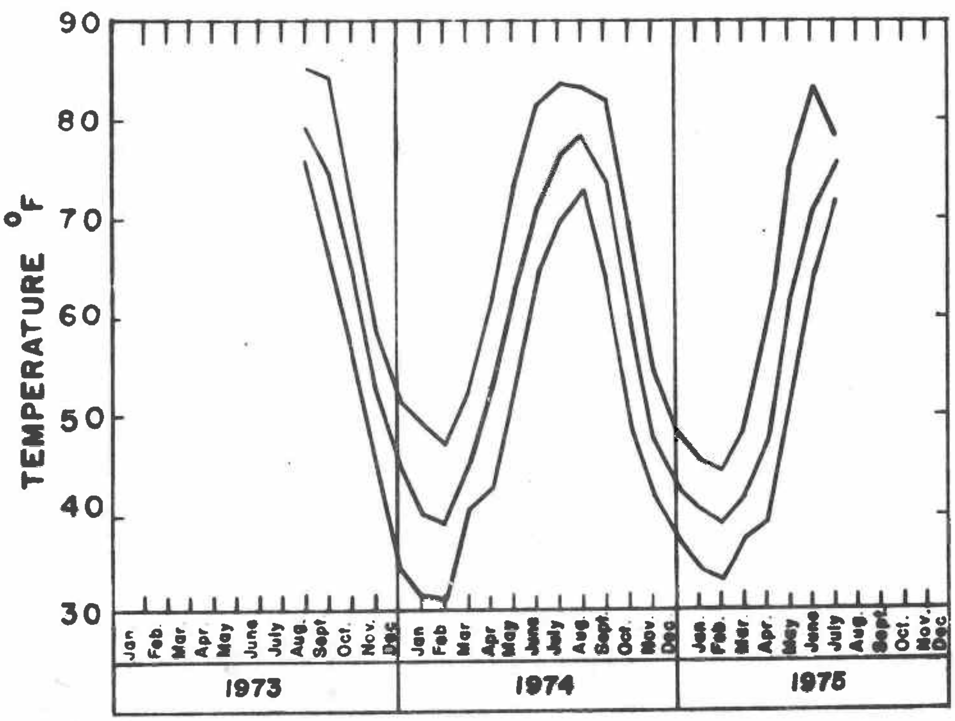
TOP LINE — maximum monthly value

CENTER LINE — average of the daily average values

BOTTOM LINE — minimum monthly value

RARITAN RIVER — VICTORY BRIDGE
station no. 4



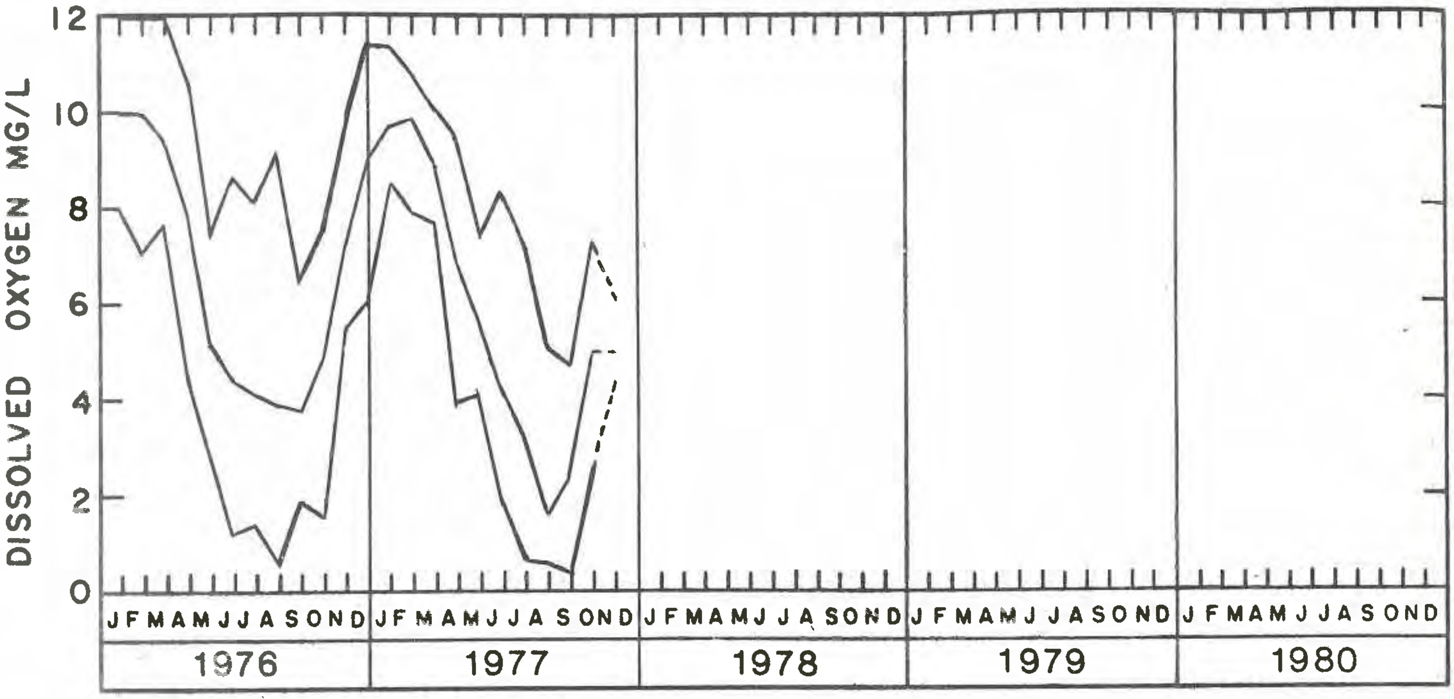


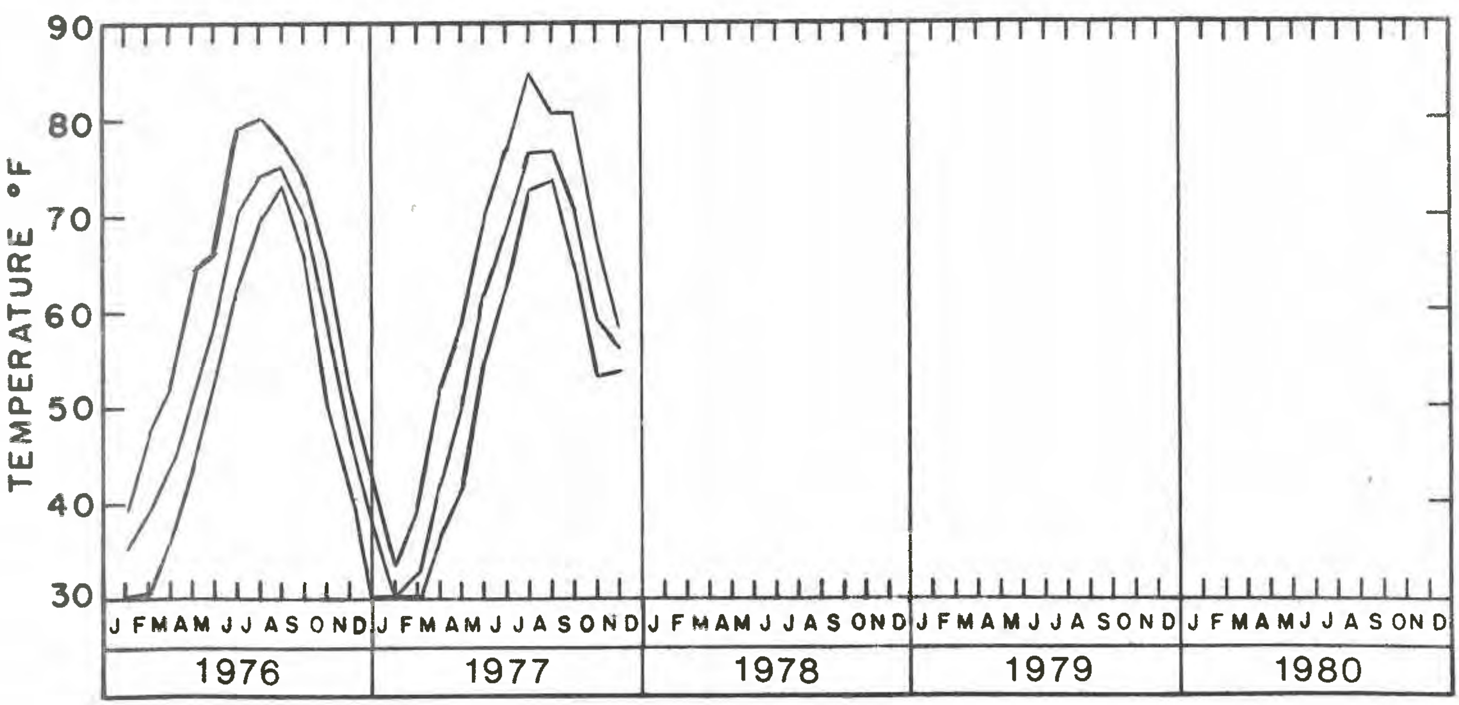
TOP LINE: MAXIMUM MONTHLY VALUE

CENTER LINE: AVERAGE OF THE DAILY AVERAGE VALUES

BOTTOM LINE: MINIMUM MONTHLY VALUE

RARITAN RIVER—VICTORY BRIDGE (station no. 4)



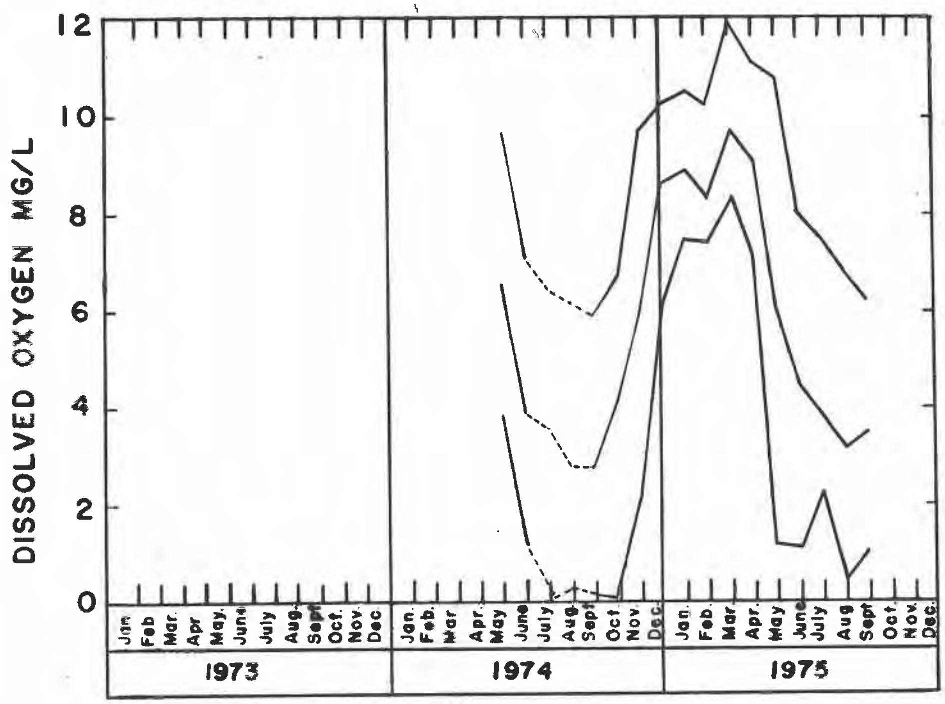


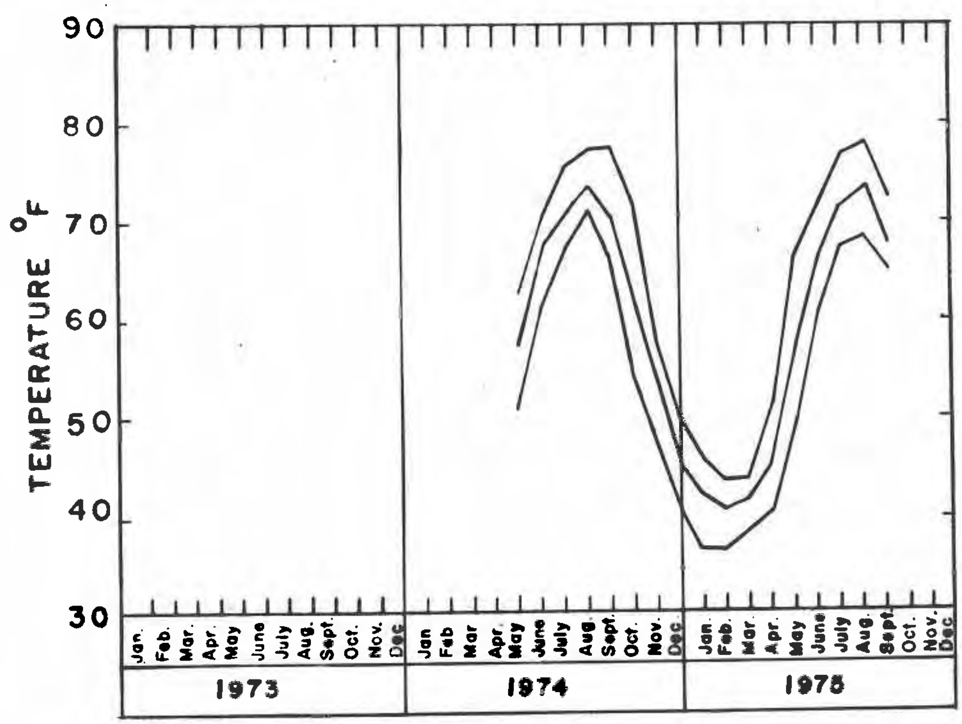
TOP LINE — maximum monthly value

CENTER LINE — average of the daily average values

BOTTOM LINE — minimum monthly value

THE NARROWS – FT. WADSWORTH
station no. 6



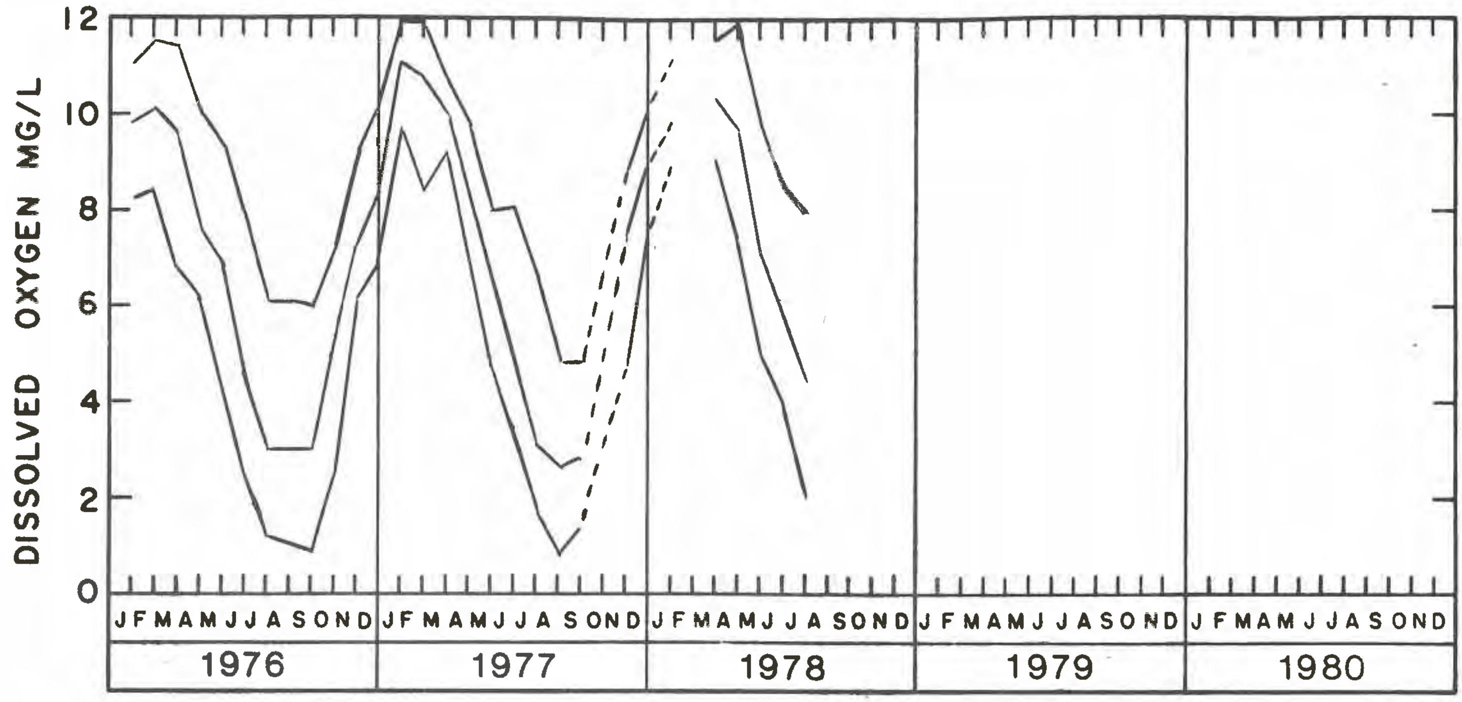


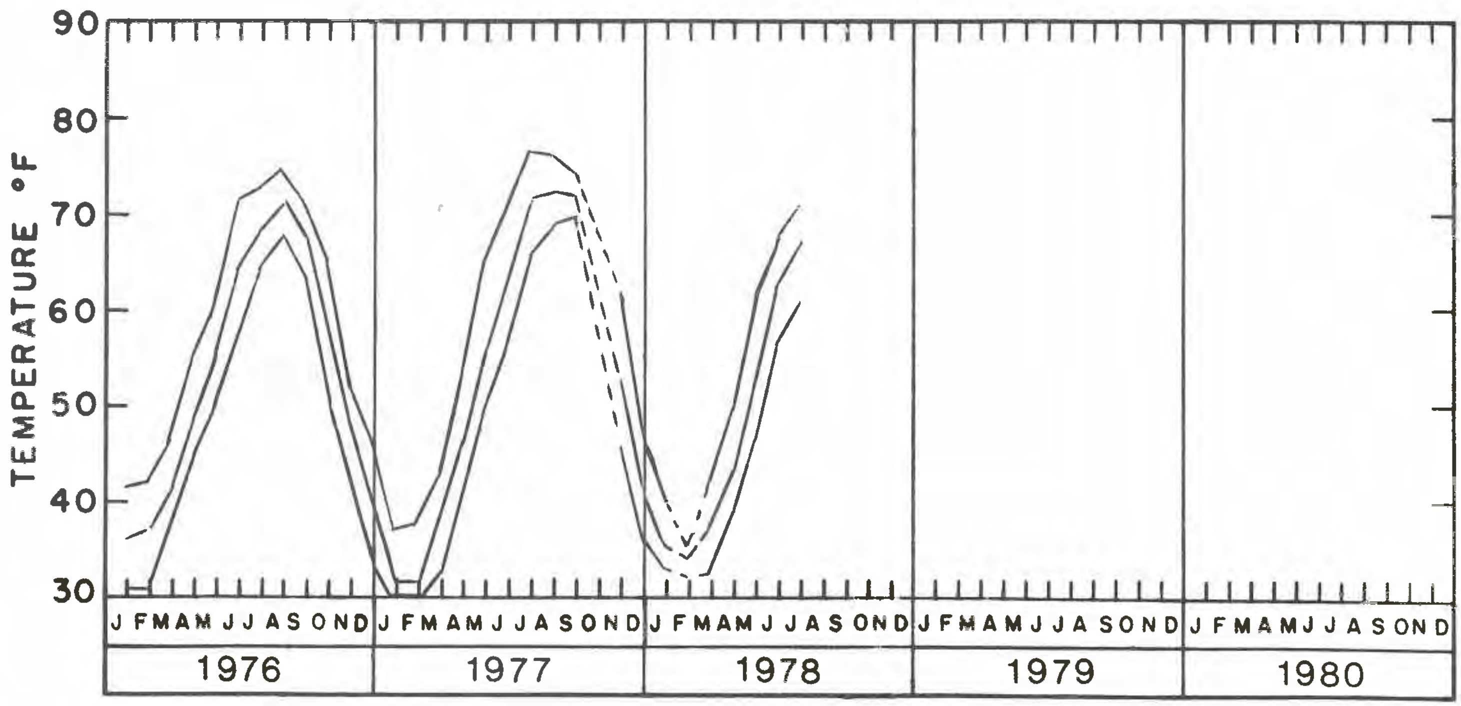
TOP LINE: MAXIMUM MONTHLY VALUE

CENTER LINE: AVERAGE OF THE DAILY AVERAGE VALUES

BOTTOM LINE: MINIMUM MONTHLY VALUE

THE NARROWS — FT. WADSWORTH (station no. 6)



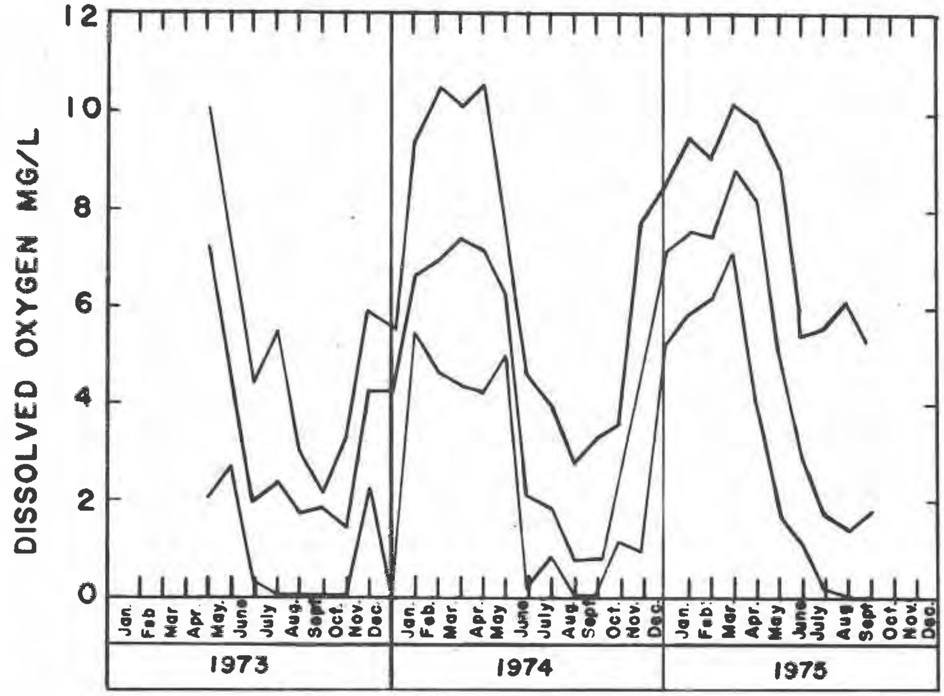


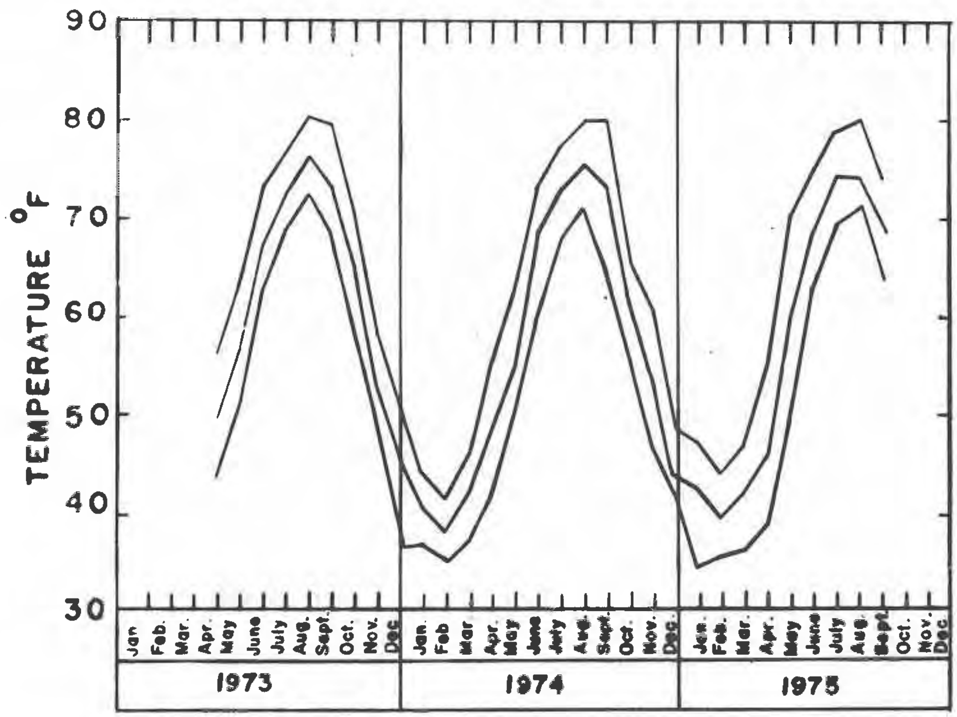
TOP LINE — maximum monthly value

CENTER LINE — average of the daily average values

BOTTOM LINE — minimum monthly value

KILL VAN KULL - U.S. GYPSUM
station no. 7



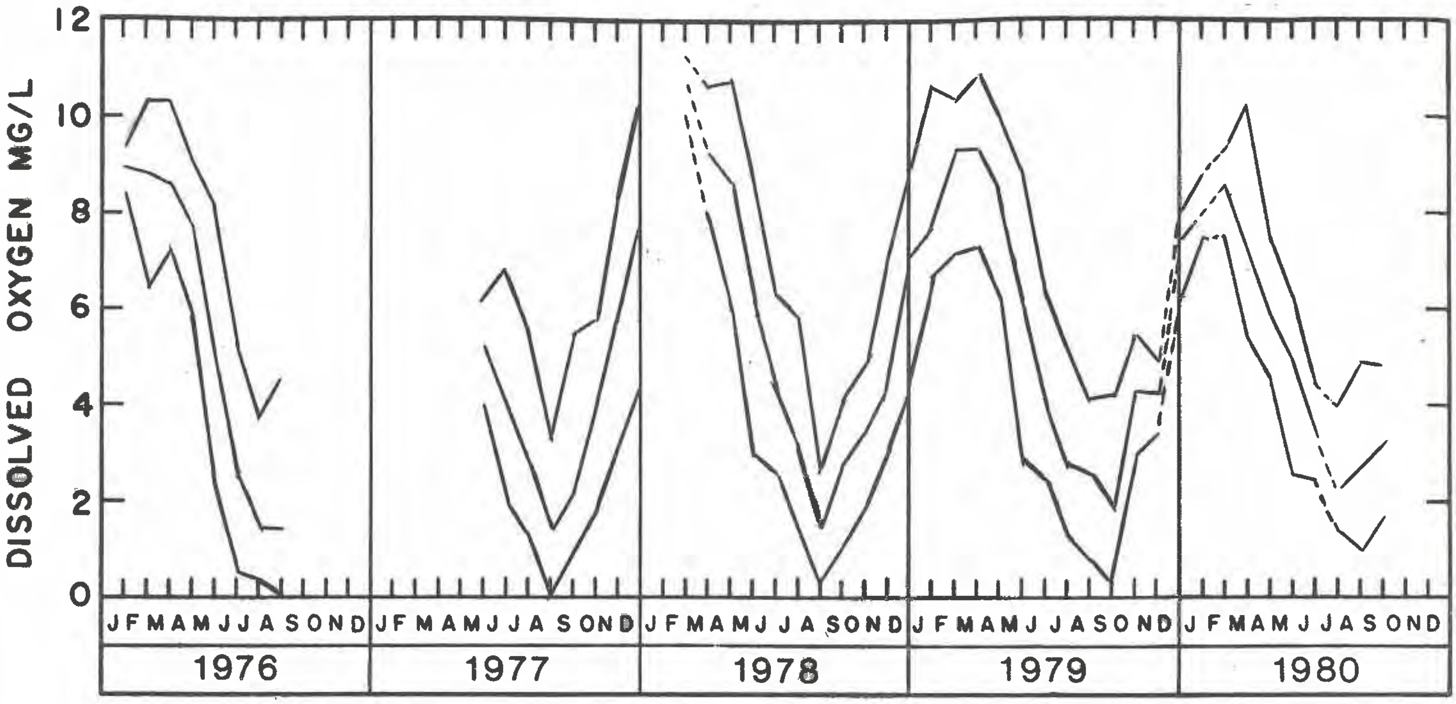


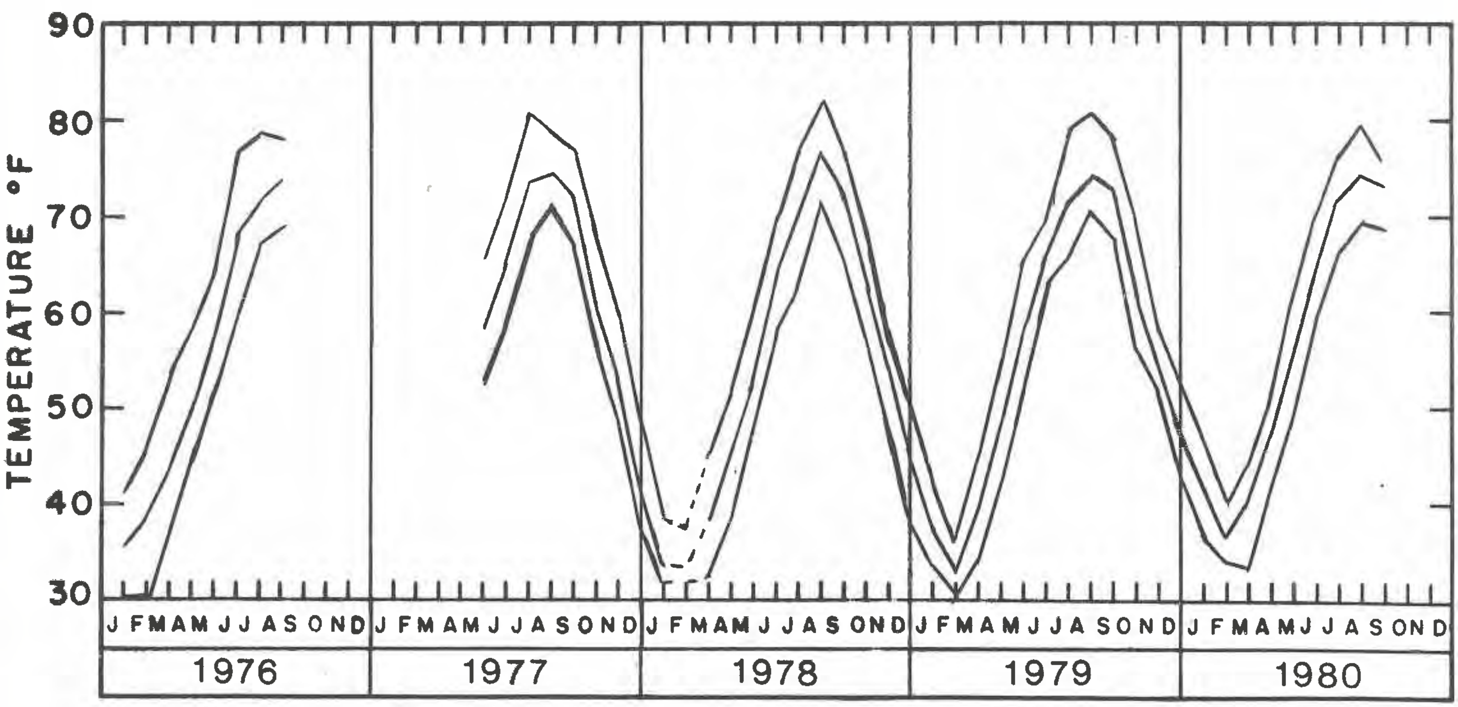
TOP LINE: MAXIMUM MONTHLY VALUE

CENTER LINE: AVERAGE OF THE DAILY AVERAGE VALUES

BOTTOM LINE: MINIMUM MONTHLY VALUE

KILL VAN KULL — U.S. GYPSUM (station no. 7)





TOP LINE — maximum monthly value

CENTER LINE — average of the daily average values

BOTTOM LINE — minimum monthly value