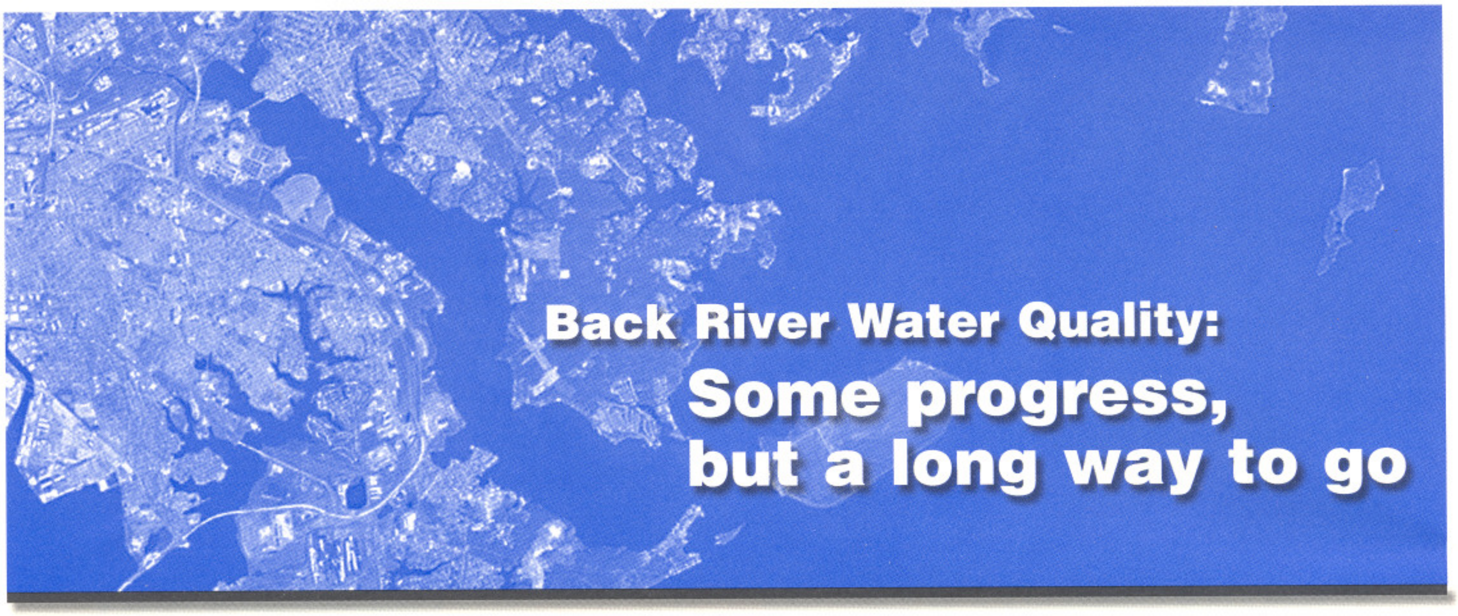


Back River Water Quality: Some progress, but a long way to go

—By John Martin, Baltimore City

INTRODUCTION AND PURPOSE

This paper describes the water quality conditions in Back River, a shallow tidal tributary of the upper Chesapeake Bay. Back River is located north of Baltimore Harbor on the western shore of the Bay in Baltimore County.

The purpose of this study was to track changes in water quality in Back River over time and correlate them to upgrades in treatment processes at the Back River plant. We chose to develop this in-house monitoring program rather than rely on data collected by other agencies such as the Maryland's Department of Natural Resources because we could select stations to focus on the portion of Back River surrounding the plant's outfall and could select a station that would function as a control.

Secondly, it would give us a body of data over which we maintain control and that we could share with other interested parties.

BACKGROUND

In the early 1900s, Back River was selected to receive effluent from the Back River Wastewater Treatment Plant because it was a sparsely populated area and it would function as a polishing system for the plant's effluent from its then state-of-the-art trickling filter process. By introducing sewage effluent into Back River, the Bay's oyster bars would be protected as was required by law. The Back River plant was very advanced for the time utilizing secondary treatment, sludge elutriation and other innovative processes not widely used in the U.S. at the time.

As the years went by and the Baltimore metropolitan region grew, flows increased and Back River water quality suffered. After World War II, growth in the area exploded, silt accumulated in the upper tidal portion of the river and, despite law suits and other environmental actions, water quality remained poor with odors, algal blooms, and floating solids from the plant.

Fast forward to the passage of the Clean Water Act in 1972 and public outrage at the condition of the nation's waterways. Back River was not even close to fishable and swimable. Clearly something had to be done and it was not going to be fast or cheap. Enter the construction grants program, an integral part of the Clean Water Act. Now federal and state grant funds were available to build new facilities. Around the country, over the next decade or more, hundreds of wastewater treatment plants were upgraded and expanded and Baltimore's plants were among them.

Large new activated sludge facilities were built and placed in service in 1988 allowing the trickling filters finally to be taken out of service. These had been operating since the plant first went into service in 1912 and although inexpensive to operate and excellent at working under varying hydraulic loads, they were not very efficient; removing only approximately 75 to 80% of influent organic waste.

In addition to these new activated sludge facilities, sand filters, new chlorine contact tanks, and a new outfall structure were built. With all these facilities in service, reductions in biochemical oxygen demand (BOD) and total suspended solids (TSS) were now on the order of 98 to 99 % while approximately 95% of phosphorus and 70% of nitrogen were removed. These removal rates continue today at the Back River plant.

On the solids processing side, air flotation thickeners were added to supplement the gravity sludge thickeners, large egg-shaped anaerobic digesters greatly improved volatile solids reduction and more recently, gravity belt thickeners were added to improve the performance of sludge thickening.

A byproduct of anaerobic digestion is methane gas, a valuable energy resource. This gas is used to heat the digestion process and to provide comfort heat for the plant's buildings. Those uses, however, do not consume all the gas produced so the surplus was flared. Recently, to address the energy wasted by flaring surplus digester gas, three large internal combustion engines, each turning a generator capable of producing one megawatt of power have been installed to put this surplus gas to good use.

In the early 1990s, the Wastewater Facilities Division (part of the Bureau of Waste and Wastewater which is in turn part of Baltimore's Department of Public Works) initiated a water quality monitoring program to track pollutant concentrations, *in situ* parameters (dissolved oxygen, temperature, salinity, and pH), Secchi disk transparency, and most importantly, chlorophyll concentration in the river.

Sampling started in 1993 and has continued from March through October or November each year ever since. During this span of years, the Back River plant was upgraded to biological nutrient removal (BNR). This took place in the late 1990s and lowered the effluent total nitrogen concentration by approximately 40% to 50%.

This paper will present the methods used and summaries of the water quality data spanning 1993 through 2009.

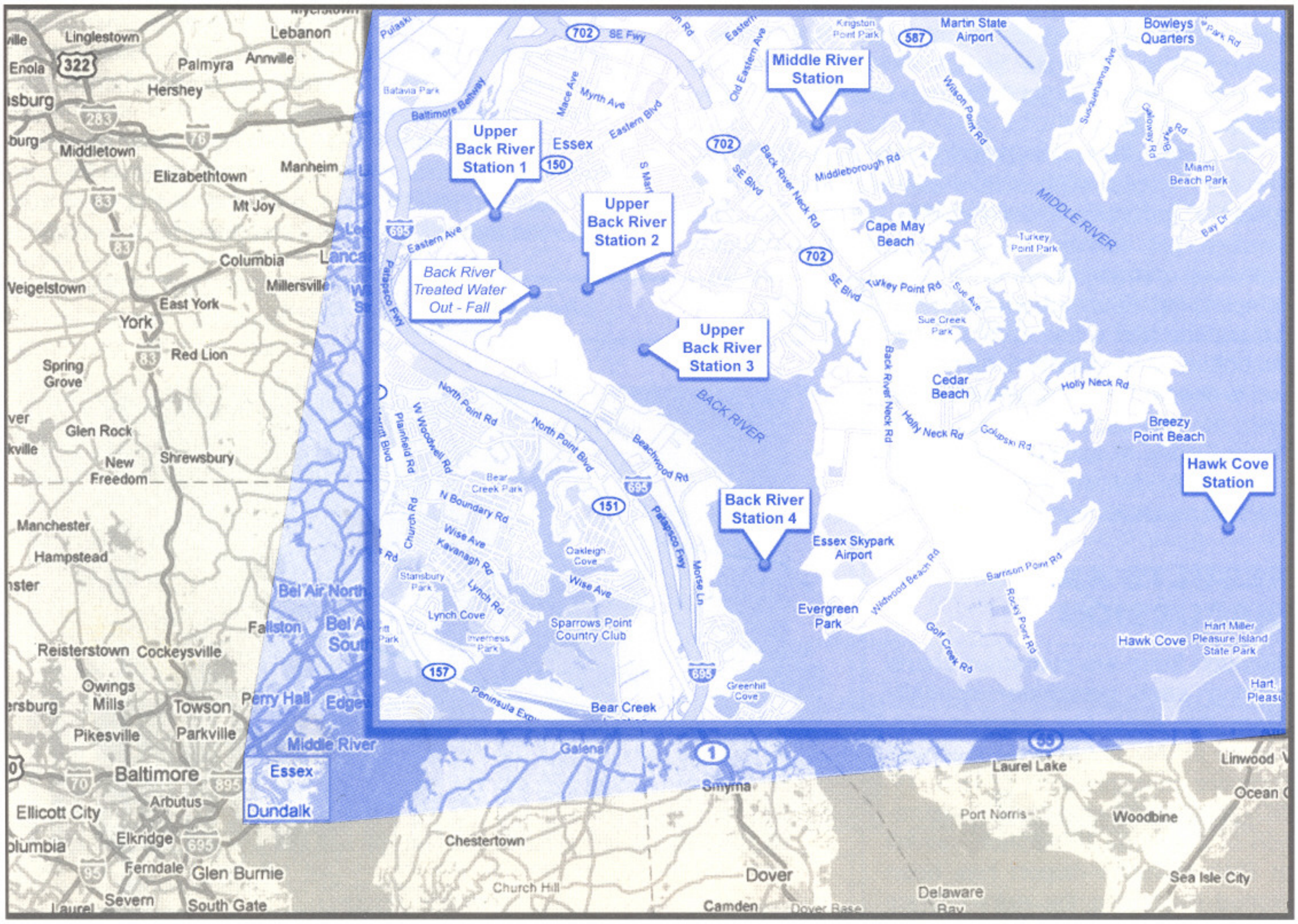
METHODS

Monthly sampling trips were made from March through October or November (depending on weather) each year to collect both water samples and field water quality data at several stations in Back River with a control station located in neighboring Middle River. Samples were collected at the surface and from just above the bottom sediment using a small electric pump mounted on a pole. Separate samples were collected for analysis of BOD, TSS, and nutrients including total Kjeldahl nitrogen (TKN), ammonia, nitrate, nitrite, orthophosphorus (OP), and total phosphorus (TP). The abbreviation NOx is used to refer to the sum of nitrate and nitrite.

Five sampling stations were visited each month starting: four in Back River and a control station in Middle River *(Figure 1)*. In Back River, stations were located 0.75 miles upstream of the plant outfall, directly off the outfall, 0.75 miles downstream of the outfall and then an additional 1.5 miles downstream. A control sample was

Continued on page 26

Figure 1



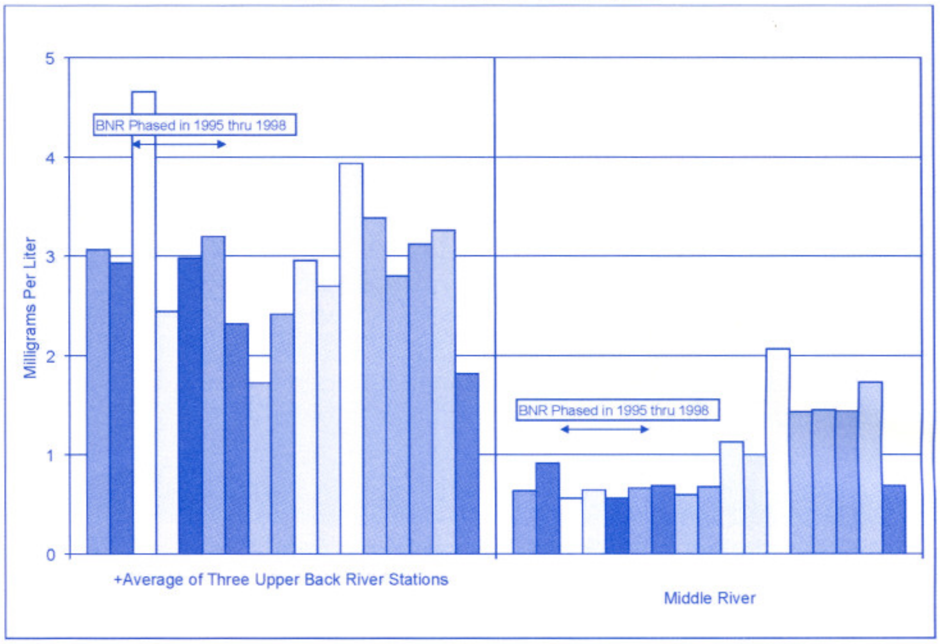
Back River

Continued from page 25

collected in the upper tidal portion of Middle River; the next river to the north and uninfluenced by a wastewater discharge. The location of the Middle River station is approximately the same distance from the main stem of the Bay as the upper Back River stations and thus is under nearly the same environmental conditions. Note that the first three stations bracket the outfall and are averaged in the presentation of the data to illustrate typical conditions found in the upper tidal portion of Back River. The fourth station is located in the lower part of the Back River estuary while the control station is in Middle River; a different tributary. *In situ* parameters were also measured at an open Bay station located off the mouth of Middle River.

Figure 2

Back River Water Quality Survey
Total Kjeldahl Nitrogen Concentrations - 1993 Through 2009



In addition to collecting samples for analysis of the parameters noted above, separate samples were collected for analysis of *E. coli* bacteria, Microtox and chlorophyll *a*. Separate samples were collected for these latter analyses as they were analyzed by different laboratories.

In situ parameters were measured using a Hydorlab Surveyor 4 and minisonde. Parameters include dissolved oxygen using a luminescence probe (LDO), temperature, pH, salinity and probe depth. The unit was calibrated immediately prior to each sampling trip. Readings were taken at the surface and a few inches above the bottom at each station. As no station is deeper than approximately ten feet, no mid-depth readings were taken. Finally, at each station a standard Secchi disk was used to measure light penetration into the water.

RESULTS AND DISCUSSION

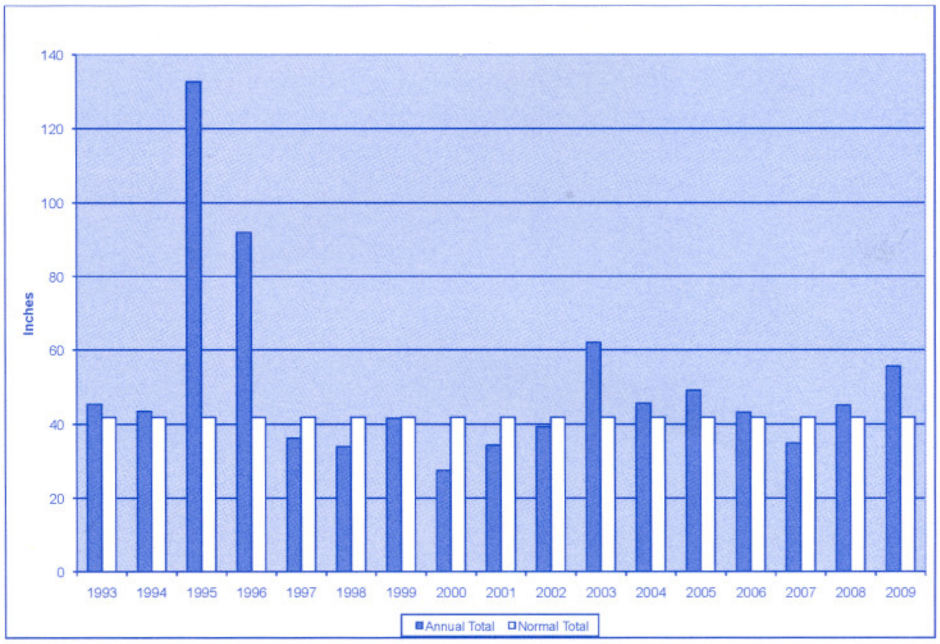
Although there are numerous charts plotting each parameter spatially down the river, the graphics presented in this paper are those that compare concentrations of TKN, TP, NOx, and chlorophyll over the duration of the study. In addition, rainfall at BWI Marshall Airport has been plotted illustrating the extraordinary amount of precipitation that occurred in this area during 1995 and 1996.

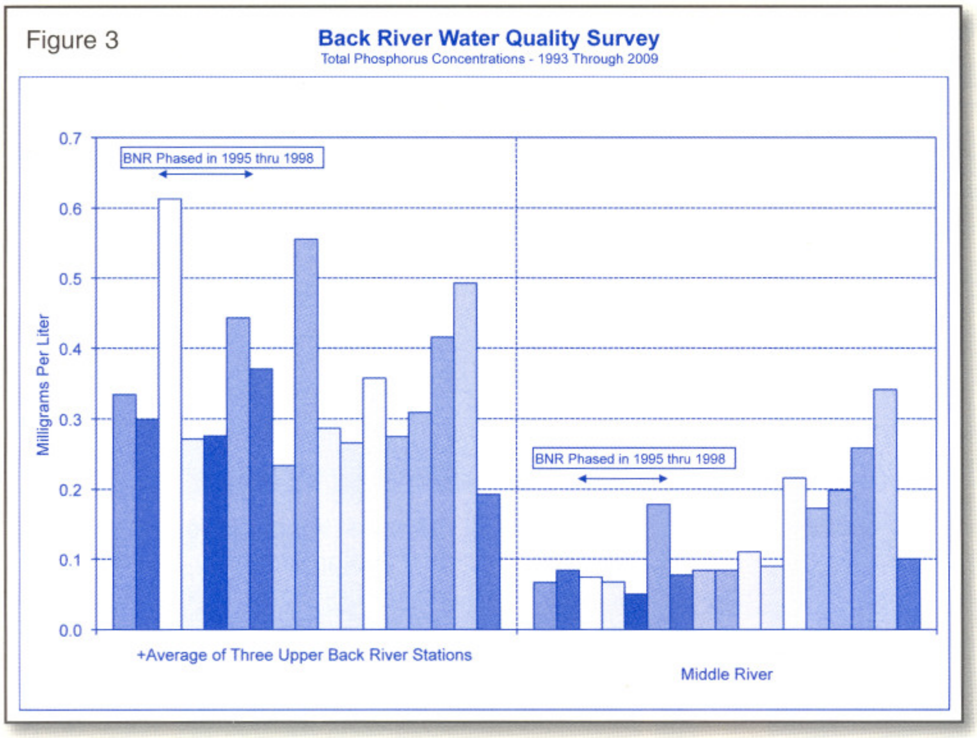
The trends during this period appear either to be fluctuating randomly from year to year but not establishing a trend in any particular direction (TKN and TP) or clearly declining in response to environmental conditions (NOx and chlorophyll).

The concentrations of TKN in Back River suggest a very slight downward trend over time while at the control station in Middle River, the trend was upward from 1993 through 2008 and then dropped back in 2009 to

Figure 6

Rainfall at BWI Marshall Airport
1993 through 2009





levels seen during the first few years of the study *(Figure 2)*. The reasons for these fluctuations are probably more related to rainfall *(Figure 6)* and more importantly, exactly when the rainfall occurred. If a very wet period follows immediately after farm fields have been fertilized, then higher TKNs would result as one of the main ingredients in fertilizer is ammonia; a form of nitrogen that is included in the TKN result.

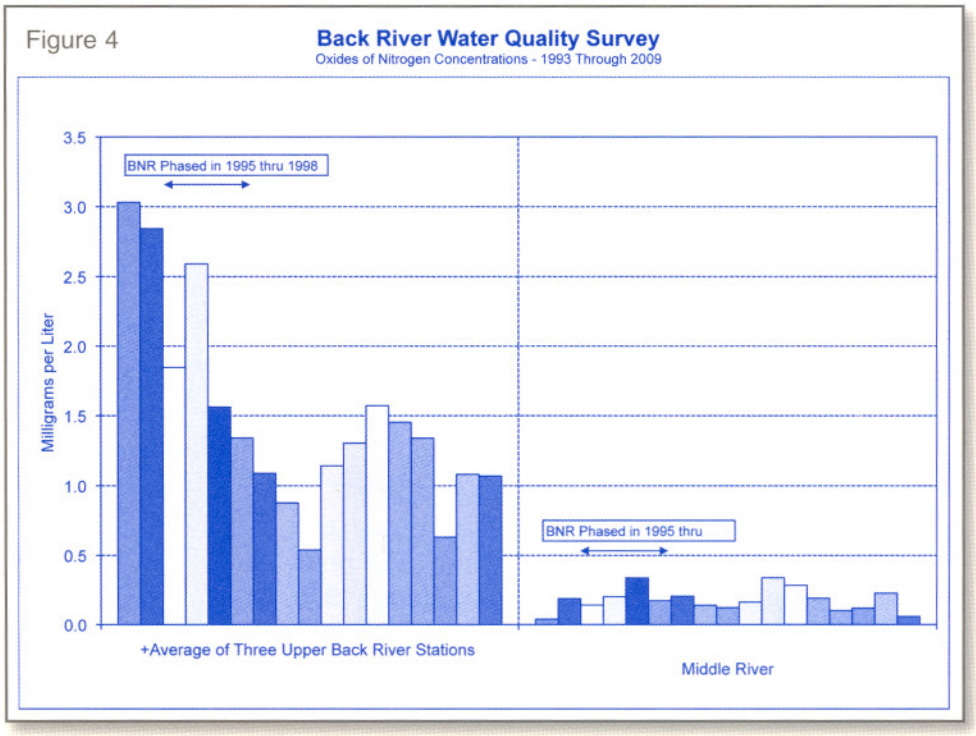
The concentrations of TP at the Back River stations also fluctuated considerably *(Figure 3)* with a high concentration in 1995 echoing the high TKN value seen that same year. Similar also is the pattern at the Middle River station where the concentrations remained fairly constant from 1993 through 2003, then rose steadily through 2008 and then declined in 2009 back to levels seen in the first few years of the study. One can only speculate at the cause of these fluctuations but rainfall remains a prime suspect *(Figure 6)*.

Two factors influence the concentration of TP in Back River. These are the phosphorus discharged by the treatment plant and the legacy phosphorus in the river sediment. Experiments have confirmed that when pH rises, sediment phosphorous solubilizes and contributes to TP in the water column above. This is likely the explanation for the TP concentrations observed in Back River since the concentrations of TP in the treatment plant effluent are below 0.2 ppm per the plant's NPDES discharge permit while TP concentrations in the river frequently exceeded this level. Only one year (2009) was the average concentration TP in Back River less than the plant's effluent concentration.

Oxides of nitrogen (NOx), primarily nitrate and nitrite, have declined noticeably in Back River *(Figure 4)*. Concentrations between 2 ppm and 3 ppm were routinely observed during the period 1993 through 1996 with 1995 being the exception. From 1997 through 2001, the NOx concentrations declined from 1.5 ppm to 0.5 ppm and although they have risen again some, they have remained at 1.5 ppm or less through 2009. Looking at the Middle River control station, NOx concentrations have remained consistently below 0.5 ppm throughout the entire 16-year study. Since the Back River WWTP was upgraded to include biological nutrient removal during the period 1995 through 1998, the decline in NOx concentration is most likely related to these improvements.

Chlorophyll concentrations in 1994 and 1995 averaged in excess of 150 µg/L *(Figure 5)* with occasional individual samples exceeding 300 µg/L. Then, rather drastically, the concentrations declined to below 100 µg/L and in a few cases less that 50 µg/L. Chlorophyll

Continued on page 28



Back River Water Quality

Continued from page 27

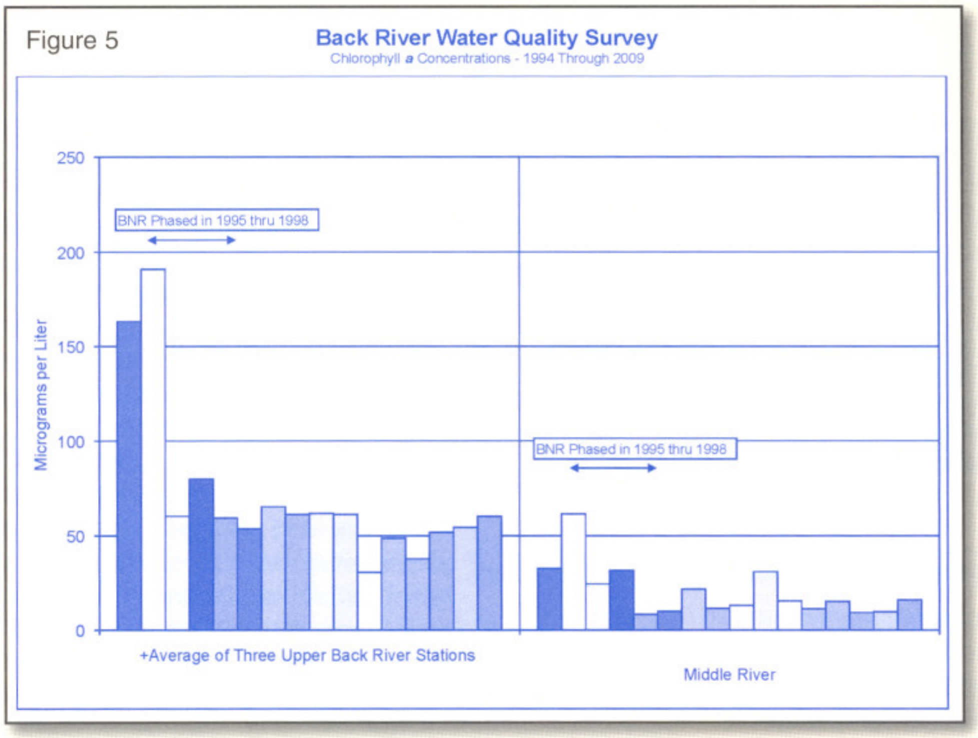


Figure 5

concentrations at the Middle River control station, except for 1995, were all less than 50 µg/L and mostly were less than 25 µg/L. Recall that the concentration of NOx also declined during the same period of time although not as dramatically as chlorophyll. The reason or reasons for the decline in chlorophyll are likely the same as the cause of the decline in NOx concentration; the Back River WWTP phased in BNR operations lowering the concentration of NOx in the effluent. Note also that in the charts illustrating both TP and TKN, concentrations were significantly lower in 2009 than they had been during the previous several years. This pattern was not observed in either NOx or chlorophyll.

The effect of rainfall is evident in the very high TKN, TP and chlorophyll concentrations observed in 1995. Note that in 1995, rainfall in the area was approximately three times the normal annual precipitation causing much erosion all across the watershed and elevated nutrient concentrations in the upper Chesapeake Bay.

CONCLUSIONS

Compared to the period prior to the late 1980s, Back River today is in far better condition than it was previously. Before the BNR upgrade was completed in 1998, algal blooms would sometimes turn the river a striking shade of iridescent green. During these blooms, as the wind swept across the river, algal cells and colonies would accumulate along the shoreline causing the water to look as though someone had poured green paint on the surface. These were the days when the chlorophyll concentration would exceed 200 µg/L and occasionally 300 µg/L. Today, algal blooms still occur but they are not nearly as severe as they were with chlorophyll concentrations now averaging 50 to 75 µg/L rather than the 200 to 300 µg/L previously seen. Although this seems like good progress, chlorophyll concentration should be more in the range of 25 to 35 µg/L.

Water quality in Back River remains impaired for nutrients for two major reasons. The discharge from the Back River WWTP still contributes significant tonnages of NOx to the river and legacy phosphorus pollution solubilizes from the sediment as the pH rises during times of peak biological activity. These two sources provide sufficient nutrients to support the algal growth still observed in Back River throughout the growing season.

These problems are being addressed as part of the overall Bay restoration strategy and also as part of the necessary steps to improve local water quality conditions in Back River. Currently under design are facilities to take the Back River Plant to enhanced nutrient removal (ENR) levels. When these facilities are competed and operating efficiently, effluent total nitrogen concentrations will be on the order of 3 to 4 mg/L rather than the 7 to 8 mg/L currently discharged. This will reduce by approximately half the concentration and therefore loadings to Back River. Several years are still needed before these facilities will be constructed and in service but when complete, reductions in nutrients, particularly nitrogen (TKN and NOx), should occur along with concomitant reductions in chlorophyll concentration and increases in Secchi disk transparency.

These improvements in water quality will likely not make the river run clear again, however, as much of the observed turbidity is due to the sediment load in the water and not to the crop of phytoplankton and associated organisms in the biological community. Until sediment and erosion controls are fully in place, water quality in Back River will continue to suffer with the river turning brown after a hard rain.

This is an on-going study and updates will be published from time to time as ENR facilities are completed and placed in service.