University of New Hampshire
Cooperative Extension

Sea Grant
New Hampshire

Great Bay Coast Watch 1990-1999

A Ten Year Report on the Volunteer Water Quality Monitoring of the Great Bay Estuarine System

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Acknowledgements

This report represents the combined efforts of many contributors. We particularly want to thank the more than 300 volunteers who have participated in the Great Bay Coast Watch community volunteer monitoring program during the past ten years. Their dedication, time, effort, and energy, as well as their financial support, have resulted in the most comprehensive long-term database of water quality data collected for the Great Bay system. The water quality information collected by the volunteers continues to be a key component of the local, regional, state, and federal natural resources decision making process within the estuarine system. The high-quality database of Great Bay water quality is one result of the volunteers' continued long-term commitment to the health of this valuable ecosystem.

We are also indebted to the following programs that have supported the Great Bay Coast Watch over the past ten years: the University of New Hampshire Cooperative Extension/Sea Grant, New Hampshire Estuarine Project, the New Hampshire Fish and Game Department, the Great Bay National Estuarine Research Reserve, the University of New Hampshire Jackson Estuarine Laboratory, New Hampshire Coastal Program, the Environmental Protection Agency, and the New Hampshire Department of Environmental Services. We also would like to thank General Electric Company of Somersworth for their financial assistance. Thanks as well to the Greater Piscataqua Community Foundation and to the 17 cities and towns of the seacoast area that have been another source of continued support. In addition to our volunteers and financial supporters, we also want to thank the scientists and technical professionals on our Technical Advisory Committee for their ongoing assistance regarding program design, implementation, data management, quality assurance, and for the preparation of this report.

Author Biographies

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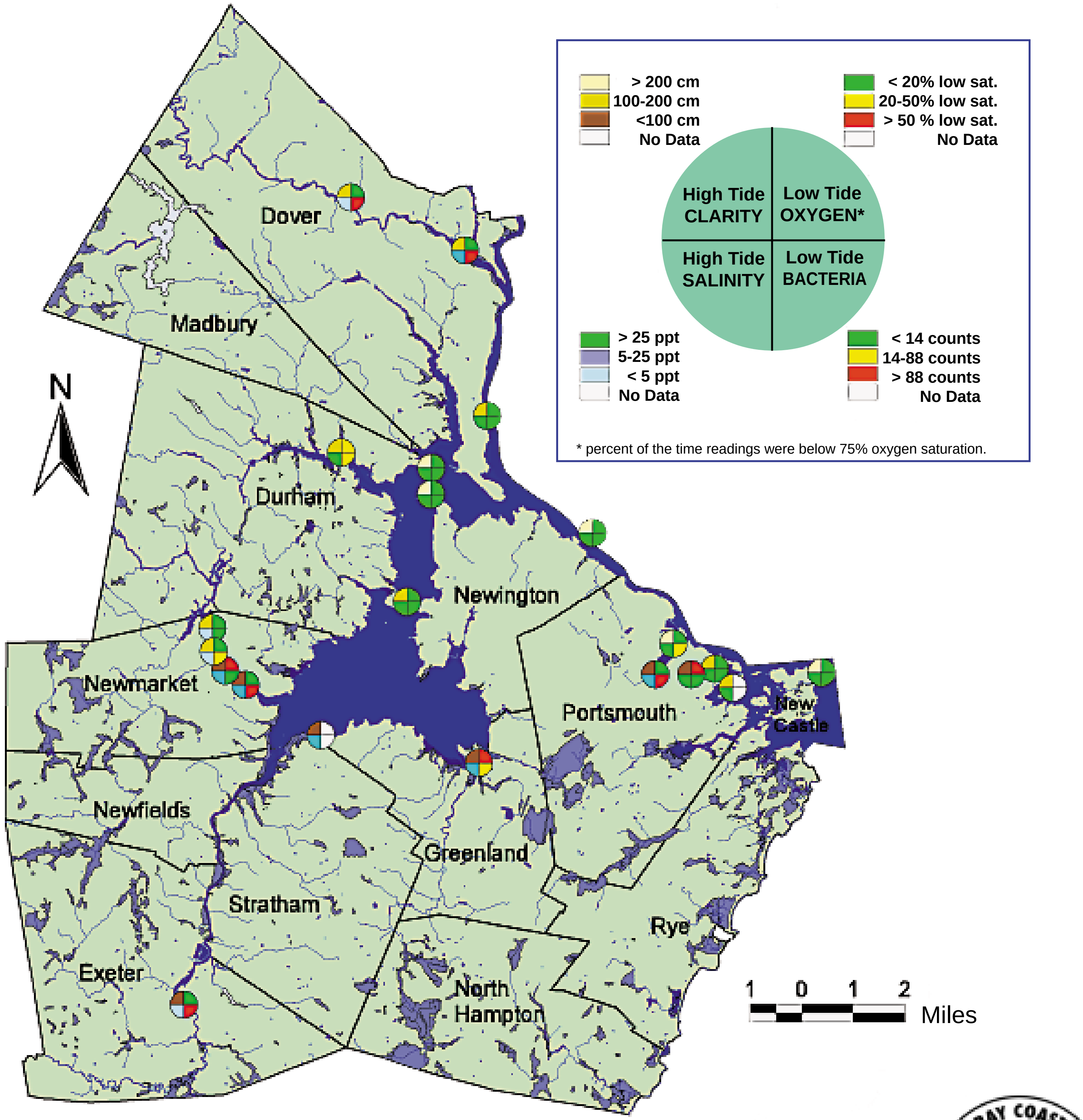
Great Bay Coast Watch
1990-1999 Water Quality Results



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Data Sources:
USGS topographic map: Source scale - 1:24000, last revision - Fall 1997
Water Quality Data collected by Great Bay Coast Watch Volunteers April 1990 through November 1999.
Sampling locations from corrected GPS data, courtesy of NH Office of State Planning.
Map created by Ray Konisky for Great Bay Coast Watch - 6/26/2000

Executive Summary

The Great Bay Coast Watch ten-year report summarizes the results of volunteer water quality monitoring conducted in the Great Bay Estuary from 1990-1999.

The Great Bay Coast Watch (GBCW) was founded in 1990 as part of the University of New Hampshire Cooperative Extension/Sea Grant outreach. The GBCW mission is to protect the long-term health of New Hampshire's coastal environment through volunteer monitoring and education programs. The purpose of this ten-year report is to describe and interpret water quality monitoring data collected by the Watch from the Great Bay Estuarine System. It is intended to benefit educators, researchers, resource managers, decision-makers, and interested citizens of the State of New Hampshire.

Since 1990, GBCW has expanded water quality monitoring coverage from seven sites to twenty-one, plus added an extra six sites for phytoplankton surveying. The database contains results from nearly 4,000 monitoring visits during the April to November monitoring season. At each visit, GBCW volunteers measure water temperature, pH, salinity, dissolved oxygen, transparency, and fecal coliform bacteria. Samples are taken at high tide and at low tide on the same day, according to the lunar calendar. All sampling activities are subject to rigorous quality control procedures.

Key indicators show good overall health of the Great Bay Estuarine System. Ten-year median dissolved oxygen saturation was 92%, well above the critical level of 75% saturation. Median fecal coliform counts were 11 colonies per 100 ml, below the state shellfish standard of 14 counts. Water clarity was good, at a median value of 1.5 meters (4.9 feet) visibility.

However, these key indicators vary with location and over time. Site by site comparisons showed considerable variability in water quality measurements. Consistently low dissolved oxygen readings were observed at sites near the mouths of the Oyster River, Lamprey River, Winnicut River, and South Mill Pond. High fecal coliform counts were often detected at Exeter and the Dover Footbridge. Six sites showed a significant relationship between fecal counts and rainfall, indicative of land-based source pollution. Five sites saw significant declines in fecal counts over time, three sites showed consistently low fecal counts, and at no sites were counts found to be increasing.

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Tidal Marsh

The Great Bay Estuarine System, extending from the coast at New Castle to the upstream reaches of Dover, Durham, Newmarket, and Exeter, represents a major geographic feature of southeastern New Hampshire.

Historically, the economic development of coastal New Hampshire has been intimately tied to the natural resources of Great Bay, and to it's utility as an inexpensive route to the ocean. Today, the Bay remains a major economic and recreational resource for the Seacoast region and the entire state of New Hampshire.

In spite of the major historical economic uses of Great Bay itself and the surrounding drainage basins, the estuary remains a relatively pristine and healthy environment (Jones 1999). In view of the substantial human impact (e.g. pollution and wetland loss) on many estuaries in the middle Atlantic region of the coastal US, Great Bay offers an important example of an essentially unperturbed, natural estuarine ecosystem. There are historic references to the impact of water-born particulate pollutants (e.g. sawdust) negatively impacting Great Bay mudflat communities (Jackson 1944), but these practices have long since ended. In the next decade and beyond, increasing residential development will create pressures that strain the ecosystem and lower its ability to rebound from pollutants and habitat destruction caused by human activities.

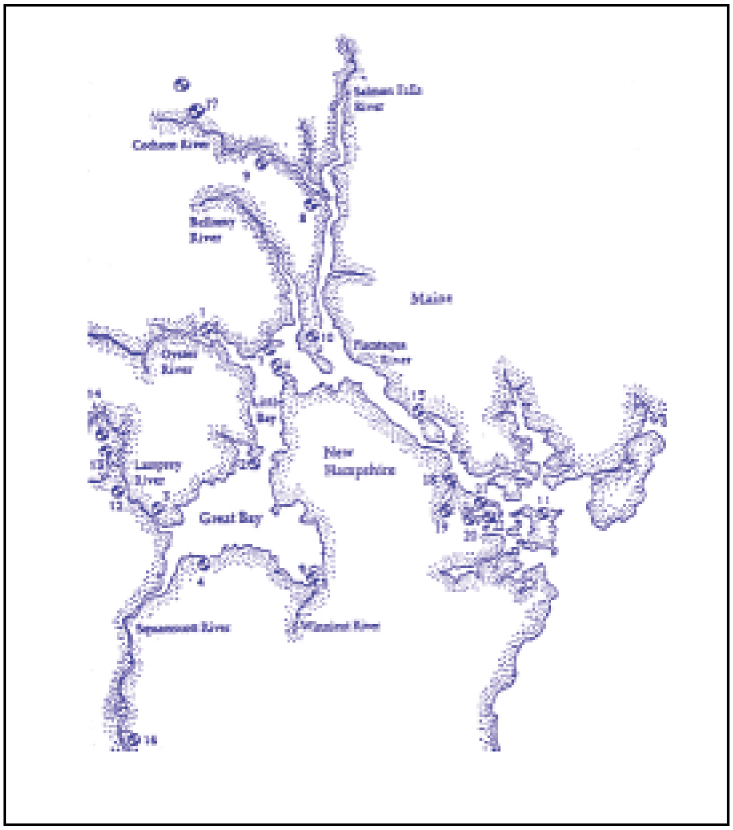
The Great Bay estuarine ecosystem is characterized by its unique hydrology. The Estuary derives its freshwater inflow from seven major rivers. Three of these rivers, the Lamprey, Squamscott and Winnicut Rivers, flow directly into Great Bay. The others, the Salmon Falls, Cocheco, Bellamy, and Oyster Rivers, flow into Little Bay and the Piscataqua River. Even so, the flows from the latter four rivers directly affect the Great Bay through tidal flushing. Estuarine tidal waters cover an enormous area, approximately 45 km^2 (17 mi^2) with a 161 km (100 mi) shoreline.

Freshwater inflow from the seven rivers entering the estuary varies seasonally, with the greatest volumes occurring as a result of spring runoff. However, throughout most of the year, the tidal component in the estuary dominates the freshwater influence. Thus, freshwater input represents only 2% or less of the total tidal volume (Reichard and Celikkol 1978, Brown and Arellano 1979).

Approximately 50% of the aerial surface of Great Bay is exposed as mudflat and seagrass beds at low tide. Additionally, extensive intertidal salt marsh borders much of the mouth of the Squamscott River, Crommett and Lubberland Creeks. Several small islands (i.e. Nannie, Swan, Vols, and the Footman Islands) occur within the Bay.

The Bay has an average depth of 2.7 m (8.9 ft). However, deeper channels extend to 17.7 m (58.1 ft). Channels from the Lamprey, Squamscott and Winnicut Rivers intersect near the center of the Bay to form the main channel which connects to Little Bay at Furber Strait. Strong tidal currents occur at Furber Strait since the tidally flushed water from Great Bay must pass through a restricted outlet. A similar tidal flow restriction occurs at Dover Point where Little Bay meets the Piscataqua River.

Great Bay is considered a mesotidal estuary with moderate tidal ranges varying from 2.5 m (8.2 ft) at the mouth of the estuary to 2.0 m (6.6 ft) at Dover Point (Reichard and Celikkol 1978). Tidal currents are greatest at Dover Point and in the Piscataqua River (1.5 to 2.0 m/sec) and decrease in Little Bay (0.75 m/sec). Due to the Coriolis Effect on water movement, flood tide currents are concentrated on the north and west shores of Great and Little Bays while ebb tide currents are strongest on the eastern shore. Our strong tidal currents act to create a mixed water column during most of the year.



Great Bay Estuary and GBCW Sites

Water temperature and salinity vary seasonally and daily with the tidal cycle. Within Great Bay, salinity may vary from fresh, essentially 0 °/₀₀ (parts salt per thousand parts water) at extreme spring runoff, to 30 °/₀₀. Similarly, temperature has a marked pattern of seasonal variation from a winter low of -1.9° C (freezing point of salt water) to 28°-30° C in the summer. The relative shallowness of Great Bay allows for rapid warming in the spring-summer and cooling in the autumn-winter.

The flushing time for water entering the head of the estuary is 58 tidal cycles (30 days) during low river flow and 48 cycles (25 days) during high river flow (Brown and Arellano 1979). Turgeon (1976) estimated a flow time of four days for a particle to traverse 4 km (2.5 mi) in the mid-estuary. This slow flushing rate allows contaminants to remain in the estuary for long periods of time. Therefore, contaminants can have a large impact on the biology and health of the estuary.

Because of the dynamic hydrology of the Great Bay Estuary, pollution at any point within the drainage basin or throughout the estuary itself will ultimately impact the entire system. Thus, it is important to acknowledge the need to manage an estuary as one system, rather than a collection of individual embayments (NHEP 2001).

Great Bay Coast Watch

The Great Bay Coast Watch (GBCW) is New Hampshire's most wide-ranging program for direct citizen involvement in monitoring estuarine waters. The GBCW is managed by a coordinator and extension specialist from UNH's Sea Grant Cooperative Extension. The Watch includes adults from all occupations, as well as students and their teachers from local schools. The Watch was formed as the Great Bay Watch in 1990 with funding from NOAA, in response to the Great Bay National Estuarine Research Reserve Management Plan, which included the formation of a citizen estuarine monitoring program as one of its objectives. The Great Bay Watch has been a part of the educational efforts of UNH Cooperative Extension/Sea Grant program for the past ten years. In 1999, to reflect a growing involvement of GBCW volunteers in coastal shoreline surveys and phytoplankton monitoring projects, the term "Coast" was added to the name.

Mission & Objectives

The mission of the GBCW is to protect the long-term health of New Hampshire's coastal waters and estuarine systems, through citizen volunteer monitoring and education projects.

The Great Bay Coast Watch has four primary objectives:

1. To establish a wide spatial array of water quality data on the Great Bay Estuarine System, and to make the data available to local and regional agencies, consulting firms, scientists, students, teachers, and the Jackson Estuarine Laboratory's long-term water quality estuarine data base;

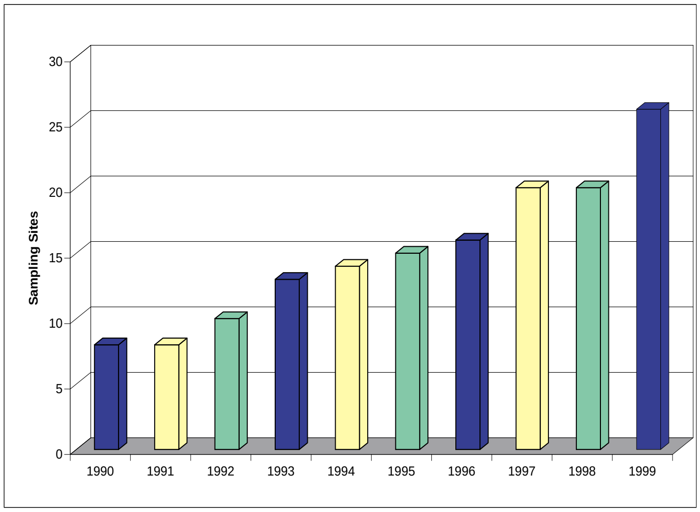
2. To monitor the fecal coliform content of water sampled at all water quality sites and report unusually high or low counts to appropriate individuals and agencies;

3. To bring the university's research community, interested citizens, and high school students together in an educational program that develops an understanding of the estuarine system as an important natural resource to be conserved;

4. To augment regional, state, and national citizen water-monitoring efforts.

Major Accomplishments

GBCW has achieved many important accomplishments in its first decade. Monitoring coverage throughout the estuarine system has been greatly expanded from 7 sites in 1990 to 26 sites in 1999 (20 for water quality, 5 for phytoplankton, and 1 site for both.)



Number of GBCW sampling sites 1990-1999

Our water quality monitoring database, collected and computerized from sampling visits conducted by the GBCW volunteers, is now approaching 4,000 total records.

The number of active volunteer monitors has tripled since 1990. More than 300 adults have been members over the past ten years, with 17 enrolled in the program since it's beginning. The volunteers include retired adults, teachers and high school students, home-schooling families, and a variety of working professionals. A number of the GBCW members are UNH Marine Docents, volunteer educators who complete a five-month education training program about the marine environment. Involvement of area high schools has grown from one school in 1990 to nine by 1999. During the past ten years, the monitors have driven thousands of miles and have given 120,000 volunteer hours to the program.

GBCW receiving the Adult Volunteer Group Award from Governor Shaheen

GBCW was recognized as the Outstanding Adult Volunteer Group in Strafford County by Governor Jeanne Shaheen's Council on Volunteerism in 1998.

We have completed a long-term contract with the N.H. Estuaries Project to recruit and train volunteers to assist in the shoreline survey of the Atlantic coast. Results of this project will be used by the Department of Environmental Services to classify shellfish-growing waters along the coast.

GBCW was recently awarded N.H. Coastal Program grants to conduct shoreline survey work and identify potential pollution sources in the towns of Newmarket and Dover. A team of volunteers presented results along with GBCW long-term monitoring data to the conservation commissions in each town.

We have successfully launched a volunteer phytoplankton monitoring program, with support from the N.H. Coastal Program and New England Grassroots Environmental Fund.

GBCW data are used by a wide range of research and policy-making agencies, including the US EPA New England Office, N.H. Department of Environmental Services (DES), N.H. Department of Health and Human Services (HHS), N.H. Coastal Program, and the University of New Hampshire's Jackson Estuarine Laboratory.

Water Quality Monitoring

GBCW conducts baseline water-quality monitoring from April to November, one day per month on the weekday closest to the new moon. Samples are collected at both the low and high tide of each sampling day. The sampling approach seeks to reflect extreme conditions (i.e. early morning for dissolved-oxygen readings). Each site has a specific time when volunteers sample, reflecting the lowest possible tide and the highest possible tide at each site. Each year's schedule is unique, based on the tide information in the Maine Geographic Calendar and Almanac by the DeLorme Map Company (corrected for each GBCW site location).

Temperature

Temperature is one of the easiest measurements to perform, and probably one of the most important parameters to be considered. It dramatically affects the rates of chemical and biochemical reactions within the water. Many biological, physical, and chemical principles are temperature dependent. Among the most common of these are the solubility of compounds in seawater, distribution and abundance of organisms living in the estuary, rates of chemical reactions, density, inversions and mixing, and current movements. Because the Bay and its tributaries are so shallow, their capacity to store heat over time is relatively small. As a result, water temperature fluctuates considerably.

pH

pH is a measure of hydrogen ion (H^+) concentration in water (H_20). The pH scale ranges from 0.0 to 14.0, with acidic waters having pH readings less than 7.0. Basic (or alkaline) waters have pH readings greater than 7.0. A pH of 7.0 is neutral (neither acidic nor basic). Distilled water has a pH reading of 7.0. Open-ocean waters tend to have a pH just over 8.0, while fresh water in New Hampshire tends to be slightly acidic (pH less than 7.0). Estuarine waters, a mixture of fresh and salt water, generally have pH readings between 6.5 and 8.5. The pH levels in Great Bay may vary slightly over a year, but in general show little seasonal fluctuation. Large changes in pH can have a great impact on estuarine life, and readings well above or well below the normal range may indicate pollution. In particular, acid pollution is caused by the emissions of automobiles and coal-fired power plants. GBCW volunteers measure pH using an electronic "pocket" pH meter (Cole Palmer pH tester 2).

Salinity

Salinity is total amount of dissolved solids in the water and is made up of all known elements. The salinity of the open ocean is approximately 35 parts per thousand ($^{o}/_{oo}$), but in the Gulf of Maine, salinity is slightly lower at about 32 $^{o}/_{oo}$ due to regional rivers and run-off. Seven rivers contribute fresh water to the Great Bay Estuary. During the spring run-off, levels of salinity have been recorded as low as 0 $^{o}/_{oo}$ in the upper reaches of the estuary. Salinity may also range as high as 32 $^{o}/_{oo}$. Tolerance of wide-ranging and sometimes rapidly changing salinity determines, more than any other single factor, which species of plants and animals can survive in an estuary. Although salinity levels are higher at the mouth of the Piscataqua River, and generally become progressively lower as we move into the Great Bay proper, winds and tides cause Little Bay and Great Bay to be well mixed. Mixing occurs top to bottom, blending the warmer, fresher water that tends to float on top with the cooler, denser salt water brought in by the tides. Aquatic life is affected by varying levels of salinity. These levels determine when and where organisms can live in the estuary (Short et al. 1992). In estuaries, salinity readings vary with the seasons and weather conditions, as well as with the tides. Rain and snowmelt cause rivers to swell, decreasing the salinity of the bay. As stream in-flow levels decrease and evaporation from the bay's surface increases during the summer months, salinity levels begin to rise. Salinity levels tend to drop again in mid to late fall as autumn rains increase river flows. This seasonal fluctuation is mirrored in the monitoring data from GBCW sites.

Dissolved Oxygen

Dissolved oxygen (DO) is one of the most important indicators of the quality of water for aquatic life. It is essential for all plants and animals inhabiting the Bay. When oxygen levels in the water fall below about 3-5 parts per million (ppm), fish and many other aquatic organisms cannot survive. Oxygen is a particularly sensitive constituent because chemicals present in the water, biological processes, and temperature exert a major influence on its availability during the year. While the overall oxygen content (in mg/L) in the water is important in assessing the health of a water body, it is also useful to look at dissolved oxygen in terms of "percent saturation." Percent saturation is the ratio of oxygen concentration that is in the water to the oxygen concentration that would be expected in the water if saturated, at a given temperature and salinity. One might expect that the highest obtainable percent saturation value to be 100 percent; however, "supersaturation" (values greater than 100 percent) can occur under certain conditions. Very high concentrations of oxygen are possible in areas with a great deal of aquatic vegetation, which produce oxygen through photosynthesis. Areas with strong wind and wave action can also add oxygen through entrainment of atmospheric oxygen into the water.

Transparency

Transparency measurements are used as a gauge of the clarity of the water. It is measured by lowering a standard white and black disk (secchi disk) into the water until it no longer can be seen. Turbid conditions, resulting in less secchi depth visibility, tend to increase in the tidal rivers and inner estuary, and then decrease nearer to the ocean and further away from the sources of turbidity. Excessive turbidity may indicate problems in the estuary. Erosion from shorelines and upland areas increases the turbidity of the water, as can plankton blooms caused by high levels of nutrients. Transparency affects fish and other aquatic life by: 1) limiting photosynthetic processes and increasing respiration (oxygen used and carbon dioxide produced), 2) clogging and damaging of fish gills by

suspended particles, and 3) obscuring vision of fish and shellfish as they hunt for food. Estuarine waters can be naturally turbid from suspended sediments and phytoplankton. If the upper waters have less than one percent of the normal light levels found at the surface, phytoplankton are not able to photosynthesize and sustain growth. Our important seagrass beds require at least 20% of the surface light to survive.

Fecal Coliform

Fecal coliform bacteria are used as an indicator of human sewage pollution. While fecal coliforms are found in the feces of all warm-blooded animals, their presence often means that other, more dangerous bacteria and viruses may be present. High numbers of coliforms can indicate pollution from improperly treated sewage effluent, waste discharges from boats, improperly functioning or failed septic systems, untreated urban storm water, runoff from agricultural operations, feces from wildlife, or other sources.

Our fecal coliform tests are performed using the membrane filtration (plate count) method. New Hampshire water quality standards for tidal waters use another kind of intestinal bacteria, enterococci, to determine if waters are safe for swimming. State standards for tidal shellfish waters, however, do specify acceptable levels of fecal coliforms. While direct application of shellfish water standards to GBCW data would not be appropriate due to differences in the procedures used, these standards can be used as a general guideline for interpreting GBCW results.

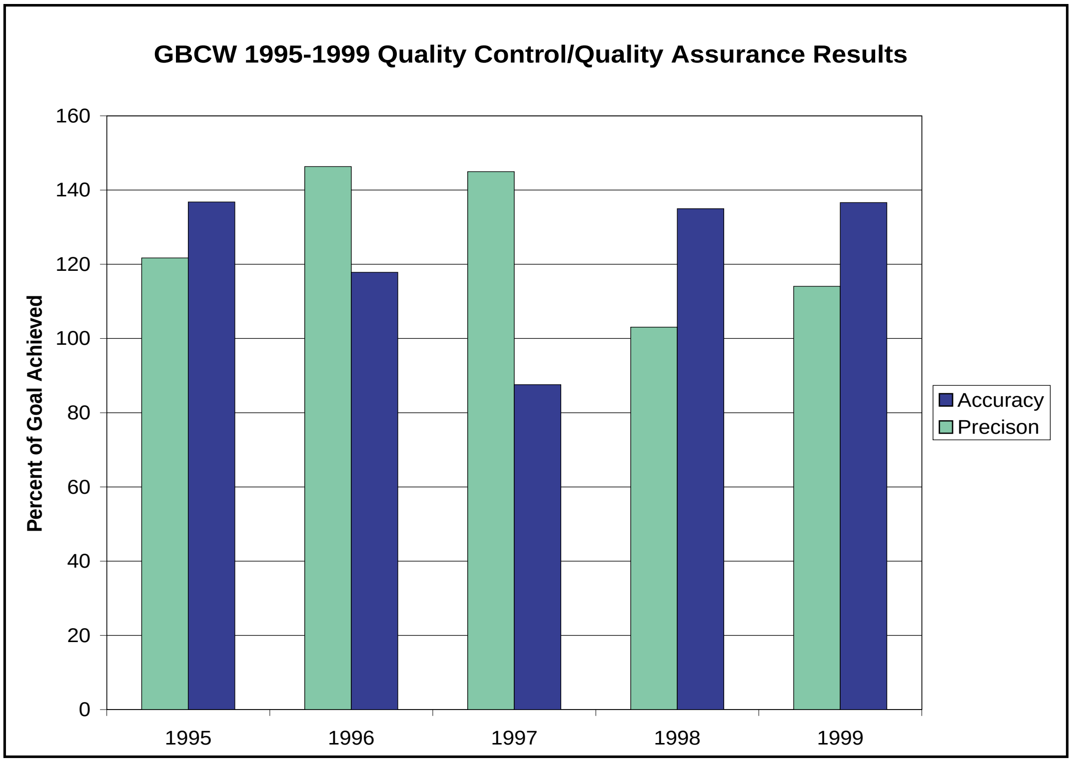
Phytoplankton Monitoring

GBCW began a pilot effort to monitor harmful algae blooms (HAB) along the New Hampshire coast in June 1999. The program recruited twenty-five volunteers to begin the project, which was based on existing programs in Maine and Massachusetts. Sampling sites were selected in Seabrook, Hampton, and Rye Harbors; New Castle; and Dover Point. With the help of experienced GBCW volunteers, new volunteers were trained in water-quality sampling methods. The coordinator of the Maine program helped GBCW staff to teach proper techniques of phytoplankton sample collection and the use of field microscopes, as well as phytoplankton identification.

Quality Assurance/Quality Control

GBCW employs several quality assurance and quality control (QAQC) activities to monitor for inconsistencies of measurements in the field and ensure the quality of the monitors' measurements. The purpose of the QAQC is to evaluate the quality of the data collected by the program and to increase confidence in the data being furnished by the volunteer monitors. Our approved quality assurance project plan is on file at the EPA New England office.

The QAQC program, ongoing since 1992, focuses on three areas. First, all new volunteers are trained and introduced to sampling techniques. Each year's returning volunteers are retrained as well. Second, all volunteer monitors are tested annually in a laboratory setting (see chart). Third, we use QAQC teams to validate volunteer data with split-field sampling. Volunteer training begins before the sampling season and includes all volunteers, new and returning. A series of "dry run" meetings are held in February or March and are designed to demonstrate sampling techniques and provide hands on experience. "Wet runs," held in April and conducted in the field, are aimed at helping volunteers gain confidence in all procedures.



QAQC has met or exceeded 100% of it's goals in all but one year.

Formal QAQC sessions are held twice a year. These sessions are designed so that problems can be identified and corrected. Volunteers test a common water sample with calibrated equipment, for several parameters. The results are reviewed and analyzed by GBCW staff. Two factors are of primary interest when evaluating the quality of data collected by volunteer monitors. The first is accuracy, or how close on average the volunteers' measurements are to the true value of the characteristic being measured. A difference between the average monitor value and the actual value is computed and reported as the level of accuracy. The second factor is precision, or how close the volunteers' measurements are to one another's. The standard deviation is used to show variance. The variation in the volunteers' measurements for a single sample is reported as the level of precision.

In 1997, we made key adjustments to our in-lab QAQC assessment sessions, to control for external factors influencing the water samples (used in comparison tests). We designed a covered container to hold the water for dissolved oxygen sampling to try to control fluctuating dissolved oxygen levels. We also used our incubator for water temperature testing to keep a constant water temperature throughout the six-hour session.

The split-sampling component of the QAQC plan is designed to "spot check" the volunteers in the field. The coordinator, or one of the trained staff, visits sites on sampling days and performs all of the tests that the volunteers do, from the same water sample.

As an organization, GBCW has achieved an outstanding QAQC record. We constantly strive to produce the highest quality data results, and to make quality assurance an integral part of the volunteer monitoring effort.

GREAT BAY COAST WATCH
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Water Quality Findings

Ten years of volunteer water quality monitoring data show that Great Bay Estuary is one of the cleanest estuaries in the eastern United States.

Despite years of human impacts, much of the Great Bay remains a pristine, healthy, and vital natural ecosystem. It is evident, however, that there are areas within the estuary system that suffer from the effects of coastal development and heavy recreational use. These impacts are reflected in the monitoring data, and show a strong interconnection between human activities and estuarine water quality.

The following sections assess water quality for the Great Bay Estuary at large, and for each of the sampling site locations. Findings presented here are based entirely on an analysis of volunteer monitoring data collected by the Great Bay Coast Watch from 1990 to 1999. Our analyses are used to characterize the general health of the entire estuarine system, and to identify water quality issues that effect one or more of the GBCW sampling sites.

System Wide Findings

General Health

Ten years of key water quality measurements show a generally good level of overall health in the Great Bay Estuary. The following indicators are used as critical indices of water quality:

- ❑ ***High-tide visibility*** is a measure of water clarity at the maximum depth of the water column
- ❑ ***Low-tide dissolved oxygen*** indicates oxygen availability for aquatic biota during the most stressful tidal conditions
- ❑ ***Low-tide fecal coliform*** measures the number of fecal colonies with minimal diluting due to tidal exchange

1990-99 median values (equal numbers of values greater than and less than) for key water quality indicators are presented below, and indicate an overall good picture of health. These values are useful as reference points only. Site-to-site and year-to-year variability in these data are described in the Key Indicators section.

Water Quality Median Values 1990-1999 *	
High Tide Visibility Depth	1.5 meters
Low Tide Dissolved Oxygen Percent Saturation	92.2 %
Low Tide Fecal Coliform Count Geomeans **	10.9 colonies per 100 ml

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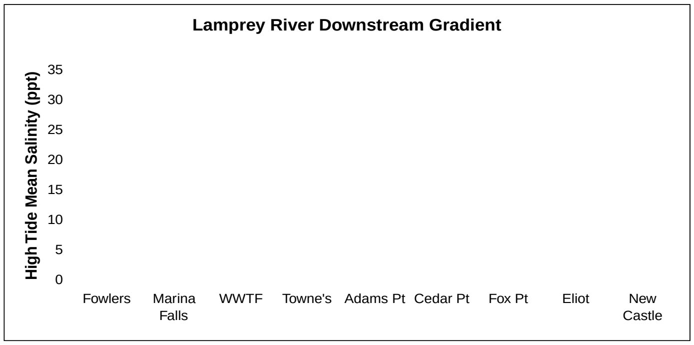
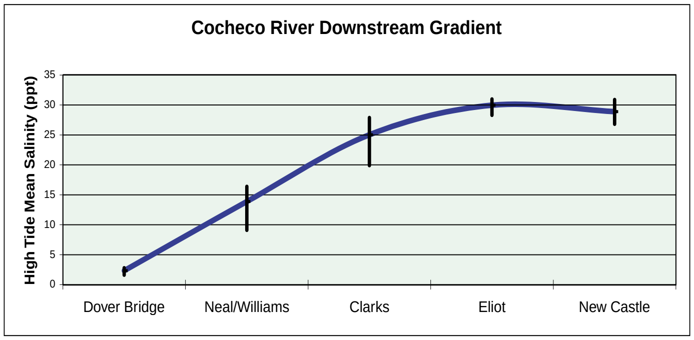
* By comparison, the New Hampshire minimum standard for "swimmable and fishable" waters is 75% dissolved oxygen saturation. State standards for shellfish bed closures are 14 fecal counts; based on different methods than used by GBCW. No standards exist for visibility depth.

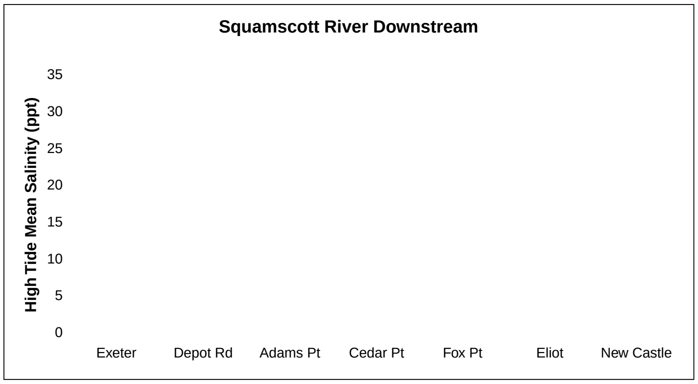
** The geomean, or geometric mean, is often used for data with very large variations. This limits the influence of occasional very high or very low values.

Gradients

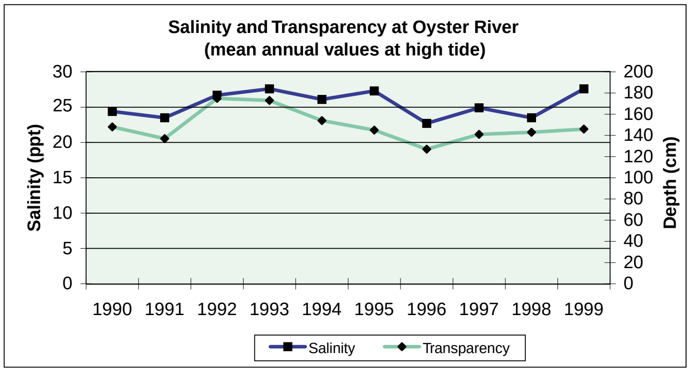
System-wide data views allow us to characterize key elements of the Great Bay ecosystem. This section describes how salinity levels are used as a key indicator of estuarine tidal flushing. Salinity levels provide a clear picture of the Great Bay estuarine gradient, from the brackish and fresh tributary streams to the open ocean. The following charts show the pattern of increasing high tide salinity along the flow of the Cocheco River, Lamprey River, and Squamscott River. Vertical bars show the high and low range of mean annual high tide salinity from 1990-99.







By tracking salinity, we can also show the relationship of tidal flushing to other water quality measures. Transparency levels can improve with tidal exchange as clear ocean waters move up into the estuary. For example, the following chart demonstrates a strong positive correlation at the Oyster River site between annual salinity levels and transparency.

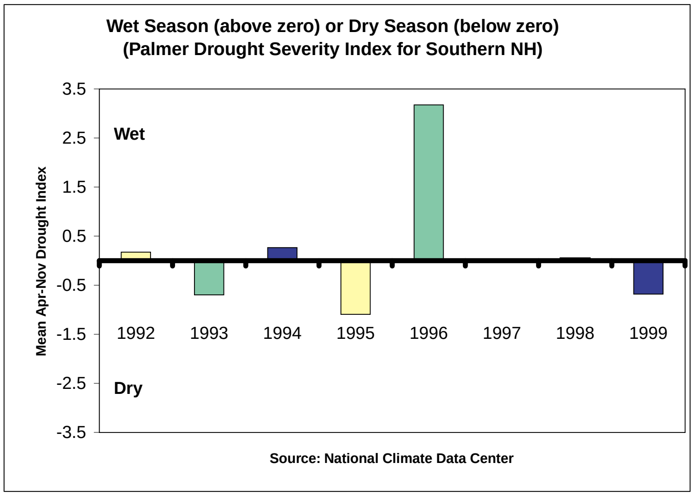


Response to Environmental Factors

As a complex ecosystem, the Great Bay Estuary is constantly in flux with the changing environment. Our monitoring indicates that the ecosystem responds to changes at a range of temporal levels, including monthly lunar tide cycles, seasonal temperature changes, annual precipitation conditions, and decade-long land use changes along the shoreline.

Abnormally high levels of precipitation have been shown to have a negative impact on water quality as pollutants are washed from the land into the estuary. To evaluate this impact on Great Bay, we first need to determine to what extent a sampling season was unusually wet or dry. The US Climate Data Center reports this information with its monthly drought index for Southern New Hampshire.

The following chart shows the 1992 to 1999 drought index during the GBCW sampling season (April through November). The data show that 1996 was an especially wet sampling season (large positive value for the index), and 1993, 1995, and 1999 were dry sampling seasons (negative index values).



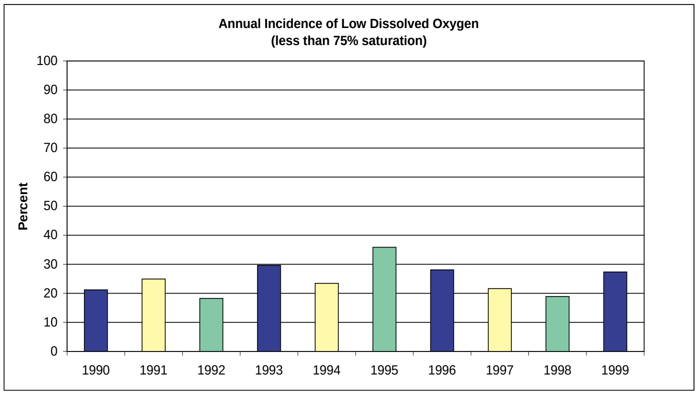
This information is useful to us as we interpret trends and anomalies in our water quality observations. In particular, we used statistical analysis to determine if observed fecal coliform counts could be related to precipitation. Statistical regression analysis showed that water quality at several sites seemed much more impacted by rainfall than other sites. These results led to more detailed analyses of rainfall and fecal coliform counts, as reported in Site Findings.

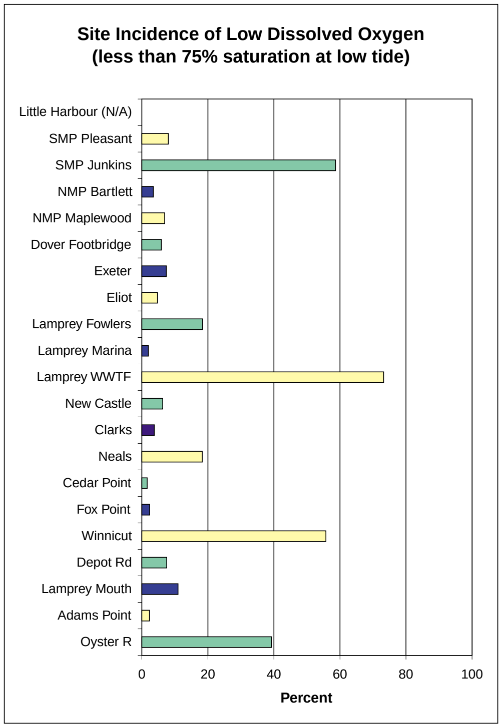
Key Indicators

Dissolved Oxygen

Data show that the Great Bay Estuary appears to have generally healthy levels of dissolved oxygen (DO), indicating good tidal exchange and little eutrophication (broad ecological changes due to excessive nutrient loading). Most sites showed average percent saturation values well above the N.H. standard of 75% for "Class B" waterways. Saturation levels less than 75% could indicate potential environmental impacts to oxygen-sensitive organisms like fish.

Low DO readings (below 75% saturation) were typically observed less than a third of the time. The peak years for low DO, 1993 and 1995, were also years of below-average precipitation. Drought conditions (warm temperatures and low rainfall) lead to low streamflow and oxygen depletion. When DO levels are examined by site, four sampling locations are notable in incidences of low DO saturation: Oyster River, Winnicut, Lamprey River (at Wastewater Treatment Facility), and South Mill Pond at Junkins Avenue. Low readings at Oyster River, Lamprey River, and South Mill Pond can be explained by the close proximity of sampling sites to known sources of nutrients and organic matter (municipal sewage discharge). At Winnicut, low DO is likely due to natural oxygen depletion along the mudflat and salt marsh shoreline at low tide.



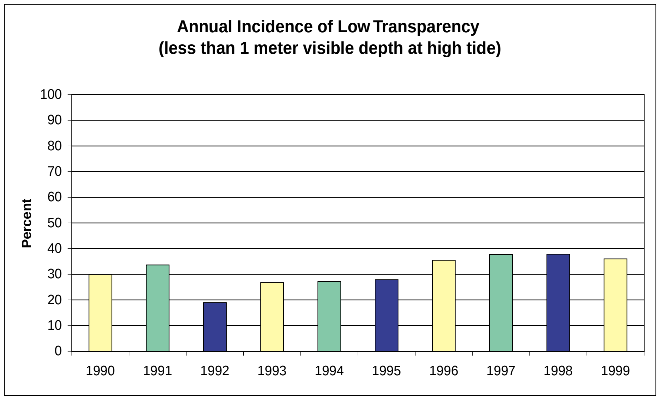


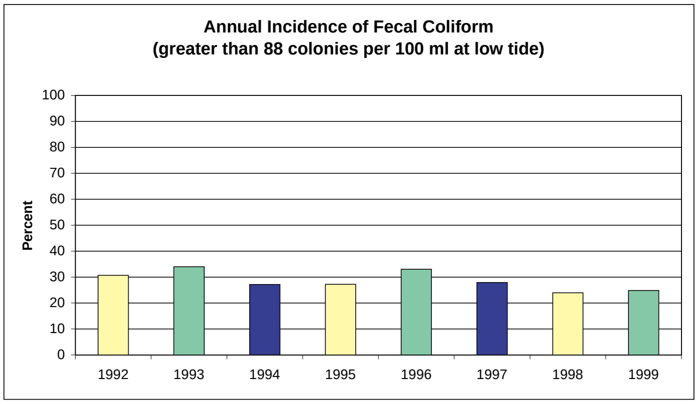
Transparency

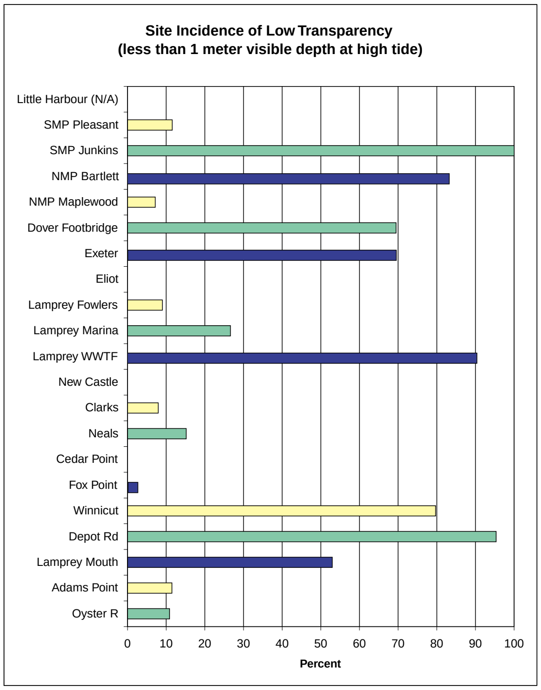
Measure of water clarity varied widely across the estuarine gradient, showing the effects of tidal mixing and diverse topography. Low visibility readings (less than 1 meter visible depth at high tide) were observed from 19% to 38% of the time, with considerable variability across sites. It is important to note that shallow water sites (Depot Road, South Mill Pond at Junkins Avenue, North Mill Pond at Bartlett Avenue) are naturally biased toward low transparency (if bottom seen, transparency depth equals water depth).

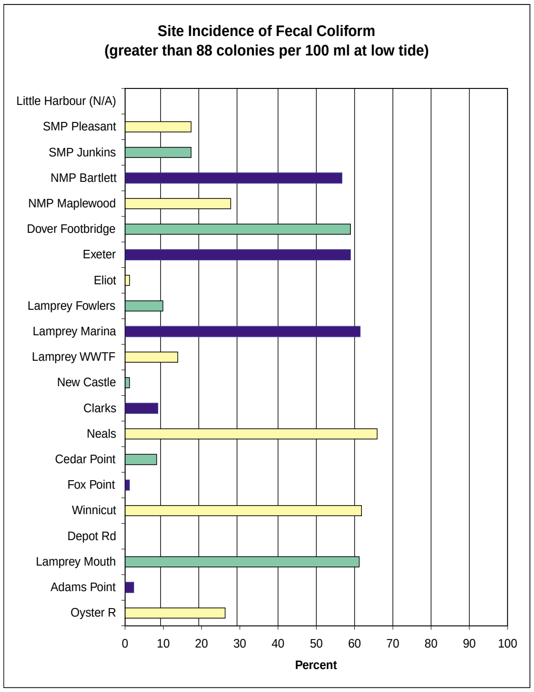
Fecal Coliform

Fecal coliform counts have been included in the data sampling procedures since 1992. We used the N.H. regulatory "contact recreation" standard of 88 counts per 100 ml sample as our reporting threshold level. Low tide fecal coliform counts have shown a slight decreasing trend from 1992 to 1999. 1996 stands out as a year that did not follow this trend, again likely related to the unusually high rainfall that year. Site distribution of elevated fecal counts is variable, with lower counts in deep water sites. The Site Findings section discusses fecal coliform counts in further detail for each sampling site.









Site Findings

This section characterizes each site in the GBCW network. For each site, we provide a brief description of the sampling location and a summary of water quality statistics. The sites are generally grouped by river system, with sites furthest from the ocean discussed first. This grouping also separates each municipality so that a clear picture of the estuarine water quality can be provided for each town.

Qualitative analyses are done based on differences among the various estuarine environments in the sampling site network. Graphs following the written descriptions of the sites give a visual indicator of water quality for each parameter. Each graph shows the ten monitoring years on the horizontal x axis, and the parameter studied on the vertical y axis.

Site-specific graphs show median values. Unless stated otherwise, values reported in the text of this section are also based on median values. Medians are identified on each graph line by horizontal hash marks. The vertical bars above and below the median hash marks show where 50% of the data occurred for each year. These ranges are also known as the 25% and 75% quartiles.

By using this type of graphical representation, we can show typical values, data variability, and year-to- year trends in a single graph. These graphs also help us to identify observations where unusually high or low values may suggest a problem or a change in natural system function.

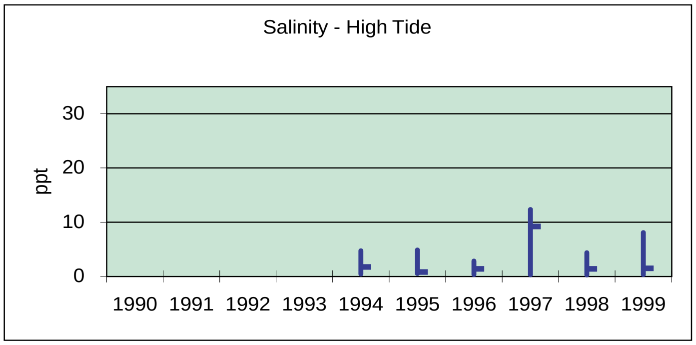
Exeter, Stratham, and Greenland

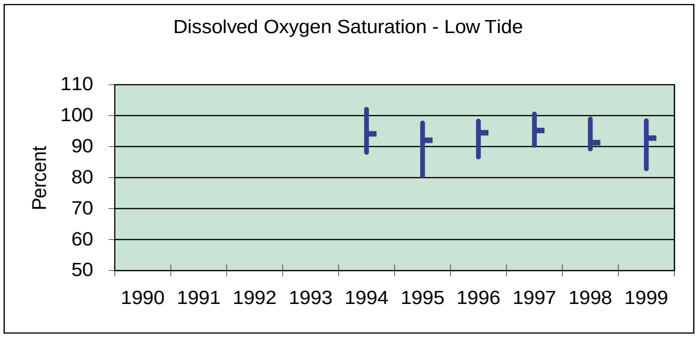
Students and teachers from Exeter, and other volunteers, cover the one site in Exeter. Water-quality data is collected at two sites in the town of Greenland.

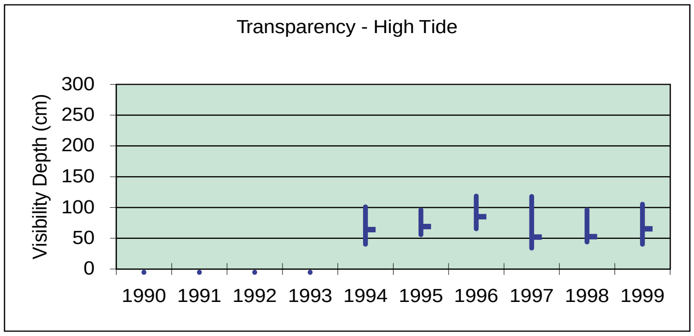
Site 16: Exeter Town Docks

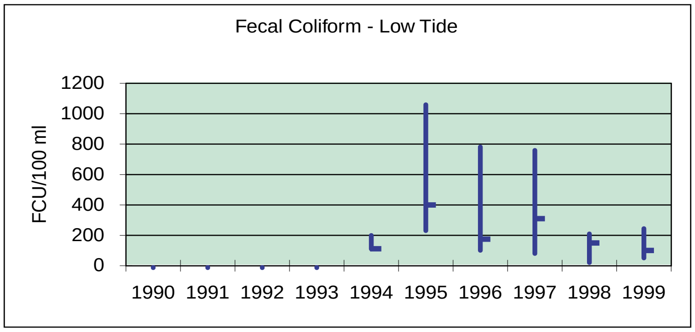
This site is on the Squamscott River, located downstream of the tidal dam in downtown Exeter and upstream from the crew docks at Phillips Exeter Academy. It was added to the program in 1994 and is one of our farthest upstream sites.

This site has one of the highest average temperature values and tidal temperature difference values: 16.8°C at low tide and 18.7°C at high tide. The values for percent saturation





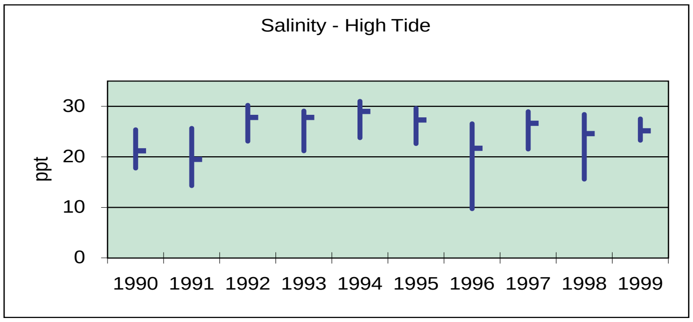


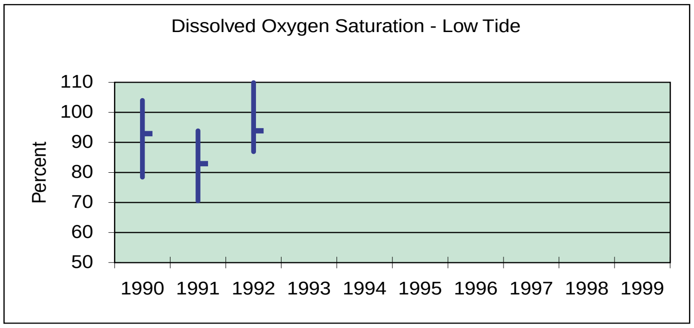


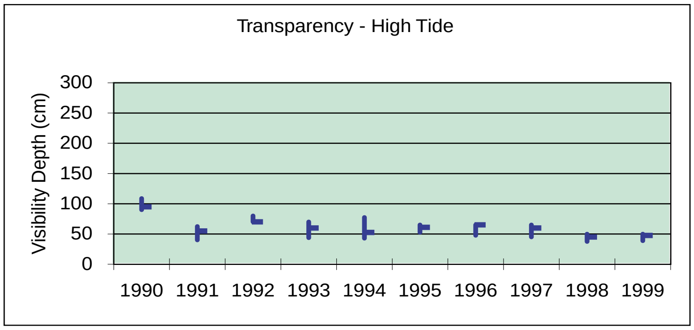
of dissolved oxygen have remained steady and slightly above 90 percent. Salinity was usually below 10 ppt. The high tide transparency held steady at 65 cm. The low tide fecal coliform peaked in 1995 at 400 counts and trends downward to 100 counts in 1999. The low tide fecal coliform range has also decreased from 230 - 1060 counts in 1995 to 50 - 245 counts in 1999. The fecal coliform at low tide was 208 counts over the past six years, and had the third highest count in the GBCW network. Fecal coliform counts showed no relationship with time (year) or rainfall (incidents in the 60-hour period prior to sampling). However, the site does have a significant level of bacteria. Recently, health officials have been making progress toward reducing bacterial sources (sewage and runoff). Further research needs to be directed toward determining the variability and source of the contamination.

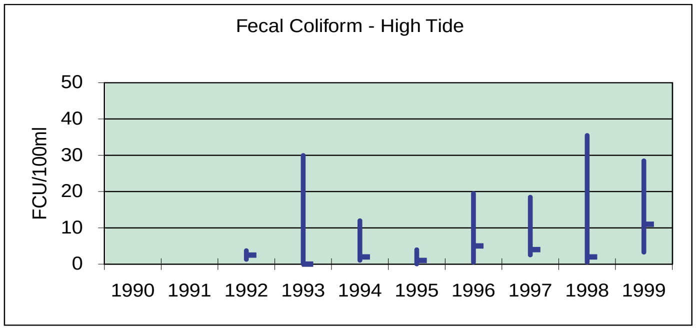
Site 4: Depot Road, Sandy Point

Site 4 is located on the southern shore of Great Bay at the Great Bay National Estuarine Research Reserve, Sandy Point Discovery Center. Because of the extensive mud flats exposed at low tide at this location, samples were collected at high tide only from 1993 on. The high tide temperature averaged 18.0°C, warmer than at nearby Adam's Point and the Portsmouth Country Club. Low tide dissolved oxygen data were not collected at this site since 1992. The salinity at high tide was between 20 and 30 ppt with a big dip in 1996 (a very wet year). High tide transparency was steady at 61 cm, but this reflects the maximum depth at the site. The fecal counts at high tide were 11 or less, with few samples exceeding 40 counts. Fecal coliform counts showed a weak relationship with time coupled with rainfall incidents in the 60-hour period prior to sampling. These results showed that greater rainfall led to higher bacteria counts. Elevated bacteria levels during rain events suggest a non-point source of pollution. However, the overall quality of the water is quite good, with bacteria levels an order of magnitude less than the ranges observed at the Exeter docks.



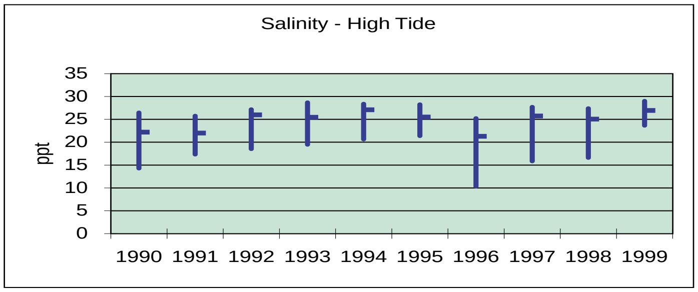


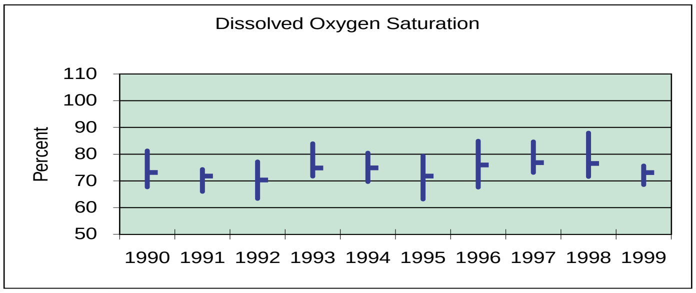


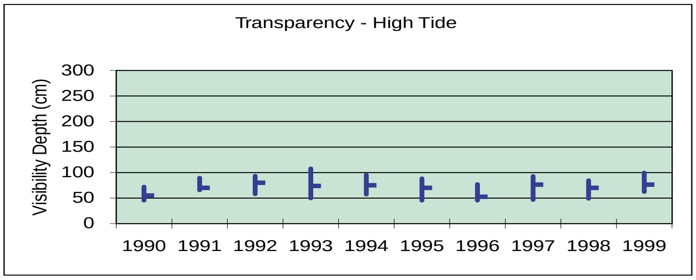


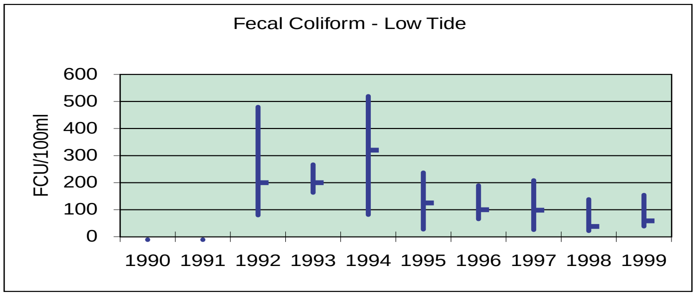
Site 5: Winnicut River at Portsmouth Country Club

Site 5 is located at the mouth of the Winnicut River. It sits on the east bank of the river at the Portsmouth Country Club. The County Club's #4 fairway leads down to where GBCW volunteers sample. The average temperature at low and high tide is 15.6°C and 18.0°C respectively. This is the largest tidal temperature difference in the GBCW network. Dissolved oxygen percent saturation at low tide was 73.9 percent. On many sampling dates, saturation levels were below the Class B standard of 75 percent, most likely due to natural marsh drainage. Salinity was steady, averaging 25 ppt at high tide, with a dip in 1996. Transparency remained consistently near 70 cm at high tide and water depth averaged 120 cm. Fecal coliform at low tide trends downward the last six years, to less than 100 counts in 1999.



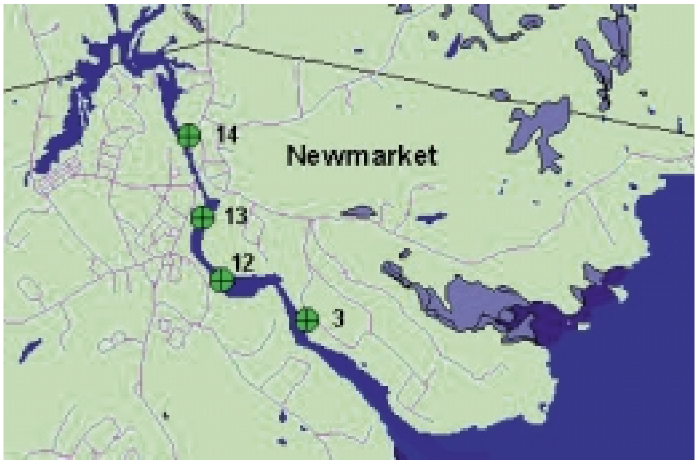






Fecal coliform counts showed a weak relationship with time coupled with rainfall incidents during the 60-hour period prior to sampling (low tide only). Of the two terms used in the analysis, time was the most influential, suggesting a reduction in point source generated pollution. The range of fecal coliform counts here was slightly lower than that of the Exeter docks.

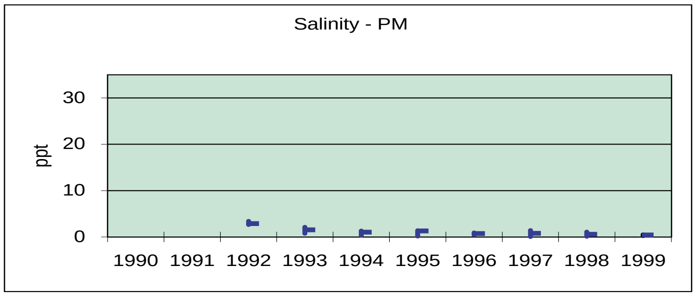
Newmarket

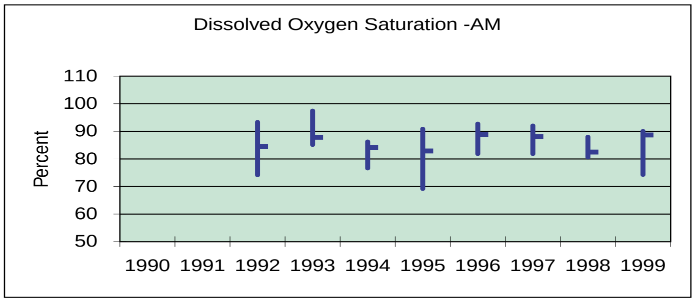


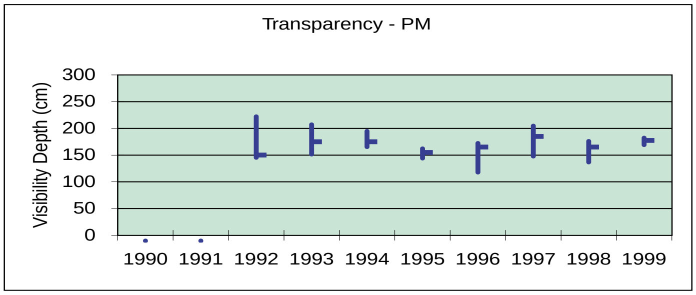
GBCW monitors four sites in the town of Newmarket on the Lamprey River.

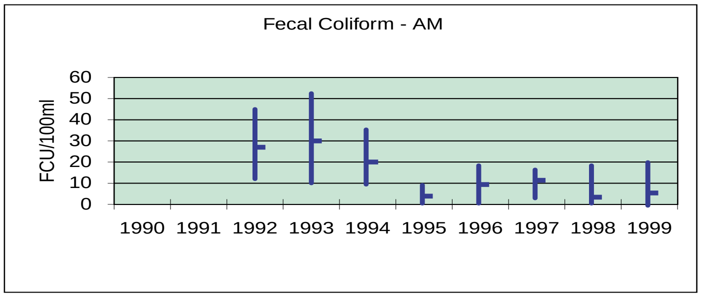
Site 14: Fowler's

Site 14, the only freshwater site in the GBCW network, is just upstream of the tidal dam (and upstream of downtown Newmarket) at the Fowler's dock on the Lamprey River. There are no low and high tide fluctuations at this site, so the difference in sampling times is described by AM (when all other sites are measured at low tide) and PM (when all other sites are measured at high tide). The water temperature averaged 17.0°C for AM readings and 18.5°C for PM readings. Dissolved oxygen was 85.9 percent, above the Class B standard. Salinity was always less than 5 ppt, indicating fresh water. Transparency was 168 cm with a slight reduction in 1996. The fecal coliform was 14 counts and trended downward during the period of sampling. For both morning and afternoon samples, the fecal coliform counts at this fresh water site showed a weak relationship with time and rainfall incidents during the 60-hour period prior to sampling.


Salinity - PM

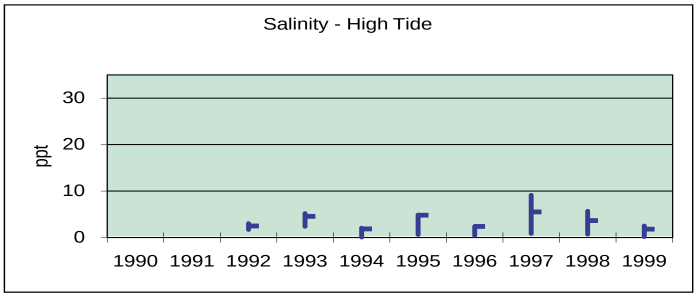

Dissolved Oxygen Saturation -AM

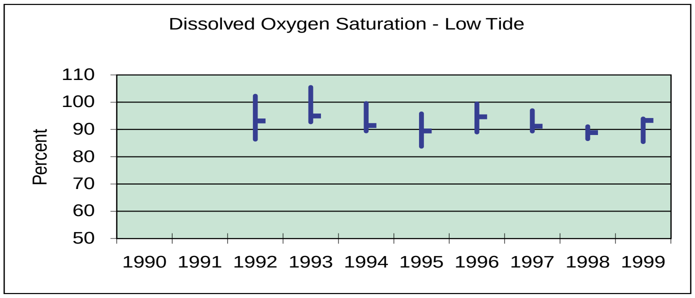

Transparency - PM

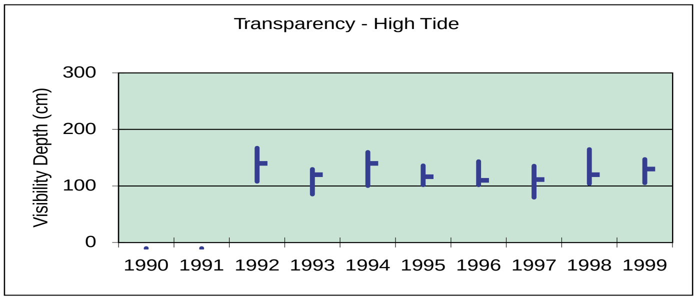

Fecal Coliform - AM

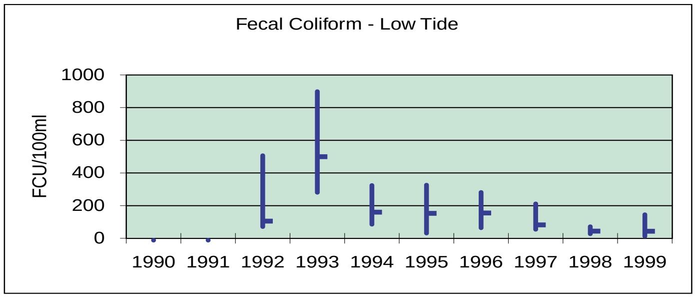
Site 13: Marina Falls Landing at Newmarket

Site 13 is located at a small boat docking facility upstream of the Town Docks in downtown Newmarket and on the Lamprey River. This site is upstream of the wastewater treatment facility, and downstream of Fowler's and the dam marking head-of-tide. Temperature at this site was relatively high, as expected at an upriver site (averaging 16.8°C at low tide; 18.0°C at high tide). The dissolved oxygen percent saturation of 92.1 percent was the highest of all the sites on the Lamprey River, possibly due to the aeration effect of the dam. Salinity at this site was very low, 3.5 ppt at high tide. Transparency stayed steady at 122 cm during high tide. The low tide fecal coliform was 155 counts, and trending lower.


Salinity - High Tide


Dissolved Oxygen Saturation - Low Tide

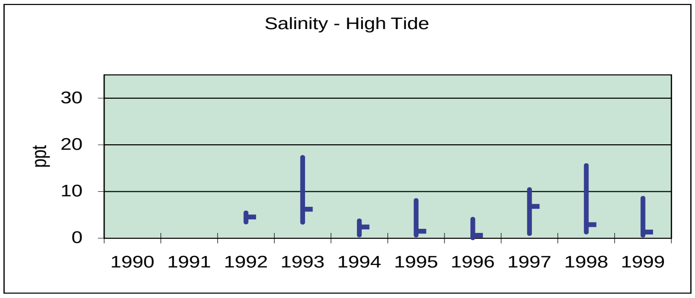

Transparency - High Tide

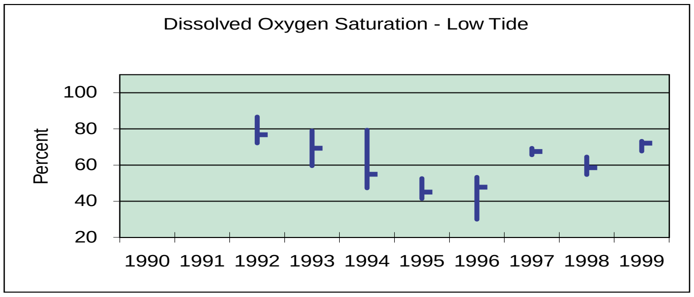

Fecal Coliform - Low Tide

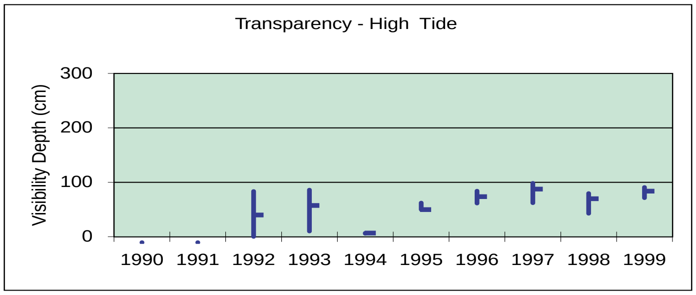
The fecal coliform counts for this site showed a weak relationship with time and rainfall incidents in the 60-hour period prior to sampling (low tide only). A reduction in point source pollution is suggested because time had the greatest effect in the analysis.

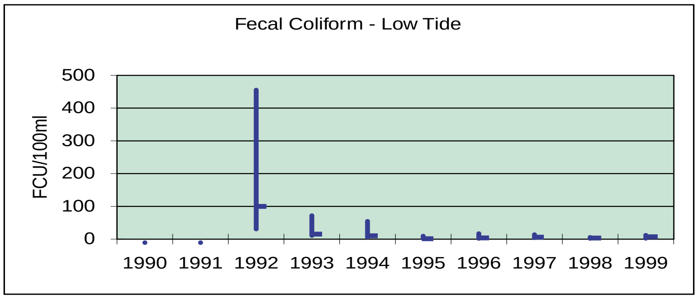
Site 12: Newmarket Wastewater Treatment Facility

Site 12 is located on the shoreline of the Lamprey River, just below the Newmarket Wastewater Treatment Facility, (WWTF). Substantial mud flats require that low tide samples be taken close to the outlet of the treatment plant. Thus low tide values are an indication of the performance of that facility.





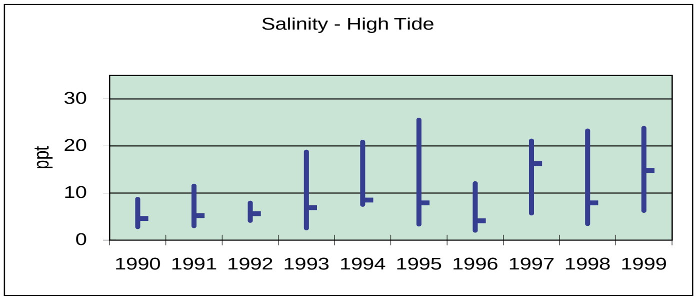


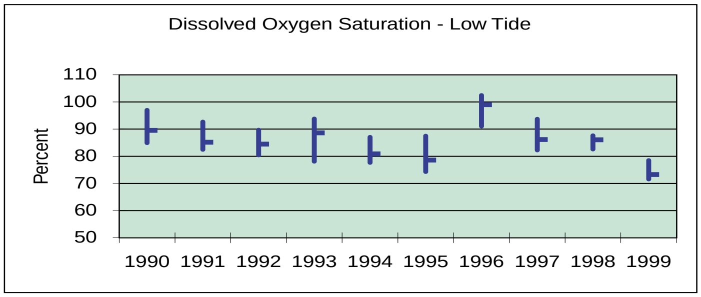


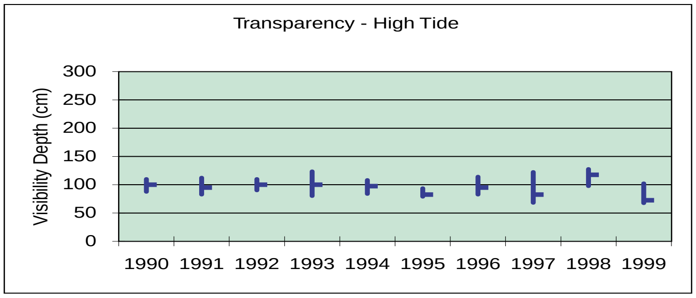
Average temperatures at this site were the highest for the Lamprey River: 18.1°C at low tide and 18.5°C at high tide. The dissolved oxygen percent saturation varied between low tide and high tide. The low tide value was 61.5 percent, while the high tide values were well above the Class B standard of 75 percent. Salinity, as anticipated, was lower than at Towne's dock, as this site is farther upriver (high tide salinity was 3.3 ppt). The high tide transparency was 67 cm, with a great reduction in 1994. The fecal coliform at low tide ranged between 1 and 15 counts after 1994. The first year of sampling showed counts of 100 in 1992. However, the overall median value was 18 counts for the entire period, and is low due to chemical treatment at the WWTF. The fecal coliform counts showed a weak relationship with time, and were independent of rainfall incidents. After 1992, fecal coliform counts at the WWTF have been some of the lowest in the GBCW network due to chemical treatment upgrades at the plant.

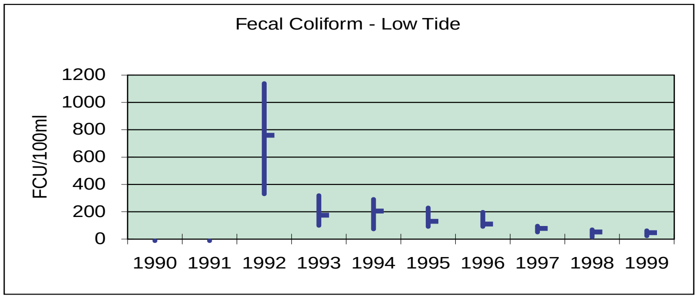
Site 3: Towne's dock (formerly Weinert's dock)

Of the four GBCW sites on the Lamprey River, Site 3, which is now located one lot downstream from Weinert's dock, is closest to where the Lamprey River enters Great Bay. The water temperature at this site was relatively warm, similar to all of the other sites along this river, averaging 17.2°C at low tide and 18.4°C at high tide. The dissolved oxygen percent saturation was 85.2 percent during low tide. In 1996, the dissolved oxygen percent saturation range was above the ranges for most other years. The salinity at this site was 8.2 ppt at high tide, the highest of the Lamprey River sites. Such salinities illustrate the brackish quality of the tidal Lamprey River. Transparency was consistent at 94 cm for high tide. Annual low tide fecal coliform dropped considerably over the sampling period, from 760 counts in 1992 to 47 counts in 1999.



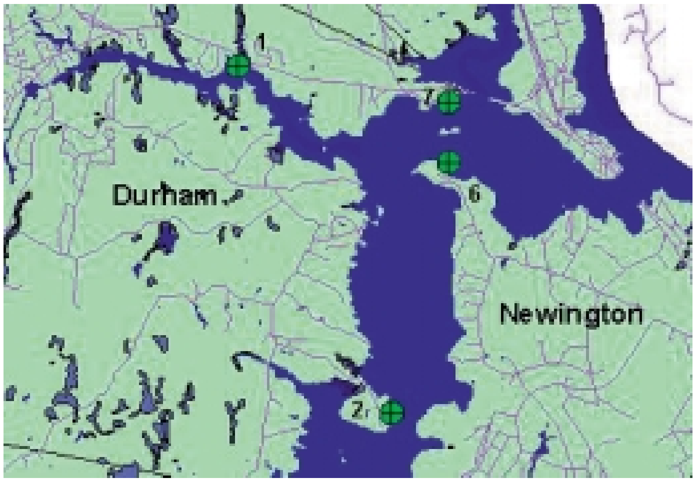






The fecal coliform counts at this site showed moderate (low tide) and good (high tide) relationships with time coupled with rainfall incidents in the 60-hour period prior to sampling. The time term was the most significant factor for both low and high tide cases. This result was the best fit of all sites for the time term in our analysis and indicates a potential reduction in point source pollution for this site.

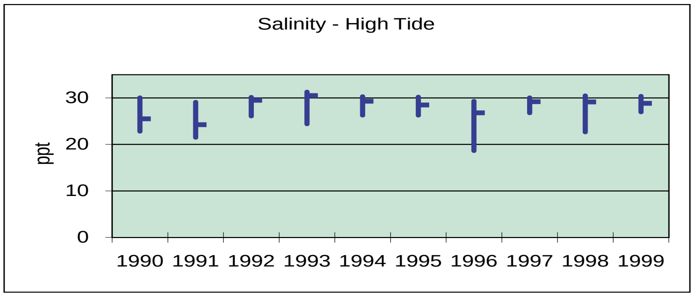
Durham & Newington

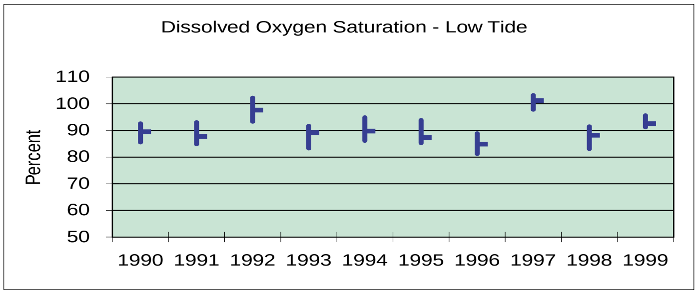


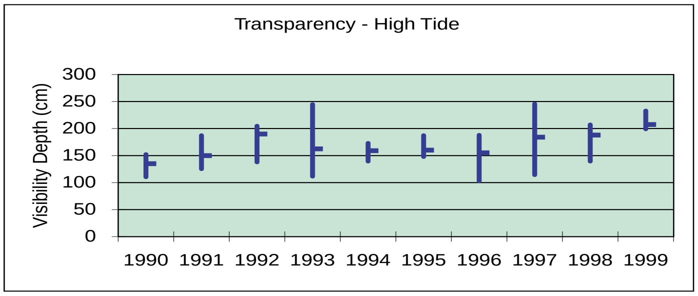
The GBCW monitors one site in Newington (Fox Point) and three sites in the town of Durham (one site on the Oyster River, one on Great Bay, and one on Little Bay).

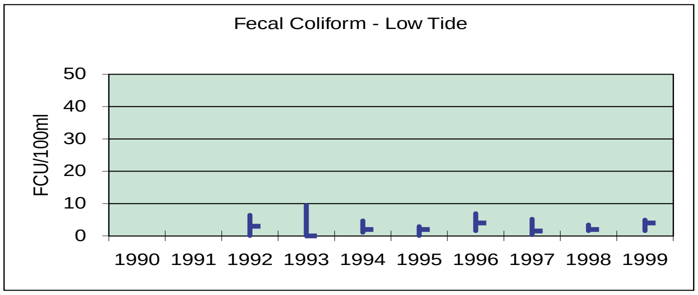
Site 2: Jackson Estuarine Laboratory

Site 2 is located at the University of New Hampshire's Jackson Estuarine Laboratory on Adams Point, approximately where Little Bay and Great Bay meet, at the eastern tip of Adams Point. Comparing this site with the GBCW sites in Greenland (Depot Road and Portsmouth CC) give us a good overall picture of the water quality of Great Bay. Average low tide temperature was 15.6°C, and high tide temperature was 15.5°C, slightly cooler than the Greenland sites. This deep-water site had the least amount of tidal temperature difference. The dissolved oxygen percent saturation was 90.8 percent at low tide, with especially high values in 1992 and 1997. The salinity was 28.2 ppt at high tide, with an expected dip in 1996 due to high rainfall. Transparency was 169 cm, with relatively lower values in years with lower salinities. The fecal coliform levels remained steady and low, with low tide observations of only 2.3 counts. This is one of the least impacted sites in the monitoring program. The fecal coliform counts at this site showed a weak relationship with rainfall incidents in the 60-hour period prior to sampling (low tide only). The flushing action of the rain seems to have slightly increased fecal coliform, indicating a potential non-point pollution source entering Great Bay. Overall, however, the site has a very low level of bacterial contamination.



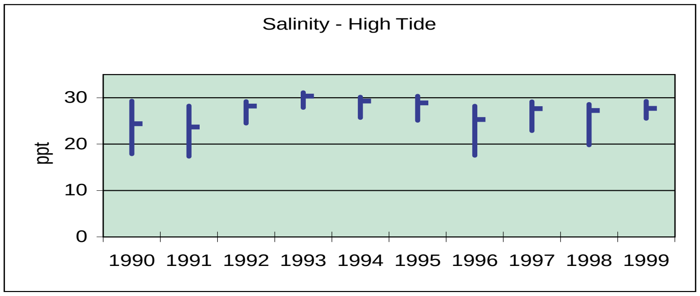


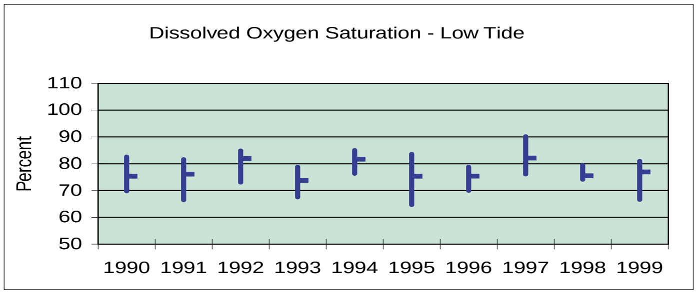


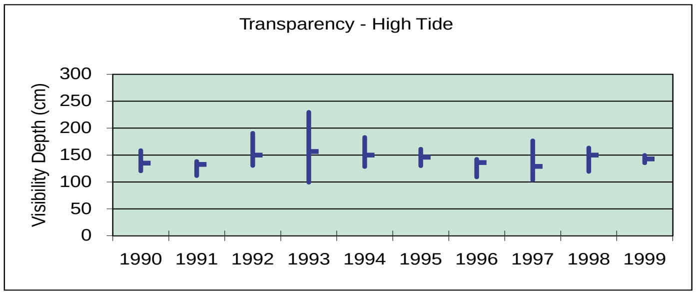


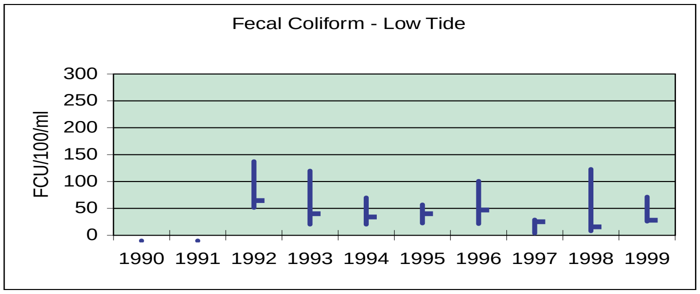
Site 1: Peninsula at Smith's Dock

Site 1 is located at the Smith's dock, upstream of Bunker Creek on the north bank of the Oyster River. This site is downstream of the Durham Wastewater Treatment Facility, and relatively closer to the river's tidal mouth than to the tidal dam in downtown Durham. The average water temperature was 16.1°C at low tide and 17.0°C at high tide, slightly higher than at Fox Point and Cedar Point, but lower than other tidal rivers farther up in the estuary (e.g. Lamprey River). The low tide dissolved oxygen percent saturation was relatively steady at 77.4 percent. For eight of the ten years monitored, a significant number of samples were below the Class B standard of 75 percent. The salinity was 27.3 ppt at high tide, with a dip in 1996. Transparency was 143 cm at high tide. The best year for visibility was 1993 (a dry year) and the worst was 1996 (a wet year). The fecal coliform sampling showed 36.8 counts for the period, with no trend evident.





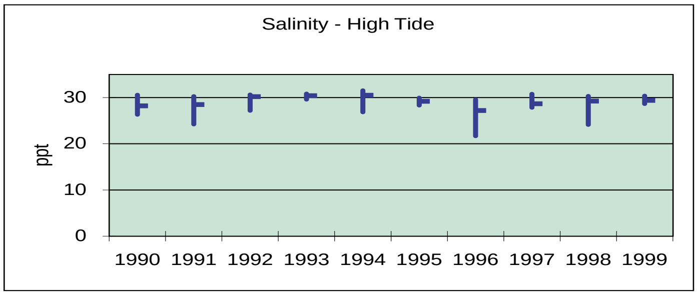


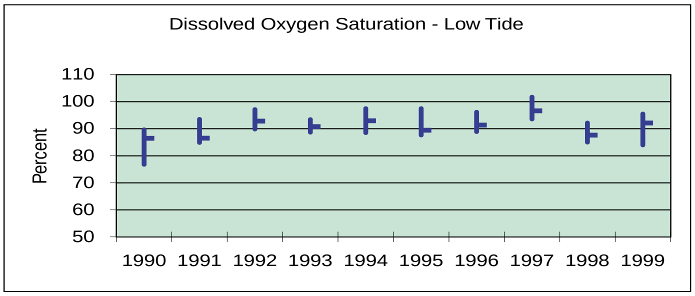


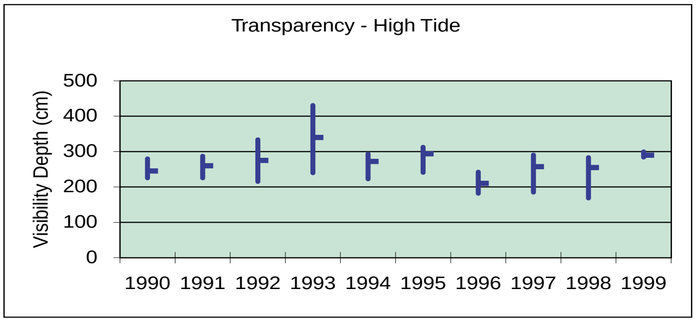
The fecal coliform counts at this site showed a weak relationship with rainfall incidents in the 60-hour period prior to sampling (high tide only). The flushing action of the rain may have led to increased fecal coliforms and may indicate a potential non-point pollution source. Since the relationship occurred during high tide, the pollution source may be downstream of the site. Further study of the area's hydrology needs to be done to identify possible contributors.

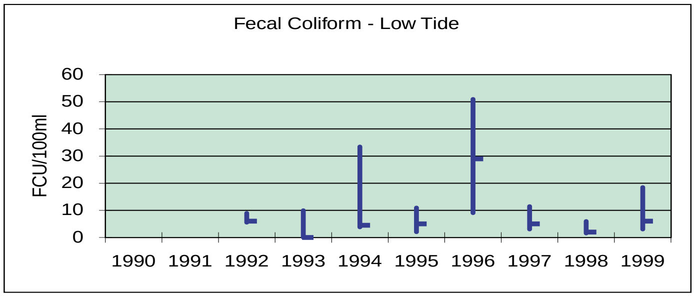
Site 7: Cedar Point

Site 7 is located at the Rosholt's dock on Cedar Point. This site is on the north shore of Little Bay between the mouths of the Oyster and Bellamy rivers, and across from Fox Point.







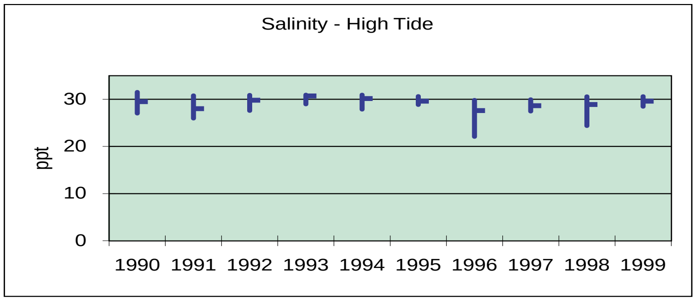


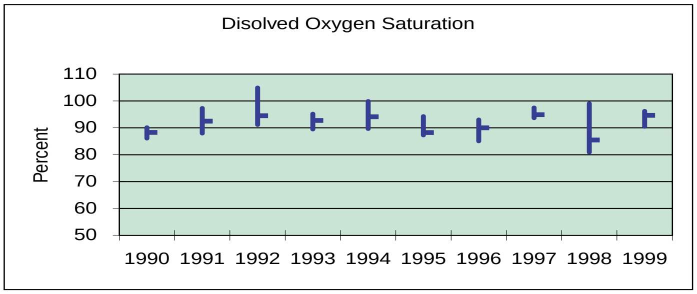
The average temperature at this site was 15.1°C at low tide and 14.6°C at high tide. These temperatures were slightly higher than the temperatures directly across the bay at Fox Point. The dissolved oxygen percent saturation was steady and high at 90.7 percent during low tide. The salinity was 29.2 ppt at high tide. Transparency was 270 cm at high tide. Like the Peninsula site, the best visibility was in 1993 and the worst in 1996. The fecal coliform at low tide was 7.2 counts, rather low despite a spike in 1996. The fecal coliform counts at this site showed a weak relationship with rainfall incidents in the 60-hour period prior to sampling (low tide only). It appears that the flushing action of rainfall contributes to a non-point pollution problem.

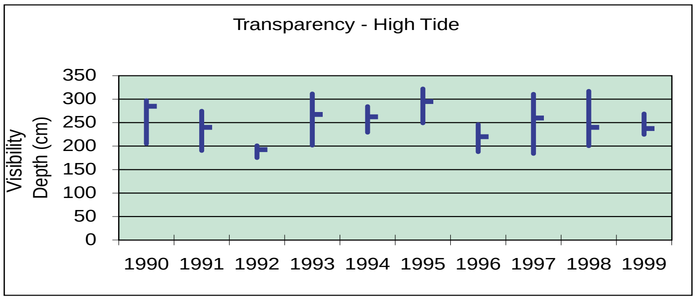
Site 6: Fox Point

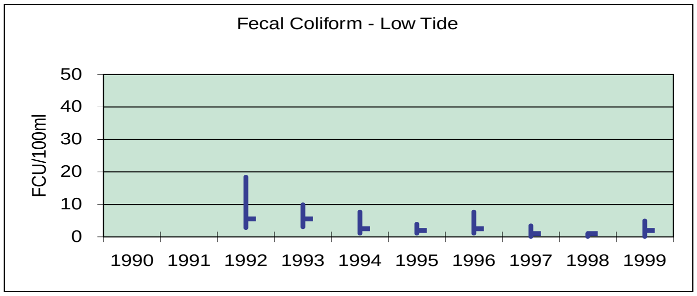
Site 6 is located at Fox Point, where Little Bay's north-south orientation takes a sharp bend to the east. The mouth of the Oyster River is located just to the west, while the mouth of the Bellamy River is to the north. The Fox Point site is located directly across Little Bay from Cedar Point.

Average temperatures at this site were 15.0°C at low tide and 13.6°C at high tide. These temperatures were slightly lower than the temperatures observed at Cedar Point. The dissolved oxygen percent saturation was 91.5 percent, well above the Class B standard of 75 percent. Salinity was 29.3 ppt at high tide, with a dip in 1996. Transparency was 249 cm during high tide, and varied between 200 and 300 cm, similar to Cedar Point. The fecal coliform levels were 2.8 counts at low tide, about half of the value at Cedar Point. With a slightly decreasing trend, this count is one of the lowest values in the GBCW network, making Fox Point one of the least impacted sites relative to fecal contamination.



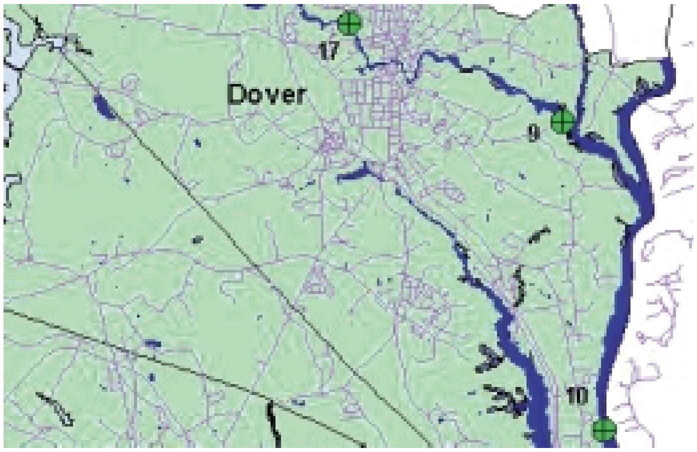






The fecal coliform count showed a good (low tide) and moderate (high tide) relationship with time coupled with rainfall incidents in the 60-hour period prior to sampling. The predominant term in both cases was rainfall, indicating potential non-point pollution sources. However, the level of fecal coliform bacteria at the site is quite low.

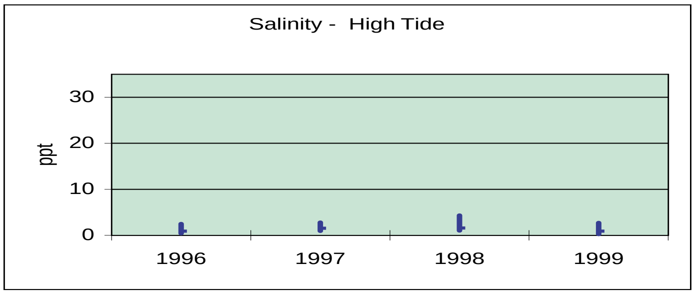
Dover

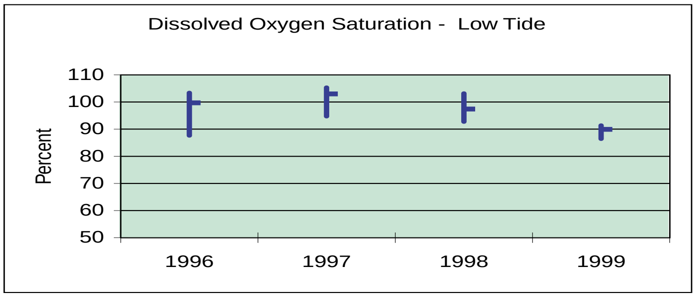


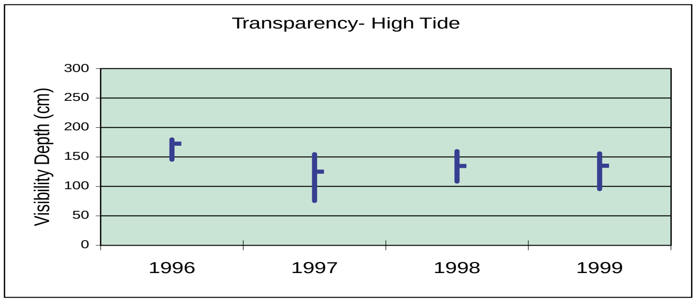
The GBCW monitors three sites in the city of Dover. Two sites are located on the Cocheco River, while the other is on the Piscataqua River.

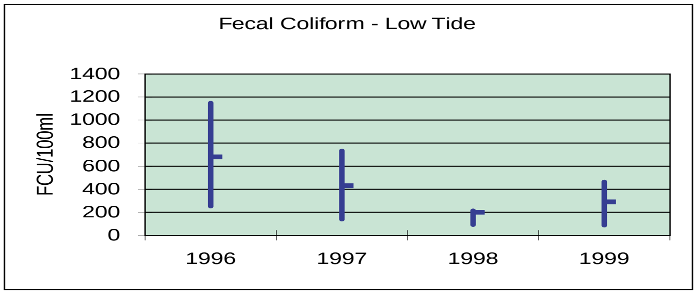
Site 17: Dover Footbridge

Site 17 was started in August of 1996 and is sampled from the new Dover footbridge, near Central Avenue in downtown Dover.







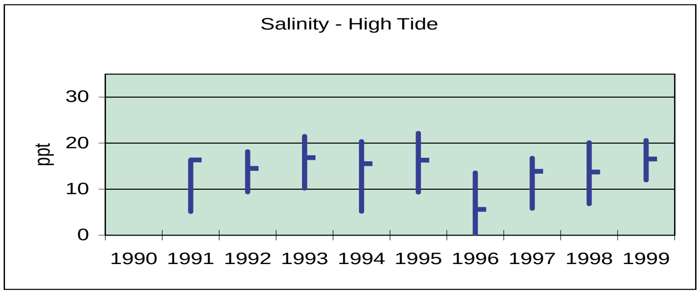


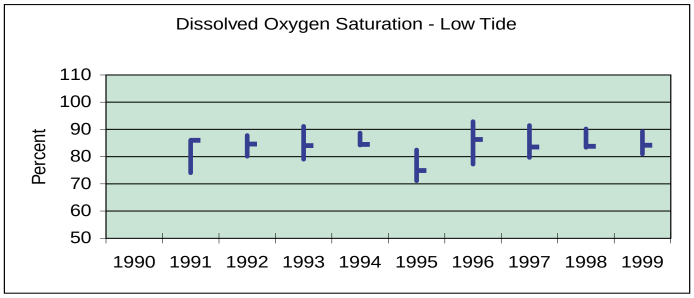
This upstream site had the highest temperature and the lowest salinity of all Dover sites (average temperatures were 16.6°C for low tide and 17.5°C for high tide). The dissolved oxygen percent saturation at low tide was 97.5 percent, very good and higher than the other two Dover sites. The salinity was 1.2 ppt at high tide, indicating the dominance of the Cocheco River. Transparency at high tide was 144 cm. The fecal coliform was 400 counts at low tide, the highest of any site in the GBCW network. The fecal coliform counts showed a weak (high tide) relationship with time, driven by the occurrence of two extremely high fecal counts in the first year of sampling. The city of Dover is working to eliminate pollution sources in this area, and we hope to document lower bacteria levels in the future.

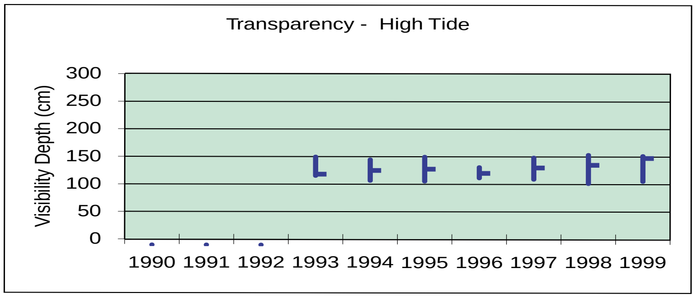
Site 9: Neal's

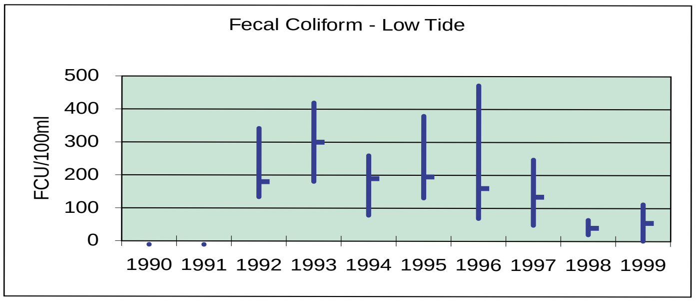
Site 9 is located at the Neal/Williams property, near the mouth of Fresh Creek on the Cocheco River. It is upstream from the Dover Wastewater Treatment Facility, and between the Footbridge and the Clark's site. Average temperatures at Site 9 were 15.3°C at low tide and 16.9°C at high tide; lower than those at the Footbridge, but similar to Clark's. The dissolved oxygen percent saturation was 83.5 percent at low tide. During the drought year of 1995, the median value dipped to 74.9 percent, below the Class B standard of 75 percent. Salinity was 14.4 ppt, midway between the observed upstream level at the Footbridge and downstream at Clark's. Transparency at this site was 129 cm at high tide. The fecal coliform levels were 157 counts at low tide. A downward trend in fecal coliform levels is evident over the sampling period.

Fecal coliform counts showed a moderate (low tide) and good (high tide) relationship with time and rainfall incidents in the 60-hour period prior to sampling. Both terms were important, indicating the presence of non-point source pollution, and a possible trend toward improvement. Still, fecal coliform observations at Neal's were high, and merit continued investigation.



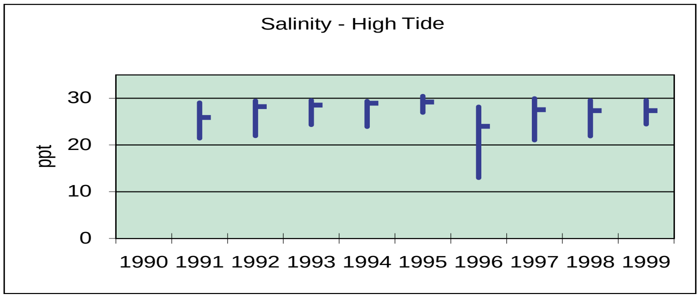


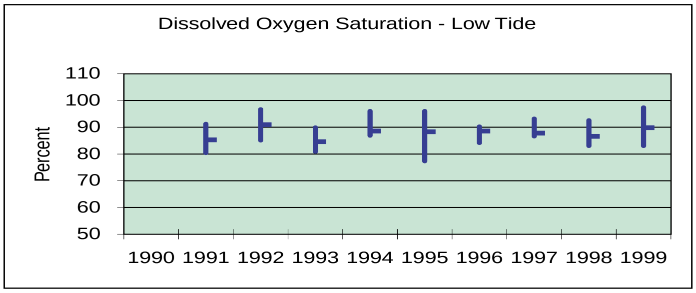


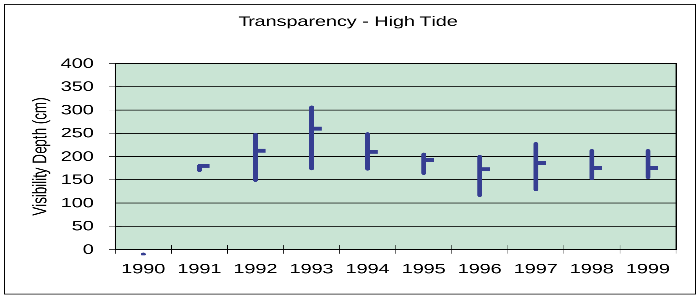


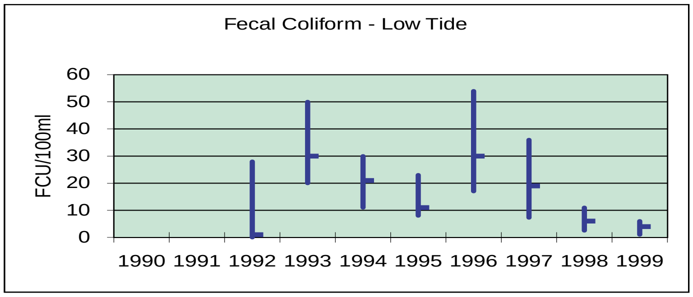
Site 10: Clark's

Site 10 is located at the Clark's property off Dover Point Road, upstream of the Patten Yacht Yard. This site is downstream of Neal's, the confluence of the Salmon Falls and Cocheco Rivers, and the outfall of the Dover Wastewater Treatment Facility. The site was moved from the nearby Dube property in 1996.





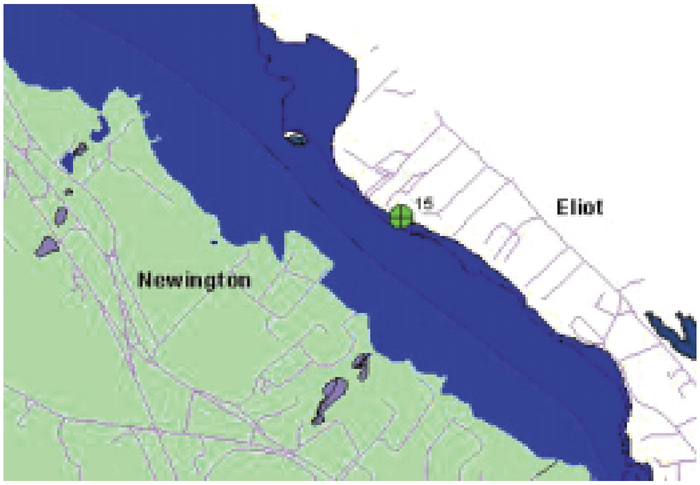




Average water temperatures at Clark's were 15.8°C at low tide and 16.0°C at high tide; similar to that of Neal's even though it is farther downstream. The dissolved oxygen percent saturation was 87.8 percent during low tide. Salinity was, as expected, lower than the downstream Patten Yacht Yard, yet higher than Neal's (27.5 ppt at high tide, with a dip in 1996). Transparency at high tide was 196 cm. The best visibility occurred in the 1993, and the worst in 1996.

The fecal coliform counts were variable but low (15 counts) and have declined from a peak in 1996. Coliform counts showed a good (low tide) and moderate (high tide) relationship with time and rainfall incidents in the 60-hour period prior to sampling. The rainfall effect was the most important factor for both low and high tide, suggesting non-point source pollution. Fecal coliform levels here are much lower than at Neal's, but given the good correlation with rainfall events, further attempts to investigate upstream sources are warranted.

Eliot

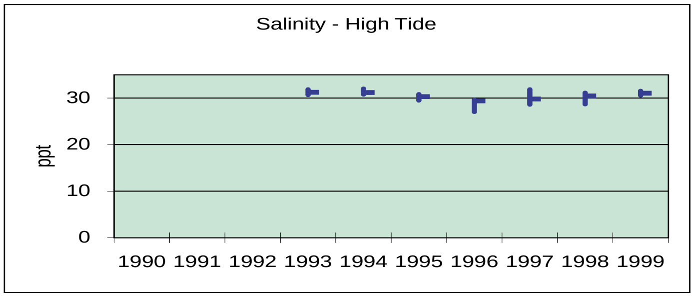


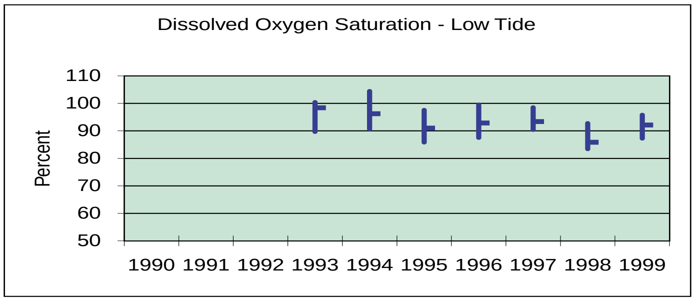
GBCW volunteers from Marshwood High School monitor one site in the town of Eliot, Maine.

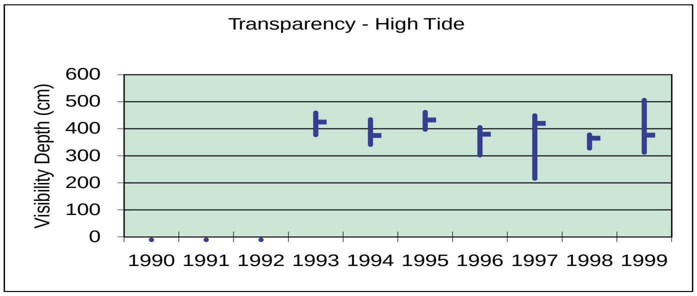
Site 15: Patten Yacht Yard, Inc.

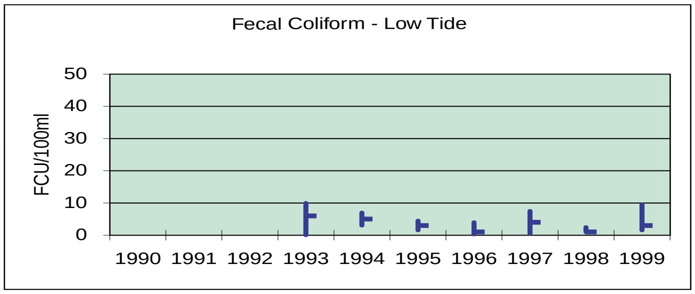
Site 15 is located in the Piscataqua River, downstream of the entrance to Little Bay, and upstream from Portsmouth, at the dock of the Patten Yacht Yard, Inc. in South Eliot, Maine. Key indicators of water quality at this site were strongly influenced by tidal exchange. Therefore, temperature readings were quite low (second coldest), and salinity readings were typically the highest in the network.

Average temperatures were 13.7°C at low tide and 12.4°C at high tide. The dissolved oxygen percent saturation was a steady 92.8 percent at low tide, well above the Class B standard of 75 percent. Salinity was 30.5 ppt at high tide. Transparency at high tide was 396 cm, (similar to observations at New Castle, Site 11). The fecal coliform at low tide was 3 counts - with consistently low observed values.



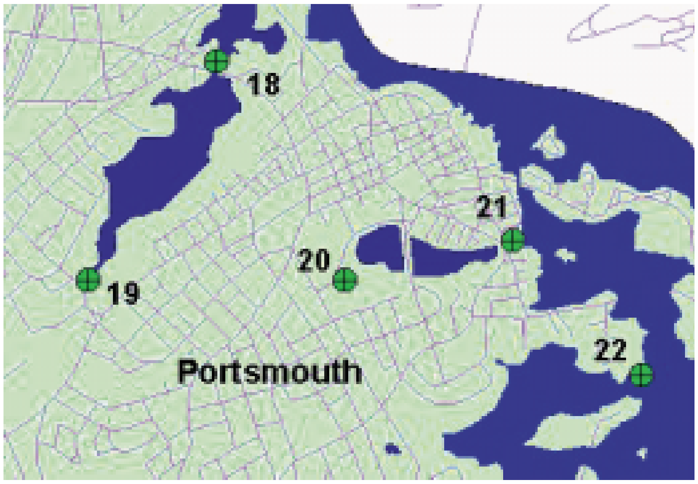






The fecal coliform counts showed a moderate relationship with rainfall incidents in the 60-hour period prior to sampling (high tide only). However, fecal coliform counts are low enough that no inferences can be made.

Portsmouth

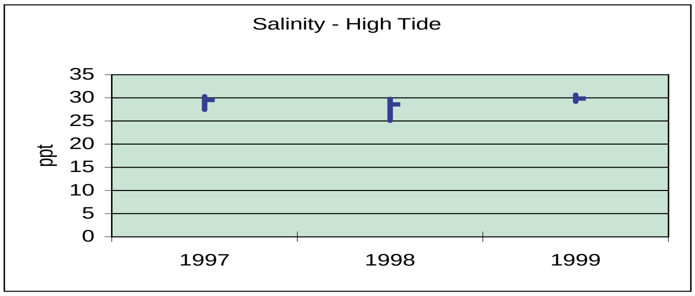


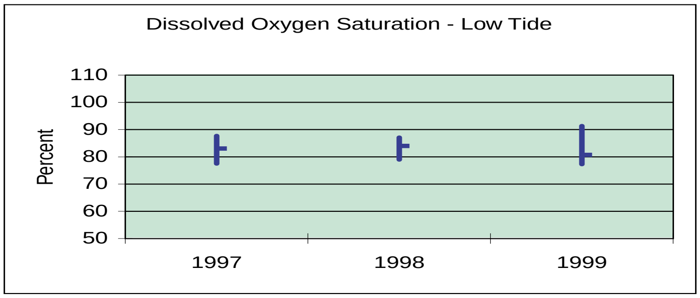
GBCW monitors five sites in the city of Portsmouth. Two sites each are located on South Mill Pond and North Mill Pond. An additional Portsmouth site is located at the Little Harbour School.

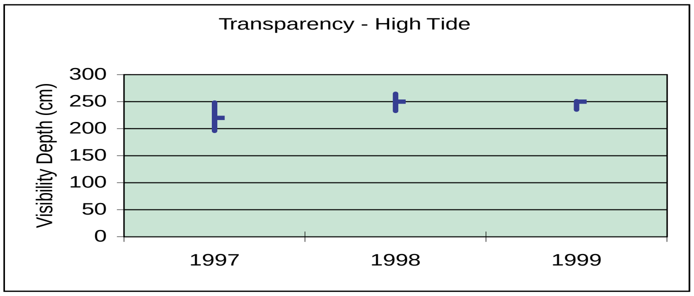
Site 18: Maplewood Avenue

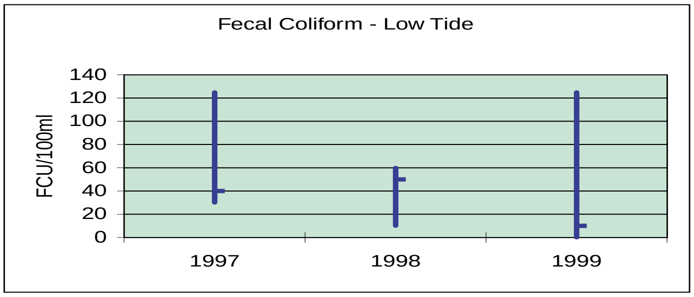
North Mill Pond is located on the west side of the Piscataqua River, just upstream from downtown Portsmouth and the Port of New Hampshire. Salt piles owned by Granite State Minerals are located adjacent to the pond. Site 18 volunteers sample at a floating dock on the eastern side of the Maplewood Avenue Bridge near Cindy Ann Cleaners.

This site's proximity to the ocean accounts for its cold average temperature readings (13.1°C at low tide and 14.2°C at high tide). Small differences in temperature at high and low tides are typical of sites influenced by Gulf of Maine waters. The dissolved oxygen percent saturation was 83 percent and declined slightly in 1999. One reading in 1999 dipped below the Class B standard of 75 percent. This site was high salinity, with little variation (26.9 ppt at low tide and 29.3 ppt at high tide). Transparency was 242 cm at high tide. The fecal coliform was 33 counts at low tide and we hope to document declines in the future as officials work to eliminate pollution sources in the area.



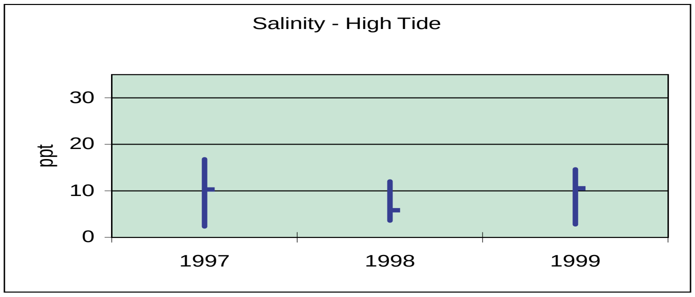


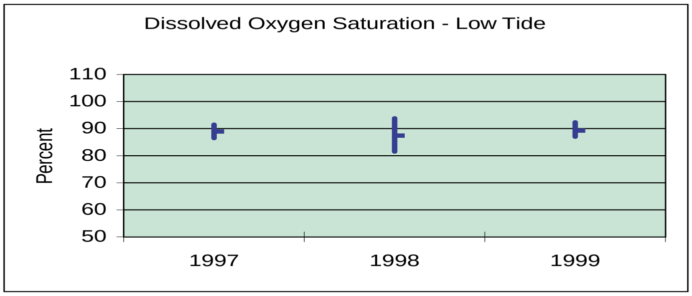


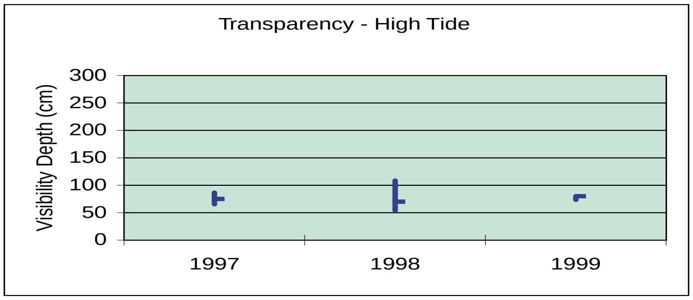


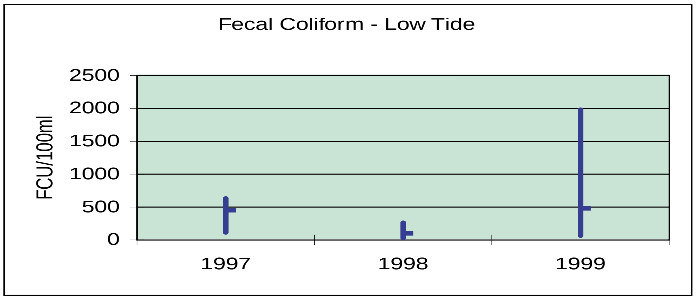
Site 19: Bartlett Avenue

Site 19 is located at the inlet of Hodgson Brook into North Mill Pond, near Ricci's Supply Company, Inc. Average temperatures at Site 19 were slightly higher than at Maplewood on the other side of the pond (13.7°C at low tide and 16.1°C at high tide). The dissolved oxygen percent saturation was 88 percent. The last reading in 1999 dipped to 63 percent, below the Class B standard of 75 percent, for the first time since our monitoring began. Salinity was markedly lower than at Maplewood and highly variable (1.7 ppt at low tide and 8.6 ppt at high tide). Being at the Hodgson Brook inlet, the water at this site is less mixed with tidal waters. The transparency was 75 cm at high tide. High levels of fecal coliform were observed at this site. The fecal coliform for Site 19 was 343 counts at low tide. This was the second highest fecal coliform count for low tide in the entire GBCW network.



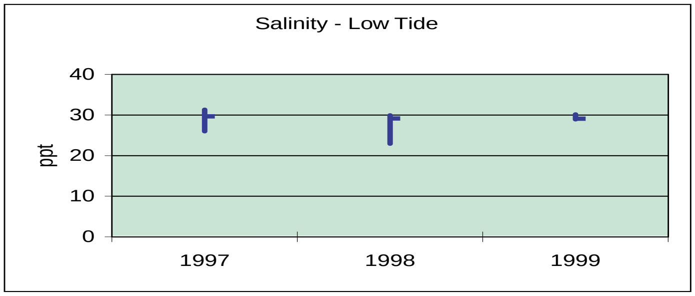


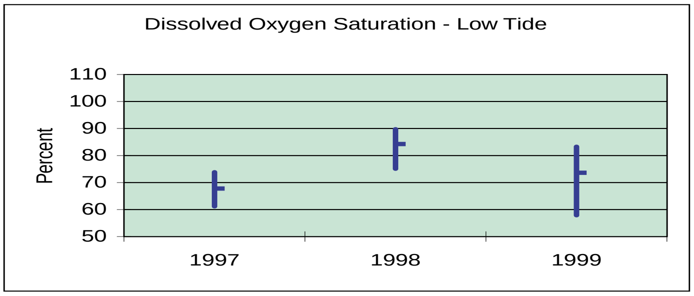


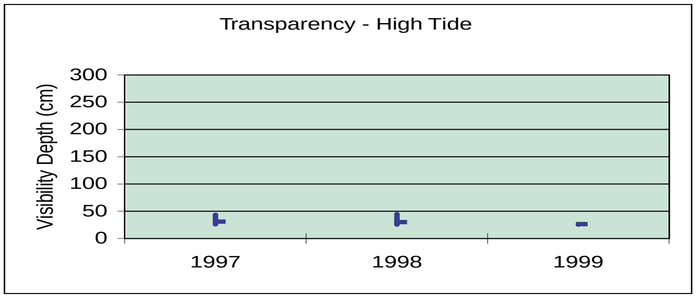


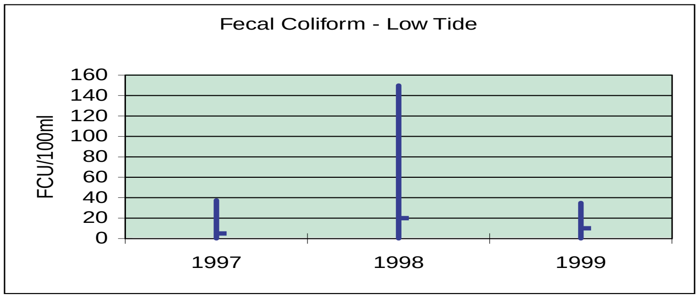
Site 20: Junkins Avenue

South Mill Pond is also located on the west side of the Piscataqua River, just south of downtown Portsmouth. The Pond is bisected by Junkins Avenue, which allows circulation to the upper portion of the Pond through two culverts under the road. This pond has floodgates at the spillway, with the floodgates opened intermittently. Site 20 is located on the upper pond, next to the South Playground and across from Portsmouth Junior High School.





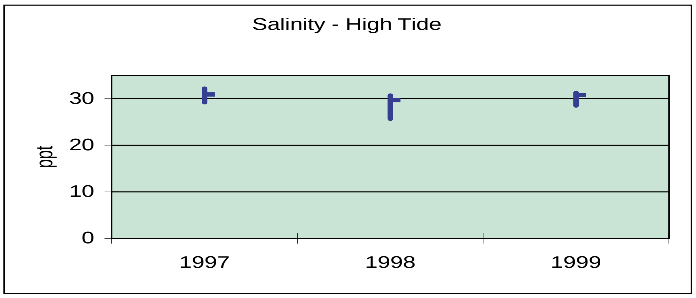


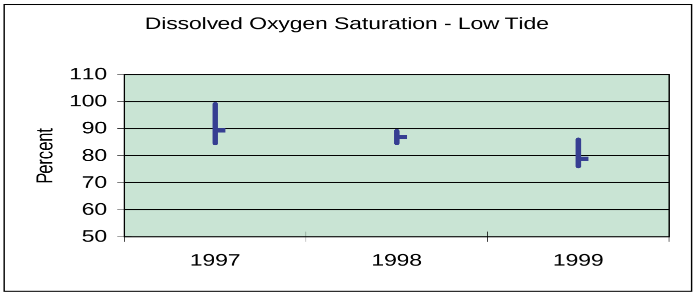


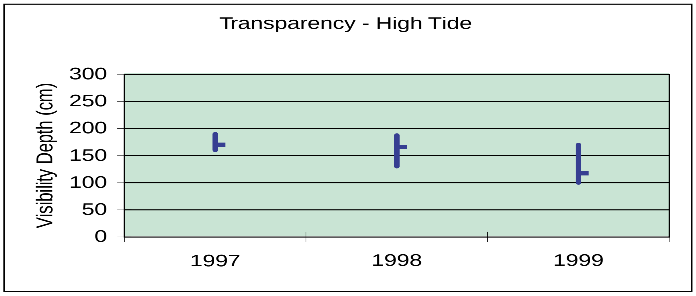
Average water temperatures at Site 20 were about midrange for all the sites in the GBCW network, (15.4°C at low tide and 18.2°C at high tide). The dissolved oxygen percent saturation was 75.2 percent, with the median value for two of the three years sampled below the Class B standard. Salinity was 27.4 ppt at low tide and 29.3 ppt at high tide. Transparency at high tide was only 29 cm, but water depths were shallow at this site. The fecal coliform levels were not as high as for North Mill Pond, at 12 counts. Annual levels have been relatively low for the entire three years of monitoring.

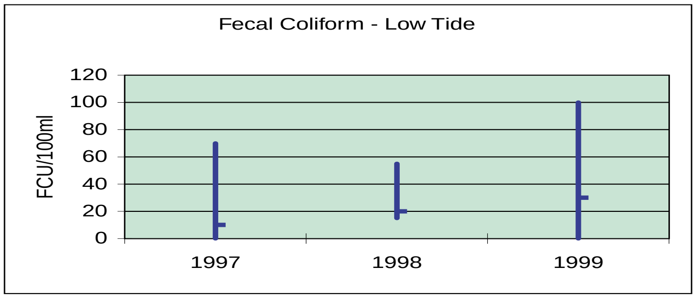
Site 21: Pleasant Street

Site 21 samples are collected from the bridge over the outflow of the pond on Pleasant Street, at the tide gates. Average temperatures at Site 21 were also about midrange for all the sites in the GBCW network (15.0°C at low tide and 16.1°C at high tide).





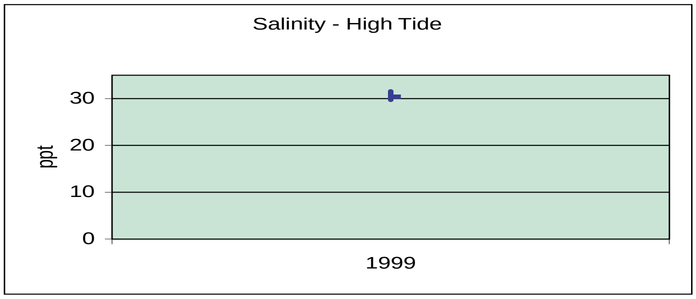


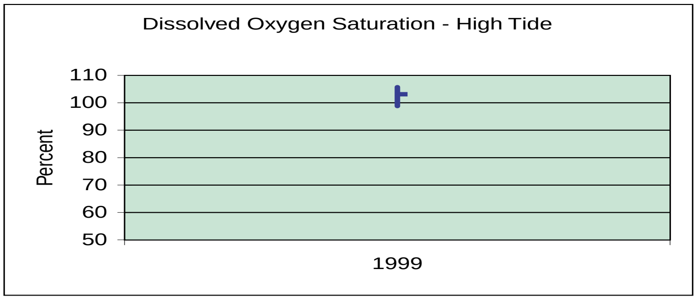


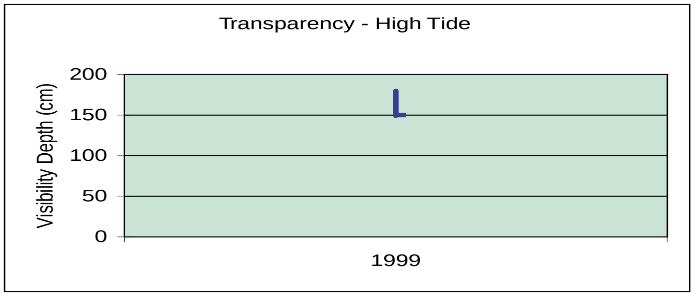
The dissolved oxygen percent saturation was 85.0 percent at low tide, better than at Junkins, and above the Class B standard. The salinity at Site 21 was high due to its close proximity to the Gulf, (28.0 ppt at low tide and 29.5 ppt at high tide). Transparency was 151 cm at high tide, showing moderately low turbidity. The fecal coliform levels at low tide were 17 counts, with considerable variability and no significant trend since monitoring began in 1997.

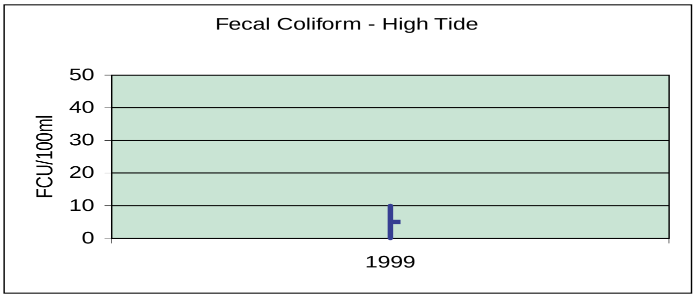
Site 22: Little Harbour School

Site 22 is GBCW's newest site, having one complete season of sampling.



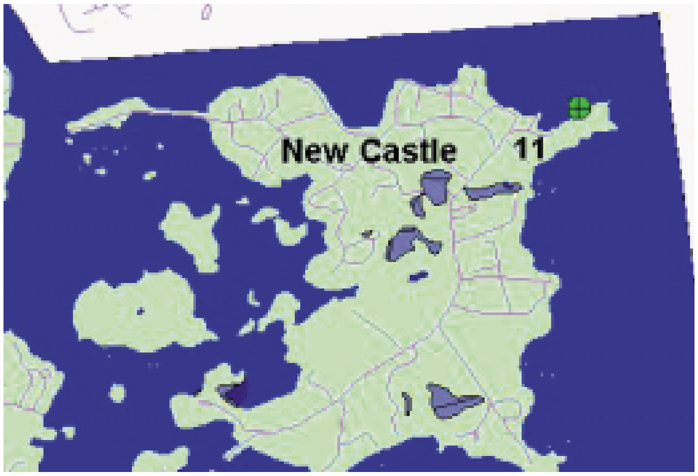






Teachers and students of Little Harbour School perform the monitoring from a dock that provides access to water at high tide only. Little Harbour School is located on Little Harbour, south of the main harbor in Portsmouth. In 1999, the only year of monitoring, average temperature was 16.3°C (high tide only). Dissolved oxygen percent saturation at high tide for this site was 101.0 percent. The salinity was consistently high at 30.4. Transparency was 150 cm (the depth of the secchi disk reading was equal to the mean water depth). The high tide fecal coliform median was 5 counts and low compared to the other Portsmouth sites.

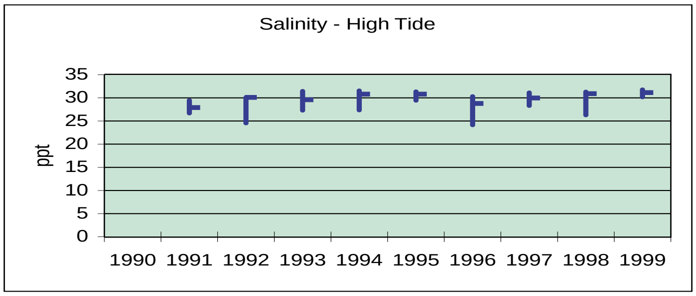
New Castle

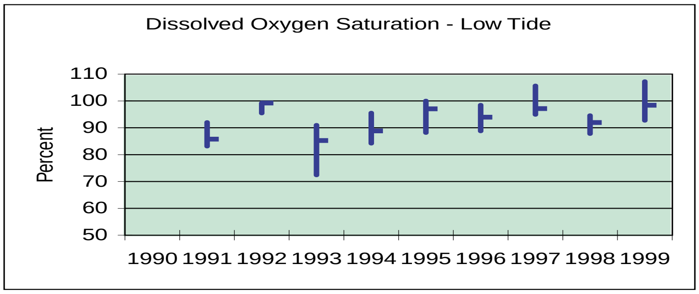


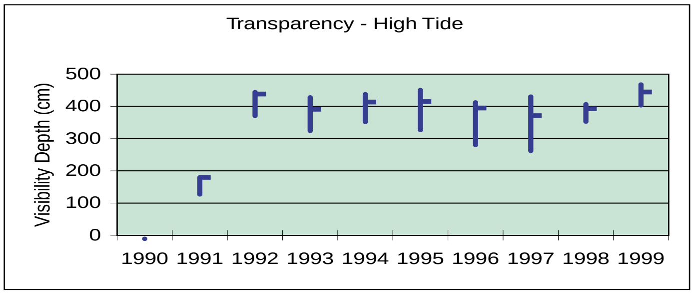
GBCW volunteers monitor one site in the town of New Castle. Staff members of the New Hampshire Coastal Program also sample once a month from a dock adjacent to the sample site, and the data are compiled as Quality Assurance Quality Control (QAQC) reference data.

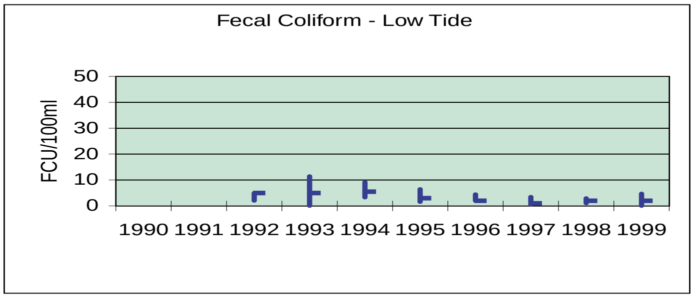
Site 11: Coastal Marine Lab

Located at the U.S. Coast Guard Station and the UNH Coastal Marine Lab in New Castle, Site 11 is where the Piscataqua River meets the Gulf of Maine. Ocean water temperatures at site 11 are typically the coldest in the network (averaging 12.0°C at low tide and 12.6°C at high tide). The dissolved oxygen percent saturation was 93.1 percent considerably above the Class B standard of 75 percent. However, a dip occurred in 1993 where a significant number of samples were below the 75 percent standard. The salinity readings were a steady 30.0 ppt., often the highest salinity values in the network. There is a relatively small fluctuation in salinity between tides due to its almost open-ocean location.









Transparency was 385 cm at high tide, with some variability. Low transparency was measured in 1991, possibly due to the use of a different dock that year. Fecal coliform counts were very low - 3 counts. These low levels have declined slightly since 1993. Fecal counts showed a weak relationship with rainfall incidents in the 60-hour period prior to sampling for both low and high tide. However, counts are too low to suggest a non-point pollution source.

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Inside Back Cover:
GBCW 1990-1999 Summary Water Quality Map

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