Lower Delaware Monitoring Program: 2000-2003 Results and Water Quality Management Recommendations

"Forks of the Delaware"

Delaware River Basin Commission
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Delaware River Basin Commission

West Trenton, New Jersey

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Executive Summary

In the May to September periods of 2000 through 2003, the Delaware River Basin Commission's (DRBC) Lower Delaware Monitoring Program (LDMP) conducted a bi-weekly water-quality survey of the Delaware River and selected tributaries located between the Delaware Water Gap and Trenton, NJ. The purpose of this report is to 1) document water quality conditions for the period 2000-2003, and 2) to present evidence and advise the Delaware River Basin Commission in its determination of the Lower Delaware River's suitability for designation as **Special Protection Waters (SPW)**. Objectives of the LDMP are to define **existing water quality (EWQ)** for this segment of the Delaware River, and subsequently to link long-term water quality monitoring to integrated water management.

This report describes existing water quality, the control point approach used to produce site-specific targets for water quality management, and results of the first four years of the five year effort to describe existing water quality in the Lower Delaware. For the Special Protection Waters eligibility determination, Lower Delaware water quality and biological monitoring results are compared with the most stringent criteria or targets available in DRBC or State rules. Delaware River results were also compared with high-quality tributary waters, specifically those designated as High Quality (HQ) and Exceptional Value (EV) waters in Pennsylvania and Category One (C-1) waters in New Jersey.

Biological results from 2001 Delaware River biomonitoring show that the Lower Delaware River contains a diverse, taxonomically rich, and pollution intolerant benthic macroinvertebrate assemblage. Selected metrics were compared with the most stringent targets: the Upper Delaware existing water quality targets for diversity and EPT Richness, and New Jersey's Hilsenhoff Biotic Index value of 4.0 defining an intolerant assemblage. All results were optimal, indicating exceptional biological value. Aquatic habitat was assessed during macroinvertebrate sampling in 2001, and scores are optimal in the Lower Delaware.

LDMP water quality results were determined to be representative of 95% of the range of flow conditions at Trenton and Belvidere. Existing water quality as defined by the 2000-2003 data set represents a range of flow from approximately 2,000 cfs to 40,000 cfs.

Reach wide existing water quality is presented for comparison with Upper and Middle Delaware reach wide targets set in the early 1990's in DRBC Special Protection Waters rules. Use of reach wide targets for the Lower Delaware is not recommended, since water quality differs substantially from Delaware Water Gap to Trenton. It is also difficult to assess water quality changes using reach wide targets.

Delaware River results indicate that existing water quality is better than criteria levels, with the exception of bacteria. Of 153 possible comparisons of EWQ to most stringent criteria (9 ICP sites, 17 parameters), 94% showed that EWQ is better than criteria.. 74% were better at all times, 20% met criteria about 90% of the time, and 6% never met criteria. For most sites and parameters, EWQ based targets would provide protection for maintenance of existing good water quality. Enterococcus bacteria concentrations are the single major problem. Fecal coliform and E. coli bacteria concentrations were problematic during storms. Phosphorus concentrations were relatively high but did not render the Lower Delaware unsuitable for aquatic life use. At certain locations, pH and TDS were naturally divergent from criteria levels, indicating that perhaps the criteria themselves need revision. EWQ targets will provide additional water quality protection by establishing targets for 10 more parameters without currently established criteria.

Additional information is shown in the report "Lower Delaware River Eligibility Determination for DRBC Declaration of Special Protection Waters" (DRBC 2004) that accompanies this document. The following recommendations are based upon LDMP 2000-2003 monitoring results:

Recommendation 1. Designate & Implement Special Protection Waters

Recommendation 2. Protect or Restore Priority Watersheds

Recommendation 3. Build Watershed Partnerships

Recommendation 4. Fill Critical Information Needs

Recommendation 5. Consider Changes to Water Quality Rules

Recommendation 6. Support Monitoring to Meet Recommendations

Lower Delaware Monitoring Program:
2000-2003 Results and Water Quality Management Recommendations

Introduction

In the May to September periods of 2000 through 2003, the Delaware River Basin Commission's (DRBC) Lower Delaware Monitoring Program (LDMP) conducted a bi-weekly water-quality survey of the Delaware River and selected tributaries located between the Delaware Water Gap and Trenton, NJ. The purpose of this report is to 1) document water quality conditions for the period 2000-2003, and 2) to present evidence and advise the Delaware River Basin Commission in its determination of the Lower Delaware River's suitability for designation as **Special Protection Waters (SPW)**. Objectives of the LDMP are to define **existing water quality (EWQ)** for this segment of the Delaware River, and subsequently to link long-term water quality monitoring to integrated water management.

Traditionally and historically, water quality standards and criteria have been developed to protect certain uses of the water resource. Resultant numeric criteria have been oriented only toward effect levels upon these uses, where negative effects upon human health, aquatic life, recreation, or suitability for water supply are likely to occur. There is a gap in water resource protection created by this approach. Poole et al. (2004) determined that while conventional standards have proved valuable in reduction of toxic substances in U.S. waters, regime-based standards are better structured to address human caused imbalances in dynamic, natural water quality parameters. In very high-quality waters, typical concentrations of water quality constituents are far better than effect levels. Existing Water Quality (EWQ) is the typical range of concentration levels of all measurable constituents of ambient waters, as determined over a defined time period. Existing Water Quality is defined either by design or by summary of historical data, and these water quality levels are used in combination with antidegradation policies to protect water quality at concentrations where they exist today. The main objective of such "no measurable change" policy is to protect water quality from degrading from current high quality levels.

Declaration of Special Protection Waters by DRBC is a major statement of antidegradation policy, or a declaration of intent that the waters of the Delaware shall be managed to maintain water quality at EWQ levels and not to allow change toward effect-level criteria or worse. Of course, natural water quality may vary widely throughout the course of the day and the season, so monitoring must capture the natural range of variation. Once sufficient data are collected to describe EWQ with confidence, the natural range of EWQ is statistically expressed either non-parametrically in terms of median, 10th and 90th percentiles; or parametrically in terms of mean and 95% confidence limits. Once EWQ is defined, the monitoring focus then shifts to determine whether water quality is changing (and why) over time using the statistically expressed range of variability to detect "measurable change."

This report presents water quality results in context of adopted water quality standards. A related report, entitled Lower Delaware River Eligibility Determination for DRBC Declaration of Special Protection Waters (DRBC 2004) uses data from this report and other evidence to make best-professional judgment recommendations concerning the Lower Delaware River's eligibility for Special Protection Waters designation. Management and policy issues are also discussed in the related report. Both reports contain recommended program requirements for future implementation.

Background and Context

The LDMP operates in support of the Lower Delaware River Management Plan, produced by the Lower Delaware River Wild and Scenic River Study Task Force and the National Park Service (1997). The first goal of the Management Plan is to **"maintain existing water-quality in the Delaware River and its tributaries from measurably degrading and improve it where practical."** The National Park Service (1999) surveyed river-corridor landowners, finding that 98% of respondents strongly support this water quality goal. The "maintain EWQ" objective requires Special Protection Waters status in order for anti-degradation policy to carry the force of law in DRBC water quality standards. On January 28, 1998, the DRBC passed Resolution No. 98-2, which endorsed the Lower Delaware River Management Plan and resolved to "…take such action as it deems appropriate to implement the goals of the plan commensurate with available resources."

Little information was available in 1998 about status and trends of Lower Delaware water quality. As a baseline for future management, EWQ is being defined using LDMP 2000-2004 water quality data. These data may be used to create water quality targets for adaptive management – meaning that targets may be refined as the data set expands and/or water quality improves. The study thus far required U.S. EPA Water Quality Monitoring Grant support of about $50,000 per year for laboratory analyses, plus DRBC General Fund support of numerous staff and interns.

Evaluation Approach

In order to determine eligibility of the Lower Delaware River for Special Protection Waters status, **evidence must be shown that these waters are considered to have exceptionally high scenic, recreational, ecological, and/or water supply values** (DRBC Water Quality Standards, 1996).

In the Upper and Middle Delaware River, the values listed above were examined using available information, but the determination of SPW status was not conducted using quantitative benchmarks or criteria. In terms of water quality, it was generally accepted that the Upper and Middle Delaware resources were of exceptional value. The same assumption cannot be made for the Lower Delaware.

In DRBC water quality regulations, the rule language provides no quantitative criteria to judge 'exceptionally high' values. Quantitative indicators for SPW determination were derived by parsing the statement from DRBC rules into measurable component parts. As the focus of this investigation, measures of water quality are judged in terms of ecological, recreational, and water supply values. As an indicator of 'exceptionally high' value, water quality was compared with only the most stringent criteria chosen from among DRBC, Pennsylvania, or New Jersey water quality standards. Water quality of the river was also compared with that of designated EV, HQ, or C1 waters. If there are no standards for a certain parameter, federal guidelines were used. For ecological value, further consideration was given to measures of biological integrity. Measurable biological traits include taxonomic richness, diversity, balance, pollution intolerance and physical habitat value.

Scenic and recreational value was discussed at length in the Lower Delaware Management Plan (1997) and the National Park Service Lower Delaware Wild and Scenic Study (1999). In segments of the Lower Delaware that were designated in the federal Wild and Scenic legislation, scenic and recreational resources are found to be of exceptional value. These reports and the federal designation provide part of the weight of evidence necessary for DRBC to make a Special Protection Waters determination.

Water supply value may be the most critical and vulnerable resource issue relevant to SPW designation. The Lower Delaware certainly can be described as an exceptional value water supply resource. Sayers (Personal Communication, 2004) related that as of 2004, an estimated 2.9 million people directly depend upon water supplied by the Lower Delaware.

Withdrawals directly from the Lower Delaware River for the purpose of public water supply total 131.6 million gallons per day. These water suppliers serve 1.1 million customers:

City of Easton;
North Penn and North Wales Water Authorities, via the Point Pleasant water diversion;
New Jersey Water Supply Authority, via the Delaware and Raritan Canal diversion;
Pennsylvania American Water Company, Yardley District;
Morrisville Borough; and
Trenton Water Works.

Additional downstream water suppliers are also dependent upon water quality of the Lower Delaware as freshwater inflow to the upper Delaware Estuary. Downstream withdrawals total 219.8 million gallons per day, serving about 1.8 million people. Customers of the Philadelphia Water Department; Lower Bucks County Joint Municipal Authority; New Jersey American Water Company Delran Intake; Bristol Borough and Burlington City are served by fresh water from the Lower Delaware.

There are undesignated gaps between the designated scenic and recreational river segments of the Lower Delaware. These are typically river segments located in the vicinity of urban and industrial centers, where such uses as industrial supply and water supply are important. It is not possible to allow water quality degradation in undesignated segments without expecting water quality to degrade in designated segments. For consistent management, the same benchmarks must be applied to all locations in the river system, without regard to artificial or political boundary lines along the longitudinal corridor.

As further evidence in support of SPW determination, this report contains four years of water quality data as well as a summary of one season of available biological and habitat data taken in 2001 by DRBC biologists. These findings represent DRBC efforts thus far to numerically define existing water quality, to measure tributary water quality influences upon the Delaware River, and to determine water quality values that inform the process of determination of Special Protection Waters eligibility. While these data do not represent the final definition of EWQ, they will facilitate the designation process. DRBC has not yet fully characterized influences, causes, or effects upon water quality. Final EWQ targets will be created after an additional year of monitoring and will be based upon data from 2000-2004.

Control Point Monitoring Concepts

Throughout this document, extensive use is made of certain terms associated with the way DRBC evaluates water quality data. Since DRBC evaluates its data along the geographical boundaries of a longitudinal river corridor, it is necessary to segment the river so that changes from upstream to downstream can be documented at particular locations. The points on the Delaware River where changes to water quality are assessed are known as **Interstate Control Points (ICP)**, since these are located along the river which is the boundary between states. Delaware River bridges are normally chosen to serve as ICP locations for safety, cost effectiveness, and ease of access for monitoring. Interstate Control Points were placed between major tributaries to the Delaware River.

A common approach to impact assessment for water resource scientists is the "upstream-downstream" evaluation, where water quality is assessed upstream of an input or point source, at the point source itself, and the combined effect is assessed downstream of the confluence of the upstream and point source inputs. In the LDMP monitoring design, each tributary is considered a discrete input or point source to the Delaware River. The LDMP monitors these **Boundary Control Points (BCP)** near to their confluence but away from backwater influence of the Delaware River. To evaluate the effects of each tributary upon the Delaware River, it is necessary to monitor the tributary BCP and to relate the resulting information to the nearest upstream and downstream ICP. This approach provides regulatory advantages in that any criteria or targets created using such a monitoring approach are site-specific. Site-specific targets can be monitored at a high accuracy level with the ability to detect water quality changes, unlike the diffuse reach-wide targets set in the early 1990's for the Upper and Middle Delaware River SPW, where DRBC and the National Park Service have since experienced difficulty implementing antidegradation policy and detecting "measurable change" to water quality. In addition, the control point approach allows for creation of watershed-specific water quality targets, where effects of each tributary upon the river are differentiated and requirements for maintenance or restoration of water quality can be modeled and quantified. The site-specific control point approach has advantage over the reach-wide target approach in current DRBC rules in that if measurable change in the Delaware River or tributary is detected, it is possible to determine the source of change and take appropriate action at small relative cost and effort.

Study Area and Water Use Overview

The River System

From the confluence of its East and West Branches at Hancock, New York, the Delaware River flows 330 miles through the Appalachian Highlands, Valley and Ridge, Piedmont, Triassic Lowlands, and Coastal Plain physiographic regions of New York, Pennsylvania, New Jersey, and Delaware. The Delaware River basin watershed area is 13,539 sq. mi. The non-tidal portion is about 200 miles long and drains 6,780 sq. mi. above the fall line at Trenton, NJ. The Delaware River is an interstate water body that forms the boundary between the basin States.

The 75-mile long study reach **(Figure 1)** is contained within the 80-mile long Lower Delaware River, which extends from the Delaware Water Gap to the head of tide at Trenton, NJ. Approximately 2,610 square miles of drainage area are located within the segment. Along the river corridor, 53 named tributaries meet the Delaware River in Bucks, Northampton, and Monroe Counties in Pennsylvania and Warren, Hunterdon, and Mercer Counties in New Jersey.

The Lower Delaware region is densely populated in the Lehigh Valley and lower Bushkill Creek watersheds, yet the rest of the study area is relatively bucolic and very scenic. The river corridor features historic small towns, agriculture, and isolated industries. Regional cities include Allentown, Bethlehem, Easton, East Stroudsburg, Phillipsburg, Lambertville, and Trenton. Major transportation corridors pass through the region, including Interstates 95, 78 and 80; U.S. Highway 22; and State Routes 611, 29, 32, and 46. Most tributary watersheds are rapidly urbanizing in headwater areas and along transportation corridors.

Figure 1. The Lower Delaware River Study Area

Uses and Designations

In DRBC Water Quality Regulations (DRBC 1996), the Lower Delaware River is designated for **water supply, primary contact recreation, industry, agriculture, and aquatic life**. These are significant and sometimes competing uses of the water resources. Maintenance of water quality and flow is critically important for present and future use of the resource.

Water Supply

This is perhaps the most critical water use category to be protected by resource managers. A distinction of the Lower Delaware is that it is a vital piece of the Delaware River Basin, a small watershed that covers only 0.4% of U.S. land area, yet serves water to more than 5% of the entire U.S. population. Much of the population of the southern portion of the Basin is directly dependent upon water from the Lower Delaware.

Significant water supply risks are associated with Lower Delaware River water quality degradation, including increased water treatment costs, taste and odor problems, reduced useful lifetime of treatment facilities, potential human health risks, loss of future supply and economic potential, and reduced wastewater assimilative capacity of the Delaware River as a receiving waterway. Water supply sources are very concentrated within the Lower Delaware and downstream. Negative changes to water quality here affect a much larger surrounding region including the Delaware Estuary, Neshaminy watershed, Schuylkill watershed, Raritan watershed, or other watersheds where Lower Delaware diversions are carried.

Recreation

Recreational use includes boating, fishing, canoeing, tubing, swimming, wildlife watching, and tourism at numerous historical and cultural sites along the river. Recreational use of the river is very substantial. The NPS Wild and Scenic Study (1999) provides evidence to this effect, though casual observance reveals the sight of people on the river at any time of day, unless the river is in flood. On hot summer days, the canoe liveries send hundreds of canoes and tubes on day trips. Delaware River Biomonitoring Program observers (unpublished DRBC field notes, 2001-2003) typically recorded about 40 boats, canoes, tubes or waders per hour passing Lower Delaware biomonitoring sites, but flotillas of up to 220 per hour have been noted. Fishing pressure is heavy, particularly when the American Shad and River Herring are running in the spring. Events centering upon the annual return of these migratory species to the Delaware River, such as the Lambertville Shad Fest, are culturally and economically significant to the region. Opportunities abound for wildlife watching. DRBC staff commonly note the presence of snakes, turtles, salamanders, hawks, owls, osprey, bald eagles, herons, egrets, and many types of songbirds. Otters are sighted occasionally, and reports of bear or deer crossing the river have been noted. River-centered recreation and tourism is of increasing economic importance, and its resource value must be protected.

Industry

The Lower Delaware River is the source of water for numerous industries. Chief among these in water use are four major power generation facilities: Portland, Martins Creek, Gilbert, and Limerick Nuclear, which is fed by the Point Pleasant Diversion. Every river town contains some industry, though not as many as in years past.

Agriculture

Once the most dominant of all uses, agriculture is no longer a major land use activity near the river. Some riverside farming remains wherever the Delaware River floodplain is wide, particularly in northern Hunterdon County, Warren County, and Northampton County. Tributary watersheds support substantial agricultural use, and pollution impacts by farming and grazing activity upon Delaware River water quality may be significant. To address these non-point source pollution effects, New Jersey's recent approval of the USDA Conservation Reserve Enhancement Program is expected to have a positive effect upon water quality of the Delaware River. At this time, Pennsylvania is working to implement a similar program. The LDMP is in position to monitor the changes to water quality resulting from these and many other management measures. No withdrawals take directly from the Delaware River for agricultural purposes.

Aquatic Life

The river's geological variety and flow regime provides suitable and very heterogeneous habitat for a diverse, rich and abundant aquatic community. The Lower Delaware is a generally wide, shallow, gravel and cobble-bottom river that flows through a very diverse landscape. Geological features such as the Piedmont's Triassic Rock outcrops and boulder-field remnants of two glaciers, combined with numerous islands, riffles, pools, aquatic vegetation beds, back-channels, and forested riparian canopy provide a wide range of habitat types for biological activities such as feeding, reproduction and refuge. The Delaware River's continuity of diverse habitat is much reduced or absent in nearly all other large rivers of the eastern U.S., where dams, levees, and channelization have fragmented the river continuum. The free-flowing nature of the Delaware River is unique and exceptional. The Delaware River Biomonitoring Program has sampled habitat and benthic macroinvertebrates since 2001, and early results are quite positive. All of the first year samples have shown that the benthic assemblage is rich, diverse, well balanced, and intolerant of pollution – scoring as well as or better than the Special Protection Waters of the Middle and Upper Delaware. While a single season of monitoring data is insufficient for a complete assessment, DRBC and USGS river biologists find that a high-quality biological community exists in the Lower Delaware River, which also indicates high water quality.

Under Pennsylvania DEP water quality standards, the Lower Delaware is classified as a Warm Water Fishery. Warm water fishes such as bass, perch, white suckers and many other species are abundant year-round; and the fish community is supplemented annually by major migrations of American Shad, American Eel, and River Herring. Owing to its free-flowing character and good water quality, the Delaware River is a major sport-fishing draw for anglers who seek these migratory species. This fishery provides enormous economic and quality of life benefits to the region.

<u>The Lower Delaware Study Area</u>

Upstream reaches determine the river's character at the beginning of the Lower Delaware study area. The Delaware River Basin's headwaters contain large New York City reservoirs that maintain flow in the river, especially during the critical May to September low-flow season covered by this survey. New York City has invested tremendous financial resources to ensure that these reservoirs continue to provide the highest quality water, and such high quality reservoir releases are barely diminished by the time the water reaches the Lower Delaware. Immediately upstream of the Lower Delaware is the Middle Delaware Scenic and Recreational River, located within the Delaware Water Gap National Recreation Area (DWGNRA). The nearest upstream large tributaries are Brodhead Creek, Bushkill Creek, and the Flat Brook, all joining the Delaware within the DWGNRA. Among these, the urbanizing Brodhead is the nearest upstream and negatively influences the Delaware River's water quality, even though the Brodhead meets all PADEP water quality criteria. PADEP 2000-2003 data were retrieved from the STORET data system and compared with reach wide EWQ in the Middle Delaware. The Brodhead increases concentrations of nutrients, bacteria, and solids in the Delaware River such that Middle Delaware EWQ is different from that at Portland, only a few miles downstream. This demonstrates how water quality at Portland, the farthest upstream monitoring site of the LDMP, integrates all upstream influences. The Portland site thus serves as the baseline station where all upstream water quality entering the Lower Delaware is measured.

Table 1 lists LDMP monitoring locations. Nine Delaware River bridge sites were chosen for description of existing water quality and establishment of Interstate Control Points. Fifteen major and minor tributaries were chosen for description of existing water quality at Boundary Control Points. It is notable that many New Jersey and Pennsylvania tributaries in **Table 1** are classified by state agencies as High Quality (HQ), Exceptional Value (EV), or Category One (C1) waters where the states apply antidegradation policy.

<u>Portland to Riegelsville</u>

The northern portion of the Lower Delaware flows through the Valley and Ridge region. This reach of the river is a transition zone where both natural and human-induced changes to water quality occur. Significant limestone bands influence water quality of the river and tributary streams. Until it receives input of these limestone streams, the river's character reflects that of its relatively nutrient-poor, low-alkalinity, and exceptionally high quality headwaters. As each limestone-influenced tributary enters the Delaware River, it imparts natural changes to water quality of the river. Here also the river flows through terminal deposits remaining from glaciers that once covered the valley, leaving boulder fields, ledges, islands, cobble/gravel riffles, mostly long and shallow pools, a few very deep pools, and scour holes that provide exceptional diversity of instream habitat and add to the river's biological, scenic and recreational value. Effects of urbanization become most apparent in the vicinity of Easton, PA, and Phillipsburg, NJ.

At Easton two major urban tributaries enter the Delaware River, the Lehigh River and Bushkill Creek. The Lehigh and Bushkill are both heavily urbanized in their lower watersheds. The Lehigh is the second largest tributary to the Delaware River, and its hydrologic influence alone changes water quality of the Delaware River. Just below the confluence of the Musconetcong River in Riegelsville, the river leaves the Valley and Ridge and enters the Piedmont Region.

Table 1. Lower Delaware Monitoring Program ICP and BCP Sites

Site Name	River Mile	Drainage Area (mi2)	Control Point Type	State AntiDeg Waters	Physiographic Province
Delaware River at Portland Footbridge	207.40	4,165.0	Interstate	-----	V/R
Paulins Kill, Warren Co., NJ	207.00	177.0	Tributary (major)	NJ C1	V/R (limestone)
Delaware River at Belvidere Bridge	197.84	4,378.0	Interstate	-----	V/R
Pequest River, Warren Co., NJ	197.80	157.0	Tributary (major)	NJ C1	V/R (limestone)
Martins Creek, Northampton Co., PA	190.80	45.5	Tributary (major)	-----	V/R (limestone)
Bushkill Creek, Northampton Co., PA	184.10	80.0	Tributary (major)	PA HQ-CWF	V/R (limestone)
Delaware River at Easton, Northampton St. Bridge	183.82	4,717.0	Interstate	-----	V/R
Lehigh River, Northampton Co., PA	183.66	1,364.0	Tributary (major)	-----	V/R
Pohatcong Creek, Warren Co., NJ	177.40	57.1	Tributary (major)	NJ C1	V/R
Delaware River at Riegelsville Bridge	174.80	6,328.0	Interstate	-----	V/R
Musconetcong River, Warren/Hunterdon Co., NJ	174.60	156.0	Tributary (major)	-----	V/R
Cooks Creek, Bucks Co., PA	173.73	29.5	Tributary (major)	PA EV	V/R
Delaware River at Milford Bridge	167.70	6,381.0	Interstate	-----	Piedmont
Nishisakawick Creek, Hunterdon Co., NJ	164.10	11.1	Tributary (minor)	NJ C1	Piedmont
Tinicum Creek, Bucks Co., PA	159.90	24.0	Tributary (minor)	PA EV	Piedmont
Tohickon Creek, Bucks Co., PA	157.00	112.0	Tributary (major)	-----	Piedmont
Paunacussing Creek, Bucks Co. PA	155.60	7.9	Tributary (minor)	PA HQ-CWF	Piedmont
Delaware River at Bulls Island Footbridge	155.40	6,598.0	Interstate	-----	Piedmont
Lockatong Creek, Hunterdon Co., NJ	154.00	23.2	Tributary (minor)	NJ C1	Piedmont
Wickecheoke Creek, Hunterdon Co., NJ	152.50	26.6	Tributary (minor)	NJ C1	Piedmont
Delaware River at Lambertville Bridge	148.70	6,680.0	Interstate	-----	Piedmont
Pidcock Creek, Bucks Co., PA	146.30	12.7	Tributary (minor)	-----	Piedmont
Delaware River at Washingtons Crossing Bridge	141.80	6,735.0	Interstate	-----	Piedmont
Delaware River at Calhoun St. Bridge	134.34	6,780.0	Interstate	-----	Piedmont

Riegelsville to Trenton

The Piedmont region of the Lower Delaware River is characterized by a severe narrowing of the watershed. Except for Tohickon Creek, direct tributaries to this reach are very small in watershed size. The tributaries originate atop the Piedmont plateau, spill through palisades or escarpments in their middle or lower reaches to the Delaware River floodplain, which is narrow in areas where the scenic and ecologically valuable palisades are close to the river. Piedmont topsoil is thin, and the fractured rock aquifer holds little water. The streams are naturally 'flashy' in their response to storm events – they rise and fall rapidly, and very low stream flow levels are common. Unless moderated by headwater or riparian wetlands, rainfall tends to run off very quickly in this area. Small towns and scattered industries are located along the river corridor. The geological features provide in-stream ledges, miles-long pools, numerous islands, and riffles with higher gravel content than the cobble-dominated ones upriver. This diversity of flow, depth, geological features, and islands creates excellent warm water habitat.

Methods – Program Design

Purpose and Design

Historical DRBC monitoring programs have been designed for very specific purposes, such as the 1987 and 1999 bacteria surveys for primary contact recreation suitability assessment, or synoptic surveys used for the 305b assessment to determine compliance with water quality standards. The design of the LDMP is different in that the results are expected to be used not only for compliance with standards, but also to create targets for adaptive management of water quality. Such management includes:

- Establishment of baseline EWQ for future comparison;
- Setting targets for maintenance of water quality where standards are met;
- Setting targets for improvement of water quality where standards are not met;
- Setting geographic and water quality priorities to meet the targets; and
- Monitoring long-term so that DRBC can consistently perform its 305b assessment, monitor trends, prioritize agency management activities, and assess effectiveness of strategy implementation.

In order to meet all of the above purposes, the design was created in order to answer straightforward but difficult questions about the Lower Delaware:

- How does water quality change from the Delaware Water Gap to Trenton?
- Which tributaries produce such changes?
- Where should limited restoration or protection resources be devoted for most water quality benefit?

This monitoring and management approach assumes that each river Interstate Control Point integrates water quality of its upstream tributary drainage. Comparing water quality at each river site to its neighboring sites segments the river and enables identification of tributary impacts within each segment. The design facilitates water quality standard compliance assessment. It also forms a longitudinal analysis template that allows for evaluation of water quality changes from upstream to downstream. Using the control point approach, the northernmost Portland site represents combined water quality effects from 4,170 square miles of drainage area entering the Lower Delaware. Similarly, the southernmost Trenton site represents combined water quality exported from the 6,780 square mile drainage area to the estuary and bay. In between, Boundary Control Points represent water quality being exported from each watershed to exert influence upon water quality of the river, which in turn is monitored at the nearest downstream Interstate Control Point. The key to the method is river segmentation small enough to be manageable, site-specific targets at input and output Interstate Control Points, and targets at Boundary Control Points contributing to each segment. Together these enable longitudinal comparison of water quality changes. Given sufficient data, water quality models can be directly assembled from this design to assess a variety of water quality management scenarios.

Methods - Tributary Watershed Analysis

Monitoring designers listed and located all 53 named tributaries, 55 potential river monitoring sites located upstream and downstream of each tributary confluence, and all water withdrawal and waste discharge points. Biweekly monitoring of such a list would be too expensive, so it was necessary to pare the list to an affordable yet effective set of monitoring locations. Tributary watershed analysis was the first step in reducing the list of candidate sites.

Major tributaries were determined by frequency analysis of tributary watershed area, with those greater than 29 sq. mi. comprising 85% of the Delaware River's drainage area between Hancock and Trenton. **Figure 2** displays results of the analysis. There are 9 major tributary watersheds within the study area. New Jersey tributaries are the Paulins Kill, Pequest, Pohatcong, and Musconetcong. Pennsylvania tributaries are the Lehigh, Tohickon, Bushkill, Martins, and Cooks. BCP sites were established near the mouth of each major tributary. Major tributaries located just outside the boundary of the study area include Brodhead Creek in Pennsylvania (upstream) and Assunpink Creek in New Jersey (downstream).

Of the remaining 44 named 'minor' tributaries of less than 29 square miles watershed area, the LDMP established a BCP on 6 due to state antidegradation status or inclusion in the Lower Delaware Wild and Scenic designation as of 2001. These included Pidcock, Paunnacussing, and Tinicum Creeks in Pennsylvania, and Nishisakawick, Wickecheoke, and Lockatong Creeks in New Jersey. Some of the remaining 38 tributaries were monitored occasionally, but not frequently enough for definition of EWQ.

Canals parallel to the river capture some tributaries. The Delaware Canal in PA receives some Lehigh River and Pidcock Creek water. Delaware Canal water spills into the Delaware River at several locations. The Delaware & Raritan Canal in NJ is an out-of-basin water supply diversion from the Delaware River to north-central NJ. The D & R Canal captures all but the highest flows of the Wickecheoke and Lockatong Creeks. Canal spillover to the Delaware River is mostly contained by regular maintenance. One large spillway active during low-flow conditions was observed along Swan Creek in Lambertville, NJ. Canal

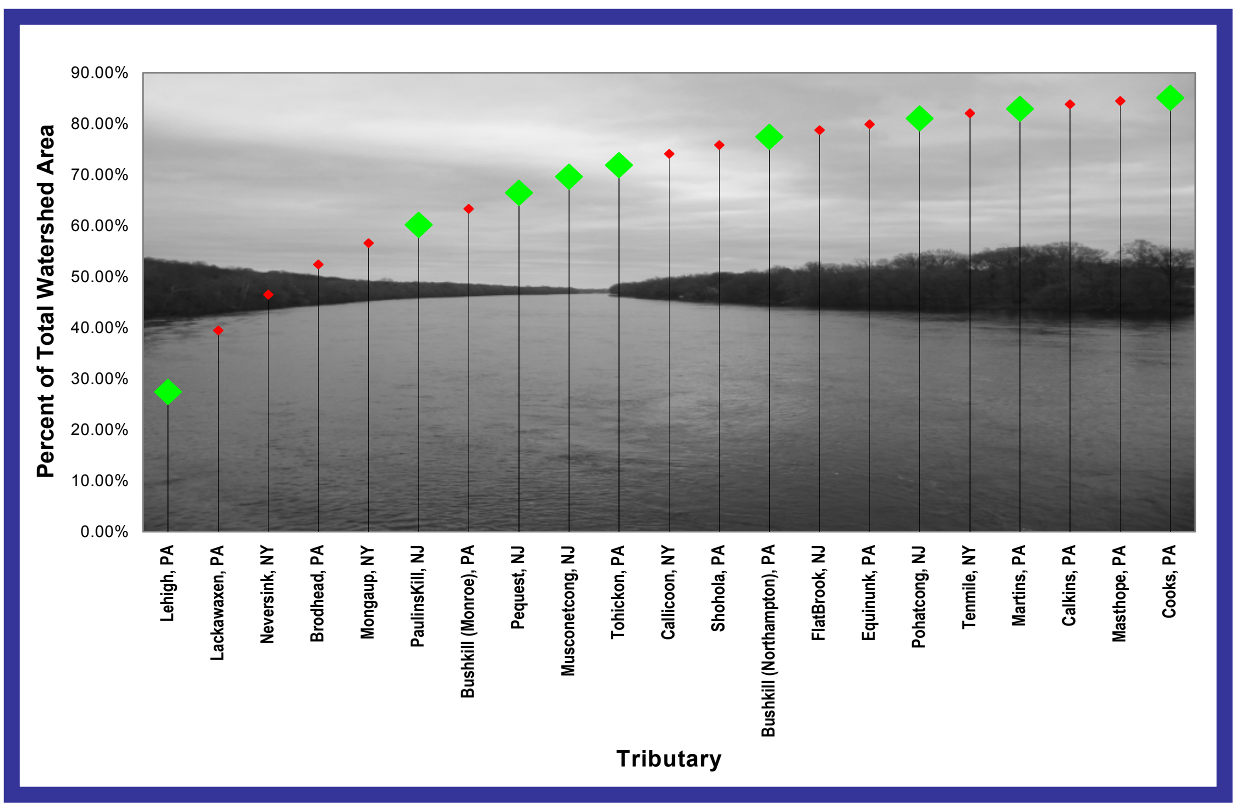


FIGURE 2. Cumulative Percent Watershed Area (top 85%) of Tributaries to the Non-Tidal Delaware River between Hancock, NY and Trenton, NJ. The East and West Branches and Assunpink Creek are located outside of the reach and were excluded from analysis. Large green diamonds represent Lower Delaware tributaries.

effects upon the river are unknown but potentially significant.

Methods – Biological and Habitat Assessment

The Delaware River Basin Commission historically has focused resource protection efforts upon traditional chemical water quality monitoring, which proved very effective at reducing impacts created by point sources of pollution. In the 1990's the basin states began to use a more holistic approach to address complex non-point source pollution problems. The basin states instituted monitoring of biological, chemical, physical, and toxics components of ecosystem function and health. Planning and regulatory efforts of the Commission have recently expanded in scope to include not only water chemistry and toxics monitoring as resource assessment and protection tools, but also monitoring of biological communities, habitat conditions, and other physical measures for sustainable protection of biological integrity. DRBC has also recently improved quality assurance practices and data quality. DRBC monitoring programs aim to provide a well-rounded view of water quality conditions in the Delaware River, and provide sufficient data for timely and meaningful management decisions.

The DRBC's Delaware River Biomonitoring Program gathers sufficient physical, chemical, and biological information to serve the following purposes:

- Implement Special Protection Waters regulations for the Upper and Middle Delaware River.
- Define EWQ and implement anti-degradation protection of the Lower Delaware River.
- Develop a Benthic Index of Biological Integrity (B-IBI) for the non-tidal Delaware River.
- Provide biological assessment information for the Delaware River 305B report.
- Increase the base of ecological knowledge of large free-flowing rivers.

The Delaware River Biomonitoring Program conducts an annual survey of benthic macroinvertebrates and habitat along the 200-mile length of the non-tidal Delaware River from Hancock, NY to Trenton, NJ. Beginning in 2001, the data set resulting from numerous annual surveys will be used to create a baseline Benthic Index of Biotic Integrity (B-IBI) for the Delaware River as well as numeric biological criteria in DRBC Water Quality Regulations. A complete and detailed method description may be found in the Delaware River Biomonitoring Program Quality Assurance Project Plan (DRBC 2003).

Macroinvertebrates are collected at each of 25 best-habitat sites on the Delaware River. Pebble counts, velocity measurements, habitat assessments, and instantaneous water quality samples are concurrently collected to characterize the habitat and water quality at the time of sampling. Habitat quality was evaluated at each Delaware River site using an adaptation of the EPA Rapid Bioassessment Protocol habitat methodology (U.S. EPA 1999). Collection occurs during an August to September index period unless flow conditions are unsafe. DRBC biologists collect macroinvertebrates and both DRBC and National Park Service (NPS) biologists collect the other parameters. DRBC biologists or contract laboratory taxonomists perform macroinvertebrate taxonomy and enumeration. DRBC and the EPA Office of Research and Development perform statistical analysis.

Biological data is compiled in the Ecological Data Application System (EDAS) created by TetraTech, Inc. All metrics are calculated in EDAS. Statistical analysis is performed using Analyze-It, a Microsoft Excel add-on program, or SAS. Data is stored at DRBC for organizational use as well as uploaded onto EPA's STORET national water quality database.

Methods – Water Quality and Flow Monitoring

For a detailed description of water quality and flow monitoring methods, see the DRBC Lower Delaware Monitoring Program Quality Assurance Project Plans (2000, 2001, 2002, and 2003). From May to September 2000-2003, DRBC monitored water quality of the Delaware and tributaries. The mission of the Lower Delaware Monitoring Program is to obtain environmental data that:

- Provides water quality data as the basis for a determination of SPW eligibility.
- Establishes targets for anti-degradation protection strategies supporting SPW policies.
- Reports on water quality status and identifies factors to maintain or improve ecological integrity.
- Expands ecological knowledge of the Lower Non-tidal Delaware River.
- Safeguards the health and safety of the river-using public.

Table 2. LDMP Chemical Parameters

General Water Quality & Descriptors
Air Temperature (F and C)
Alkalinity Concentration mg/l
Chloride Concentration mg/l
Discharge (cfs)
Dissolved Oxygen % Saturation – calculated
Dissolved Oxygen Concentration mg/l
Hardness Concentration mg/l
PH
Specific Conductance umhos/cm
Total Dissolved Solids Concentration mg/l
Total Suspended Solids Concentration mg/l
Turbidity Concentration NTU
Water Temperature (F and C)

Nutrients & Primary Production
Ammonia NH3-N Concentration mg/l
Chlorophyll A Concentration mg/m3
Nitrate NO3-N Concentration mg/l
Orthophosphate Concentration mg/l
Phytoplankton Biomass (mg/m3) – calculated
Total Nitrogen:Total Phosphorus ratio – calc.
Total Kjeldahl Nitrogen mg/l
Total Nitrogen mg/l*
Total Phosphorus mg/l

Bacteria
E. coli col/100ml
Enterococcus col/100ml
Fecal Coliform col/100ml

The Lower Delaware Monitoring Program consists of routine baseline monitoring of water chemistry. A list of parameters (measured or calculated) is shown in **Table 2**. Sampling was conducted bi-weekly at 9 Delaware River sites and 15 tributary sites listed in Table 1. A total of 10 samples per site per year were collected from 24 sites during the 2000-2003 seasons. A contract laboratory measured nutrient, bacteria, and physical parameters using only U.S. EPA-approved laboratory methods. Field measurements were conducted on site by DRBC staff. Discharge was measured or estimated (Wahl et al. 1995) and calculated pollutant-loading rates were associated with each sample. All data were managed using Microsoft Excel and uploaded into the STORET national database. Statistical tests and checks of extreme data were made using Analyse-It v. 1.68, by Analyse-It Software Ltd., an add-on statistical program for Microsoft Excel. The Lower Delaware Monitoring Program database is available for download at **http://www.state.nj.us/drbc**. The data base includes all data used for this report as well as data from numerous additional Lower Delaware sites excluded from this analysis where the number of the samples was insufficient for statistical comparisons ($n<20$).

Gage heights were associated with a flow-rating curve specific to each water body. A series of discharge measurements ($n>5$) were taken over the expected range of flows. With each discharge measurement, the gage height was recorded so that the measurement could be related to a point on the flow-rating curve. Rating curves were developed using liner regression techniques, and are presented in **Appendix D**. Discharge values generated by the United States Geological Survey (USGS) were used for the Delaware River and tributaries with USGS stream gages. At sites where the USGS gage is not located at the sampling point but existed elsewhere in the watershed, a discharge value was calculated based on drainage area weighting.

For this report, non-detect values were assigned as ½ the minimum detection limit as long as less than 20% of all values were non-detects. This allowed for representation of low concentrations while avoiding bias of the dataset. If more than 20% of samples were non-detects, data were censored to retain only the reported values, and the frequency of non-detect values was highlighted as a potential water quality indicator for future trend analysis.

Methods – Statistical Analysis

Once data were checked and placed into the Microsoft Excel database, several additional steps were taken using Microsoft Excel and Analyse-It to compute additional parameters and prepare the data set for statistical comparison of ICP and BCP water quality:

1. Site characteristics were encoded to enable water quality comparisons by low vs. high flow; month; time of day; state; physiographic region, riffle vs. pool sites; river vs. tributary sites; and by river mile. Future reports will highlight results of these analyses.
2. Drainage areas were computed and entered.
3. The 100% dissolved oxygen saturation value was computed for each measurement of water temperature, and observed DO was divided by the computed 100% saturation value to produce the DO% Saturation parameter.
4. The TN:TP Ratio parameter was calculated by summing Nitrate, Nitrite, and TKN Concentrations (TKN already includes Ammonia) to arrive at Total Nitrogen (TN) in mg/l. This was divided by Total Phosphorus (TP) in mg/l to arrive at the TN:TP unit-less ratio. N:P ratios are used o determine nutrient limitations and as indicators of reservoir or lake eutrophication. Interpretation of N:P ratios in flowing water is less well-known, and is a subject of current research interest at DRBC.
5. The Phytoplankton Biomass parameter was calculated by multiplying the Chlorophyll A concentration by a coefficient of 67. It is estimated in Standard Methods for the Examination of Water and Wastewater, 20th Ed. (APHA et. al, 1998) that Chlorophyll A comprises 1.5% of phytoplankton biomass by weight (thus, 1/1.5 = 66.667).
6. Pollutant loading rates were calculated using the formula Concentration (mg/l) x Flow (cfs) x 5.39378 conversion factor = Loading in Lbs/Day (not presented in this report, see data base).
7. To compare pollutant-loading rates between large and small tributaries, the loading in lbs/day per square mile of drainage area was calculated (not presented in this report, see data base).
8. EWQ tables were prepared for each site and reach wide for the entire Lower Delaware River. Each table contains parametric and non-parametric summaries of all parameters measured: included in each table is N; mean; upper and lower 95% confidence limits of the mean; median; and the 10th and 90th percentiles.
9. Data distributions and normality were checked (Shapiro-Wilks test) for every parameter at every site. As a result, mean values are not compared in this report due to non-normality of site-specific data. Only non-parametric comparisons were performed (except for the normally-distributed log-transformed bacteria data).
10. Data transformations were tried for non-normal data, but failed to produce normality. Only fecal coliform, enterococcus, and E. coli bacteria data were invariably normal once log-transformed. Geometric mean values were compared using t-tests and 1-way analysis of variance with multiple comparisons.
11. All other site-specific comparisons were conducted using non-parametric statistical tests, comparing median values using the Mann-Whitney test, which formally tests for a difference between the medians of 2 independent samples. The Mann-Whitney U test, also commonly referred to as the Wilcoxon rank-sum test, is the most powerful (and is often a more powerful) alternative to the independent samples t-test. The confidence interval around the difference between medians is computed using the Hodges-Lehman method, as both samples are measured on a continuous scale.
12. Graphical presentation of the data includes longitudinal plots of constituent concentrations vs. water quality criteria.

Methods – Comparison of Existing Water Quality to Standards

For this study, water quality was compared to the most stringent rules or guidelines available, regardless of jurisdictional boundaries. **Table** 3 shows all DRBC, state, or federal criteria that apply to the Lower Delaware River. Use of only the most stringent of these provided a single and uncomplicated assessment perspective that enabled a politically blind determination of how the most stringent criteria are related to EWQ. Such universal application of the most stringent criteria, no matter which government body created such criteria, is not valid assessment according to Clean Water Act objectives (e.g., Pennsylvania criteria are not valid for assessment of New Jersey waters). The state 305B reports should be consulted for such assessments, as criteria are significantly different between jurisdictional boundaries. An example of non-jurisdictional assessment is use of DRBC river criteria to assess the water quality of tributary waters. Where DRBC stream quality objectives are more stringent than state criteria, the DRBC stream quality objectives were used to assess the state tributaries to determine how tributary water quality relates to that of the Delaware River.

Table 3 shows only EWQ parameters with existing quantitative criteria or guidelines. For parameters with no criteria, EWQ targets may serve to provide some protection for resource uses that these parameters affect. EWQ also serves as baseline information for future criteria development by the agencies.

Table 3. DRBC Stream Quality Objectives and State Criteria Used for Determination of Lower Delaware River Eligibility for Special Protection Water Status. BOLD are most stringent criteria used for SPW determination.

Parameter	**DRBC Zone 1D**	**DRBC Zone 1E**	**PADEP Rules**	**NJDEP Rules**
Classification	Water Supply, Aquatic Life, Recreation	Water Supply, Aquatic Life, Recreation	Warm Water Fishery	Fresh Water 2-Non Tidal
DO mg/l	**5.0 24 hr, min 4.0**	**5.0 24 hr, min 4.0**	**5.0 24 hr, min 4.0**	**5.0 24 hr, min 4.0**
DO %	n/a	n/a	n/a	n/a
Water Temperature F	Discharge only no ambient	Discharge only no ambient	**5/1-15=64, 16-31=72 6/1-15=80, 16-30=84 7/1-31=87 8/1-31=87 9/1-15=84, 16-30=78**	Discharge only no ambient
PH	6.0-8.5	6.0-8.5	6.0-9.0	**6.5-8.5**
TDS mg/l	**120; 500 max**	**266; 500 max**	Mo Avg 500; 750 max	500 max
TSS mg/l	n/a	n/a	n/a	**40 max**
Alkalinity CaCO3 mg/l	n/a	n/a	**min 20 mg/l**	n/a
Turbidity NTU	30-d 20; max 150	30-d 30; max 150	n/a	**30-d max 15; max 50**
Total Phosphorus P mg/l	n/a	n/a	n/a	**0.1 mg/l**
Orthophosphate P mg/l	n/a	n/a	n/a	n/a
Chloride mg/l	n/a	n/a	**max 250 Public Water Supply**	**max 250 (human); max 860 (acute bio); max 230 (chronic bio)**
Nitrate NO3-N mg/l	n/a	n/a	**max 10 PWS**	**max 10 (human)**
Ammonia NH3-N mg/l	n/a	n/a	**pH & temp formula**	**pH and temp formula**
Enterococcus colonies/100ml	n/a	n/a	n/a	**33 30-d avg; max 61**
Fecal Coliform colonies/100ml	**200**	**200**	**200 30-d avg; 400 max**	**200 30-d avg; 400 max**
E. Coli colonies/100ml	n/a	n/a	n/a	**Federal 126 30-d avg**
Macroinvertebrates: EPT	**Use UPDE mean EWQ = 15.5**			
Macroinvertebrates: Diversity	**Use UPDE mean EWQ = 3.6**			
Macroinvertebrates: HBI				**4.0 or below is intolerant**
RBP Habitat	**RBP habitat score OPTIMAL range**			

Results and Discussion

In the evaluation approach description, measurable components or indicators were derived from narrative requirements for SPW designation in DRBC rules. The following sections describe measurable results of DRBC's physical, chemical, and biological monitoring activities. Each indicator is interpreted by the most stringent known criterion and judged for SPW suitability.

Benthic Macroinvertebrates and Habitat

Biological integrity and habitat quality are two directly measurable aspects of ecological condition. Only the first season's results of the Delaware River Biomonitoring Program were available for this evaluation. When DRBC Special Protection Waters rules were enacted in the early 1990's, three biological metric targets were included in the definition of EWQ: Shannon Wiener Diversity; Equitability; and EPT Richness. In the late 1990's, equitability was found to be an unresponsive indicator of changes to biological integrity. DRBC biologists are presently refining a list of macroinvertebrate community metrics that respond best to water quality changes in the Delaware River. Lower Delaware biological diversity and taxonomic richness scores from 2001 were compared with exceptional quality Middle and Upper Delaware River biological targets from DRBC's water quality rules. Healthy macroinvertebrate assemblages score higher in diversity and EPT richness than stressed assemblages. Lower Delaware macroinvertebrate data were also compared with New Jersey's most stringent pollution tolerance criterion (Hilsenhoff Biotic Index score of 4.0). The lower the Hilsenhoff score, the better and less tolerant of pollution is the macroinvertebrate assemblage. Though results are inconclusive due to small sample size, the data are presented below. Delaware River biocriteria development is underway through 2005 or 2006 with assistance from the U.S. EPA.

In terms of habitat quality, desirable and measurable traits were examined, including numerous parameters listed in the U.S. EPA Rapid Bioassessment Protocols for Use in Wadeable Streams and Rivers (1999). Not all of the Rapid Bioassessment Protocol's habitat parameters translate well to large rivers, but parameters that do so include substrate heterogeneity and stability; heterogeneous flow and depth regimes, sediment deposition indicators; channel flow status; bank stability and vegetative protection; and overall habitat complexity and cover. Even in low flow periods the Lower Delaware received optimal habitat scores at every site. Such evidence indicates that the Lower Delaware possesses exceptional habitat conditions for aquatic life. These results must be taken in their context, however, as DRBC chooses biological monitoring sites based on presence of best-available river habitat. Where such habitat exists, RBP habitat scores are optimal. Such locations are numerous and well distributed throughout the Lower Delaware. Riffle-pool frequency is a normal 6:1 channel widths or better, a characteristic of free flowing streams not fragmented by dams and channelization. There are known locations where habitat limitations exist, but habitat value has not been fully delineated throughout the reach.

Preliminary benthic macroinvertebrate results suggest that that the biological community of the non-tidal Lower Delaware River is exceptional and appears worthy of Special Protection Waters designation. Lower Delaware benthic community data collected during August-September 2001 compared favorably with existing targets for the Special Protection Waters of the Upper Delaware River. Because biocriteria do not currently exist for the Lower Delaware, the Upper Delaware's most conservative thresholds were used. Results indicate that Special Protection Waters protection is appropriate, since the Lower Delaware River largely scored as well as or better than target values set for waters already so designated.

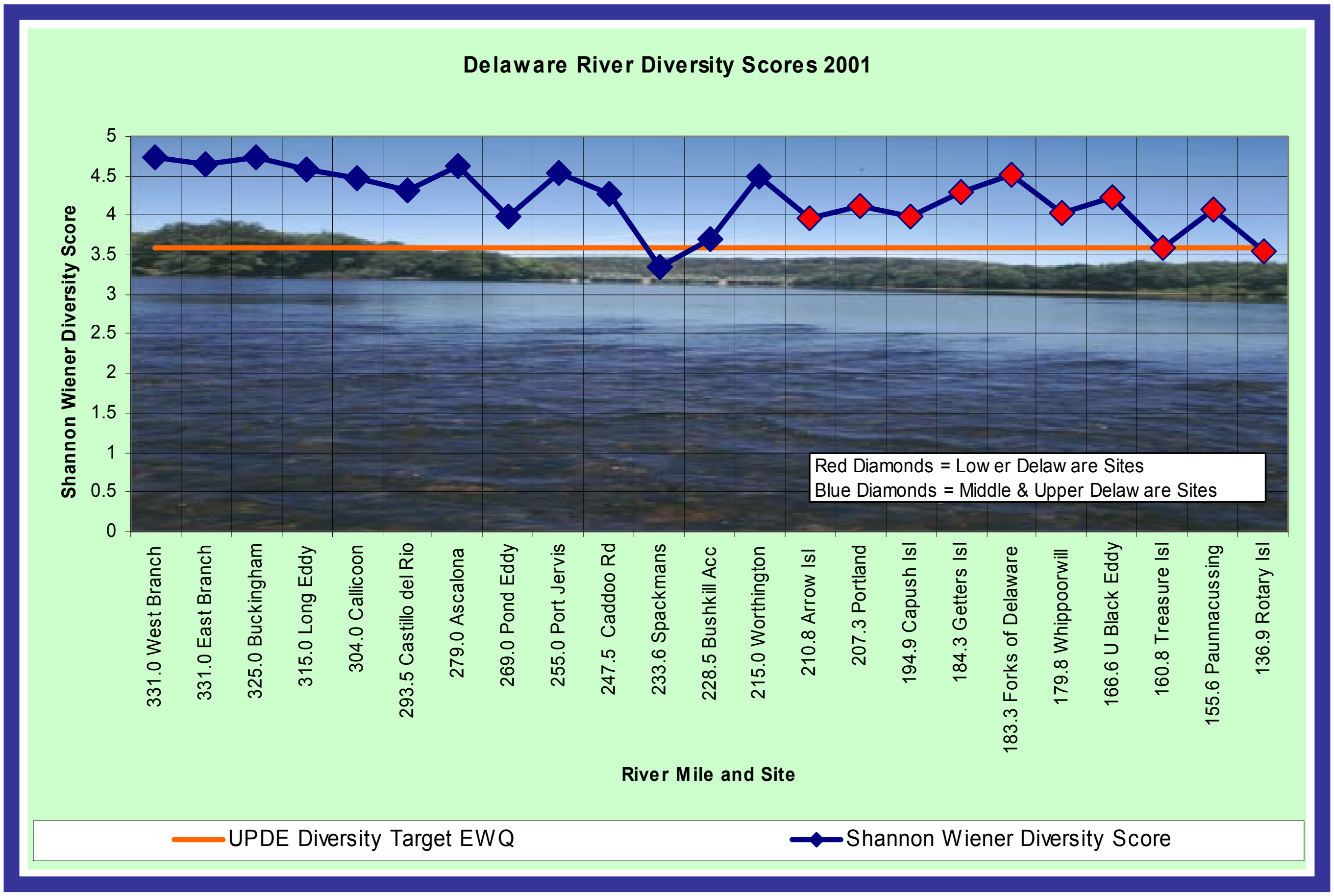


Figure 3. Shannon-Wiener diversity scores for macroinvertebrate samples taken in 2001 from best-habitat riffle sites along 200 miles of the non-tidal Delaware River. Lower Delaware sites are markes by red diamonds, Upper and Middle Delaware sites by blue. The orange line is the diversity biological target set as Existing Water Quality in DRBC water quality rules for the Upper Delaware Scenic and Recreational River.

Figure 3 shows results of biological monitoring using the Shannon-Wiener Index, a measure of diversity of the macroinvertebrate assemblage. Lower Delaware diversity appears low at 2 sites (Trenton and Treasure Island), but those scores that missed the Upper Delaware's mean EWQ diversity target of 3.6 were within 95% confidence limits of the mean. These limited results suggest that the Lower Delaware River possesses a highly diverse macroinvertebrate assemblage, meriting SPW status.

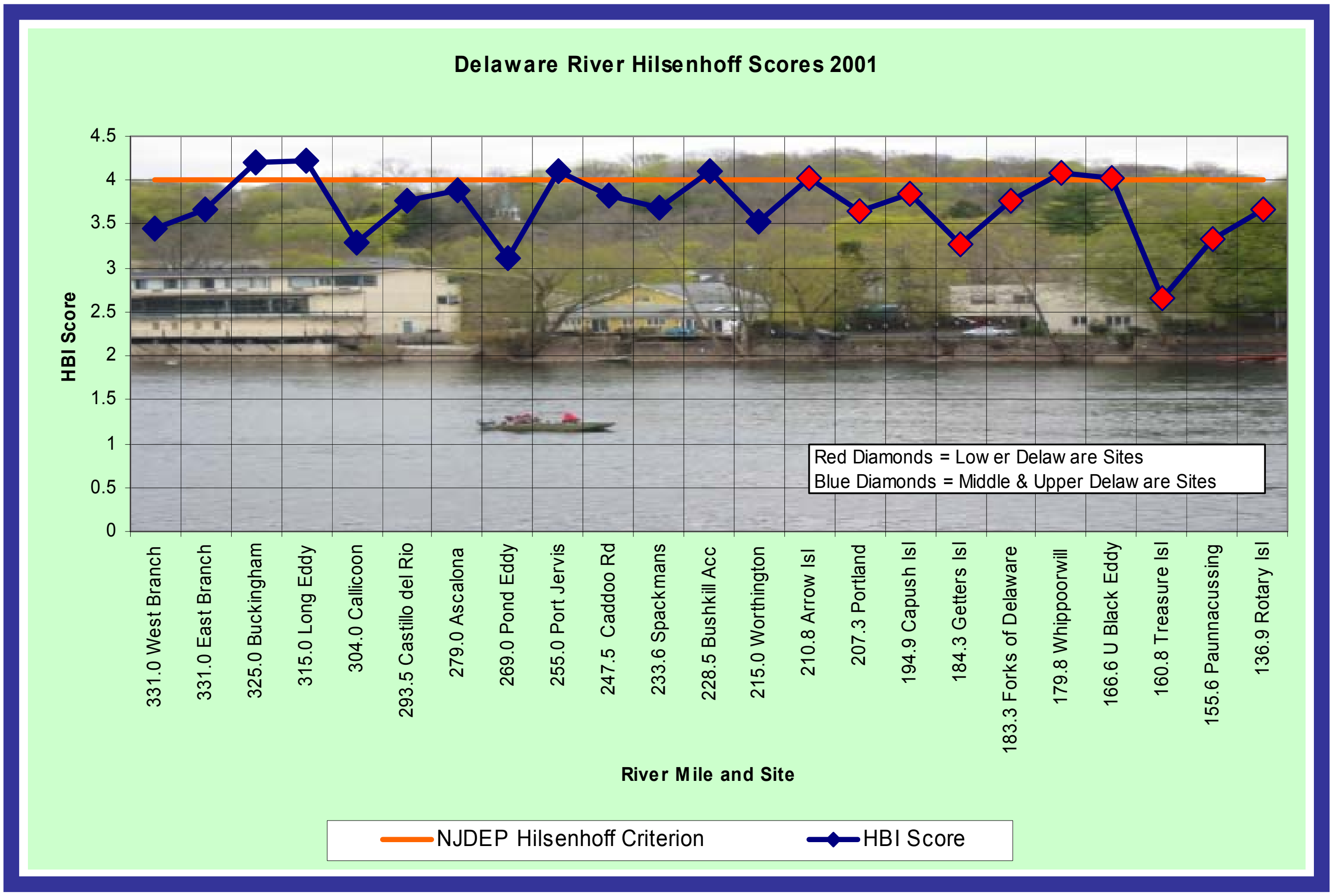


Figure 4. Hilsenhoff Biotic Index scores for samples taken in 2001 along 200 miles of the non-tidal Delaware River. Lower Delaware sites are marked by red diamonds, Upper and Middle Delaware sites by blue. Low Hilsenhoff scores indicate intolerance to pollution and better water quality. The orange line is New Jersey's Hilsenhoff criterion of 4, used to indicate an optimal pollution tolerance score.

The Hilsenhoff Biotic Index value was calculated for each sample and then compared against the strictest criterion. New Jersey's HBI of 4.0 is their threshold for intolerance. **Figure 4** shows that the threshold was met at all but 3 sites (Arrow Island, Whippoorwill Island and Upper Black Eddy). Values above 4.0 still fell under EPA's recommended HBI of 4.5 for definition of intolerant. These very limited data suggest that the Lower Delaware River's benthic macroinvertebrate assemblage is intolerant of pollution, indicates excellent water quality, and merits SPW status.

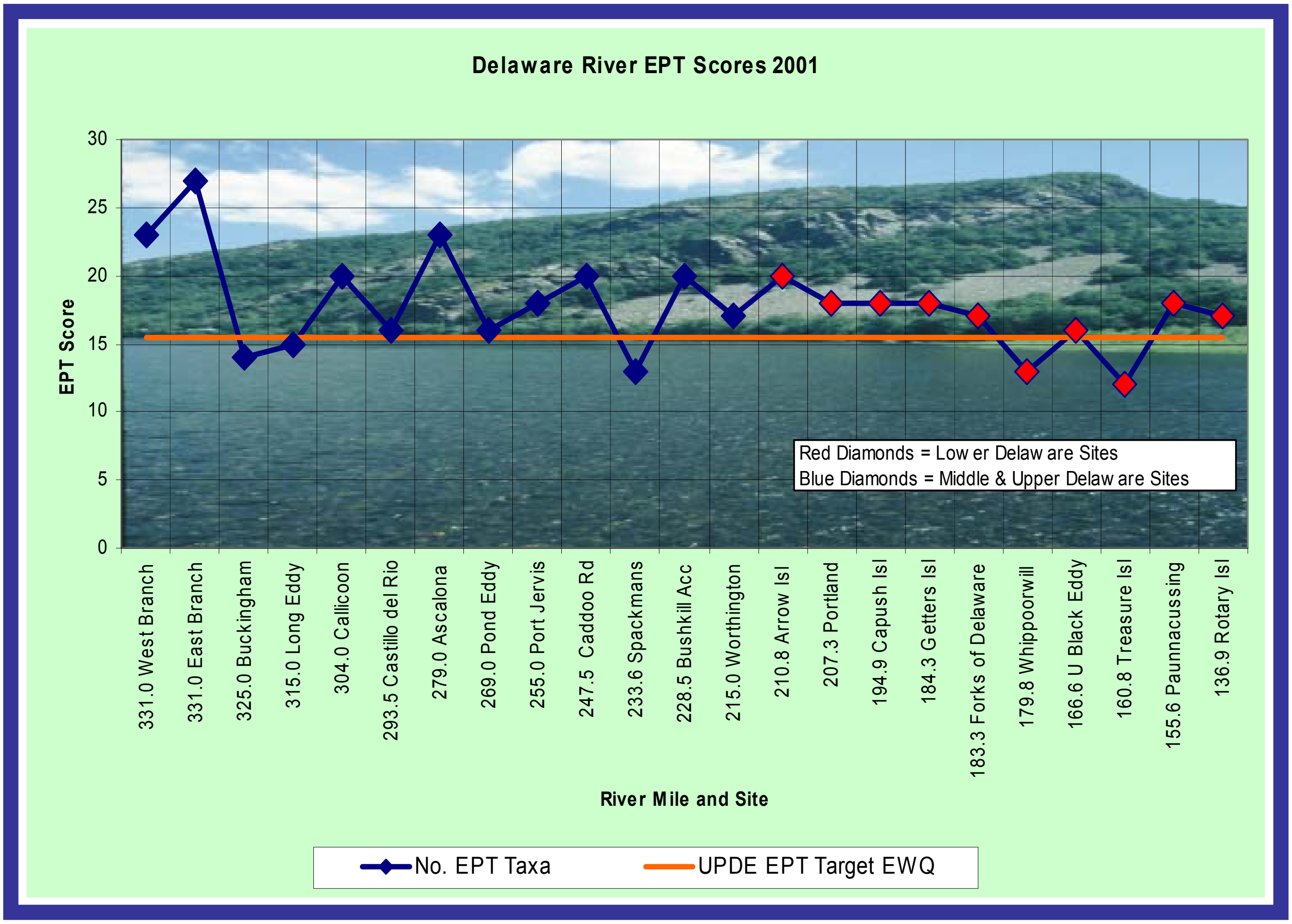


Figure 5. Genus-level EPT Richness scores for samples taken during the August-September 2001 macroinvertebrate survey of 200 miles of the Delaware River. Lower Delaware sites are marked by red diamonds, Upper and Middle Delaware sites by blue. High EPT scores indicate better water quality by virtue of the presence of genera representing three pollution-intolerant orders of aquatic insects: the Ephemeroptera (mayflies); Plecoptera (stoneflies); and Trichoptera (caddisflies). The orange line is the Upper Delaware mean EWQ target EPT richness of 15.5, representing excellent water quality.

At all but 2 sites, the Lower Delaware biological community met the Upper Delaware EWQ target (mean EPT of 15.5) for the presence of Ephemeroptera, Plecoptera, and Trichoptera taxa (EPT), a measure of the presence of the most pollution sensitive taxa in aquatic systems. **Figure 5** shows that those scores that did not meet the threshold (at Treasure Island and Whippoorwill Island) still fell within the 95% confidence limits of the threshold. It will require several more years of data to conclusively verify these results, however, as data above represent only a single macroinvertebrate sample taken from each site. These limited results suggest that the Lower Delaware River benthic macroinvertebrate assemblage is very well represented by pollution intolerant genera; to such a degree that EPT taxa often dominate macroinvertebrate samples taken from the Lower Delaware. This indicates excellent water quality, and supports SPW status.

Hydrologic Regime Represented by Water Quality Data

Figures 6 and 7 show probability plots of flow at Trenton and Belvidere, respectively, for the entire period of record at those USGS gages. Points displayed are flow measured during times water quality samples were taken between May 2000 and September 2003. These give an indication of the flow conditions represented by the data, and the range of flow conditions under which existing water quality was defined. In terms of capturing a wide range of flow conditions, these results show that 2000-2003 data are representative of the historical range of flow in the Delaware River. When interpreting future water quality results versus EWQ targets, comparison would be invalid for samples taken when flow is greater than 40,000 cfs or less than 2,000 cfs at Trenton or Belvidere. Expansion of the data set defining EWQ to include water quality samples taken from higher or lower flows will improve the applicability of resultant EWQ targets.

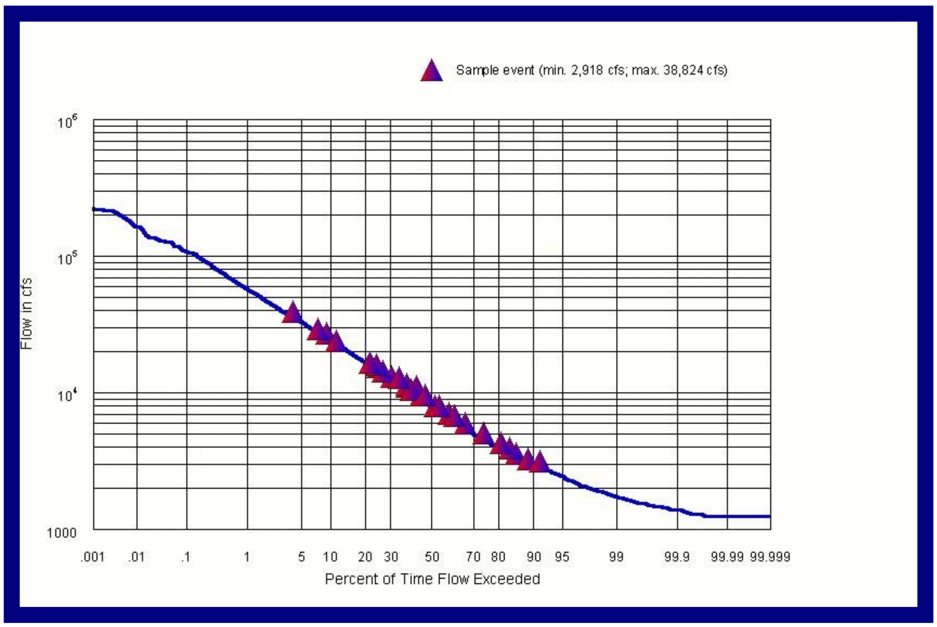


Figure 6. Probability Plot of Delaware River Flow (cfs) at Trenton, NJ. Marks indicate water quality sample events.

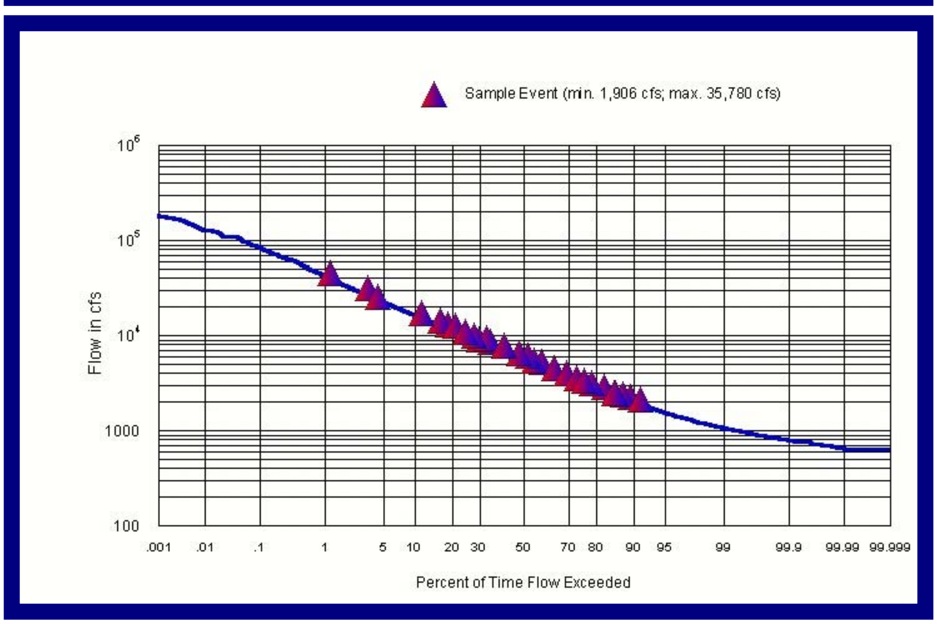


Figure 7. Probability plot of Delaware River flow (cfs) at Belvidere, NJ. Marks indicate water quality sample events.

Existing Water Quality – Reach Wide Summary

2000-2003 Reachwide Existing Water Quality for the Lower Delaware River														
Parameter	n	Mean	SD	SE	95% CI of Mean		Median	95% CI of Median		10%ile	25%ile	50%ile	75%ile	90%ile
Ammonia NH3-N	274	0.048	0.040	0.002	0.044	0.053	0.025	0.025	0.030	0.025	0.025	0.025	0.060	0.108
CaCO3 Alkalinity	350	39.7	20.7	1.1	37.5	41.8	36.0	34.0	39.0	20.0	27.0	36.0	50.0	59.0
CaCO3 Hardness	350	54.8	20.1	1.1	52.7	57.0	52.0	48.0	59.0	30.0	38.0	52.0	72.5	79.0
Chloride	347	13.8	7.1	0.4	13.0	14.5	15.0	14.0	16.0	1.9	10.0	15.0	19.8	22.0
Chlorophyll A mg/m3	306	2.69	2.33	0.13	2.43	2.95	2.14	2.00	2.67	0.50	0.97	2.14	3.60	5.34
Dissolved Oxygen	347	8.8	1.1	0.1	8.6	8.9	8.7	8.6	8.8	7.4	7.9	8.7	9.5	10.3
Dissolved Oxygen % Saturation	347	97.7%	8.4%	0.4%	96.8%	98.6%	96.4%	95.6%	97.0%	89.1%	92.3%	96.4%	101.3%	108.1%
E. coli (mean is geometric)	270	33					30	22	36	4	10	30	80	280
Enterococcus (mean is geometric)	309	61					58	48	70	8	20	58	180	530
Fecal Coliform (mean is geometric)	309	61					56	48	70	8	20	56	142	530
Nitrate NO3-N	331	1.108	0.567	0.031	1.047	1.169	1.010	0.970	1.090	0.572	0.750	1.010	1.320	1.558
Orthophosphate PO4-P	295	0.045	0.033	0.002	0.041	0.049	0.040	0.030	0.040	0.005	0.020	0.040	0.070	0.090
pH	349	7.64	0.48	0.03	7.59	7.69	7.60	7.53	7.61	7.08	7.36	7.60	7.90	8.20
Phytoplankton Biomass mg/m3	306	180	156	9	163	198	143	134	179	34	65	143	241	358
Specific Conductance umhos/cm	350	159.0	50.5	2.7	153.7	164.3	156.5	142.0	164.0	94.1	117.0	156.5	204.3	229.0
Total Dissolved Solids	319	133.7	40.0	2.2	129.3	138.1	130.0	130.0	140.0	86.0	110.0	130.0	160.0	170.0
Total Nitrogen : Total Phosphorus ratio	270	20.2	11.4	0.7	18.8	21.5	17.3	16.8	18.2	10.9	13.2	17.3	24.4	30.8
Total Kjeldahl Nitrogen	270	0.479	0.568	0.035	0.411	0.547	0.340	0.310	0.380	0.080	0.190	0.340	0.583	0.957
Total Nitrogen	270	1.474	0.704	0.043	1.389	1.558	1.410	1.300	1.470	0.826	1.025	1.410	1.763	2.189
Total Phosphorus	278	0.091	0.062	0.004	0.084	0.098	0.080	0.070	0.090	0.030	0.050	0.080	0.120	0.140
Total Suspended Solids	319	9.5	19.2	1.1	7.4	11.6	4.5	4.0	5.0	1.0	2.5	4.5	8.5	18.0
Turbidity	350	5.7	12.1	0.6	4.5	7.0	2.6	2.2	3.1	0.8	1.2	2.6	6.0	10.0
Water Temperature F	350	69.9	7.8	0.4	69.1	70.7	71.1	69.1	72.3	59.3	64.1	71.1	75.9	80.6

Table 4. Reach Wide Existing Water Quality of the Lower Delaware River (Preliminary 2000-2003 monitoring data).

Table 4 summarizes reach wide Existing Water Quality in the Lower Delaware River. The 2000-2003 data set is the basis for this table, which will be supplemented by additional 2004 data. Although useful for general characterization, and to note site differences from the reach as a whole, Special Protection Waters rules would be difficult and unfair to implement using a reach wide table such as this. Natural water quality changes drastically from Portland to Trenton. Breidt and Boes (1989) recommended that reach wide criteria should not be used in the Middle Delaware because water quality at Port Jervis differed so much from that at the Delaware Water Gap. Based on the data set, they also recommended a site specific, non-parametric approach to water quality protection (Breidt et al. 1992). Perhaps these results were unavailable to resource managers at the time, but the DRBC Staff Report on Scenic Rivers Water Quality Protection (1990) contains no mention of site specific or non-parametric targets. EWQ at individual sites was not equal throughout the Middle Delaware, and it is even less so in the Lower Delaware. Site-specific targets (defined using values shown in **Appendix A**) are the proper means to fairly apply rules based upon EWQ, and to confidently distinguish measurable changes to EWQ.

Lower Delaware reach wide data were compared with Middle Delaware EWQ from DRBC Water Quality Regulations (1996). The Lower Delaware contains higher concentrations of hardness, alkalinity, TDS and specific conductance. Limestone effects and urbanization can cause these increased concentrations. Lower Delaware and Middle Delaware River fecal coliform bacteria, dissolved oxygen, ammonia, pH, and TSS concentrations are similar. Nitrate, TKN, and Total Phosphorus concentrations are much higher in the Lower Delaware. Lower Delaware Nitrate concentrations are 5 times, TKN concentrations are twice, and Total Phosphorus concentrations are 3 times that of the Middle Delaware.

Such comparison may be unfair due to natural longitudinal water quality changes, as stated earlier. However, the results indicate that the Lower Delaware may be at risk of eutrophication due to excess nutrient inputs. Nutrient levels do not render the Lower Delaware unsuitable for its uses, but unknown at this time is what effect increased nutrient levels produce in the Delaware River. Nutrient dynamics must be investigated in the river system, and nutrient criteria must be established. Meanwhile, protection of water quality at existing levels through Special Protection Waters status is recommended.

Wastewater and Stormwater Represented in Existing Water Quality

Appendix E contains an inventory of municipal, institutional, and industrial wastewater dischargers of over 100,000 gallons per day to streams in the Lower Delaware watershed. The wastewater from these facilities is included in the definition of existing water quality, and these facilities as permitted would not be subject to additional treatment requirements set forth in DRBC's water quality rules for Special Protection Waters. Only new and expanded discharge facilities would be subject to such rules. In terms of average monthly wastewater effluent flow during the 2000-2003 study period, Pennsylvania dischargers operated at 71% of their overall permitted flow, and New Jersey dischargers operated at 66% of their overall capacity.

Existing water quality might or might not measurably change if all of the permitted dischargers increase their effluent rate to 100% of their capacity. As defined during the 2000-2003 study period, existing water quality reflects a very broad range of discharge situations from extreme low flow conditions to relatively high flow conditions, when most dischargers operated at far beyond normal flow rates. Thus the statistical definition of existing water quality includes such cases of high flow events. Under such conditions the dischargers achieved their permitted water quality limits without permit violations or severe increases in the rate of pollutant loading to the Delaware River. A few treatment facilities continue to experience infiltration and inflow (I and I) problems related to storm events, which forces the facility to treat stormwater in addition to sanitary sewage flow. Maintenance of I and I is an excellent step toward ensuring that existing water quality is maintained or improved.

Of much more concern is non-point source water pollution, or that caused by stormwater runoff. The increase in non-point source pollution associated with future growth and development is very likely to measurably change existing water quality if it increases unmanaged. It is expected, however, that existing water quality will continue to improve even as the wastewater treatment facilities grow toward their full capacity. New stormwater rules and policies are taking effect in New Jersey and Pennsylvania, efforts to improve riparian buffer zones continue to grow and evolve, residential and business stormwater management practices are improving, and education of municipal officials and the general public on stormwater issues is becoming more widespread. These powerful tools improve water quality and allow for growth and development.

To ensure that existing water quality is maintained or improved, the control point monitoring approach should be used to document cumulative effects of combined point source and non-point source water management. The water quality targets at Boundary Control Points must not be exceeded, or water quality of the Delaware River will degrade. The targets may also be used as a reference to quantify trends and improvements in water quality resulting from combined efforts to manage dischargers and non-point source pollution in each watershed.

Existing Water Quality vs. Standards – Site-Specific Summary Analyses

Table 5 summarizes EWQ status versus standards. Each small cell in the matrix represents a water quality comparison to the most stringent criteria or guidelines available. 14 chemical parameters were statistically compared to standards for 9 river and 15 tributary sites. Three biological metrics were calculated using the 2001 Delaware River macroinvertebrate data set and examined versus the most stringent available targets. No criteria exist for 10 of the 24 Lower Delaware parameters.

Delaware River results indicate that existing water quality is generally better than criteria levels, with the exception of enterococcus bacteria. Of 153 possible comparisons (9 sites, 14 chemical parameters and 3 biological metrics), 94% showed that EWQ is better than or meets criteria. EWQ based targets can provide additional protection of existing water quality for most sites and parameters.

A few parameters exceeded criteria due to natural conditions. Total phosphorus concentrations exceeded

Table 5. Lower Delaware River Existing Water Quality Versus Standards.

EWQ Better	EWQ is better than criteria
EWQ Better Except for High Flow	EWQ is better than criteria except during high flow events (E. coli, Fecal coliform bacteria)
Criteria exceeded by natural conditions	EWQ is evidenced to be naturally higher than criteria (TDS, pH)
TP criterion exceeded but use not limited	EWQ higher than NJ 0.1 criterion, but suitable for designated uses (Total Phosphorus)
EWQ Exceeds Criteria	EWQ Exceeds Criteria for >10% of Samples
Not Assessed	Not Assessed

Parameter	Del @ Portland	Del @ Belvidere	Del @ Easton	Del @ Riegelsville	Del @ Milford	Del @ Bulls Island	Del @ Lambertville	Del @ Washington Xing	Del @ Trenton	Most Stringent Criterion
Bio - EPT (N=1)	EWQ Better	EWQ Better	EWQ Better	EWQ Better	EWQ Better	EWQ Better	EWQ Better	EWQ Better	EWQ Better	UPDE EWQ
Bio - HBI (N=1)	EWQ Better	EWQ Better	EWQ Better	EWQ Better	EWQ Better	EWQ Better	EWQ Better	EWQ Better	EWQ Better	NJ 4.0
Bio - Diversity (N=1)	EWQ Better	EWQ Better	EWQ Better	EWQ Better	EWQ Better	EWQ Better	EWQ Better	EWQ Better	EWQ Better	UPDE EWQ
Dissolved Oxygen	EWQ Better	EWQ Better	EWQ Better	EWQ Better	EWQ Better	EWQ Better	EWQ Better	EWQ Better	EWQ Better	5 (all)
pH	EWQ Better	EWQ Better	EWQ Better	EWQ Better	EWQ Better	Criteria exceeded by natural conditions	EWQ Better	EWQ Better	Criteria exceeded by natural conditions	6.5-8.5 (NJ)
Water Temperature F	EWQ Better	EWQ Better	EWQ Better	EWQ Better	EWQ Better	EWQ Better	EWQ Better	EWQ Better	EWQ Better	Seasonal (PA)
Turbidity	EWQ Better	EWQ Better	EWQ Better	EWQ Better	EWQ Better	EWQ Better	EWQ Better	EWQ Better	EWQ Better	15 (NJ)
CaCO3 Alkalinity	EWQ Better	EWQ Better	EWQ Better	EWQ Better	EWQ Better	EWQ Better	EWQ Better	EWQ Better	EWQ Better	Min 20 (PA)
Chloride	EWQ Better	EWQ Better	EWQ Better	EWQ Better	EWQ Better	EWQ Better	EWQ Better	EWQ Better	EWQ Better	250 (all)
Nitrate NO3-N	EWQ Better	EWQ Better	EWQ Better	EWQ Better	EWQ Better	EWQ Better	EWQ Better	EWQ Better	EWQ Better	10 (PA,NJ)
Ammonia NH3-N	EWQ Better	EWQ Better	EWQ Better	EWQ Better	EWQ Better	EWQ Better	EWQ Better	EWQ Better	EWQ Better	Formula (PA,NJ)
Total Phosphorus	EWQ Better	EWQ Better	TP criterion exceeded but use not limited	TP criterion exceeded but use not limited	TP criterion exceeded but use not limited	TP criterion exceeded but use not limited	TP criterion exceeded but use not limited	TP criterion exceeded but use not limited	TP criterion exceeded but use not limited	0.1 (NJ)
Total Dissolved Solids	Criteria exceeded by natural conditions	Criteria exceeded by natural conditions	Criteria exceeded by natural conditions	EWQ Better	EWQ Better	EWQ Better	EWQ Better	EWQ Better	EWQ Better	120/256 (DRBC)
Total Suspended Solids	EWQ Better	EWQ Better	EWQ Better	EWQ Better	EWQ Better	EWQ Better	EWQ Better	EWQ Better	EWQ Better	40 (NJ)
E. coli geometric mean	EWQ Better Except for High Flow	EWQ Better Except for High Flow	EWQ Better Except for High Flow	EWQ Better Except for High Flow	EWQ Better Except for High Flow	EWQ Better Except for High Flow	EWQ Better Except for High Flow	EWQ Better Except for High Flow	EWQ Better Except for High Flow	126 (EPA)
Fecal Coliform geometric mean	EWQ Better Except for High Flow	EWQ Better Except for High Flow	EWQ Better Except for High Flow	EWQ Better Except for High Flow	EWQ Better Except for High Flow	EWQ Better Except for High Flow	EWQ Better Except for High Flow	EWQ Better Except for High Flow	EWQ Better Except for High Flow	200,400 (all)
Enterococcus geometric mean	EWQ Exceeds Criteria	EWQ Exceeds Criteria	EWQ Exceeds Criteria	EWQ Exceeds Criteria	EWQ Exceeds Criteria	EWQ Exceeds Criteria	EWQ Exceeds Criteria	EWQ Exceeds Criteria	EWQ Exceeds Criteria	33,61 (NJ)
Biocriteria	**NO STANDARD**									None
CaCO3 Hardness	**NO STANDARD**									None
Chlorophyll A mg/m3	**NO STANDARD**									None
Dissolved Oxygen % Saturation	**NO STANDARD**									None
Orthophosphate PO4-P	**NO STANDARD**			**EWQ definition would create targets for parameters without standards**						None
Phytoplankton Biomass mg/m3	**NO STANDARD**									None
Specific Conductance umhos/cm	**NO STANDARD**									None
Total Nitrogen : Total Phosphorus ratio	**NO STANDARD**									None
Total Kjeldahl Nitrogen	**NO STANDARD**									None
Total Nitrogen	**NO STANDARD**									None

New Jersey's 0.1 mg/l criterion at several Delaware River locations, but did not render the Delaware River unsuitable for designated uses according to NJDEP guidance on interpretation of the total phosphorus standard (NJDEP 2003). More than 10% of total dissolved solids concentrations exceeded the DRBC stream quality objective at 3 Delaware River locations, but this was determined to be the result of limestone influences at low flow and thus a natural condition. More than 10% of pH samples exceeded the DRBC stream quality objective at 2 Delaware River locations due to natural plant activity during extended periods of low flow. Fecal coliform and E. coli concentrations exceeded criteria during high flow events, but geometric mean concentrations were well below criteria levels at all Delaware River locations.

Enterococcus bacteria counts (**Figure 8**) exceeded New Jersey's freshwater criterion of 33 colonies per 100 ml at every river and tributary site. Only the Delaware River sites had enterococcus counts of less than 100 colonies per 100 ml. Geometric mean counts ranged from 37 at Calhoun Street Bridge to 174 at Easton. If enterococcus criteria existed for Delaware River Zones 1D-1E, they would be used to determine the Delaware River's suitability for primary contact recreational use. At the recommended criteria levels, the Lower Delaware and all of its tributaries would not be suitable for such use. Low flow samples exceeded criteria nearly as frequently as high flow samples.

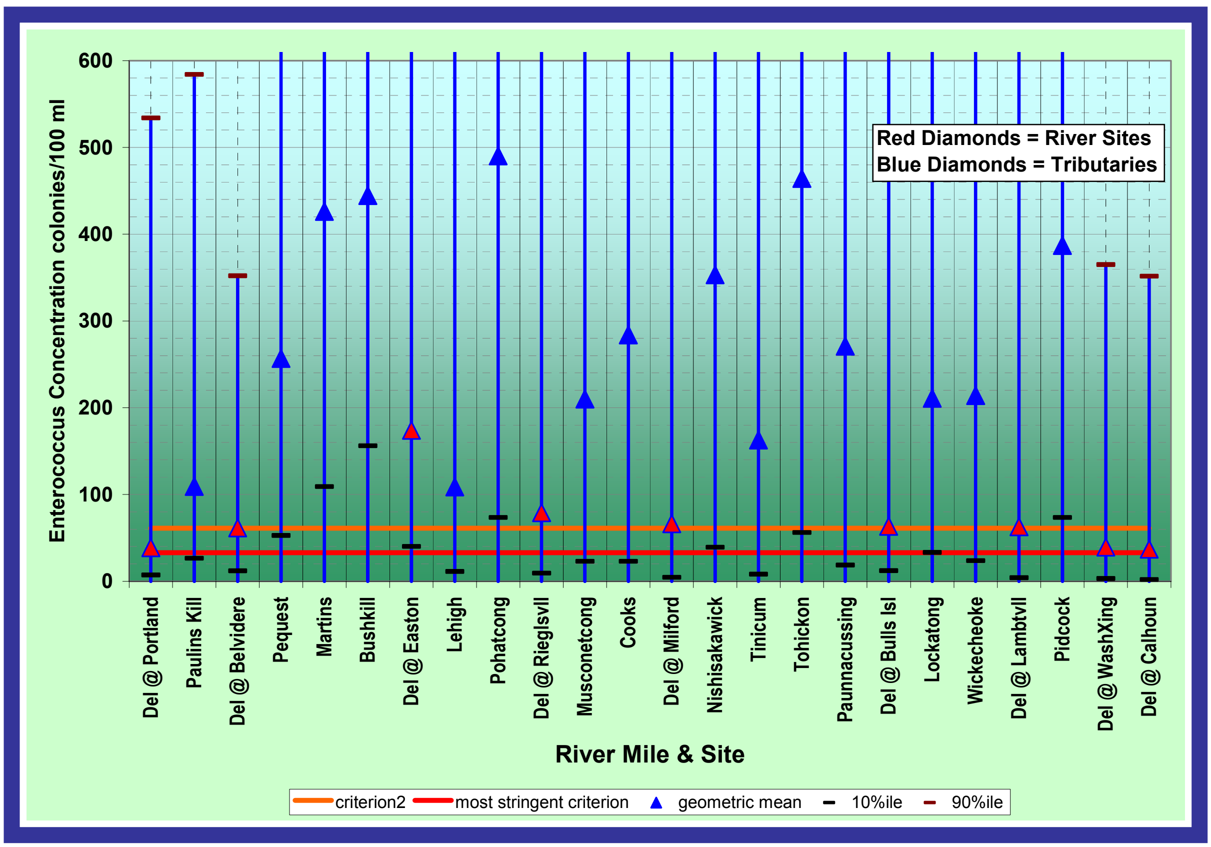


Figure 8. Enterococcus Geometric Mean Concentrations in the Lower Delaware River and its Tributaries. Blue lines extending above 600 colonies per 100 ml indicate that the 90th percentile of these bacteria counts are higher than the range of this display. The most stringent criterion is New Jersey's 33/100ml geometric mean and single sample maximum of 61/100ml.

Figure 9 shows median Total Phosphorus concentrations in the Lower Delaware and its tributaries. In the Delaware River, TP concentrations remain low (around 0.05 mg/l) until the Lehigh River confluence. Not only were the highest TP concentrations found in the Lehigh, but also the Lehigh is the second largest tributary to the Delaware River. The Total Phosphorus load entering the Delaware River from the Lehigh

River is enormous. From this point down to Trenton, Delaware River TP concentrations remain above the most stringent criterion level of 0.1 mg/l established by New Jersey DEP. At present, no Total Phosphorus criteria exist in DRBC or PADEP rules for this zone of the river. **Figure 9** also shows that the 0.1 mg/l TP criterion is exceeded in more than 10% of samples taken from the following additional tributaries: Pequest, Martins, Pohatcong, Musconetcong, Nishisakawick, Paunnacussing, Lockatong, Wickecheoke, and Pidcock. In all of these streams, median concentrations were significantly higher than that of the neighboring Delaware River sites (p=0.05). Since no criteria exist other than in New Jersey, an appropriate management decision would be to use EWQ and Special Protection Waters rules to restore water quality to levels below 0.1 mg/l. This would require significant phosphorus load reductions from intrastate waters.

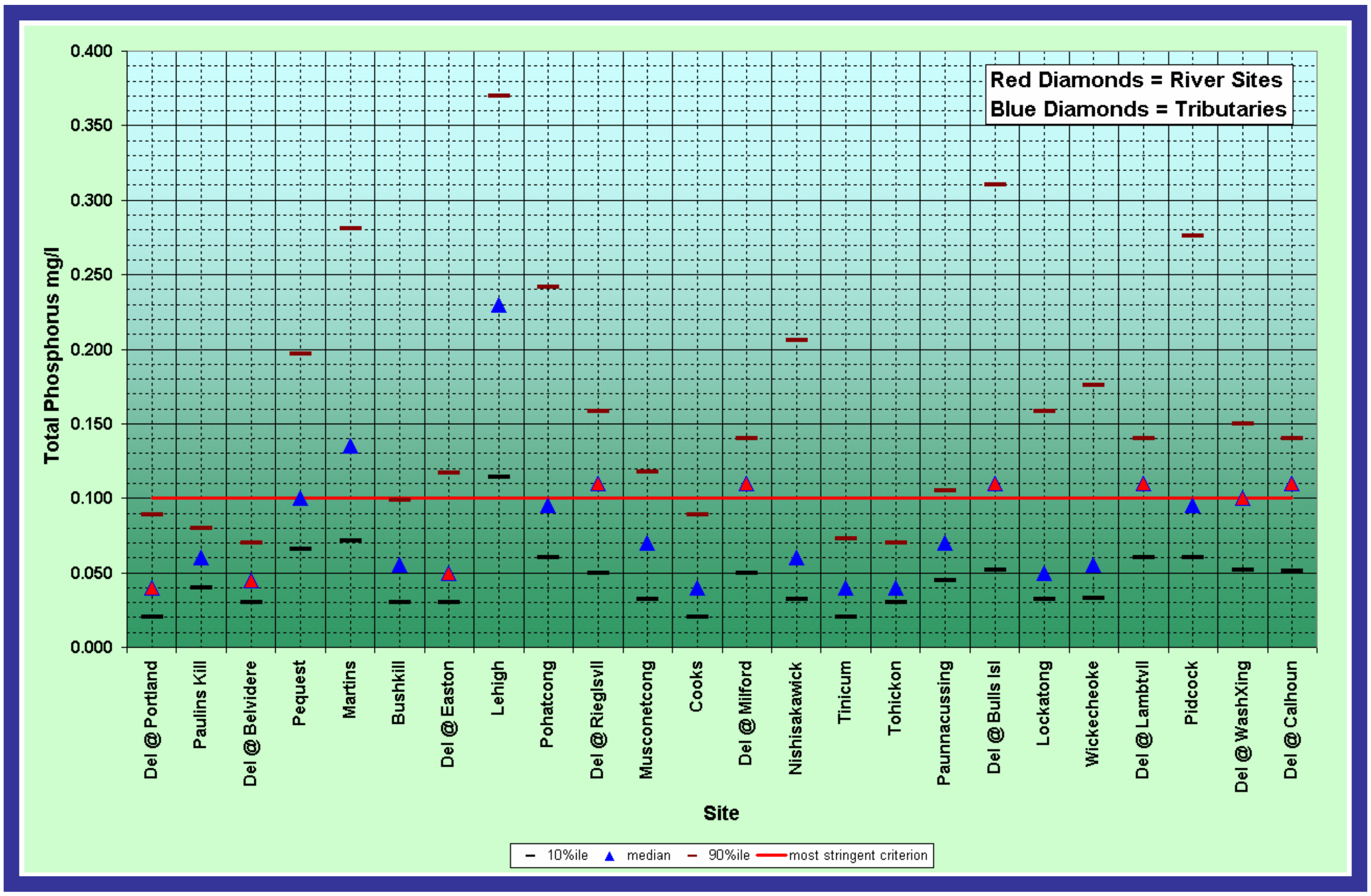


Figure 9. Total Phosphorus concentrations in the Lower Delaware River and tributaries. The most stringent criterion is New Jersey's 0.1 mg/l limit. The Lehigh River significantly increases TP concentrations in the Lower

A third water quality problem in the Lower Delaware River and its tributaries is E. coli bacteria pollution. Figure 10 shows geometric mean concentrations, 10^{th} and 90^{th} percentiles, and the federal guideline geometric mean level of 126 colonies per 100 ml. No E. coli criteria exist in DRBC, Pennsylvania or New Jersey rules at present. However, criteria development is being considered since the U.S. EPA recommended that E. coli and enterococcus criteria are better indicators than fecal coliforms of water quality suitability for primary contact recreation. Geometric mean values in the Delaware River are better than the guideline threshold at all sites. However, more than 10% of samples exceed the guideline at every site, a violation frequency that may indicate a problem. **Table 6** shows that Delaware

River guideline violations can be explained by high flow events. E. coli criteria should be developed for the Lower Delaware. Swimmers should be advised of E. coli risks during high flow events.

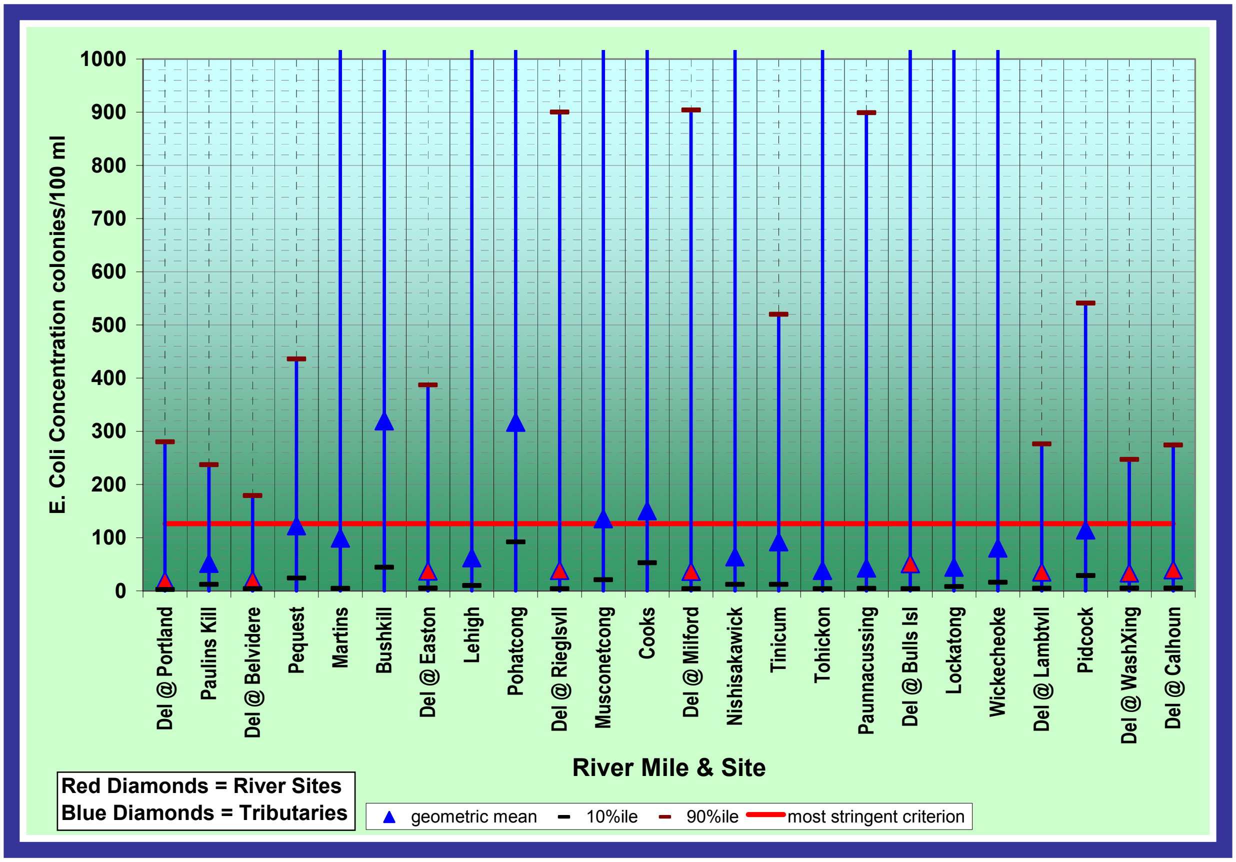


Figure 10. E. coli geometric mean concentrations in the Lower Delaware River and Tributaries. Also displayed are 10th and 90th percentiles and the red line is a recommended federal guideline geometric

Table 6. Median E. coli concentrations by flow percentile.

Flow Percentile	N	Median E. coli	10th %ile	to	90th%ile
<10th	32	12	4	to	47
10th to 25th	50	16	4	to	79
25th to 50th	53	20	3	to	243
50th to 75th	66	24	5	to	280
75th to 90th	45	50	12	to	2,000
>90th	24	200	54	to	920

The fourth potential Lower Delaware water quality problem is fecal coliform bacteria pollution **(Figure 11)**. DRBC and state criteria set a 30-day geometric mean concentration of 200 colonies per 100 ml. The required sampling frequency of 5 samples per 30-day period was not practiced by DRBC. The geometric mean of LDMP data represents 10 samples per May-September period, known as a summer seasonal geometric mean. Water quality rules also state that no more than 10% of samples may exceed a maximum concentration of 400 colonies per 100 ml. **Figure 11** shows that all Delaware River geometric mean values were much better than the criterion. Tributaries worse than the 200/100ml criterion were Martins;

Bushkill; Pohatcong; Musconetcong; Cooks; Tinicum; and Pidcock. Evaluation of the frequency of violations of the 400/100ml criterion revealed that all sites except for the Delaware River at Belvidere, Lambertville, and Washington's Crossing exceeded the criterion for more than 10% of samples. Most violations occurred during high flow events **(Table 7)**.

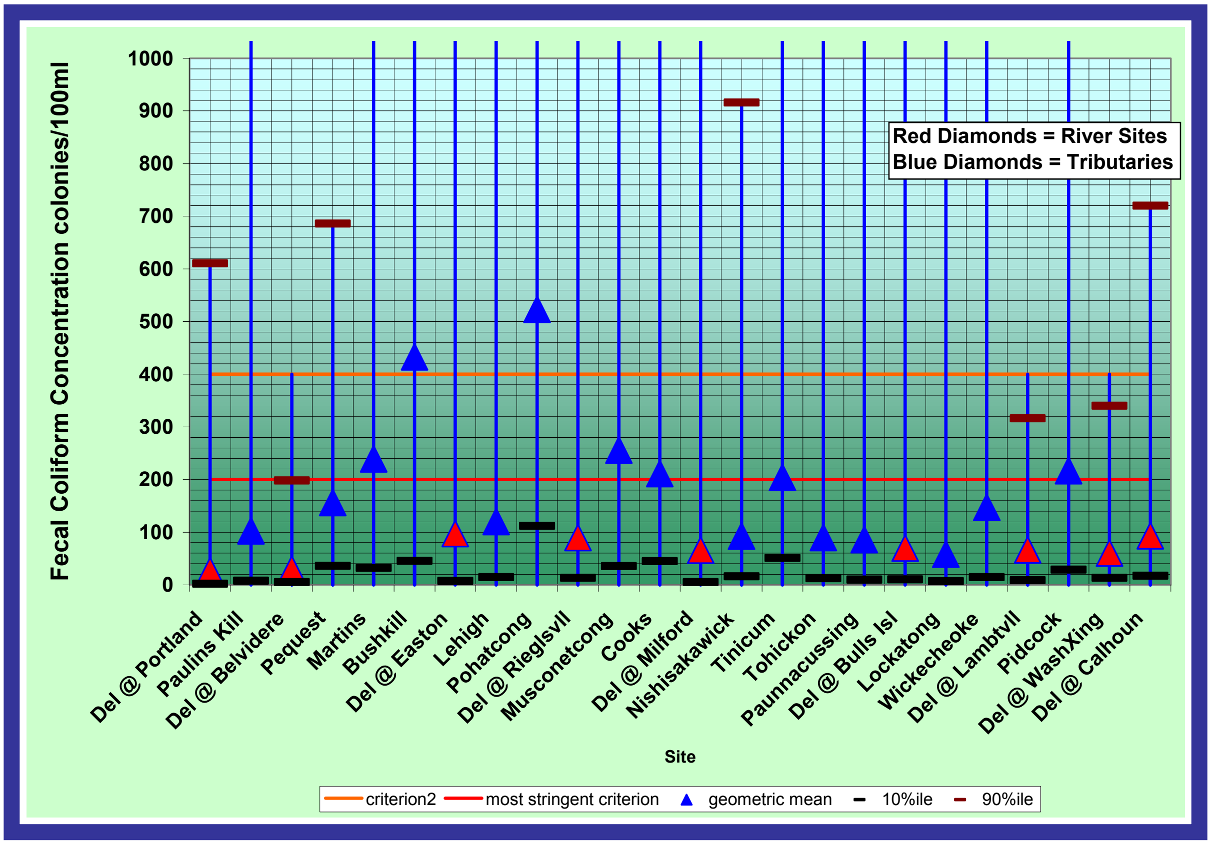


Figure 11. Fecal coliform geometric mean concentrations in the Lower Delaware River and Tributaries. Also displayed are 10th and 90th percentiles. The red and orange lines are DRBC criteria levels of 200 colonies per 100 ml 30-day geometric mean, and 400 colonies per 100 ml single sample maximum.

Table 7. Lower Delaware River Fecal Coliform Median Concentrations by Flow Percentile.

Flow Percentile	N	Median Fecal Coliform	10^{th}%ile	to	90^{th}%ile
<10th	32	18	5	to	111
10^{th} to 25^{th}	55	50	5	to	130
25^{th} to 50^{th}	80	50	5	to	820
50^{th} to 75^{th}	66	52	16	to	461
75^{th} to 90^{th}	52	80	20	to	3,070
>90th	24	190	57	to	1,450

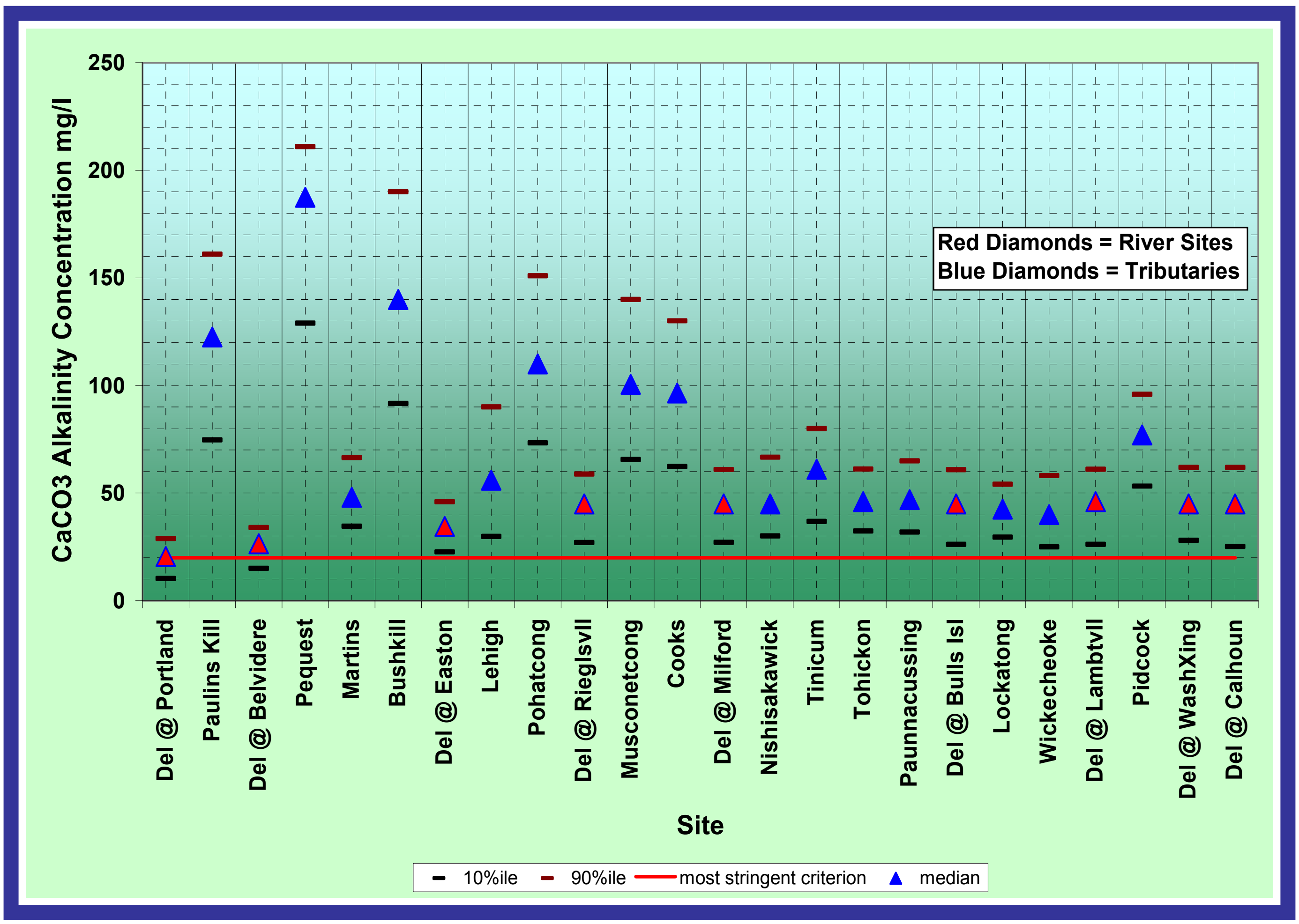
Existing Water Quality vs. Standards – Longitudinal Plots

The next several pages show longitudinal water quality plots of the Lower Delaware River and tributaries. Plots of parameters (alphabetically ordered) for which criteria have been established are shown in this section, and **Appendix B** contains similar representations of water quality constituents for which no criteria are established. EWQ targets should be created for all parameters.

Longitudinal plots show median concentrations; 10th and 90th percentiles of the data; and the most stringent criterion chosen from DRBC, Pennsylvania, or New Jersey standards. Tributary BCP's were statistically compared with upstream and downstream Delaware River ICP sites (**Appendix C**).

<u>Alkalinity as CaCO3</u>

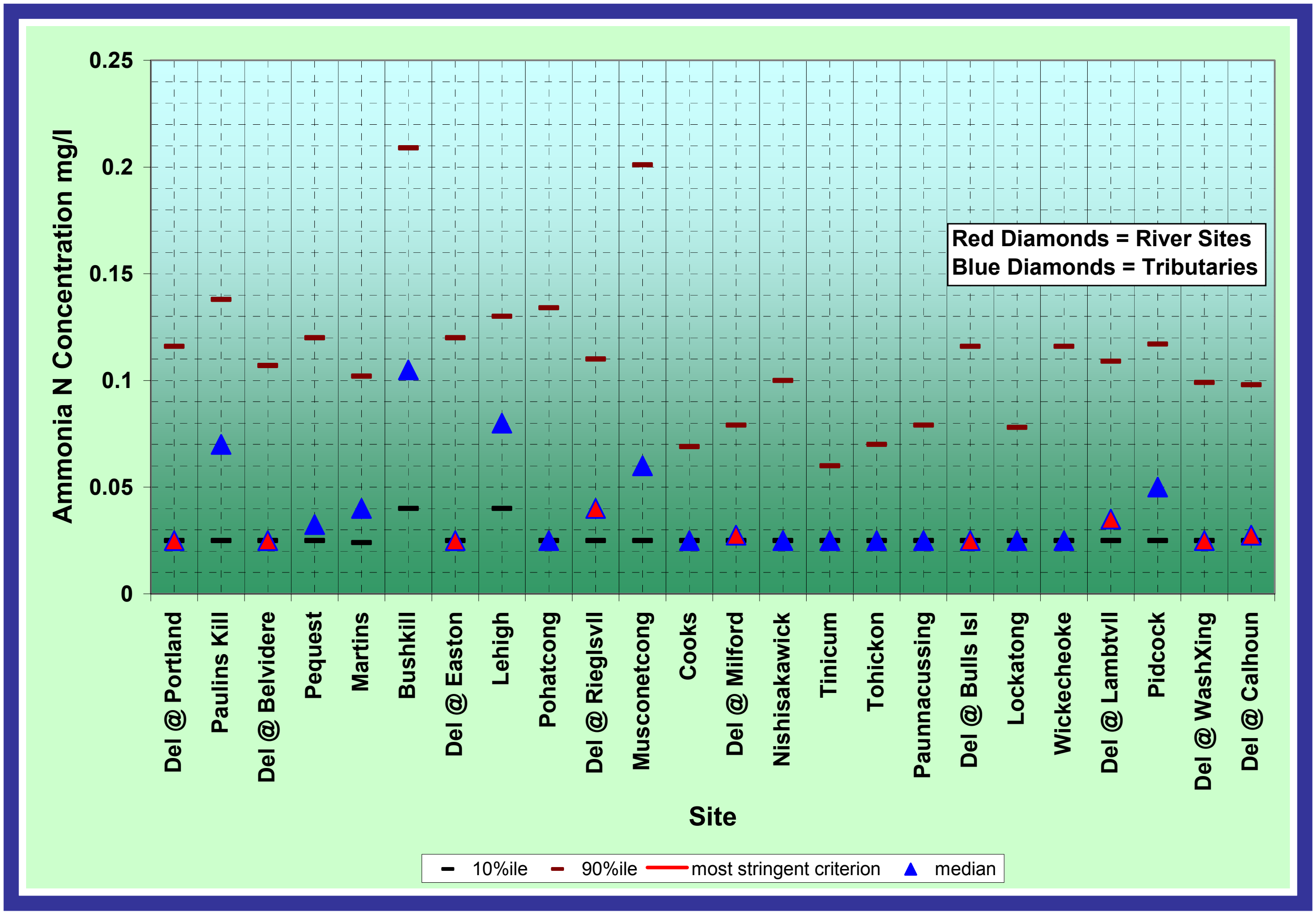
Figure 12. Lower Delaware Alkalinity vs. Standards.



The most striking pattern observed in **Figure 12** is that displayed by alkalinity concentrations of limestone streams. All tributaries in the northern part of the Lower Delaware contribute significant alkalinity to the Delaware River. Portland and Belvidere retain the low alkalinity characteristic of the Middle Delaware. All Delaware River sites downstream are significantly higher in alkalinity (p=.05).

Ammonia (Un-Ionized NH3-N)

Figure 13. Lower Delaware Ammonia Concentrations, Longitudinal Plot.

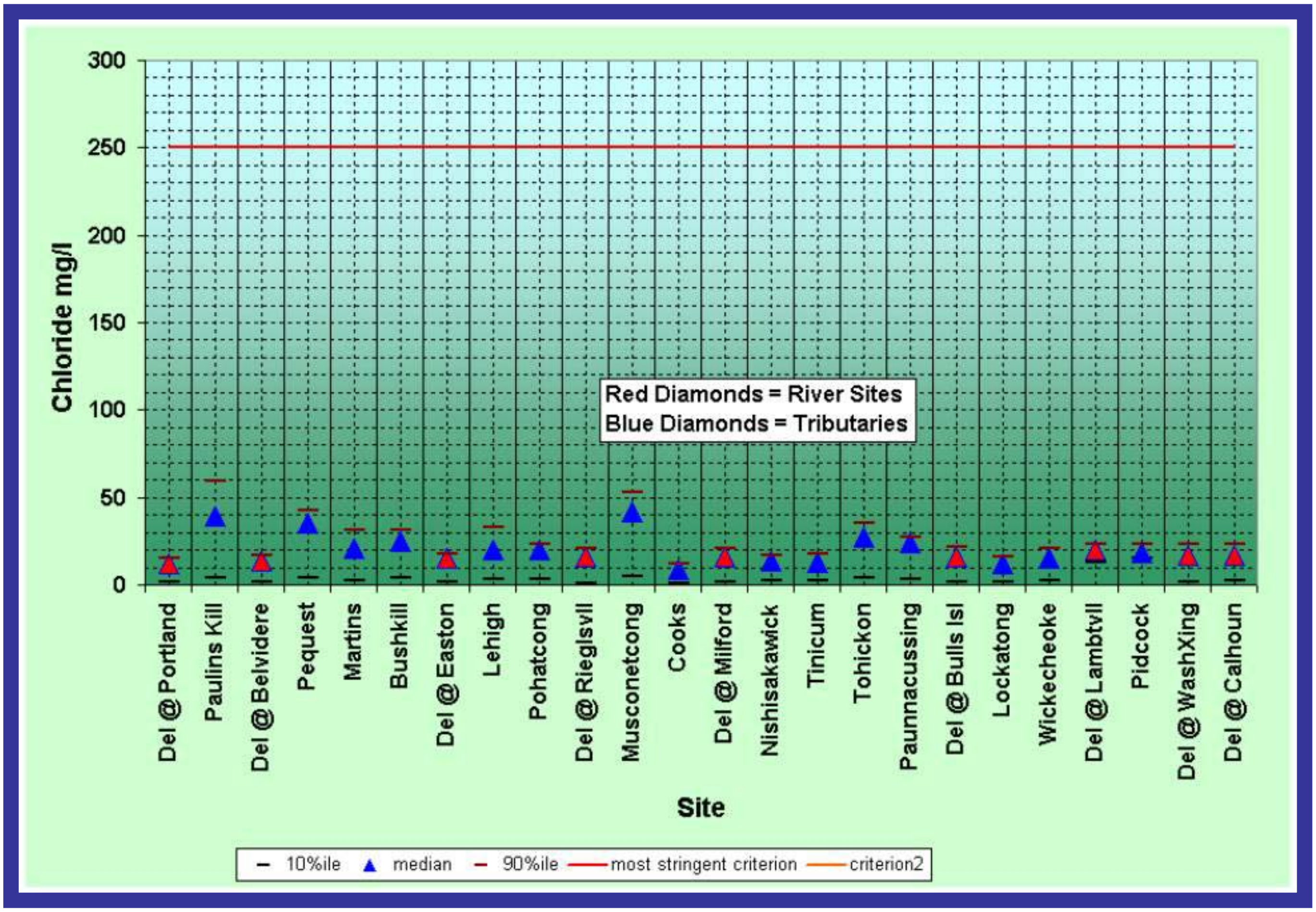


Un-ionized Ammonia (NH3-N) concentrations were compared with State criteria, which are complex formulae (see Pennsylvania and New Jersey water quality standards) that are difficult to display graphically. As calculated from this data set, ammonia criteria levels ranged from 0.001 mg/l to 4.697 mg/l. Each data value was compared to this temperature and pH dependent criterion, and the difference between the criterion level and the observed level was calculated. In the entire data set (n=713), only 5 instantaneous values exceeded criteria (a rate of 0.7%). The median departure of observed values versus criteria was (–0.718 mg/l), and the 97.5th percentile of departure was (–0.164 mg/l). This indicates that ammonia EWQ (which ranges from 0.02 mg/l to 0.42 mg/l) is much better than criteria.

Creation and use of EWQ Ammonia targets is recommended. In addition to target levels, a baseline should also be set for minimum number of non-detect values per site (MDL was 0.05 mg/l). There were a large number of non-detect values in the water quality data, which caused the pattern seen in **Figure 13** above, where median values nearly equal ½ of the MDL for many sites.

Chloride Concentration

Figure 14. Lower Delaware Chloride Concentrations, Longitudinal Plot.



When plotted against the 250 mg/l human health criterion, chloride concentrations in the Lower Delaware River and its tributaries appear miniscule **(Figure 14)**. Establishment of EWQ targets would provide an additional level of protection to ambient water quality for this parameter.

Dissolved Oxygen

Figure 15. Lower Delaware Dissolved Oxygen Concentrations, Longitudinal Plot.

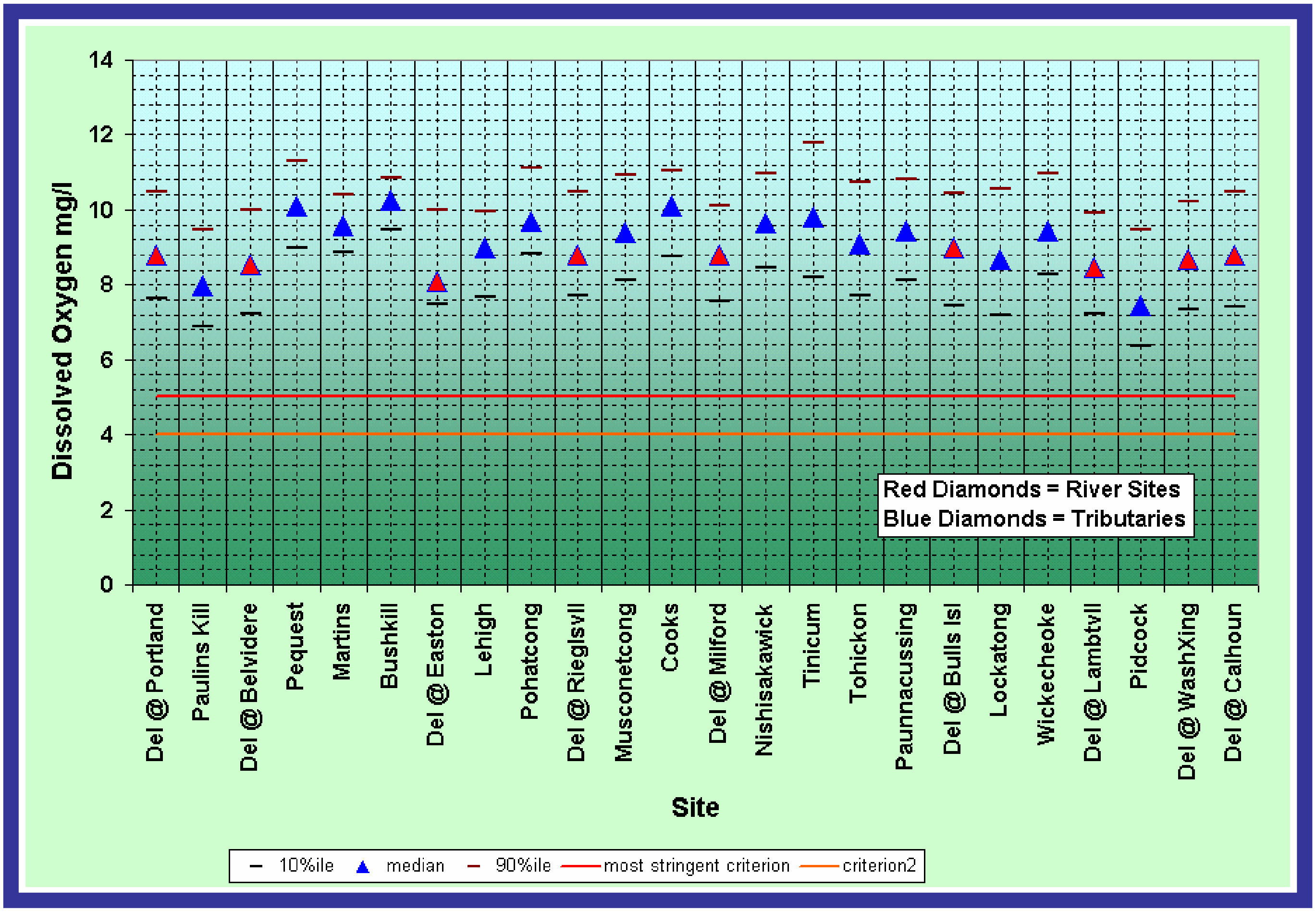


Figure 15 displays median dissolved oxygen concentrations in the Lower Delaware River and its tributaries. Most of these samples were taken near mid-day, so these concentrations approximate maximum daytime values. These results indicate existing water quality is far better than criteria. To verify these findings using data taken around the clock, **Figure 16** displays continuous results taken from the U.S. Geological Survey monitor on the Delaware River at Point Pleasant, PA.

Dissolved Oxygen – Continuous Monitor at Point Pleasant, PA

Figure 16. Point Pleasant Dissolved Oxygen Concentrations 2000-2003.

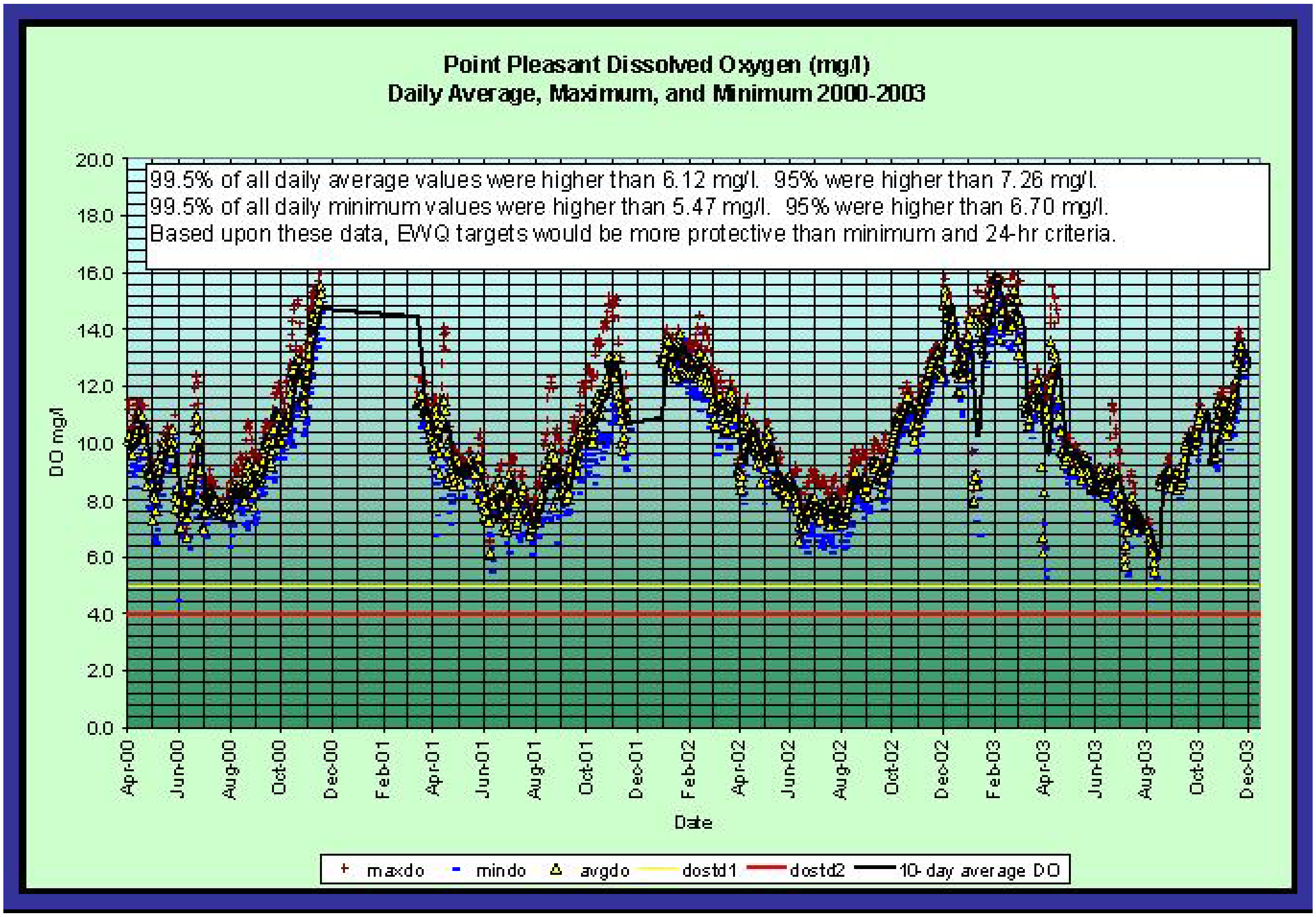


Figure 16 shows that EWQ is much better than criteria, verifying the mid-day instantaneous sample results taken by the LDMP. Even nighttime minimum dissolved oxygen during a severe drought very rarely fell below 5.5 mg/l. The daily range of dissolved oxygen change (daytime average DO versus nighttime average DO) was tested to determine whether elevated total phosphorus concentrations produced an undesirable effect upon aquatic plant activity. According to NJDEP guidance for interpretation of the phosphorus rule, a daily swing of more than 3.0 mg/l is one of the factors considered to render the Delaware River unsuitable for designated uses. This occurred only 1% of over 1,100 days tested. Another DO test for the phosphorus rule is the frequency of days below the minimum DO criterion level. At Point Pleasant, Delaware River DO concentrations never fell below criteria levels. These results indicate that phosphorus concentrations, though elevated above the 0.1 mg/l criterion, do not produce an undesirable effect upon aquatic plant production in the Lower Delaware.

Nitrate (NO3 as N)

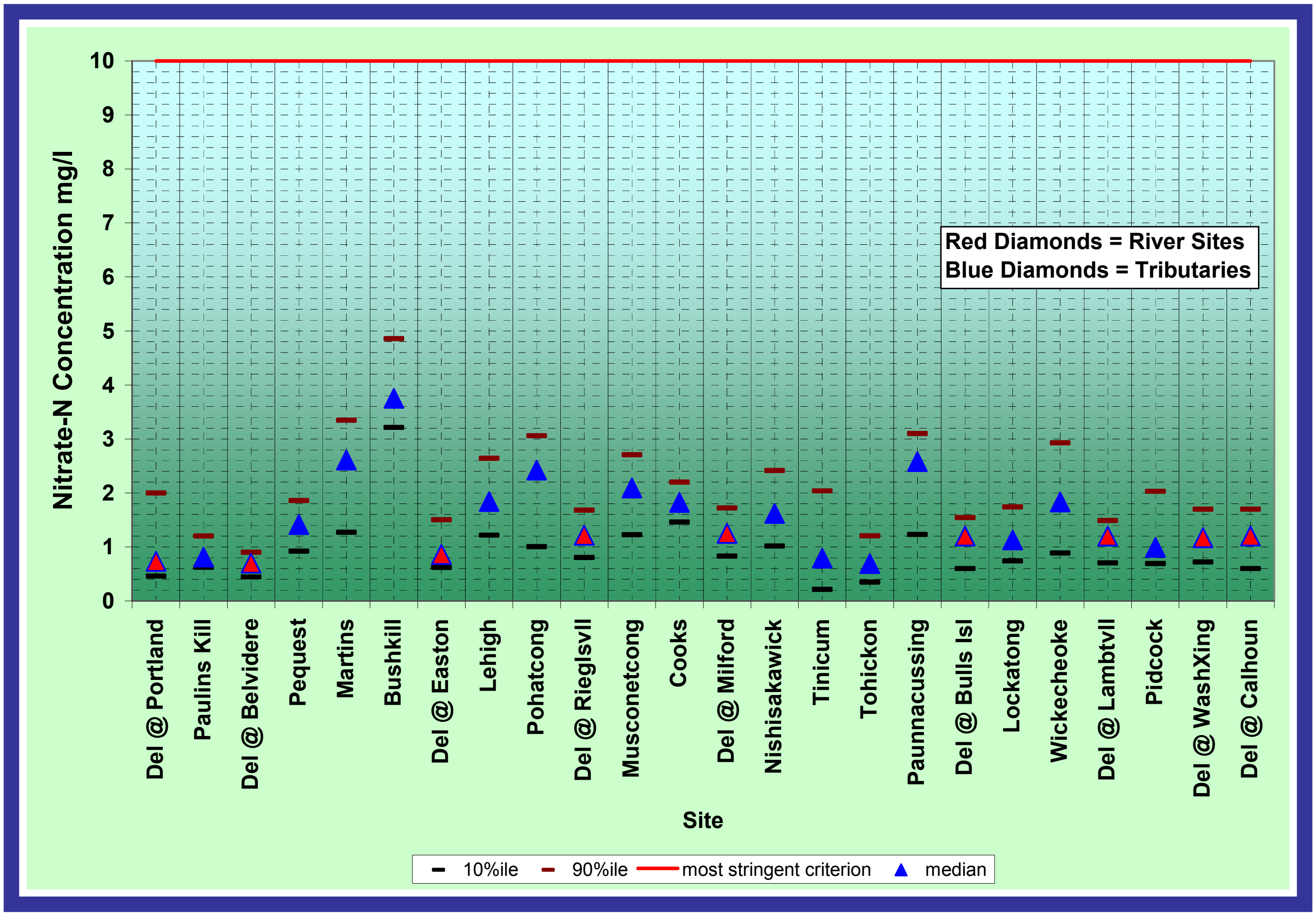


Figure 17. Lower Delaware Nitrate Concentrations, Longitudinal Plot.

There are no nitrate criteria for this reach of the Delaware River. The PA and NJ public supply criterion is 10 mg/l, a human health criterion that is far higher than EWQ (**Figure 17**). Nitrate effects upon the degree of eutrophication in the Delaware River are unknown. It is recommended that EWQ targets be established in order to prevent nutrient concentrations from rising above manageable levels.

pH

Figure 18. Median pH of the Lower Delaware River and Tributaries.

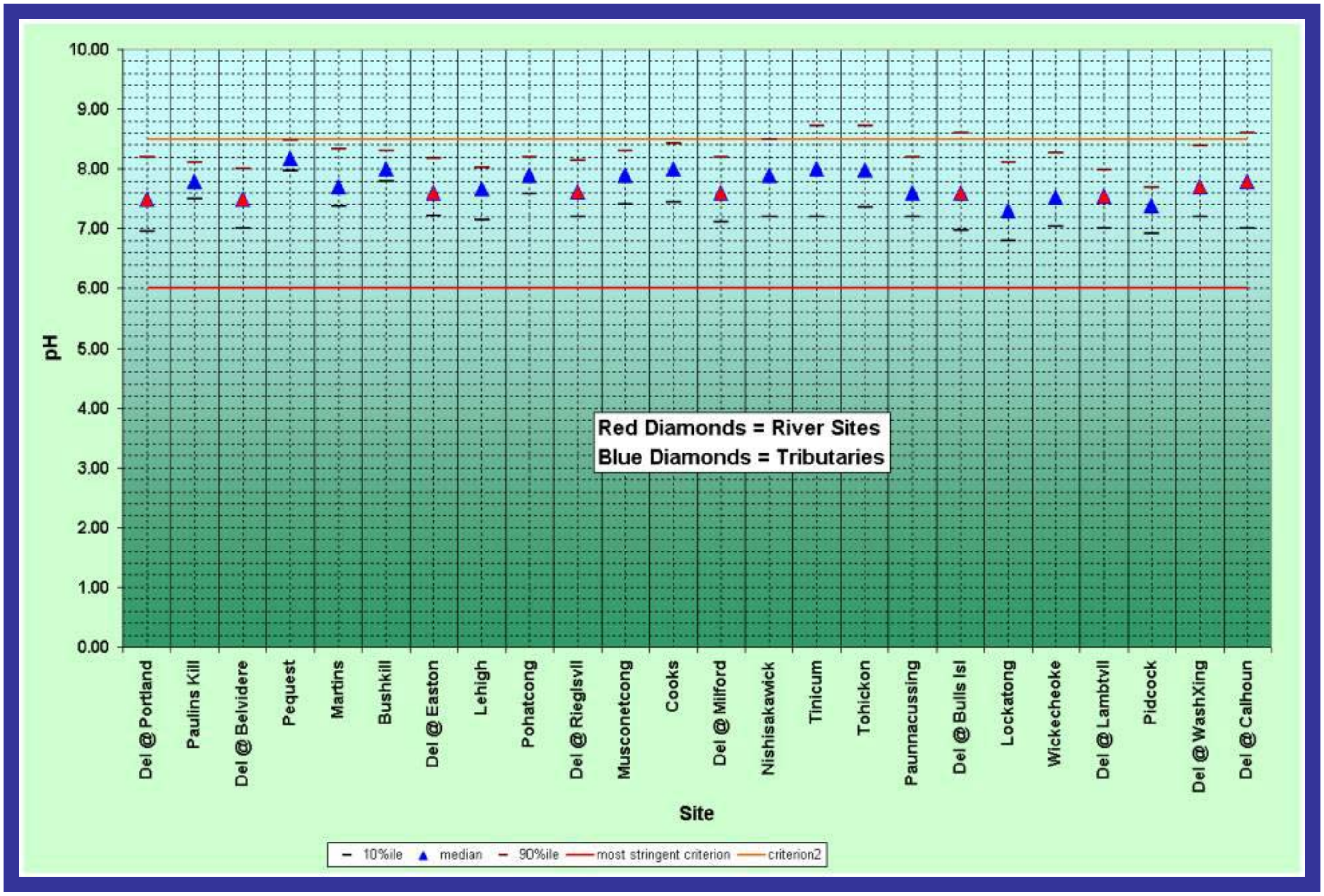
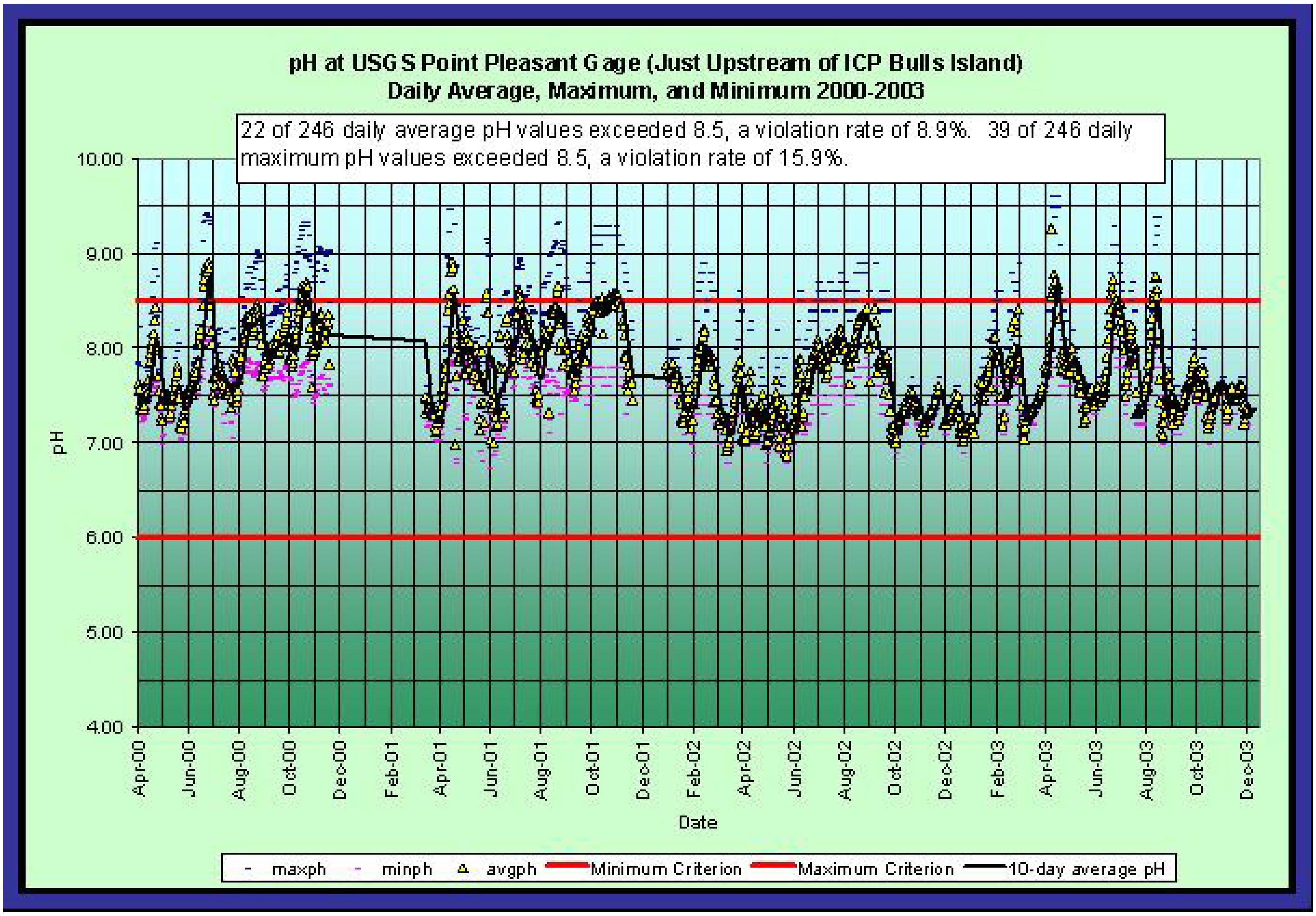


Figure 18 compares Lower Delaware pH with Stream Quality Objectives for Zones 1D-1E: 6.0-8.5 Units. About 10% of observations exceeded 8.5. These data are skewed toward daily maxima because they represent midday instantaneous measurements. pH may exceed 8.5 due to either natural conditions or nuisance aquatic plant growth. If natural conditions cause high pH, perhaps Pennsylvania's upper pH limit of 9 units better represents natural conditions in the Delaware River.

pH – Point Pleasant Continuous Monitor

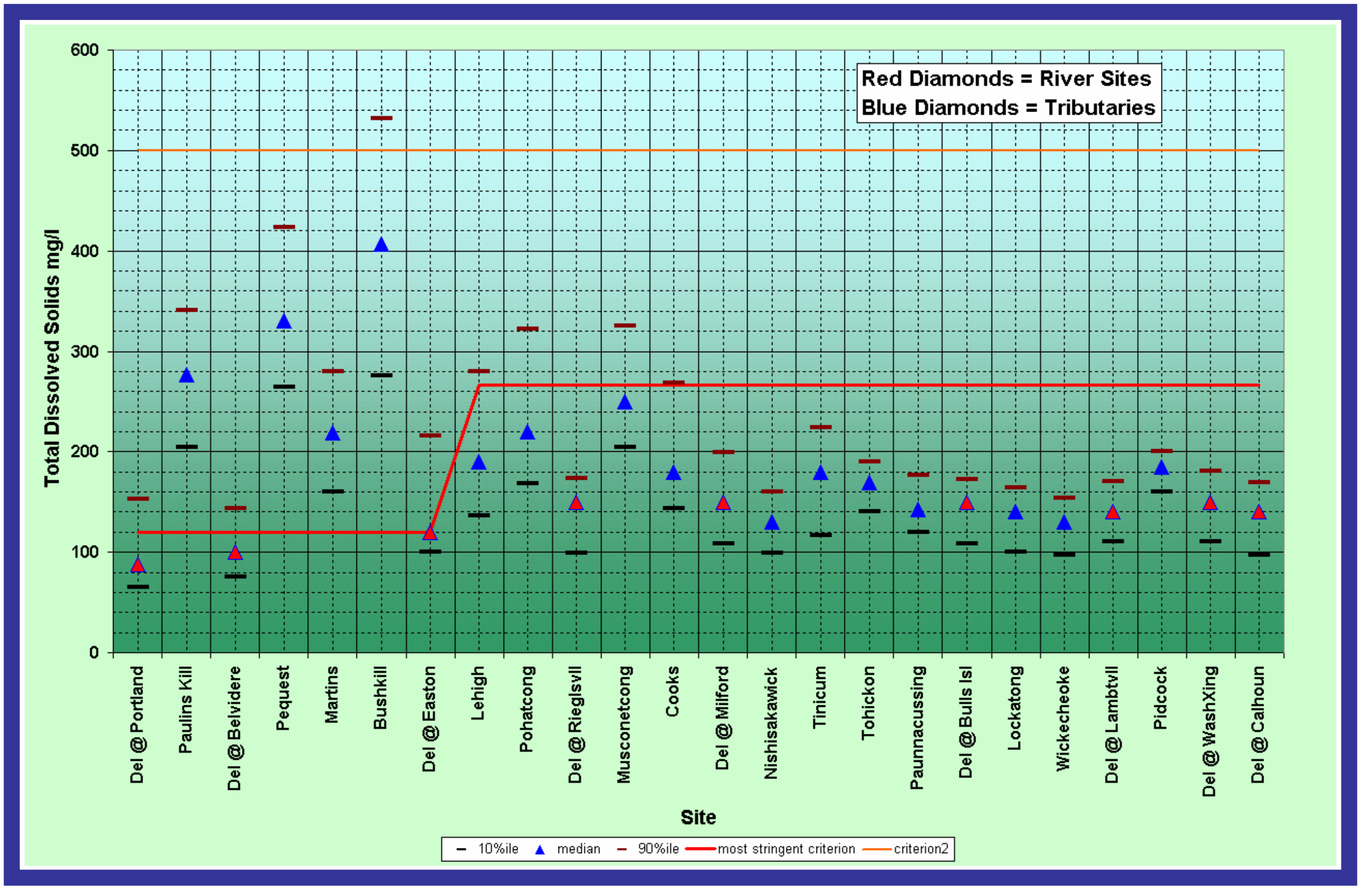
Figure 19. Daily pH at Point Pleasant Continuous Monitor, 2000-2003.



pH undergoes a daily cycle due to aquatic plant growth. Continuous data from the monitor at Point Pleasant provides information daily pH fluctuations. Figure 19 shows that 15.9% of daily maxima at Point Pleasant exceeded the DRBC criterion. By DRBC standards, pH is a problem here. Nuisance aquatic plant growth may be the cause, as large beds of Myriophyllum, Elodea, and Cladophora were observed at and upstream of this location during extended drought periods. During long low flow periods, when the river's flow is mainly supported by minimal reservoir releases, and no flood pulses are available to wash out aquatic plants, the density and coverage of rooted aquatic plants accumulates to such a degree as to accumulate fine sediments, trash, and even enable blooms of duckweed, the small floating aquatic plant normally dispersed by the river's velocity. This occurs at several locations from mid to late summer. The presence of dense mats of duckweed along the river may be an indicator of negative water quality effects of flow management policies that allow long periods of minimum flow in the river.

Total Dissolved Solids

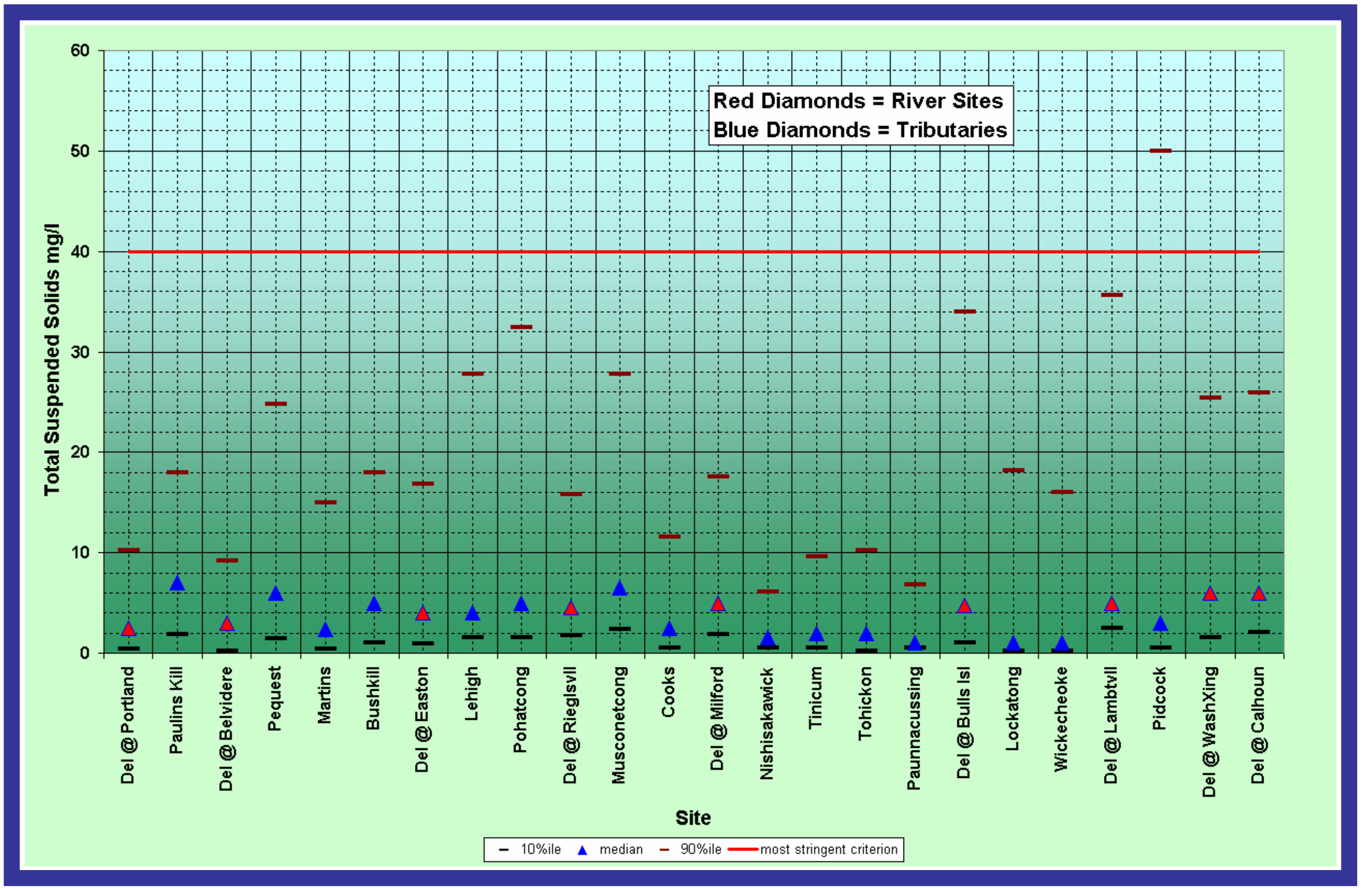
Figure 20. Total Dissolved Solids, Lower Delaware and Tributaries



More than 10% of Delaware River samples exceeded DRBC's 133% of background TDS objectives (**Figure 20**). However, this occurred only in areas of the river fed by limestone streams. It appears that the background concentration defined in the water quality regulations is not representative of natural TDS.

Total Suspended Solids

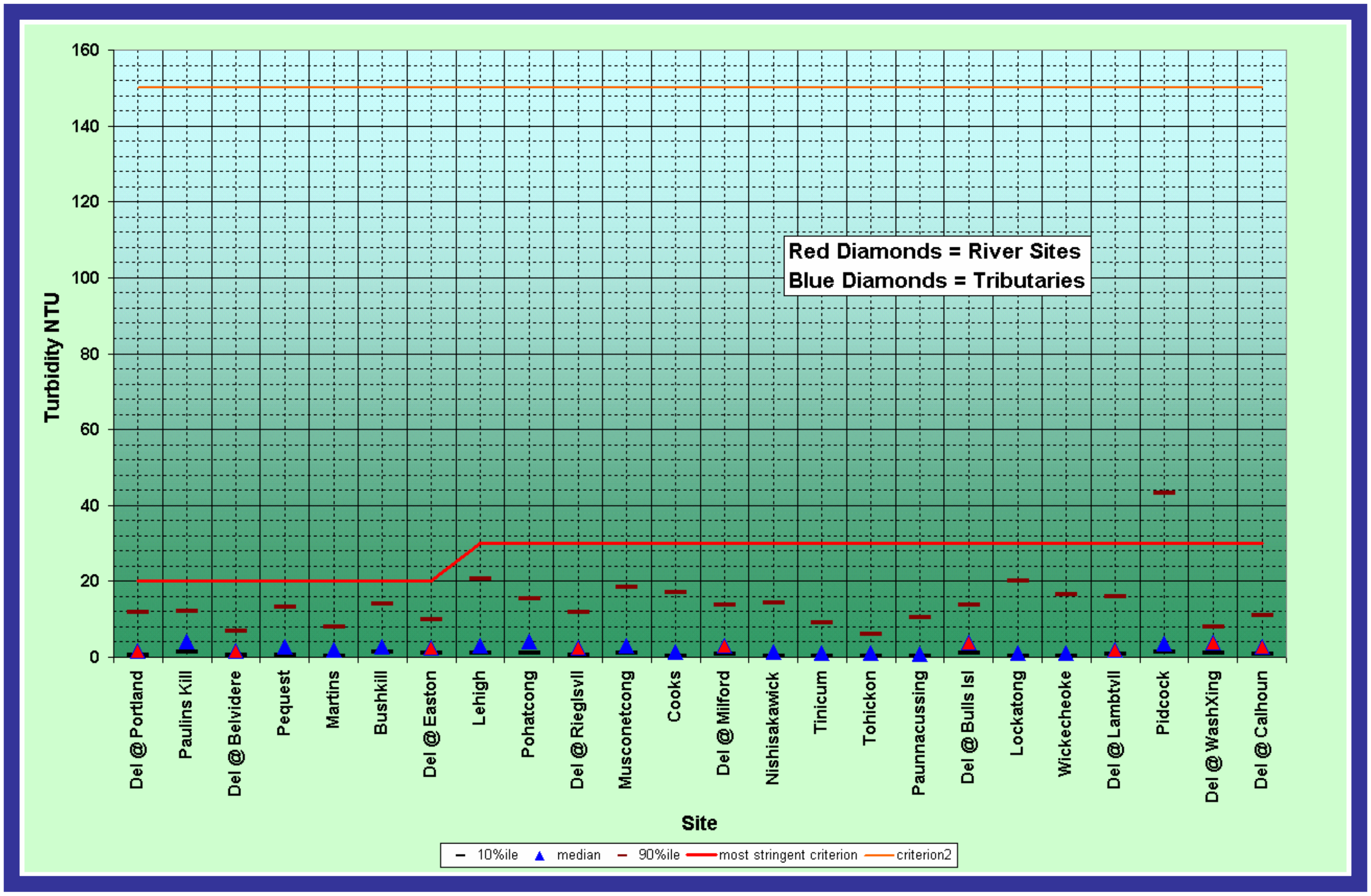
Figure 21. Total Suspended Solids, Lower Delaware and Tributaries.



Only Pidcock Creek exceeded New Jersey's most stringent criterion of 40 mg/l TSS for more than 10% of samples (**Figure 21**). At all other sites, EWQ is much better than criteria. TSS concentration is strongly associated with flow (Spearman Rank Correlation of 0.72).

Turbidity (NTU)

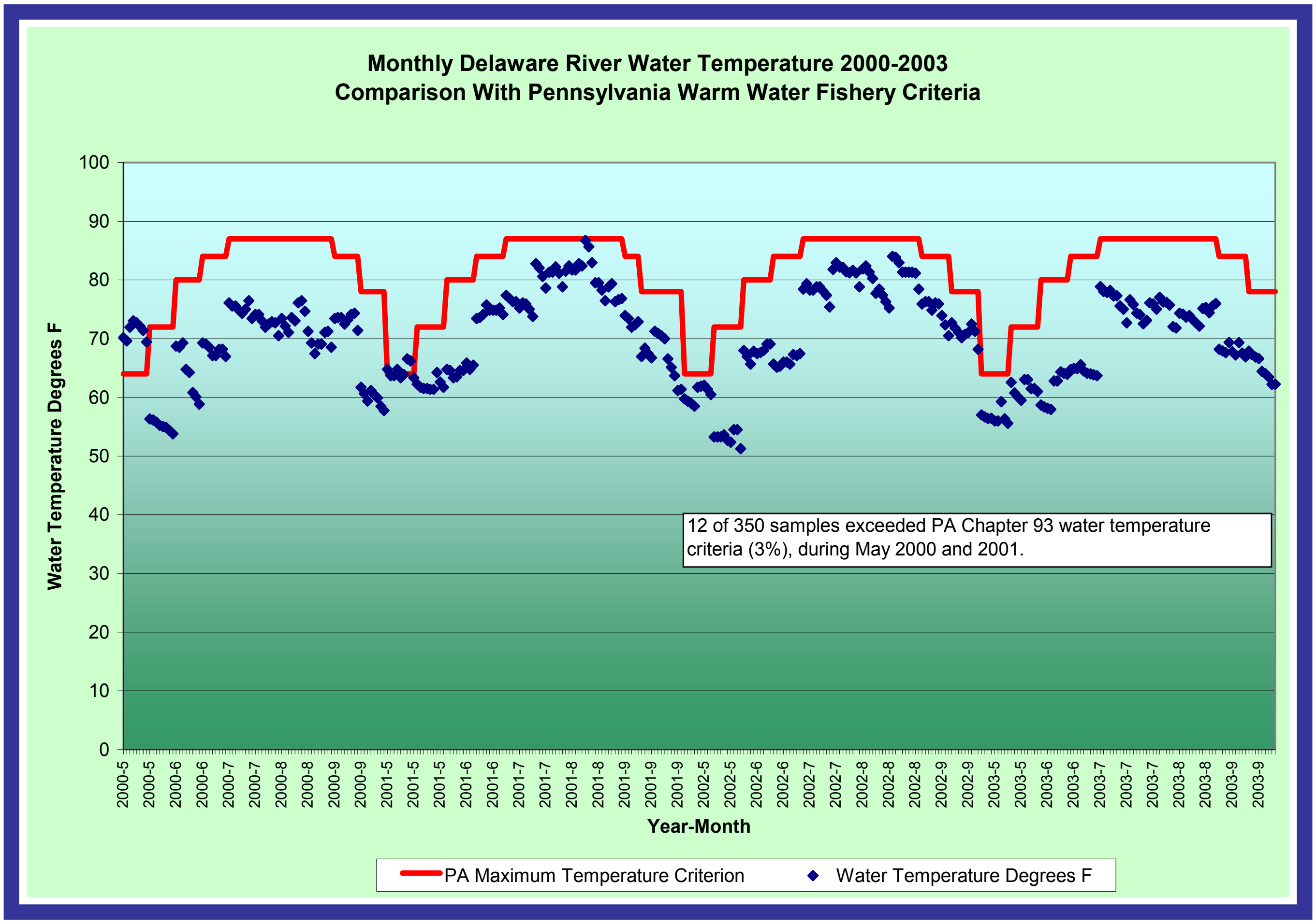
Figure 22. Turbidity in the Lower Delaware and Tributaries



Only Pidcock Creek exceeded DRBC turbidity criteria for more than 10% of samples (**Figure 22**). EWQ at Delaware River sites also meets the most stringent 15 NTU 30-day limit set for New Jersey waters. Turbidity is strongly associated with flow (Spearman Rank Correlation of 0.55).

Water Temperature – Delaware River

Figure 23. Water Temperature in the Lower Delaware River, 2000-2003



Delaware River temperature data were plotted against Pennsylvania's most stringent seasonal ambient warm water criteria. The Delaware River exceeded criteria only in May of 2000. There was an unusually hot spell that May, followed by a cooler summer and numerous high-flow events that drove water temperatures much lower than criteria. Overall, Delaware River temperature meets the most stringent Pennsylvania warm water criteria – even during a severe drought. These criteria should be adopted for the Delaware River, and are recommended as EWQ targets for Special Protection Waters rules. Water temperature is negatively associated with increasing flow (Spearman Rank Correlation of –0.58)

Monitoring, Assessment and Reporting Recommendations

Recommendation 1. Designate & Implement Special Protection Waters

Where the Scenic Rivers legislation designated segments of the Delaware River, Outstanding Basin Waters should be applied where feasible. The segments in-between and those pending Wild and Scenic Rivers Act designation should be declared Significant Resource Waters. Final SPW targets should be adopted using the 2000-2004 data set.

Recommendation 2. Protect or Restore Priority Watersheds

Recommendation 3. Build Watershed Partnerships

- Memoranda of understanding with states and NPS
- Capacity building with non-governmental organizations related to meeting EWQ targets
- Monitor and coordinate water quality actions and plans in the Lower Delaware region
- Create and market guidance for maintenance and improvement of EWQ
- Strategies to maintain and protect water quality for water suppliers

Recommendation 4. Fill Critical Information Needs

- Understand canal-river relationships
- Perform cause and effect surveys within river reaches
- Quantify effects of nutrients and primary production on water quality
- Manage nuisance vegetation and invasive species

Recommendation 5. Consider Changes to Water Quality Rules

- Introduce nutrient and/or eutrophication criteria
- Create numeric aquatic life biocriteria for macroinvertebrates
- Revise Middle and Upper Delaware reach wide EWQ targets to site-specific targets.
- Introduce bacteria standards for non-tidal river
- Adopt Pennsylvania warm water temperature standards for protection of aquatic life
- Consider raising pH upper limit to 9 instead of current 8.5
- Consider raising TDS limit above Easton to reflect natural limestone influences
- Raise minimum Dissolved Oxygen to 5.5 mg/l in Zones 1D and 1E.

Recommendation 6. Support Monitoring to Meet Recommendations

- Add ICP sites between major tributaries for improved cause-effect resolution.
- Continuous monitors at Belvidere, Riegelsville, Paulins Kill. Maintain existing monitors.
- Reduce frequency of DRBC monitoring of minor tributaries
- Maintain frequency of monitoring for ICP and major BCP sites.
- Streamline and make concurrent EWQ assessment and 305B assessments
- Rotate synoptic surveys of minor tributaries for compliance monitoring
- Combine Upper, Middle, Lower Delaware monitoring programs into Scenic Rivers Program.
- Support EWQ monitoring of major tributaries and ICP locations from Hancock to Trenton.
- Create water quality model to serve planning for protection or restoration of water quality.

References

American Public Health Association, American Water Works Association, and Water Environment Federation. 1998. Standard Methods for the Examination of Water and Wastewater, 20th Edition. United Book Press, Inc., Baltimore, MD.

Barbour, M.T., J. Gerritsen, B.D. Snyder, and J.B. Stribling. 1999. Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates and Fish, Second Edition. EPA 841-B-99-002. U.S. Environmental Protection Agency, Office of Water, Washington, D.C.

Breidt, F.J., and D.C. Boes. 1989. Statistical Analysis of Historic Water Quality Data from the Middle Delaware Scenic and Recreational River. CSU Technical Report 90-2, Department of Statistics, Colorado State University, Ft. Collins, Colorado.

Breidt, F.J., D.C. Boes, J.I Wagner, and M.D. Flora. 1991. Antidegradation water quality criteria for the Delaware River: a distribution-free statistical approach. Water Resources Bulletin 27(5): 849-858.

Delaware River Basin Commission. 1990. Staff Report on Scenic Rivers Water Quality Protection: Hancock, New York to the Delaware Water Gap. Delaware River Basin Commission, West Trenton, NJ.

Delaware River Basin Commission. 1996. Administrative Manual – Part III: Water Quality Regulations. Delaware River Basin Commission, West Trenton, NJ.

Delaware River Basin Commission. 2000. Quality Assurance Project Plan For The Lower Delaware Monitoring Program: Calendar Year 2000. Delaware River Basin Commission, West Trenton, NJ.

Delaware River Basin Commission. 2001. Quality Assurance Project Plan 2001 Update. The Lower Delaware Monitoring Program: Fixed Water Chemistry Network For The Lower Non-Tidal Delaware River And Biological Monitoring Of The Upper, Middle, And Lower Non-Tidal Delaware River. Document Control Number: DRBC QA2001-001 / July 16, 2001. Delaware River Basin Commission, West Trenton, NJ.

Delaware River Basin Commission. 2002. Lower Delaware Monitoring Program: Fixed Water Chemistry Network for the Lower Non-tidal Delaware River and Biological Monitoring of the Upper, Middle, and Lower Non-tidal Delaware River, Quality Assurance Project Plan. Document Control No. DRBC QA2002-001/ January 2002.

Delaware River Basin Commission. 2003. Lower Delaware Water Quality Monitoring Program Quality Assurance Project Plan. Document Control Number: DRBC QA2003-001 / July 2003. Delaware River Basin Commission, West Trenton, NJ.

Delaware River Basin Commission. 2004. 2004 Integrated List Assessment Methodology. Delaware River Basin Commission, West Trenton, NJ.

Delaware River Basin Commission. 2004. Lower Delaware River Eligibility Determination for DRBC Declaration of Special Protection Waters. Delaware River Basin Commission, West Trenton, NJ.

Lower Delaware Wild and Scenic River Study Task Force. 1997. Lower Delaware River Management Plan. Prepared with assistance for the National Park Service, Northeast Field Area, Philadelphia, PA.

National Park Service. 1999. Lower Delaware National Wild and Scenic River Study Report. National Park Service, Northeast Region, Philadelphia, PA.

New Jersey Department of Environmental Protection. 2003. Technical Manual for Phosphorus Evaluations for NJPDES Discharge to Surface Water Permits. N.J.A.C. 7:9B-1.14(c). NJDEP Division of Water Quality, Trenton, NJ. March 2003.

Poole, G.C., J.B. Dunham, D.M. Keenan, S.T. Sauter, D.A. McCullough, C. Mebane, J.C. Lockwood, D.A. Essig, M.P. Hicks, D.J. Sturdevant, E.J. Materna, S.A. Spalding, J. Risley, and M. Deppman. 2004. The case for regime-based water quality standards. BioScience 54(2): 155-161.

Sayers, D. 2004. Personal Communication: DRBC water use database retrieval & population estimates.

Wahl, K.L., W.O. Thomas, Jr., and R. M. Hirsch. 1995. Stream-gaging Program of the U.S. Geological Survey. U.S. Geological Survey Circular 1123. Reston, VA.

Appendix A: Site Specific Existing Water Quality

Calhoun Street Bridge, PA-NJ – River Mile 134.34
Interstate Control Point

2000-2003 Site Specific Existing Water Quality											
type	**ST**	**rmi**	**Site**	**Parameter**	**N**	**mean**	**lower95%**	**upper95%**	**median**	**10%ile**	**90%ile**
ICP	DR	134.34	Del @ Calhoun	Alkalinity mg/l	40	47.53	37.92	57.14	45.00	25.20	61.90
ICP	DR	134.34	Del @ Calhoun	Ammonia NH3-N mg/l	30	0.048	0.035	0.061	0.028	0.025	0.098
ICP	DR	134.34	Del @ Calhoun	Chloride mg/l	39	15.101	12.608	17.594	17.000	2.600	23.000
ICP	DR	134.34	Del @ Calhoun	Chlorophyll A mg/m3	37	3.184	2.325	4.043	2.700	0.500	7.480
ICP	DR	134.34	Del @ Calhoun	Discharge (cfs)	40	10,131.47	7,599.97	12,662.97	7,762.00	3,256.09	22,133.00
ICP	DR	134.34	Del @ Calhoun	DO % Saturation	40	100.0%	96.6%	103.4%	96.9%	86.4%	117.1%
ICP	DR	134.34	Del @ Calhoun	DO mg/l	40	8.889	8.505	9.274	8.790	7.396	10.480
ICP	DR	134.34	Del @ Calhoun	E. coli col/100ml	30	40 geom			42	5	274
ICP	DR	134.34	Del @ Calhoun	Enterococcus col/100ml	35	37 geom			44	2	352
ICP	DR	134.34	Del @ Calhoun	Fecal Coliform col/100ml	35	93 geom			88	17	720
ICP	DR	134.34	Del @ Calhoun	Hardness mg/l	40	64.188	59.391	68.984	70.500	40.100	79.000
ICP	DR	134.34	Del @ Calhoun	Nitrate NO3-N mg/l	39	1.172	1.049	1.294	1.200	0.600	1.700
ICP	DR	134.34	Del @ Calhoun	Orthophosphate mg/l	33	0.057	0.046	0.068	0.050	0.030	0.096
ICP	DR	134.34	Del @ Calhoun	pH	40	7.80	7.62	7.98	7.80	7.00	8.60
ICP	DR	134.34	Del @ Calhoun	Phytoplankton Biomass (mg/m3)**	35	219.988	159.844	280.131	180.900	33.500	501.160
ICP	DR	134.34	Del @ Calhoun	Specific Conductance umhos/cm	40	183.2	168.5	197.9	191.5	120.2	238.9
ICP	DR	134.34	Del @ Calhoun	TDS mg/l	37	145.405	134.051	156.760	140.000	97.400	169.000
ICP	DR	134.34	Del @ Calhoun	TN:TP ratio (unitless)	30	19.511	15.582	23.440	15.662	11.314	40.440
ICP	DR	134.34	Del @ Calhoun	Total Kjeldahl Nitrogen mg/l	30	0.589	0.392	0.786	0.495	0.154	0.879
ICP	DR	134.34	Del @ Calhoun	Total Nitrogen mg/l*	30	1.704	1.471	1.937	1.675	0.986	2.348
ICP	DR	134.34	Del @ Calhoun	Total Phosphorus mg/l	30	0.100	0.086	0.113	0.110	0.051	0.140
ICP	DR	134.34	Del @ Calhoun	TSS mg/l	37	9.047	6.114	11.980	6.000	2.050	25.900
ICP	DR	134.34	Del @ Calhoun	Turbidity NTU	40	4.90	3.29	6.51	2.80	0.80	10.90
ICP	DR	134.34	Del @ Calhoun	Water Temperature F	40	70.6	68.1	73.2	71.2	58.8	81.8

Washington Crossing Bridge, PA-NJ – River Mile 141.80
Interstate Control Point

2000-2003 Site Specific Existing Water Quality											
type	**ST**	**rmi**	**Site**	**Parameter**	**N**	**mean**	**lower95%**	**upper95%**	**median**	**10%ile**	**90%ile**
ICP	DR	141.80	Del @ WashXing	Alkalinity mg/l	40	45.93	38.97	52.89	45.00	28.03	61.90
ICP	DR	141.80	Del @ WashXing	Ammonia NH3-N mg/l	30	0.047	0.032	0.063	0.025	0.025	0.099
ICP	DR	141.80	Del @ WashXing	Chloride mg/l	39	15.162	12.808	17.515	17.000	1.900	23.000
ICP	DR	141.80	Del @ WashXing	Chlorophyll A mg/m3	38	3.143	2.241	4.046	2.300	0.371	6.439
ICP	DR	141.80	Del @ WashXing	Discharge (cfs)	40	10,141.33	7,616.63	12,666.04	8,087.50	3,241.70	22,306.40
ICP	DR	141.80	Del @ WashXing	DO % Saturation	40	98.3%	95.6%	101.0%	97.6%	87.9%	107.1%
ICP	DR	141.80	Del @ WashXing	DO mg/l	40	8.778	8.420	9.135	8.700	7.346	10.235
ICP	DR	141.80	Del @ WashXing	E. coli col/100ml	30	34 geom			33	5	247
ICP	DR	141.80	Del @ WashXing	Enterococcus col/100ml	35	39 geom			50	3	365
ICP	DR	141.80	Del @ WashXing	Fecal Coliform col/100ml	35	61 geom			60	13	340
ICP	DR	141.80	Del @ WashXing	Hardness mg/l	40	62.520	57.042	67.998	67.000	36.300	80.000
ICP	DR	141.80	Del @ WashXing	Nitrate NO3-N mg/l	39	1.199	1.059	1.339	1.170	0.720	1.700
ICP	DR	141.80	Del @ WashXing	Orthophosphate mg/l	34	0.054	0.045	0.063	0.050	0.025	0.090
ICP	DR	141.80	Del @ WashXing	pH	40	7.76	7.60	7.91	7.70	7.20	8.40
ICP	DR	141.80	Del @ WashXing	Phytoplankton Biomass (mg/m3)**	38	210.592	150.127	271.056	154.100	24.850	431.413
ICP	DR	141.80	Del @ WashXing	Specific Conductance umhos/cm	40	182.7	168.2	197.2	191.0	119.3	235.8
ICP	DR	141.80	Del @ WashXing	TDS mg/l	37	146.784	136.748	156.819	150.000	110.000	180.800
ICP	DR	141.80	Del @ WashXing	TN:TP ratio (unitless)	30	18.648	14.540	22.756	16.174	10.140	31.867
ICP	DR	141.80	Del @ WashXing	Total Kjeldahl Nitrogen mg/l	30	0.561	0.377	0.745	0.365	0.142	1.362
ICP	DR	141.80	Del @ WashXing	Total Nitrogen mg/l*	31	1.686	1.459	1.913	1.655	0.962	2.501
ICP	DR	141.80	Del @ WashXing	Total Phosphorus mg/l	31	0.108	0.092	0.124	0.100	0.052	0.150
ICP	DR	141.80	Del @ WashXing	TSS mg/l	37	9.020	5.898	12.142	6.000	1.500	25.400
ICP	DR	141.80	Del @ WashXing	Turbidity NTU	40	4.20	3.29	5.12	3.80	1.00	8.00
ICP	DR	141.80	Del @ WashXing	Water Temperature F	40	70.3	67.7	72.9	70.3	58.5	82.4

Pidcock Creek, Bucks County, PA – River Mile 146.30
Pennsylvania Boundary Control Point

2000-2003 Site Specific Existing Water Quality											
type	ST	rmi	site	Parameter	N	mean	lower95%	upper95%	median	10%ile	90%ile
BCP	PA	146.30	Pidcock	Alkalinity mg/l	30	75.97	69.95	81.99	77.00	53.20	95.80
BCP	PA	146.30	Pidcock	Ammonia NH3-N mg/l	30	0.062	0.036	0.088	0.050	0.025	0.117
BCP	PA	146.30	Pidcock	Chloride mg/l	30	18.997	17.865	20.128	18.500	15.100	23.000
BCP	PA	146.30	Pidcock	Discharge (cfs)	30	8.72	4.89	12.55	4.87	0.66	20.02
BCP	PA	146.30	Pidcock	DO % Saturation	30	83.2%	80.2%	86.2%	80.9%	74.4%	95.3%
BCP	PA	146.30	Pidcock	DO mg/l	30	7.796	7.370	8.220	7.450	6.347	9.467
BCP	PA	146.30	Pidcock	E. coli col/100ml	30	115 geom			91	29	541
BCP	PA	146.30	Pidcock	Enterococcus col/100ml	30	387 geom			485	74	2,333
BCP	PA	146.30	Pidcock	Fecal Coliform col/100ml	30	217 geom			195	29	1,818
BCP	PA	146.30	Pidcock	Hardness mg/l	30	103.100	97.671	108.529	107.500	79.800	120.000
BCP	PA	146.30	Pidcock	Nitrate NO3-N mg/l	30	1.162	0.979	1.346	0.990	0.692	2.030
BCP	PA	146.30	Pidcock	Orthophosphate mg/l	30	0.078	0.062	0.093	0.070	0.040	0.139
BCP	PA	146.30	Pidcock	pH	30	7.33	7.23	7.42	7.39	6.91	7.69
BCP	PA	146.30	Pidcock	Specific Conductance umhos/cm	30	251.1	236.8	265.4	255.0	193.6	295.8
BCP	PA	146.30	Pidcock	TDS mg/l	30	181.100	174.695	187.505	185.000	160.000	200.000
BCP	PA	146.30	Pidcock	TN:TP ratio (unitless)	30	17.092	13.682	20.503	16.458	7.361	31.800
BCP	PA	146.30	Pidcock	Total Kjeldahl Nitrogen mg/l	30	0.590	0.422	0.757	0.500	0.071	1.345
BCP	PA	146.30	Pidcock	Total Nitrogen mg/l*	30	1.752	1.490	2.013	1.630	0.871	2.868
BCP	PA	146.30	Pidcock	Total Phosphorus mg/l	30	0.125	0.095	0.155	0.095	0.060	0.276
BCP	PA	146.30	Pidcock	TSS mg/l	30	18.252	-1.406	37.909	3.000	0.550	50.000
BCP	PA	146.30	Pidcock	Turbidity NTU	30	10.34	3.21	17.47	3.70	1.41	43.10
BCP	PA	146.30	Pidcock	Water Temperature F	30	66.1	63.3	68.9	66.9	56.2	75.6

Lambertville-New Hope Bridge, NJ-PA – River Mile 148.70
Interstate Control Point

2000-2003 Site Specific Existing Water Quality											
type	ST	rmi	Site	Parameter	N	mean	lower95%	upper95%	median	10%ile	90%ile
ICP	DR	148.70	Del @ Lambtvll	Alkalinity mg/l	30	44.20	39.09	49.31	46.00	26.10	61.00
ICP	DR	148.70	Del @ Lambtvll	Ammonia NH3-N mg/l	30	0.050	0.037	0.064	0.035	0.025	0.109
ICP	DR	148.70	Del @ Lambtvll	Chloride mg/l	30	18.547	17.227	19.866	19.700	13.000	23.000
ICP	DR	148.70	Del @ Lambtvll	Chlorophyll A mg/m3	30	3.382	2.498	4.266	2.950	0.500	6.670
ICP	DR	148.70	Del @ Lambtvll	Discharge (cfs)	30	10,548.94	7,379.32	13,718.56	8,035.50	3,247.20	24,145.60
ICP	DR	148.70	Del @ Lambtvll	DO % Saturation	30	94.3%	91.9%	96.7%	93.5%	86.9%	104.6%
ICP	DR	148.70	Del @ Lambtvll	DO mg/l	30	8.425	8.059	8.792	8.450	7.222	9.934
ICP	DR	148.70	Del @ Lambtvll	E. coli col/100ml	30	35 geom			24	5	276
ICP	DR	148.70	Del @ Lambtvll	Enterococcus col/100ml	30	63 geom			52	4	841
ICP	DR	148.70	Del @ Lambtvll	Fecal Coliform col/100ml	30	66 geom			52	9	316
ICP	DR	148.70	Del @ Lambtvll	Hardness mg/l	30	63.667	57.621	69.713	69.500	39.200	81.000
ICP	DR	148.70	Del @ Lambtvll	Nitrate NO3-N mg/l	30	1.126	1.014	1.237	1.200	0.702	1.490
ICP	DR	148.70	Del @ Lambtvll	Orthophosphate mg/l	30	0.055	0.044	0.066	0.040	0.021	0.100
ICP	DR	148.70	Del @ Lambtvll	pH	30	7.53	7.38	7.68	7.54	7.01	7.99
ICP	DR	148.70	Del @ Lambtvll	Phytoplankton Biomass (mg/m3)**	30	226.594	167.395	285.793	197.650	33.500	446.957
ICP	DR	148.70	Del @ Lambtvll	Specific Conductance umhos/cm	30	182.0	164.3	199.7	195.5	116.7	234.7
ICP	DR	148.70	Del @ Lambtvll	TDS mg/l	30	143.233	134.541	151.926	140.000	110.000	170.000
ICP	DR	148.70	Del @ Lambtvll	TN:TP ratio (unitless)	30	18.874	14.001	23.748	16.682	10.221	26.090
ICP	DR	148.70	Del @ Lambtvll	Total Kjeldahl Nitrogen mg/l	30	0.748	0.294	1.202	0.475	0.065	1.206
ICP	DR	148.70	Del @ Lambtvll	Total Nitrogen mg/l*	30	1.874	1.377	2.370	1.725	0.956	2.377
ICP	DR	148.70	Del @ Lambtvll	Total Phosphorus mg/l	30	0.109	0.091	0.127	0.110	0.060	0.140
ICP	DR	148.70	Del @ Lambtvll	TSS mg/l	30	13.802	5.281	22.322	5.000	2.500	35.600
ICP	DR	148.70	Del @ Lambtvll	Turbidity NTU	30	7.26	0.78	13.74	2.05	0.80	15.99
ICP	DR	148.70	Del @ Lambtvll	Water Temperature F	30	70.3	67.1	73.5	70.8	58.2	81.6

Wickecheoke Creek, Hunterdon County, NJ – River Mile 152.50
New Jersey Boundary Control Point

2000-2003 Site Specific Existing Water Quality											
type	**ST**	**rmi**	**site**	**Parameter**	**N**	**mean**	**lower95%**	**upper95%**	**median**	**10%ile**	**90%ile**
BCP	NJ	152.50	Wickecheoke	Alkalinity mg/l	38	39.71	35.90	43.52	40.00	25.00	58.10
BCP	NJ	152.50	Wickecheoke	Ammonia NH3-N mg/l	30	0.045	0.030	0.061	0.025	0.025	0.116
BCP	NJ	152.50	Wickecheoke	Chloride mg/l	38	13.253	11.111	15.390	15.000	2.290	21.100
BCP	NJ	152.50	Wickecheoke	Discharge (cfs)	38	13.19	5.37	21.01	3.12	0.59	34.50
BCP	NJ	152.50	Wickecheoke	DO % Saturation	38	100.6%	98.2%	103.0%	100.7%	90.3%	108.3%
BCP	NJ	152.50	Wickecheoke	DO mg/l	38	9.532	9.186	9.880	9.450	8.271	10.960
BCP	NJ	152.50	Wickecheoke	E. coli col/100ml	30	81 geom			52	16	2,804
BCP	NJ	152.50	Wickecheoke	Enterococcus col/100ml	35	214 geom			170	24	4,320
BCP	NJ	152.50	Wickecheoke	Fecal Coliform col/100ml	35	147 geom			92	14	4,000
BCP	NJ	152.50	Wickecheoke	Hardness mg/l	38	57.789	54.255	61.320	57.500	43.600	72.300
BCP	NJ	152.50	Wickecheoke	Nitrate NO3-N mg/l	33	1.948	1.655	2.240	1.830	0.886	2.926
BCP	NJ	152.50	Wickecheoke	Orthophosphate mg/l	31	0.036	0.027	0.044	0.030	0.006	0.068
BCP	NJ	152.50	Wickecheoke	pH	38	7.61	7.44	7.78	7.53	7.04	8.27
BCP	NJ	152.50	Wickecheoke	Specific Conductance umhos/cm	38	178.0	166.9	189.1	183.0	127.3	213.1
BCP	NJ	152.50	Wickecheoke	TDS mg/l	37	128.216	119.048	137.400	130.000	97.400	153.600
BCP	NJ	152.50	Wickecheoke	TN:TP ratio (unitless)	30	53.730	36.222	71.239	39.800	19.408	122.325
BCP	NJ	152.50	Wickecheoke	Total Kjeldahl Nitrogen mg/l	30	0.731	0.394	1.067	0.435	0.095	1.651
BCP	NJ	152.50	Wickecheoke	Total Nitrogen mg/l*	30	2.517	2.082	2.953	2.120	1.640	3.750
BCP	NJ	152.50	Wickecheoke	Total Phosphorus mg/l	32	0.084	0.049	0.119	0.055	0.033	0.176
BCP	NJ	152.50	Wickecheoke	TSS mg/l	37	9.265	-2.931	21.460	1.000	0.250	16.000
BCP	NJ	152.50	Wickecheoke	Turbidity NTU	38	8.39	-0.95	17.73	1.20	0.23	16.40
BCP	NJ	152.50	Wickecheoke	Water Temperature F	38	64.8	62.5	67.1	66.4	53.4	73.8

Lockatong Creek, Hunterdon County, NJ – River Mile 154.00
New Jersey Boundary Control Point

2000-2003 Site Specific Existing Water Quality											
type	ST	rmi	site	Parameter	N	mean	lower95%	upper95%	median	10%ile	90%ile
BCP	NJ	154.00	Lockatong	Alkalinity mg/l	38	41.29	38.07	44.51	42.50	29.50	54.10
BCP	NJ	154.00	Lockatong	Ammonia NH3-N mg/l	30	0.046	0.028	0.063	0.025	0.025	0.078
BCP	NJ	154.00	Lockatong	Chloride mg/l	38	10.442	8.776	12.110	12.000	1.870	16.100
BCP	NJ	154.00	Lockatong	Discharge (cfs)	38	13.25	3.52	22.97	5.72	0.71	23.87
BCP	NJ	154.00	Lockatong	DO % Saturation	38	93.4%	89.6%	97.1%	94.2%	84.2%	106.3%
BCP	NJ	154.00	Lockatong	DO mg/l	38	8.800	8.331	9.270	8.700	7.190	10.573
BCP	NJ	154.00	Lockatong	E. coli col/100ml	30	45 geom			33	8	2,371
BCP	NJ	154.00	Lockatong	Enterococcus col/100ml	35	211 geom			260	33	1,940
BCP	NJ	154.00	Lockatong	Fecal Coliform col/100ml	35	58 geom			32	7	2,103
BCP	NJ	154.00	Lockatong	Hardness mg/l	38	58.974	55.490	62.460	60.000	41.800	72.200
BCP	NJ	154.00	Lockatong	Nitrate NO3-N mg/l	35	1.258	1.052	1.464	1.130	0.740	1.738
BCP	NJ	154.00	Lockatong	Orthophosphate mg/l	31	0.040	0.023	0.056	0.030	0.008	0.058
BCP	NJ	154.00	Lockatong	pH	38	7.40	7.24	7.55	7.30	6.80	8.11
BCP	NJ	154.00	Lockatong	Specific Conductance umhos/cm	38	169.7	159.3	180.1	180.0	115.9	198.1
BCP	NJ	154.00	Lockatong	TDS mg/l	37	133.838	125.061	142.600	140.000	99.800	164.000
BCP	NJ	154.00	Lockatong	TN:TP ratio (unitless)	30	32.793	23.904	41.682	26.958	12.595	56.100
BCP	NJ	154.00	Lockatong	Total Kjeldahl Nitrogen mg/l	30	0.589	0.326	0.853	0.385	0.025	1.763
BCP	NJ	154.00	Lockatong	Total Nitrogen mg/l*	30	1.762	1.443	2.081	1.555	0.968	3.008
BCP	NJ	154.00	Lockatong	Total Phosphorus mg/l	31	0.083	0.047	0.119	0.050	0.032	0.158
BCP	NJ	154.00	Lockatong	TSS mg/l	37	11.986	-4.566	28.539	1.000	0.250	18.200
BCP	NJ	154.00	Lockatong	Turbidity NTU	38	9.31	-0.07	18.70	1.15	0.25	20.00
BCP	NJ	154.00	Lockatong	Water Temperature F	38	65.5	63.1	68.0	66.7	52.8	74.6

Bulls Island Foot Bridge, NJ/PA – River Mile 155.40
Interstate Control Point

2000-2003 Site Specific Existing Water Quality											
type	**ST**	**rmi**	**site**	**Parameter**	**N**	**mean**	**lower95%**	**upper95%**	**median**	**10%ile**	**90%ile**
ICP	DR	155.40	Del @ Bulls Isl	Alkalinity mg/l	40	43.79	39.80	47.77	45.00	26.10	60.80
ICP	DR	155.40	Del @ Bulls Isl	Ammonia NH3-N mg/l	30	0.045	0.031	0.059	0.025	0.025	0.116
ICP	DR	155.40	Del @ Bulls Isl	Chloride mg/l	39	14.505	12.091	16.920	16.000	1.700	22.000
ICP	DR	155.40	Del @ Bulls Isl	Chlorophyll A mg/m3	33	3.318	1.894	4.742	2.700	0.500	7.996
ICP	DR	155.40	Del @ Bulls Isl	Discharge (cfs)	40	10,095.96	7,650.10	12,541.83	7,982.00	3,277.35	22,492.30
ICP	DR	155.40	Del @ Bulls Isl	DO % Saturation	40	100.4%	96.5%	104.4%	98.5%	86.6%	116.3%
ICP	DR	155.40	Del @ Bulls Isl	DO mg/l	40	9.008	8.607	9.408	8.995	7.455	10.445
ICP	DR	155.40	Del @ Bulls Isl	E. coli col/100ml	30	51 geom			42	4	2,093
ICP	DR	155.40	Del @ Bulls Isl	Enterococcus col/100ml	35	64 geom			44	12	1,064
ICP	DR	155.40	Del @ Bulls Isl	Fecal Coliform col/100ml	35	70 geom			60	10	2,608
ICP	DR	155.40	Del @ Bulls Isl	Hardness mg/l	40	64.350	59.456	69.244	69.500	42.100	80.900
ICP	DR	155.40	Del @ Bulls Isl	Nitrate NO3-N mg/l	36	1.168	0.999	1.336	1.200	0.600	1.544
ICP	DR	155.40	Del @ Bulls Isl	Orthophosphate mg/l	33	0.059	0.046	0.073	0.060	0.024	0.090
ICP	DR	155.40	Del @ Bulls Isl	pH	40	7.67	7.48	7.85	7.60	6.96	8.61
ICP	DR	155.40	Del @ Bulls Isl	Phytoplankton Biomass (mg/m3)**	33	222.306	126.869	317.744	180.900	33.500	535.732
ICP	DR	155.40	Del @ Bulls Isl	Specific Conductance umhos/cm	40	180.9	166.7	195.1	189.0	121.3	232.6
ICP	DR	155.40	Del @ Bulls Isl	TDS mg/l	37	144.703	135.061	154.345	150.000	108.000	172.000
ICP	DR	155.40	Del @ Bulls Isl	TN:TP ratio (unitless)	30	16.949	13.773	20.125	14.411	9.988	31.080
ICP	DR	155.40	Del @ Bulls Isl	Total Kjeldahl Nitrogen mg/l	30	0.498	0.306	0.690	0.315	0.028	1.007
ICP	DR	155.40	Del @ Bulls Isl	Total Nitrogen mg/l*	30	1.629	1.385	1.873	1.523	0.951	2.549
ICP	DR	155.40	Del @ Bulls Isl	Total Phosphorus mg/l	31	0.126	0.091	0.162	0.110	0.052	0.310
ICP	DR	155.40	Del @ Bulls Isl	TSS mg/l	37	16.191	3.315	29.066	4.800	1.000	34.000
ICP	DR	155.40	Del @ Bulls Isl	Turbidity NTU	40	10.47	3.04	17.90	3.90	1.01	13.80
ICP	DR	155.40	Del @ Bulls Isl	Water Temperature F	40	69.7	67.3	72.2	70.1	58.0	80.1

Paunnacussing Creek, Bucks County, PA – River Mile 155.60
Pennsylvania Boundary Control Point

2000-2003 Site Specific Existing Water Quality												
type	ST	rmi	site	Parameter	N	mean	lower95%	upper95%	median	10%ile	90%ile
BCP	PA	155.60	Paunnacussing	Alkalinity mg/l	37	48.05	44.03	52.08	47.00	31.80	65.00
BCP	PA	155.60	Paunnacussing	Ammonia NH3-N mg/l	30	0.037	0.000	0.044	0.025	0.025	0.079
BCP	PA	155.60	Paunnacussing	Chloride mg/l	37	19.608	16.760	22.460	24.000	3.140	27.000
BCP	PA	155.60	Paunnacussing	DO % Saturation	37	99.2%	96.1%	102.3%	98.5%	90.3%	113.1%
BCP	PA	155.60	Paunnacussing	DO mg/l	37	9.418	9.040	9.800	9.420	8.116	10.800
BCP	PA	155.60	Paunnacussing	E. coli col/100ml	30	43 geom			28	4	899
BCP	PA	155.60	Paunnacussing	Enterococcus col/100ml	35	271 geom			320	19	3,008
BCP	PA	155.60	Paunnacussing	Fecal Coliform col/100ml	35	86 geom			80	10	1,342
BCP	PA	155.60	Paunnacussing	Hardness mg/l	37	80.054	76.371	83.740	80.000	65.800	95.000
BCP	PA	155.60	Paunnacussing	Nitrate NO3-N mg/l	35	2.359	2.134	2.584	2.580	1.230	3.100
BCP	PA	155.60	Paunnacussing	Orthophosphate mg/l	30	0.050	0.040	0.060	0.050	0.030	0.060
BCP	PA	155.60	Paunnacussing	pH	37	7.63	7.49	7.76	7.60	7.20	8.20
BCP	PA	155.60	Paunnacussing	Specific Conductance umhos/cm	37	221.9	209.2	234.7	229.0	155.8	259.4
BCP	PA	155.60	Paunnacussing	TDS mg/l	37	147.703	140.220	155.200	143.000	120.000	176.800
BCP	PA	155.60	Paunnacussing	Time of Day (hrs)	37	10:37	10:00	11:14	9:30	8:50	13:12
BCP	PA	155.60	Paunnacussing	TN:TP ratio (unitless)	30	46.351	39.420	53.282	40.938	26.279	74.880
BCP	PA	155.60	Paunnacussing	Total Kjeldahl Nitrogen mg/l	30	0.344	0.211	0.477	0.295	0.025	0.580
BCP	PA	155.60	Paunnacussing	Total Nitrogen mg/l*	30	2.889	2.713	3.066	2.955	2.100	3.487
BCP	PA	155.60	Paunnacussing	Total Phosphorus mg/l	34	0.074	0.062	0.085	0.070	0.045	0.105
BCP	PA	155.60	Paunnacussing	TSS mg/l	37	3.446	0.717	6.175	1.000	0.500	6.800
BCP	PA	155.60	Paunnacussing	Turbidity NTU	37	4.37	0.86	7.87	0.80	0.25	10.40
BCP	PA	155.60	Paunnacussing	Water Temperature F	37	64.6	62.4	66.8	63.9	55.5	73.8

Tohickon Creek, Bucks County, PA – River Mile 157.00
Pennsylvania Boundary Control Point

2000-2003 Site Specific Existing Water Quality											
type	**ST**	**rmi**	**site**	**Parameter**	**N**	**mean**	**lower95%**	**upper95%**	**median**	**10%ile**	**90%ile**
BCP	PA	157.00	Tohickon	Alkalinity mg/l	37	45.11	41.66	48.55	46.00	32.40	61.20
BCP	PA	157.00	Tohickon	Ammonia NH3-N mg/l	30	0.038	0.029	0.047	0.025	0.025	0.070
BCP	PA	157.00	Tohickon	Chloride mg/l	37	23.216	19.729	26.700	27.000	3.820	35.000
BCP	PA	157.00	Tohickon	Chlorophyll A mg/m3	30	3.649	1.795	5.500	2.140	0.500	8.170
BCP	PA	157.00	Tohickon	Discharge (cfs)	37	128.79	-9.88	267.46	30.11	4.33	317.22
BCP	PA	157.00	Tohickon	DO % Saturation	37	101.3%	97.9%	104.6%	100.9%	91.0%	112.8%
BCP	PA	157.00	Tohickon	DO mg/l	37	9.039	8.632	9.450	9.100	7.704	10.760
BCP	PA	157.00	Tohickon	E. coli col/100ml	30	39 geom			36	4	1,122
BCP	PA	157.00	Tohickon	Enterococcus col/100ml	35	464 geom			590	56	5,856
BCP	PA	157.00	Tohickon	Fecal Coliform col/100ml	35	90 geom			78	12	1,127
BCP	PA	157.00	Tohickon	Hardness mg/l	37	66.324	63.347	69.300	65.000	55.000	80.200
BCP	PA	157.00	Tohickon	Nitrate NO3-N mg/l	33	0.757	0.606	0.908	0.690	0.346	1.206
BCP	PA	157.00	Tohickon	Orthophosphate mg/l	30	0.017	0.011	0.023	0.015	0.005	0.030
BCP	PA	157.00	Tohickon	pH	37	7.99	7.82	8.17	7.99	7.36	8.72
BCP	PA	157.00	Tohickon	Phytoplankton Biomass (mg/m3)**	30	244.505	120.297	368.713	143.380	33.500	547.390
BCP	PA	157.00	Tohickon	Specific Conductance umhos/cm	37	216.8	205.8	227.9	218.0	174.0	268.4
BCP	PA	157.00	Tohickon	TDS mg/l	37	165.297	157.034	173.600	169.000	140.000	190.000
BCP	PA	157.00	Tohickon	TN:TP ratio (unitless)	30	24.946	20.303	29.590	20.125	12.500	42.075
BCP	PA	157.00	Tohickon	Total Kjeldahl Nitrogen mg/l	30	0.381	0.261	0.501	0.355	0.025	0.715
BCP	PA	157.00	Tohickon	Total Nitrogen mg/l*	30	1.111	0.907	1.315	1.023	0.506	1.680
BCP	PA	157.00	Tohickon	Total Phosphorus mg/l	30	0.053	0.036	0.070	0.040	0.030	0.070
BCP	PA	157.00	Tohickon	TSS mg/l	37	5.022	0.361	9.682	2.000	0.250	10.200
BCP	PA	157.00	Tohickon	Turbidity NTU	37	3.34	0.29	6.39	1.00	0.25	6.06
BCP	PA	157.00	Tohickon	Water Temperature F	37	70.4	67.6	73.2	70.8	58.5	83.6

Tinicum Creek, Bucks County, PA – River Mile 161.60
Pennsylvania Boundary Control Point

2000-2003 Site Specific Existing Water Quality											
type	ST	rmi	site	Parameter	N	mean	lower95%	upper95%	median	10%ile	90%ile
BCP	PA	161.60	Tinicum	Alkalinity mg/l	36	60.11	54.74	65.48	61.00	36.80	80.00
BCP	PA	161.60	Tinicum	Ammonia NH3-N mg/l	29	0.033	0.028	0.038	0.025	0.025	0.060
BCP	PA	161.60	Tinicum	Chloride mg/l	36	11.775	9.875	13.680	13.000	2.130	18.000
BCP	PA	161.60	Tinicum	Discharge (cfs)	26	23.31	11.87	34.75	11.57	0.07	68.29
BCP	PA	161.60	Tinicum	DO % Saturation	35	106.0%	101.7%	110.4%	103.6%	90.6%	129.8%
BCP	PA	161.60	Tinicum	DO mg/l	35	9.769	9.315	10.220	9.800	8.188	11.780
BCP	PA	161.60	Tinicum	E. coli col/100ml	29	92 geom			80	12	520
BCP	PA	161.60	Tinicum	Enterococcus col/100ml	34	163 geom			200	8	4,072
BCP	PA	161.60	Tinicum	Fecal Coliform col/100ml	34	204 geom			155	51	2,215
BCP	PA	161.60	Tinicum	Hardness mg/l	36	89.361	80.807	97.920	90.500	55.800	123.000
BCP	PA	161.60	Tinicum	Nitrate NO3-N mg/l	34	0.973	0.651	1.295	0.790	0.215	2.035
BCP	PA	161.60	Tinicum	Orthophosphate mg/l	29	0.016	0.009	0.022	0.010	0.005	0.040
BCP	PA	161.60	Tinicum	pH	36	7.99	7.82	8.15	8.00	7.20	8.73
BCP	PA	161.60	Tinicum	Specific Conductance umhos/cm	36	229.7	209.2	250.1	247.0	116.8	298.2
BCP	PA	161.60	Tinicum	TDS mg/l	36	175.028	158.994	191.100	180.000	117.000	224.400
BCP	PA	161.60	Tinicum	TN:TP ratio (unitless)	29	27.733	21.832	33.634	28.714	10.750	40.000
BCP	PA	161.60	Tinicum	Total Kjeldahl Nitrogen mg/l	29	0.316	0.226	0.407	0.300	0.025	0.760
BCP	PA	161.60	Tinicum	Total Nitrogen mg/l*	29	1.012	0.839	1.186	1.140	0.210	1.540
BCP	PA	161.60	Tinicum	Total Phosphorus mg/l	30	0.042	0.034	0.051	0.040	0.020	0.073
BCP	PA	161.60	Tinicum	TSS mg/l	36	4.049	1.527	6.571	2.000	0.500	9.650
BCP	PA	161.60	Tinicum	Turbidity NTU	36	3.24	1.20	5.28	1.10	0.25	9.00
BCP	PA	161.60	Tinicum	Water Temperature F	35	67.3	64.7	69.8	67.3	58.2	77.5

Nishisakawick Creek, Hunterdon County, NJ – River Mile 164.10
New Jersey Boundary Control Point

2000-2003 Site Specific Existing Water Quality											
type	**ST**	**rmi**	**site**	**Parameter**	**N**	**mean**	**lower95%**	**upper95%**	**median**	**10%ile**	**90%ile**
BCP	NJ	164.10	Nishisakawick	Alkalinity mg/l	37	47.57	43.15	51.98	45.00	30.00	66.60
BCP	NJ	164.10	Nishisakawick	Ammonia NH3-N mg/l	32	0.046	0.033	0.059	0.025	0.025	0.100
BCP	NJ	164.10	Nishisakawick	Chloride mg/l	37	12.157	10.415	13.900	14.000	2.280	17.000
BCP	NJ	164.10	Nishisakawick	Discharge (cfs)	35	9.63	4.22	15.05	2.68	0.22	32.29
BCP	NJ	164.10	Nishisakawick	DO % Saturation	36	102.8%	100.0%	105.6%	101.0%	93.1%	115.7%
BCP	NJ	164.10	Nishisakawick	DO mg/l	36	9.684	9.359	10.010	9.650	8.463	10.980
BCP	NJ	164.10	Nishisakawick	E. coli col/100ml	30	64 geom			48	12	1,571
BCP	NJ	164.10	Nishisakawick	Enterococcus col/100ml	35	353 geom			240	39	6,160
BCP	NJ	164.10	Nishisakawick	Fecal Coliform col/100ml	35	93 geom			85	16	916
BCP	NJ	164.10	Nishisakawick	Hardness mg/l	37	61.000	57.244	64.760	60.000	43.000	75.000
BCP	NJ	164.10	Nishisakawick	Nitrate NO3-N mg/l	33	1.743	1.500	1.986	1.620	1.016	2.412
BCP	NJ	164.10	Nishisakawick	Orthophosphate mg/l	30	0.041	0.033	0.050	0.040	0.020	0.068
BCP	NJ	164.10	Nishisakawick	pH	37	7.82	7.67	7.97	7.89	7.20	8.50
BCP	NJ	164.10	Nishisakawick	Specific Conductance umhos/cm	37	174.9	165.4	184.3	181.0	118.2	203.2
BCP	NJ	164.10	Nishisakawick	TDS mg/l	37	130.270	122.448	138.100	130.000	99.200	160.000
BCP	NJ	164.10	Nishisakawick	TN:TP ratio (unitless)	30	38.293	29.909	46.677	33.671	16.205	72.400
BCP	NJ	164.10	Nishisakawick	Total Kjeldahl Nitrogen mg/l	30	0.431	0.319	0.543	0.345	0.072	0.888
BCP	NJ	164.10	Nishisakawick	Total Nitrogen mg/l*	30	2.091	1.897	2.285	2.093	1.432	2.726
BCP	NJ	164.10	Nishisakawick	Total Phosphorus mg/l	31	0.086	0.055	0.117	0.060	0.032	0.206
BCP	NJ	164.10	Nishisakawick	TSS mg/l	37	9.095	-3.976	22.165	1.500	0.500	6.100
BCP	NJ	164.10	Nishisakawick	Turbidity NTU	37	11.17	-5.24	27.58	1.30	0.25	14.40
BCP	NJ	164.10	Nishisakawick	Water Temperature F	37	64.9	62.7	67.2	66.2	56.5	73.9

Milford-Upper Black Eddy Bridge, NJ/PA – River Mile 167.70
Interstate Control Point

2000-2003 Site Specific Existing Water Quality											
type	**ST**	**rmi**	**site**	**Parameter**	**N**	**mean**	**lower95%**	**upper95%**	**median**	**10%ile**	**90%ile**
ICP	DR	167.70	Del @ Milford	Alkalinity mg/l	40	45.40	40.27	50.53	45.00	27.10	60.90
ICP	DR	167.70	Del @ Milford	Ammonia NH3-N mg/l	30	0.046	0.034	0.057	0.028	0.025	0.079
ICP	DR	167.70	Del @ Milford	Chloride mg/l	40	14.118	11.740	16.495	16.000	1.730	21.000
ICP	DR	167.70	Del @ Milford	Chlorophyll A mg/m3	35	2.045	1.534	2.557	1.800	0.353	4.270
ICP	DR	167.70	Del @ Milford	Discharge (cfs)	40	9,904.61	7,154.09	12,655.14	7,605.00	2,997.90	21,818.40
ICP	DR	167.70	Del @ Milford	DO % Saturation	39	97.7%	95.3%	100.2%	96.1%	90.3%	109.2%
ICP	DR	167.70	Del @ Milford	DO mg/l	39	8.769	8.425	9.114	8.800	7.580	10.100
ICP	DR	167.70	Del @ Milford	E. coli col/100ml	30	37 geom			24	4	904
ICP	DR	167.70	Del @ Milford	Enterococcus col/100ml	35	66 geom			60	5	1,351
ICP	DR	167.70	Del @ Milford	Fecal Coliform col/100ml	35	66 geom			50	5	2,534
ICP	DR	167.70	Del @ Milford	Hardness mg/l	40	64.725	59.421	70.029	68.500	43.100	84.700
ICP	DR	167.70	Del @ Milford	Nitrate NO3-N mg/l	39	1.273	1.126	1.420	1.250	0.830	1.720
ICP	DR	167.70	Del @ Milford	Orthophosphate mg/l	33	0.063	0.052	0.074	0.060	0.030	0.096
ICP	DR	167.70	Del @ Milford	pH	40	7.67	7.51	7.83	7.60	7.11	8.20
ICP	DR	167.70	Del @ Milford	Phytoplankton Biomass (mg/m3)**	35	137.227	103.050	171.405	120.600	23.640	286.090
ICP	DR	167.70	Del @ Milford	Specific Conductance umhos/cm	40	181.4	167.6	195.1	193.0	117.5	236.9
ICP	DR	167.70	Del @ Milford	TDS mg/l	37	151.730	137.994	165.466	150.000	108.000	199.600
ICP	DR	167.70	Del @ Milford	TN:TP ratio (unitless)	30	17.301	15.120	19.482	16.958	11.438	27.927
ICP	DR	167.70	Del @ Milford	Total Kjeldahl Nitrogen mg/l	30	0.438	0.317	0.559	0.335	0.150	0.969
ICP	DR	167.70	Del @ Milford	Total Nitrogen mg/l*	30	1.594	1.430	1.758	1.605	1.005	2.159
ICP	DR	167.70	Del @ Milford	Total Phosphorus mg/l	32	0.106	0.082	0.129	0.110	0.050	0.140
ICP	DR	167.70	Del @ Milford	TSS mg/l	37	11.723	4.058	19.388	5.000	1.900	17.600
ICP	DR	167.70	Del @ Milford	Turbidity NTU	40	7.30	2.18	12.43	2.90	0.82	13.80
ICP	DR	167.70	Del @ Milford	Water Temperature F	40	69.6	67.2	72.1	71.3	61.2	81.1

Cooks Creek, Bucks County, PA – River Mile 173.70
Pennsylvania Boundary Control Point

2000-2003 Site Specific Existing Water Quality											
type	**ST**	**rmi**	**site**	**Parameter**	**N**	**mean**	**lower95%**	**upper95%**	**median**	**10%ile**	**90%ile**
BCP	PA	173.70	Cooks	Alkalinity mg/l	38	95.34	87.33	103.35	96.50	62.30	130.00
BCP	PA	173.70	Cooks	Ammonia NH3-N mg/l	30	0.042	0.031	0.054	0.025	0.025	0.069
BCP	PA	173.70	Cooks	Chloride mg/l	38	8.075	6.847	9.300	8.950	0.800	12.000
BCP	PA	173.70	Cooks	Discharge (cfs)	36	42.73	30.45	55.02	35.32	6.11	107.51
BCP	PA	173.70	Cooks	DO % Saturation	37	104.1%	101.6%	106.7%	103.9%	94.6%	113.8%
BCP	PA	173.70	Cooks	DO mg/l	37	10.092	9.809	10.370	10.100	8.758	11.040
BCP	PA	173.70	Cooks	E. coli col/100ml	30	151 geom			98	52	2,820
BCP	PA	173.70	Cooks	Enterococcus col/100ml	35	284 geom			360	23	6,939
BCP	PA	173.70	Cooks	Fecal Coliform col/100ml	35	211 geom			150	45	3,768
BCP	PA	173.70	Cooks	Hardness mg/l	38	115.474	108.493	122.450	120.000	84.300	140.000
BCP	PA	173.70	Cooks	Nitrate NO3-N mg/l	30	1.822	1.715	1.929	1.825	1.458	2.200
BCP	PA	173.70	Cooks	Orthophosphate mg/l	31	0.028	0.014	0.043	0.010	0.005	0.102
BCP	PA	173.70	Cooks	pH	38	8.01	7.88	8.13	8.00	7.45	8.42
BCP	PA	173.70	Cooks	Specific Conductance umhos/cm	38	248.9	235.2	262.7	254.0	166.8	288.8
BCP	PA	173.70	Cooks	TDS mg/l	37	189.351	173.267	205.400	180.000	144.000	268.400
BCP	PA	173.70	Cooks	TN:TP ratio (unitless)	30	54.639	45.168	64.111	50.825	25.213	94.500
BCP	PA	173.70	Cooks	Total Kjeldahl Nitrogen mg/l	30	0.335	0.209	0.460	0.215	0.060	0.845
BCP	PA	173.70	Cooks	Total Nitrogen mg/l*	30	2.156	2.007	2.306	2.075	1.571	2.672
BCP	PA	173.70	Cooks	Total Phosphorus mg/l	30	0.053	0.037	0.069	0.040	0.020	0.089
BCP	PA	173.70	Cooks	TSS mg/l	37	10.765	-1.024	22.554	2.500	0.500	11.600
BCP	PA	173.70	Cooks	Turbidity NTU	38	10.19	-0.49	20.88	1.50	0.25	17.00
BCP	PA	173.70	Cooks	Water Temperature F	38	62.3	60.6	64.1	62.9	55.2	69.3

Musconetcong River, Hunterdon/Warren County, NJ – River Mile 174.60
New Jersey Boundary Control Point

2000-2003 Site Specific Existing Water Quality											
type	**ST**	**rmi**	**site**	**Parameter**	**N**	**mean**	**lower95%**	**upper95%**	**median**	**10%ile**	**90%ile**
BCP	NJ	174.60	Musconetcong	Alkalinity mg/l	38	105.47	96.20	114.75	100.50	65.60	140.00
BCP	NJ	174.60	Musconetcong	Ammonia NH3-N mg/l	30	0.094	0.059	0.129	0.060	0.025	0.201
BCP	NJ	174.60	Musconetcong	Chloride mg/l	38	35.387	29.457	41.320	42.000	4.950	53.300
BCP	NJ	174.60	Musconetcong	Chlorophyll A mg/m3	32	3.321	2.609	4.030	3.200	0.500	6.770
BCP	NJ	174.60	Musconetcong	Discharge (cfs)	38	218.55	169.62	267.48	179.09	46.86	524.94
BCP	NJ	174.60	Musconetcong	DO % Saturation	37	101.0%	98.4%	103.7%	99.3%	92.5%	116.5%
BCP	NJ	174.60	Musconetcong	DO mg/l	37	9.449	9.110	9.790	9.400	8.120	10.920
BCP	NJ	174.60	Musconetcong	E. coli col/100ml	30	136 geom			105	21	1,274
BCP	NJ	174.60	Musconetcong	Enterococcus col/100ml	35	210 geom			220	23	2,490
BCP	NJ	174.60	Musconetcong	Fecal Coliform col/100ml	35	256 geom			250	35	2,408
BCP	NJ	174.60	Musconetcong	Hardness mg/l	38	142.842	134.623	151.060	145.000	110.000	180.000
BCP	NJ	174.60	Musconetcong	Nitrate NO3-N mg/l	36	2.033	1.804	2.263	2.090	1.227	2.706
BCP	NJ	174.60	Musconetcong	Orthophosphate mg/l	31	0.031	0.020	0.043	0.020	0.005	0.064
BCP	NJ	174.60	Musconetcong	pH	38	7.89	7.77	8.00	7.90	7.40	8.30
BCP	NJ	174.60	Musconetcong	Phytoplankton Biomass (mg/m3)**	32	222.509	174.836	270.182	214.400	33.500	453.590
BCP	NJ	174.60	Musconetcong	Specific Conductance umhos/cm	38	383.7	365.9	401.4	383.0	291.3	450.1
BCP	NJ	174.60	Musconetcong	TDS mg/l	37	258.297	243.156	273.400	250.000	204.800	324.800
BCP	NJ	174.60	Musconetcong	TN:TP ratio (unitless)	30	50.711	32.927	68.496	44.286	14.783	74.660
BCP	NJ	174.60	Musconetcong	Total Kjeldahl Nitrogen mg/l	30	0.736	0.541	0.931	0.490	0.232	1.357
BCP	NJ	174.60	Musconetcong	Total Nitrogen mg/l*	30	2.713	2.454	2.972	2.645	1.867	3.553
BCP	NJ	174.60	Musconetcong	Total Phosphorus mg/l	31	0.087	0.057	0.117	0.070	0.032	0.118
BCP	NJ	174.60	Musconetcong	TSS mg/l	37	15.561	5.605	25.516	6.500	2.400	27.800
BCP	NJ	174.60	Musconetcong	Turbidity NTU	38	7.50	3.38	11.61	3.00	1.18	18.40
BCP	NJ	174.60	Musconetcong	Water Temperature F	38	65.5	63.7	67.3	65.1	57.5	72.3

Riegelsville Bridge, NJ/PA – River Mile 174.80
Interstate Control Point

2000-2003 Site Specific Existing Water Quality											
type	ST	rmi	site	Parameter	N	mean	lower95%	upper95%	median	10%ile	90%ile
ICP	DR	174.80	Del @ Rieglsvll	Alkalinity mg/l	40	46.85	39.06	54.64	45.00	27.00	58.80
ICP	DR	174.80	Del @ Rieglsvll	Ammonia NH3-N mg/l	34	0.057	0.040	0.074	0.040	0.025	0.110
ICP	DR	174.80	Del @ Rieglsvll	Chloride mg/l	40	13.808	11.439	16.176	16.000	1.070	21.000
ICP	DR	174.80	Del @ Rieglsvll	Chlorophyll A mg/m3	30	2.833	2.253	3.412	2.420	0.580	5.256
ICP	DR	174.80	Del @ Rieglsvll	Discharge (cfs)	40	9,614.72	7,004.65	12,224.79	7,343.00	2,991.55	21,341.50
ICP	DR	174.80	Del @ Rieglsvll	DO % Saturation	39	99.0%	96.9%	101.1%	97.7%	92.3%	108.0%
ICP	DR	174.80	Del @ Rieglsvll	DO mg/l	39	8.882	8.559	9.206	8.800	7.720	10.500
ICP	DR	174.80	Del @ Rieglsvll	E. coli col/100ml	30	39 geom			36	4	900
ICP	DR	174.80	Del @ Rieglsvll	Enterococcus col/100ml	35	79 geom			79	9	1,511
ICP	DR	174.80	Del @ Rieglsvll	Fecal Coliform col/100ml	35	90 geom			76	13	1,376
ICP	DR	174.80	Del @ Rieglsvll	Hardness mg/l	40	62.588	57.133	68.042	66.500	40.200	79.000
ICP	DR	174.80	Del @ Rieglsvll	Nitrate NO3-N mg/l	40	1.269	1.126	1.412	1.215	0.805	1.683
ICP	DR	174.80	Del @ Rieglsvll	Orthophosphate mg/l	33	0.065	0.053	0.077	0.060	0.030	0.116
ICP	DR	174.80	Del @ Rieglsvll	pH	40	7.66	7.54	7.79	7.63	7.20	8.14
ICP	DR	174.80	Del @ Rieglsvll	Phytoplankton Biomass (mg/m3)**	30	189.789	150.977	228.600	162.140	38.860	352.152
ICP	DR	174.80	Del @ Rieglsvll	Specific Conductance umhos/cm	40	178.3	164.9	191.7	189.5	115.9	232.5
ICP	DR	174.80	Del @ Rieglsvll	TDS mg/l	36	150.167	134.592	165.742	150.000	99.000	174.000
ICP	DR	174.80	Del @ Rieglsvll	TN:TP ratio (unitless)	30	16.594	14.235	18.952	14.657	8.952	26.733
ICP	DR	174.80	Del @ Rieglsvll	Total Kjeldahl Nitrogen mg/l	30	0.313	0.246	0.380	0.300	0.062	0.574
ICP	DR	174.80	Del @ Rieglsvll	Total Nitrogen mg/l*	30	1.457	1.328	1.587	1.460	0.919	1.879
ICP	DR	174.80	Del @ Rieglsvll	Total Phosphorus mg/l	31	0.099	0.084	0.114	0.110	0.050	0.158
ICP	DR	174.80	Del @ Rieglsvll	TSS mg/l	37	9.061	3.535	14.586	4.500	1.800	15.800
ICP	DR	174.80	Del @ Rieglsvll	Turbidity NTU	40	5.56	2.01	9.11	2.55	0.51	11.80
ICP	DR	174.80	Del @ Rieglsvll	Water Temperature F	40	69.7	67.2	72.1	71.4	60.5	81.0

Pohatcong Creek, Warren County, NJ – River Mile 177.40
New Jersey Boundary Control Point

2000-2003 Site Specific Existing Water Quality											
type	**ST**	**rmi**	**site**	**Parameter**	**N**	**mean**	**lower95%**	**upper95%**	**median**	**10%ile**	**90%ile**
BCP	NJ	177.40	Pohatcong	Alkalinity mg/l	38	110.89	100.75	121.04	110.00	73.30	151.00
BCP	NJ	177.40	Pohatcong	Ammonia NH3-N mg/l	30	0.053	0.035	0.071	0.025	0.025	0.134
BCP	NJ	177.40	Pohatcong	Chloride mg/l	38	16.613	14.335	18.890	20.000	3.300	23.000
BCP	NJ	177.40	Pohatcong	Discharge (cfs)	38	42.95	28.10	57.80	29.51	8.77	81.64
BCP	NJ	177.40	Pohatcong	DO % Saturation	38	99.9%	97.6%	102.3%	98.0%	91.9%	108.7%
BCP	NJ	177.40	Pohatcong	DO mg/l	38	9.817	9.495	10.140	9.710	8.835	11.130
BCP	NJ	177.40	Pohatcong	E. coli col/100ml	30	317 geom			250	92	2,753
BCP	NJ	177.40	Pohatcong	Enterococcus col/100ml	35	490 geom			560	73	4,372
BCP	NJ	177.40	Pohatcong	Fecal Coliform col/100ml	35	523 geom			540	112	3,664
BCP	NJ	177.40	Pohatcong	Hardness mg/l	38	140.658	130.374	150.940	140.000	94.500	181.000
BCP	NJ	177.40	Pohatcong	Nitrate NO3-N mg/l	36	2.273	2.025	2.520	2.420	1.002	3.058
BCP	NJ	177.40	Pohatcong	Orthophosphate mg/l	31	0.071	0.052	0.091	0.060	0.030	0.152
BCP	NJ	177.40	Pohatcong	pH	38	7.89	7.80	7.97	7.90	7.59	8.20
BCP	NJ	177.40	Pohatcong	Specific Conductance umhos/cm	38	320.2	301.1	339.4	337.0	243.0	385.3
BCP	NJ	177.40	Pohatcong	TDS mg/l	37	238.054	215.915	260.200	220.000	168.000	322.000
BCP	NJ	177.40	Pohatcong	TN:TP ratio (unitless)	30	35.305	26.987	43.623	28.486	13.185	58.513
BCP	NJ	177.40	Pohatcong	Total Kjeldahl Nitrogen mg/l	30	0.413	0.290	0.535	0.340	0.121	0.759
BCP	NJ	177.40	Pohatcong	Total Nitrogen mg/l*	30	2.904	2.677	3.130	3.045	1.826	3.459
BCP	NJ	177.40	Pohatcong	Total Phosphorus mg/l	30	0.120	0.085	0.155	0.095	0.060	0.242
BCP	NJ	177.40	Pohatcong	TSS mg/l	37	15.520	4.452	26.588	5.000	1.500	32.400
BCP	NJ	177.40	Pohatcong	Turbidity NTU	38	10.28	2.69	17.86	4.10	1.18	15.30
BCP	NJ	177.40	Pohatcong	Water Temperature F	38	61.5	59.8	63.3	61.0	56.1	68.4

Lehigh River, Northampton County, PA – River Mile 183.66
Pennsylvania Boundary Control Point

2000-2003 Site Specific Existing Water Quality											
type	**ST**	**rmi**	**site**	**Parameter**	**N**	**mean**	**lower95%**	**upper95%**	**median**	**10%ile**	**90%ile**
BCP	PA	183.66	Lehigh	Alkalinity mg/l	38	59.58	52.26	66.90	56.00	29.80	90.00
BCP	PA	183.66	Lehigh	Ammonia NH3-N mg/l	31	0.089	0.073	0.104	0.080	0.040	0.130
BCP	PA	183.66	Lehigh	Chloride mg/l	38	19.024	15.596	22.450	20.000	3.060	33.100
BCP	PA	183.66	Lehigh	Chlorophyll A mg/m3	32	3.081	2.333	3.830	2.700	0.500	6.347
BCP	PA	183.66	Lehigh	Discharge (cfs)	37	2,553.15	1,665.22	3,441.09	1,716.29	665.10	5,471.51
BCP	PA	183.66	Lehigh	DO % Saturation	38	97.4%	95.0%	99.7%	97.7%	87.9%	106.5%
BCP	PA	183.66	Lehigh	DO mg/l	38	8.937	8.616	9.260	8.970	7.660	9.972
BCP	PA	183.66	Lehigh	E. coli col/100ml	30	62 geom			44	10	1,170
BCP	PA	183.66	Lehigh	Enterococcus col/100ml	35	109 geom			100	11	2,588
BCP	PA	183.66	Lehigh	Fecal Coliform col/100ml	35	120 geom			100	14	1,917
BCP	PA	183.66	Lehigh	Hardness mg/l	38	91.579	82.182	100.980	95.500	55.300	130.000
BCP	PA	183.66	Lehigh	Nitrate NO3-N mg/l	35	2.043	1.704	2.382	1.840	1.216	2.640
BCP	PA	183.66	Lehigh	Orthophosphate mg/l	31	0.153	0.122	0.185	0.120	0.050	0.278
BCP	PA	183.66	Lehigh	pH	38	7.63	7.50	7.77	7.67	7.14	8.02
BCP	PA	183.66	Lehigh	Phytoplankton Biomass (mg/m3)**	32	206.402	156.336	256.467	180.900	33.500	425.249
BCP	PA	183.66	Lehigh	Specific Conductance umhos/cm	38	262.1	236.3	287.8	276.0	153.2	354.7
BCP	PA	183.66	Lehigh	TDS mg/l	37	193.730	173.945	213.500	190.000	136.000	280.000
BCP	PA	183.66	Lehigh	TN:TP ratio (unitless)	30	13.524	11.576	15.472	12.432	8.028	21.387
BCP	PA	183.66	Lehigh	Total Kjeldahl Nitrogen mg/l	30	0.638	0.483	0.793	0.505	0.281	1.323
BCP	PA	183.66	Lehigh	Total Nitrogen mg/l*	30	2.621	2.398	2.844	2.565	1.866	3.228
BCP	PA	183.66	Lehigh	Total Phosphorus mg/l	31	0.242	0.188	0.297	0.230	0.114	0.370
BCP	PA	183.66	Lehigh	TSS mg/l	37	10.243	4.075	16.411	4.000	1.500	27.800
BCP	PA	183.66	Lehigh	Turbidity NTU	38	7.04	4.37	9.71	3.05	1.19	20.60
BCP	PA	183.66	Lehigh	Water Temperature F	38	67.6	65.6	69.6	68.4	58.6	75.7

Easton-Phillipsburg Bridge (Northampton St.), PA/NJ – River Mile 183.82
Interstate Control Point

2000-2003 Site Specific Existing Water Quality											
type	ST	rmi	site	Parameter	N	mean	lower95%	upper95%	median	10%ile	90%ile
ICP	DR	183.82	Del @ Easton	Alkalinity mg/l	40	34.14	31.35	36.93	34.50	22.65	45.90
ICP	DR	183.82	Del @ Easton	Ammonia NH3-N mg/l	30	0.047	0.033	0.062	0.025	0.025	0.120
ICP	DR	183.82	Del @ Easton	Chloride mg/l	40	12.305	10.278	14.332	15.000	1.910	18.000
ICP	DR	183.82	Del @ Easton	Chlorophyll A mg/m3	38	2.044	1.510	2.578	1.450	0.500	4.584
ICP	DR	183.82	Del @ Easton	Discharge (cfs)	40	7,376.98	5,183.44	9,570.51	4,956.50	2,326.36	13,521.70
ICP	DR	183.82	Del @ Easton	DO % Saturation	39	95.7%	93.6%	97.7%	95.0%	87.8%	104.4%
ICP	DR	183.82	Del @ Easton	DO mg/l	39	8.550	8.220	8.890	8.100	7.500	10.000
ICP	DR	183.82	Del @ Easton	E. coli col/100ml	30	37 geom			30	5	387
ICP	DR	183.82	Del @ Easton	Enterococcus col/100ml	34	174 geom			162	40	995
ICP	DR	183.82	Del @ Easton	Fecal Coliform col/100ml	34	97 geom			85	8	1,050
ICP	DR	183.82	Del @ Easton	Hardness mg/l	40	47.163	44.282	50.043	46.000	35.000	59.900
ICP	DR	183.82	Del @ Easton	Nitrate NO3-N mg/l	39	0.973	0.844	1.103	0.860	0.620	1.500
ICP	DR	183.82	Del @ Easton	Orthophosphate mg/l	33	0.022	0.017	0.027	0.020	0.005	0.040
ICP	DR	183.82	Del @ Easton	pH	40	7.63	7.51	7.75	7.60	7.21	8.18
ICP	DR	183.82	Del @ Easton	Phytoplankton Biomass (mg/m3)**	38	136.936	101.148	172.723	97.150	33.500	307.128
ICP	DR	183.82	Del @ Easton	Specific Conductance umhos/cm	40	140.2	129.9	150.5	145.5	96.2	177.5
ICP	DR	183.82	Del @ Easton	TDS mg/l	37	128.568	116.389	140.746	120.000	100.000	216.000
ICP	DR	183.82	Del @ Easton	TN:TP ratio (unitless)	30	23.958	19.519	28.397	22.350	10.887	39.550
ICP	DR	183.82	Del @ Easton	Total Kjeldahl Nitrogen mg/l	30	0.455	0.317	0.594	0.350	0.140	0.925
ICP	DR	183.82	Del @ Easton	Total Nitrogen mg/l*	30	1.296	1.138	1.453	1.270	0.860	1.839
ICP	DR	183.82	Del @ Easton	Total Phosphorus mg/l	32	0.073	0.043	0.103	0.050	0.030	0.117
ICP	DR	183.82	Del @ Easton	TSS mg/l	37	7.250	3.455	11.045	4.000	0.900	16.800
ICP	DR	183.82	Del @ Easton	Turbidity NTU	40	4.63	3.02	6.24	2.55	1.00	9.82
ICP	DR	183.82	Del @ Easton	Water Temperature F	40	70.5	68.1	73.0	72.3	60.0	81.1

Bushkill Creek, Northampton County, PA – River Mile 184.10
Pennsylvania Boundary Control Point

2000-2003 Site Specific Existing Water Quality											
type	**ST**	**rmi**	**site**	**Parameter**	**N**	**mean**	**lower95%**	**upper95%**	**median**	**10%ile**	**90%ile**
BCP	PA	184.10	Bushkill	Alkalinity mg/l	38	140.45	128.98	151.92	140.00	91.60	190.00
BCP	PA	184.10	Bushkill	Ammonia NH3-N mg/l	30	0.121	0.093	0.149	0.105	0.040	0.209
BCP	PA	184.10	Bushkill	Chloride mg/l	38	21.758	18.559	24.960	25.000	3.680	31.000
BCP	PA	184.10	Bushkill	Discharge (cfs)	36	137.88	113.93	161.84	122.87	75.65	222.19
BCP	PA	184.10	Bushkill	DO % Saturation	38	104.5%	102.5%	106.4%	103.0%	98.7%	112.7%
BCP	PA	184.10	Bushkill	DO mg/l	38	10.265	10.060	10.470	10.250	9.458	10.866
BCP	PA	184.10	Bushkill	E. coli col/100ml	30	320 geom			425	44	1,869
BCP	PA	184.10	Bushkill	Enterococcus col/100ml	35	445 geom			410	156	1,880
BCP	PA	184.10	Bushkill	Fecal Coliform col/100ml	35	433 geom			580	46	3,754
BCP	PA	184.10	Bushkill	Hardness mg/l	38	216.605	202.045	231.170	217.500	159.000	280.000
BCP	PA	184.10	Bushkill	Nitrate NO3-N mg/l	30	3.942	3.694	4.190	3.750	3.210	4.857
BCP	PA	184.10	Bushkill	Orthophosphate mg/l	31	0.035	0.027	0.044	0.030	0.012	0.060
BCP	PA	184.10	Bushkill	pH	38	8.02	7.94	8.10	8.00	7.79	8.30
BCP	PA	184.10	Bushkill	Specific Conductance umhos/cm	38	563.4	521.2	605.6	572.0	369.1	717.4
BCP	PA	184.10	Bushkill	TDS mg/l	37	401.054	369.159	432.900	407.000	276.000	532.000
BCP	PA	184.10	Bushkill	TN:TP ratio (unitless)	30	96.683	75.357	118.009	88.300	38.900	138.150
BCP	PA	184.10	Bushkill	Total Kjeldahl Nitrogen mg/l	31	1.154	-0.156	2.463	0.430	0.168	0.960
BCP	PA	184.10	Bushkill	Total Nitrogen mg/l*	30	5.113	3.766	6.460	4.390	3.505	5.438
BCP	PA	184.10	Bushkill	Total Phosphorus mg/l	30	0.078	0.039	0.117	0.055	0.030	0.099
BCP	PA	184.10	Bushkill	TSS mg/l	37	9.366	3.963	14.769	5.000	1.000	18.000
BCP	PA	184.10	Bushkill	Turbidity NTU	38	7.23	3.13	11.34	2.80	1.50	14.10
BCP	PA	184.10	Bushkill	Water Temperature F	38	61.3	60.1	62.5	61.5	56.2	66.9

Martins Creek, Northampton County, PA – River Mile 190.58
Pennsylvania Boundary Control Point

2000-2003 Site Specific Existing Water Quality											
type	**ST**	**rmi**	**site**	**Parameter**	**N**	**mean**	**lower95%**	**upper95%**	**median**	**10%ile**	**90%ile**
BCP	PA	190.58	Martins	Alkalinity mg/l	25	49.04	44.20	53.88	48.00	34.60	66.40
BCP	PA	190.58	Martins	Ammonia NH3-N mg/l	17	0.051	0.030	0.072	0.040	0.024	0.102
BCP	PA	190.58	Martins	Chloride mg/l	25	16.788	12.322	21.250	21.000	2.200	31.600
BCP	PA	190.58	Martins	Discharge (cfs)	25	72.08	51.71	92.45	73.26	8.28	152.55
BCP	PA	190.58	Martins	DO % Saturation	25	98.1%	96.5%	99.6%	98.7%	91.8%	102.7%
BCP	PA	190.58	Martins	DO mg/l	25	9.606	9.376	9.840	9.600	8.890	10.420
BCP	PA	190.58	Martins	E. coli col/100ml	17	100 (geom)			150	4	1,460
BCP	PA	190.58	Martins	Enterococcus col/100ml	22	426 (geom)			375	109	2,070
BCP	PA	190.58	Martins	Fecal Coliform col/100ml	22	240 (geom)			315	32	1,150
BCP	PA	190.58	Martins	Hardness mg/l	25	118.000	104.672	131.330	120.000	82.400	150.000
BCP	PA	190.58	Martins	Nitrate NO3-N mg/l	21	2.435	2.114	2.756	2.610	1.272	3.346
BCP	PA	190.58	Martins	Orthophosphate mg/l	18	0.147	0.102	0.193	0.115	0.040	0.269
BCP	PA	190.58	Martins	pH	25	7.72	7.58	7.85	7.70	7.38	8.34
BCP	PA	190.58	Martins	Specific Conductance umhos/cm	25	312.3	287.9	336.6	322.0	220.2	393.4
BCP	PA	190.58	Martins	TDS mg/l	24	221.250	203.777	238.700	219.000	160.000	280.000
BCP	PA	190.58	Martins	TN:TP ratio (unitless)	17	24.156	16.218	32.093	19.500	10.740	54.211
BCP	PA	190.58	Martins	Total Kjeldahl Nitrogen mg/l	17	0.418	0.276	0.560	0.340	0.077	0.868
BCP	PA	190.58	Martins	Total Nitrogen mg/l*	17	3.069	2.732	3.405	3.040	2.266	4.130
BCP	PA	190.58	Martins	Total Phosphorus mg/l	18	0.159	0.120	0.198	0.135	0.072	0.281
BCP	PA	190.58	Martins	TSS mg/l	24	4.783	2.105	7.461	2.400	0.375	15.000
BCP	PA	190.58	Martins	Turbidity NTU	25	3.14	1.95	4.32	1.80	0.32	8.00
BCP	PA	190.58	Martins	Water Temperature F	25	61.6	59.9	63.3	61.7	55.8	66.6

Pequest River, Warren County, NJ – River Mile 197.80
New Jersey Boundary Control Point

2000-2003 Site Specific Existing Water Quality											
type	ST	rmi	site	Parameter	N	mean	lower95%	Upper95%	median	10%ile	90%ile
BCP	NJ	197.80	Pequest	Alkalinity mg/l	38	180.37	168.89	191.84	187.50	129.00	211.00
BCP	NJ	197.80	Pequest	Ammonia NH3-N mg/l	30	0.055	0.038	0.071	0.033	0.025	0.120
BCP	NJ	197.80	Pequest	Chloride mg/l	38	30.326	25.163	35.490	35.500	4.230	42.300
BCP	NJ	197.80	Pequest	Chlorophyll A mg/m3	25	2.512	1.882	3.140	2.140	0.500	4.698
BCP	NJ	197.80	Pequest	Discharge (cfs)	36	160.91	90.60	231.23	84.02	0.10	619.79
BCP	NJ	197.80	Pequest	DO % Saturation	38	104.6%	101.7%	107.6%	104.6%	93.4%	117.1%
BCP	NJ	197.80	Pequest	DO mg/l	38	10.062	9.783	10.340	10.100	8.996	11.310
BCP	NJ	197.80	Pequest	E. coli col/100ml	30	123 (geom)			135	24	436
BCP	NJ	197.80	Pequest	Enterococcus col/100ml	35	257 (geom)			250	53	1,472
BCP	NJ	197.80	Pequest	Fecal Coliform col/100ml	35	156 (geom)			162	36	686
BCP	NJ	197.80	Pequest	Hardness mg/l	38	224.553	216.074	233.030	227.500	199.000	260.500
BCP	NJ	197.80	Pequest	Nitrate NO3-N mg/l	36	1.407	1.294	1.519	1.415	0.919	1.858
BCP	NJ	197.80	Pequest	Orthophosphate mg/l	31	0.066	0.054	0.078	0.060	0.032	0.108
BCP	NJ	197.80	Pequest	pH	38	8.20	8.13	8.28	8.19	7.98	8.48
BCP	NJ	197.80	Pequest	Phytoplankton Biomass (mg/m3)**	25	168.331	126.072	210.589	143.380	33.500	314.766
BCP	NJ	197.80	Pequest	Specific Conductance umhos/cm	38	481.2	463.4	499.0	488.0	393.6	545.2
BCP	NJ	197.80	Pequest	TDS mg/l	37	330.838	305.553	356.100	330.000	264.000	423.200
BCP	NJ	197.80	Pequest	TN:TP ratio (unitless)	30	23.194	13.185	33.204	17.429	12.583	29.514
BCP	NJ	197.80	Pequest	Total Kjeldahl Nitrogen mg/l	30	0.521	0.349	0.693	0.470	0.112	0.981
BCP	NJ	197.80	Pequest	Total Nitrogen mg/l*	30	1.895	1.739	2.051	1.875	1.381	2.388
BCP	NJ	197.80	Pequest	Total Phosphorus mg/l	32	0.108	0.091	0.125	0.100	0.066	0.197
BCP	NJ	197.80	Pequest	TSS mg/l	37	10.386	5.564	15.209	6.000	1.400	24.800
BCP	NJ	197.80	Pequest	Turbidity NTU	38	4.62	3.13	6.12	2.75	0.50	13.10
BCP	NJ	197.80	Pequest	Water Temperature F	38	63.1	61.6	64.7	63.5	56.4	69.7

Belvidere-Riverton Bridge, NJ/PA – River Mile 197.84
Interstate Control Point

2000-2003 Site Specific Existing Water Quality											
type	**ST**	**rmi**	**site**	**Parameter**	**N**	**mean**	**lower95%**	**upper95%**	**median**	**10%ile**	**90%ile**
ICP	DR	197.84	Del @ Belvidere	Alkalinity mg/l	40	27.20	22.35	32.05	26.50	15.00	34.00
ICP	DR	197.84	Del @ Belvidere	Ammonia NH3-N mg/l	30	0.045	0.030	0.060	0.025	0.025	0.107
ICP	DR	197.84	Del @ Belvidere	Chloride mg/l	40	11.068	9.206	12.929	13.500	1.520	16.720
ICP	DR	197.84	Del @ Belvidere	Chlorophyll A mg/m3	30	2.070	1.552	2.588	1.900	0.500	4.270
ICP	DR	197.84	Del @ Belvidere	Discharge (cfs)	40	7,131.94	4,914.22	9,349.66	4,610.50	2,162.52	12,817.20
ICP	DR	197.84	Del @ Belvidere	DO % Saturation	40	95.3%	93.1%	97.4%	93.9%	88.4%	106.0%
ICP	DR	197.84	Del @ Belvidere	DO mg/l	40	8.553	8.190	8.920	8.540	7.207	9.979
ICP	DR	197.84	Del @ Belvidere	E. coli col/100ml	30	20 (geom)			18	4	179
ICP	DR	197.84	Del @ Belvidere	Enterococcus col/100ml	35	62 (geom)			56	12	352
ICP	DR	197.84	Del @ Belvidere	Fecal Coliform col/100ml	35	30 (geom)			20	5	198
ICP	DR	197.84	Del @ Belvidere	Hardness mg/l	40	33.950	31.430	36.470	35.000	25.100	43.000
ICP	DR	197.84	Del @ Belvidere	Nitrate NO3-N mg/l	30	0.652	0.569	0.735	0.700	0.443	0.900
ICP	DR	197.84	Del @ Belvidere	Orthophosphate mg/l	33	0.014	0.011	0.017	0.010	0.005	0.028
ICP	DR	197.84	Del @ Belvidere	pH	40	7.46	7.32	7.61	7.50	7.00	8.00
ICP	DR	197.84	Del @ Belvidere	Phytoplankton Biomass (mg/m3)**	30	138.690	103.982	173.398	127.300	33.500	286.090
ICP	DR	197.84	Del @ Belvidere	Specific Conductance umhos/cm	40	112.3	105.3	119.3	114.5	81.0	136.9
ICP	DR	197.84	Del @ Belvidere	TDS mg/l	37	105.730	94.940	116.519	100.000	75.400	144.000
ICP	DR	197.84	Del @ Belvidere	TN:TP ratio (unitless)	30	23.873	18.536	29.210	22.225	9.660	30.642
ICP	DR	197.84	Del @ Belvidere	Total Kjeldahl Nitrogen mg/l	30	0.353	0.218	0.489	0.300	0.061	0.838
ICP	DR	197.84	Del @ Belvidere	Total Nitrogen mg/l*	30	1.005	0.858	1.152	0.955	0.599	1.380
ICP	DR	197.84	Del @ Belvidere	Total Phosphorus mg/l	30	0.049	0.040	0.058	0.045	0.030	0.070
ICP	DR	197.84	Del @ Belvidere	TSS mg/l	37	4.730	2.240	7.220	3.000	0.250	9.200
ICP	DR	197.84	Del @ Belvidere	Turbidity NTU	40	3.33	1.82	4.84	1.60	0.61	6.87
ICP	DR	197.84	Del @ Belvidere	Water Temperature F	40	70.0	67.5	72.5	71.3	58.6	81.0

Paulins Kill River, Warren County, NJ – River Mile 207.00
New Jersey Boundary Control Point

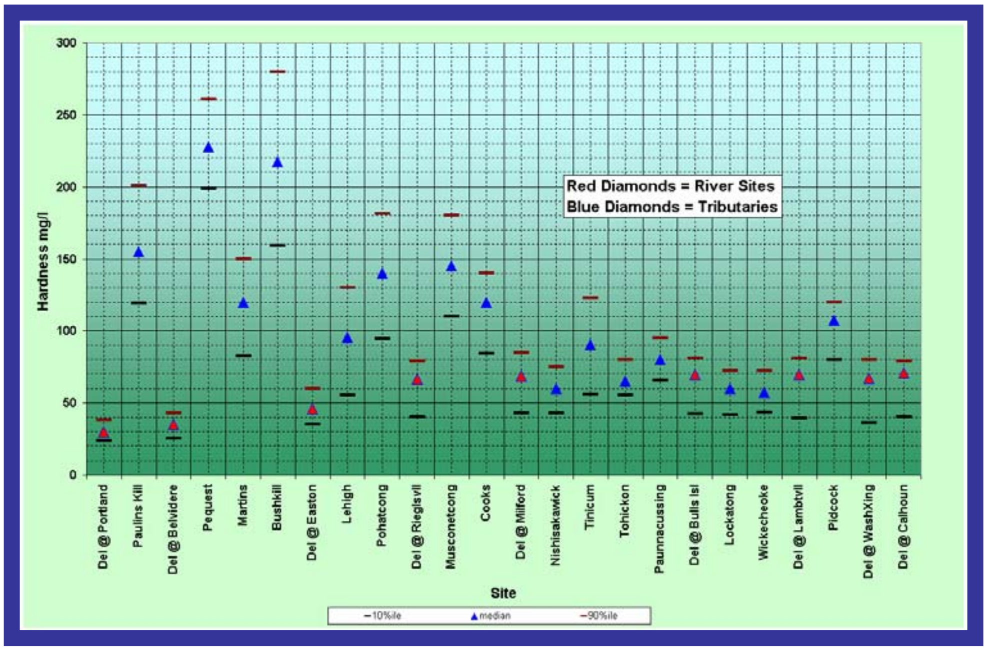
2000-2003 Site Specific Existing Water Quality											
type	**ST**	**rmi**	**site**	**Parameter**	**N**	**mean**	**lower95%**	**upper95%**	**median**	**10%ile**	**90%ile**
BCP	NJ	207.00	Paulins Kill	Alkalinity mg/l	38	121.50	110.01	132.99	122.50	74.70	161.00
BCP	NJ	207.00	Paulins Kill	Ammonia NH3-N mg/l	30	0.078	0.063	0.092	0.070	0.025	0.138
BCP	NJ	207.00	Paulins Kill	Chloride mg/l	38	35.258	28.791	41.720	39.000	4.380	59.000
BCP	NJ	207.00	Paulins Kill	Chlorophyll A mg/m3	30	4.868	2.433	7.300	3.300	0.500	7.442
BCP	NJ	207.00	Paulins Kill	Discharge (cfs)	38	222.07	149.80	294.33	165.77	29.40	627.25
BCP	NJ	207.00	Paulins Kill	DO % Saturation	38	88.1%	85.1%	91.1%	87.9%	77.3%	103.4%
BCP	NJ	207.00	Paulins Kill	DO mg/l	38	8.090	7.705	8.470	7.975	6.876	9.460
BCP	NJ	207.00	Paulins Kill	E. coli col/100ml	30	52 (geom)			50	12	237
BCP	NJ	207.00	Paulins Kill	Enterococcus col/100ml	35	109 (geom)			100	26	584
BCP	NJ	207.00	Paulins Kill	Fecal Coliform col/100ml	35	103 (geom)			100	8	1,208
BCP	NJ	207.00	Paulins Kill	Hardness mg/l	38	158.026	145.062	170.990	155.000	119.500	201.000
BCP	NJ	207.00	Paulins Kill	Nitrate NO3-N mg/l	35	0.940	0.729	1.151	0.810	0.622	1.200
BCP	NJ	207.00	Paulins Kill	Orthophosphate mg/l	31	0.023	0.017	0.029	0.020	0.005	0.040
BCP	NJ	207.00	Paulins Kill	pH	38	7.77	7.64	7.89	7.80	7.49	8.11
BCP	NJ	207.00	Paulins Kill	Phytoplankton Biomass (mg/m3)**	30	326.178	163.019	489.338	221.100	33.500	498.614
BCP	NJ	207.00	Paulins Kill	Specific Conductance umhos/cm	38	411.0	385.7	436.3	417.0	300.5	500.6
BCP	NJ	207.00	Paulins Kill	TDS mg/l	37	266.135	243.863	288.400	277.000	204.000	341.200
BCP	NJ	207.00	Paulins Kill	TN:TP ratio (unitless)	30	23.994	20.227	27.762	22.125	13.400	35.145
BCP	NJ	207.00	Paulins Kill	Total Kjeldahl Nitrogen mg/l	30	0.477	0.343	0.611	0.375	0.172	0.974
BCP	NJ	207.00	Paulins Kill	Total Nitrogen mg/l*	30	1.277	1.141	1.413	1.180	0.930	1.719
BCP	NJ	207.00	Paulins Kill	Total Phosphorus mg/l	33	0.063	0.052	0.074	0.060	0.040	0.080
BCP	NJ	207.00	Paulins Kill	TSS mg/l	37	7.886	6.033	9.740	7.000	1.900	18.000
BCP	NJ	207.00	Paulins Kill	Turbidity NTU	38	5.17	3.74	6.60	4.00	1.39	12.00
BCP	NJ	207.00	Paulins Kill	Water Temperature F	38	67.7	65.7	69.6	67.9	60.1	75.9

Portland-Columbia Foot Bridge, PA/NJ – River Mile 207.40
Interstate Control Point

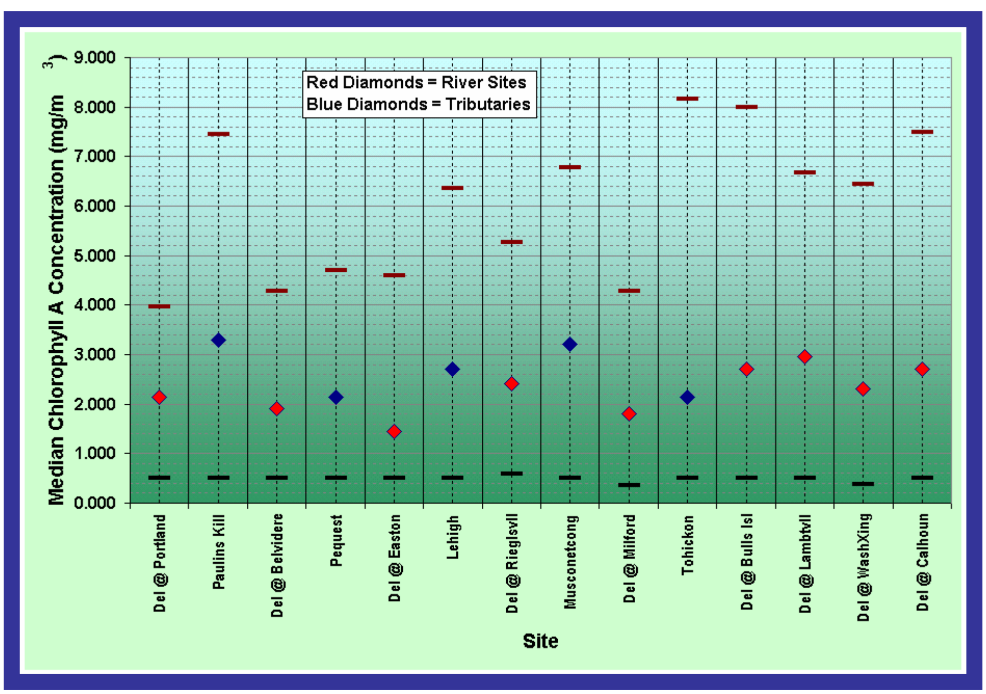
2000-2003 Site Specific Existing Water Quality											
type	**ST**	**rmi**	**site**	**Parameter**	**N**	**mean**	**lower95%**	**upper95%**	**median**	**10%ile**	**90%ile**
ICP	DR	207.40	Del @ Portland	Alkalinity mg/l	40	23.00	17.33	28.67	20.50	10.30	28.90
ICP	DR	207.40	Del @ Portland	Ammonia NH3-N mg/l	30	0.048	0.030	0.065	0.025	0.025	0.116
ICP	DR	207.40	Del @ Portland	Chloride mg/l	40	10.550	8.344	12.756	12.000	1.230	15.000
ICP	DR	207.40	Del @ Portland	Chlorophyll A mg/m3	36	2.229	1.781	2.678	2.130	0.500	3.956
ICP	DR	207.40	Del @ Portland	Discharge (cfs)	40	6,907.49	4,761.22	9,053.76	4,466.00	2,027.69	12,187.20
ICP	DR	207.40	Del @ Portland	DO % Saturation	40	97.5%	95.5%	99.5%	97.2%	89.7%	104.0%
ICP	DR	207.40	Del @ Portland	DO mg/l	40	8.885	8.538	9.232	8.800	7.647	10.480
ICP	DR	207.40	Del @ Portland	E. coli col/100ml	30	19 (geom.)			14	2	280
ICP	DR	207.40	Del @ Portland	Enterococcus col/100ml	35	39 (geom)			32	7	534
ICP	DR	207.40	Del @ Portland	Fecal Coliform col/100ml	35	27 (geom)			20	2	610
ICP	DR	207.40	Del @ Portland	Hardness mg/l	40	32.663	25.635	39.690	30.000	24.000	38.000
ICP	DR	207.40	Del @ Portland	Nitrate NO3-N mg/l	40	0.909	0.632	1.186	0.730	0.460	2.000
ICP	DR	207.40	Del @ Portland	Orthophosphate mg/l	33	0.015	0.009	0.020	0.010	0.005	0.036
ICP	DR	207.40	Del @ Portland	pH	39	7.52	7.37	7.67	7.50	6.95	8.20
ICP	DR	207.40	Del @ Portland	Phytoplankton Biomass (mg/m3)**	37	146.123	116.156	176.091	142.710	33.500	265.060
ICP	DR	207.40	Del @ Portland	Specific Conductance umhos/cm	40	96.0	90.9	101.1	98.0	71.2	114.8
ICP	DR	207.40	Del @ Portland	TDS mg/l	37	99.541	85.377	113.704	88.000	65.000	152.800
ICP	DR	207.40	Del @ Portland	TN:TP ratio (unitless)	30	25.717	20.147	31.287	23.175	12.830	50.333
ICP	DR	207.40	Del @ Portland	Total Kjeldahl Nitrogen mg/l	30	0.356	0.205	0.507	0.285	0.025	1.018
ICP	DR	207.40	Del @ Portland	Total Nitrogen mg/l*	30	1.020	0.857	1.182	0.933	0.553	1.493
ICP	DR	207.40	Del @ Portland	Total Phosphorus mg/l	31	0.048	0.038	0.059	0.040	0.020	0.089
ICP	DR	207.40	Del @ Portland	TSS mg/l	37	4.858	2.145	7.572	2.500	0.450	10.200
ICP	DR	207.40	Del @ Portland	Turbidity NTU	40	4.44	2.45	6.43	1.55	0.50	11.80
ICP	DR	207.40	Del @ Portland	Water Temperature F	40	68.5	66.1	70.8	69.0	57.8	78.2

Appendix B: Water Quality Plots for Parameters Without Criteria

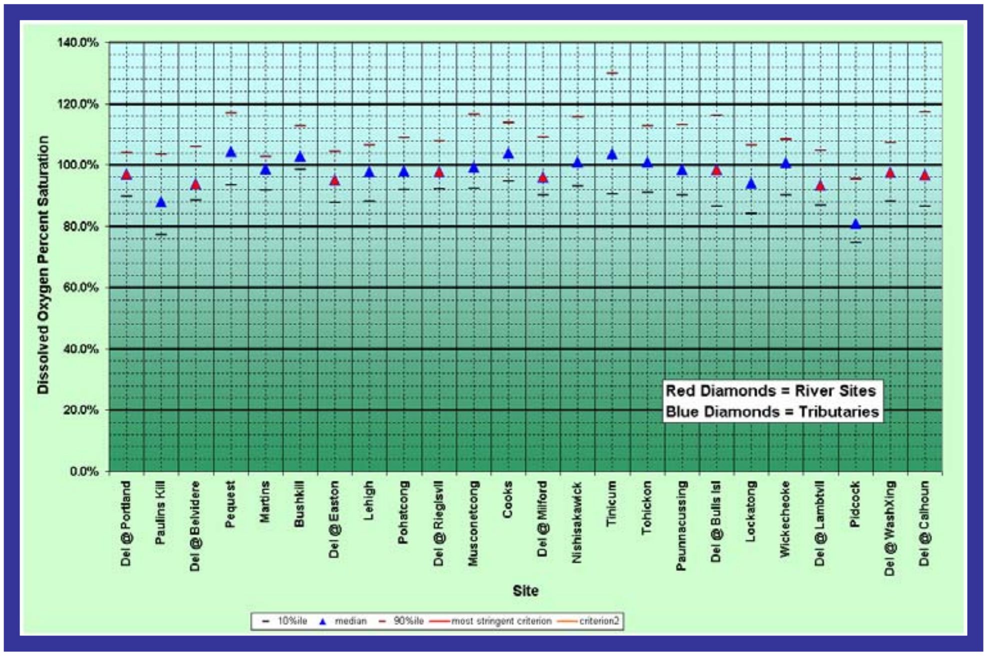
CaCO3 Hardness mg/l in the Lower Delaware River and Tributaries



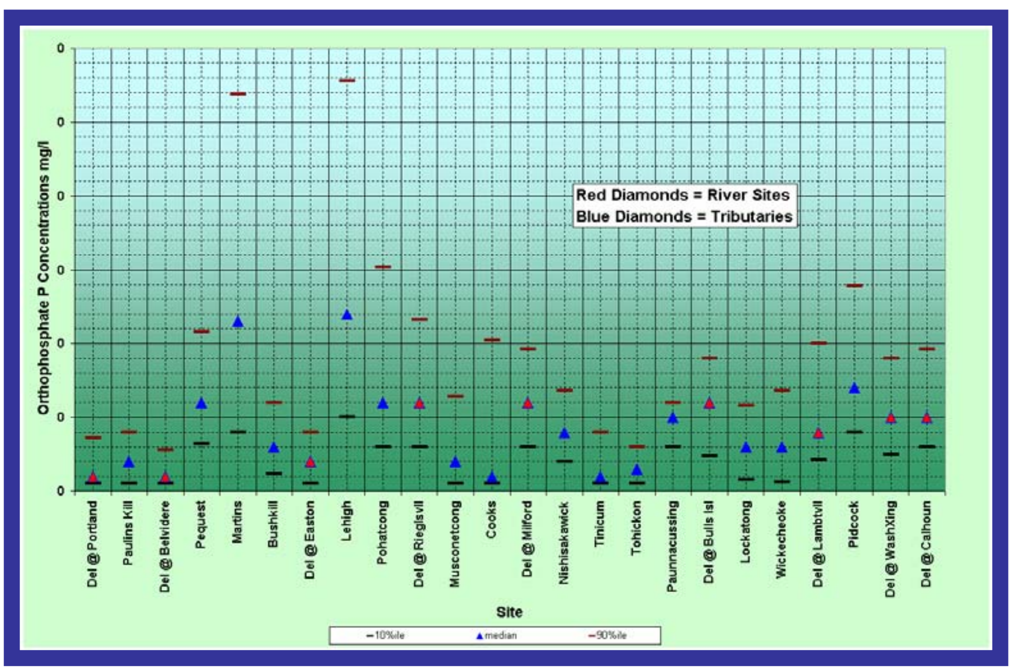
Chlorophyll A Concentrations in the Lower Delaware River and Large Tributaries



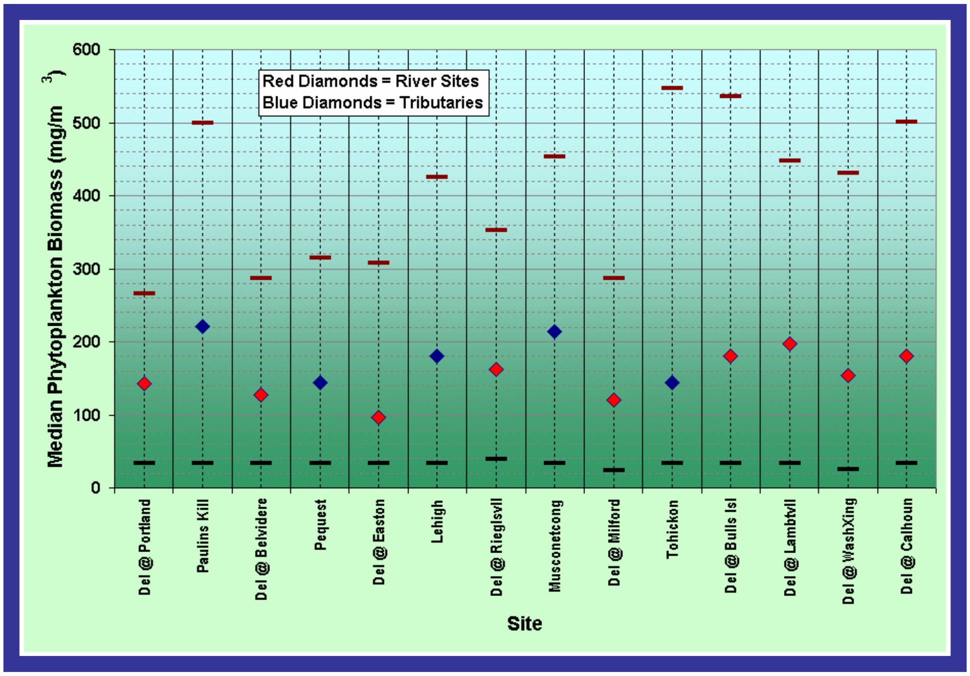
Dissolved Oxygen Percent Saturation in the Lower Delaware River and Tributaries



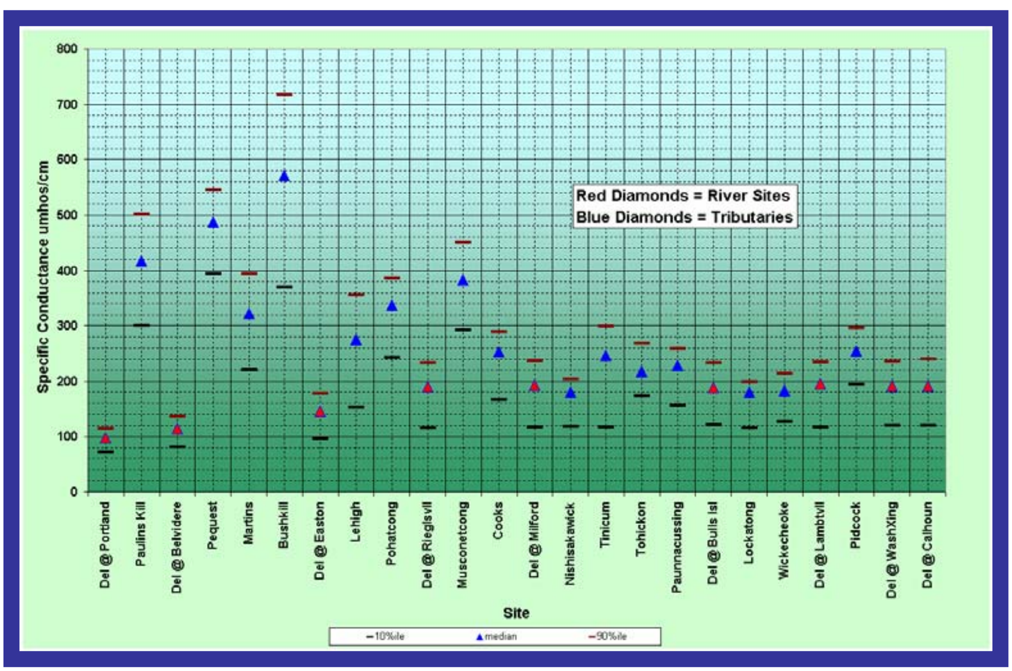
Orthophosphate Phosphorus in the Lower Delaware River and Tributaries



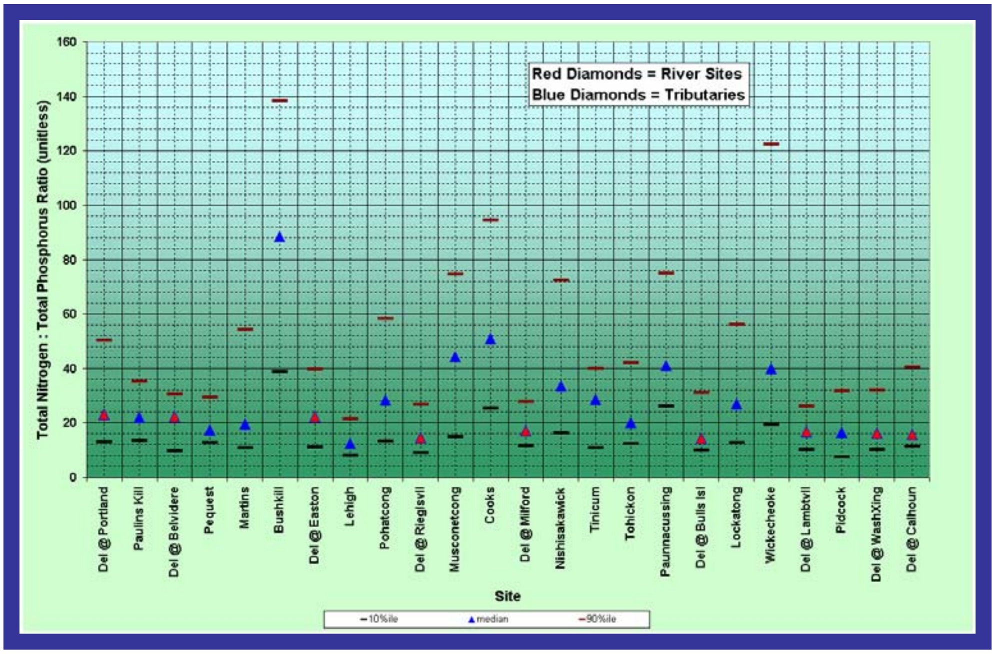
Phytoplankton Biomass in the Lower Delaware River and Selected Large Tributaries



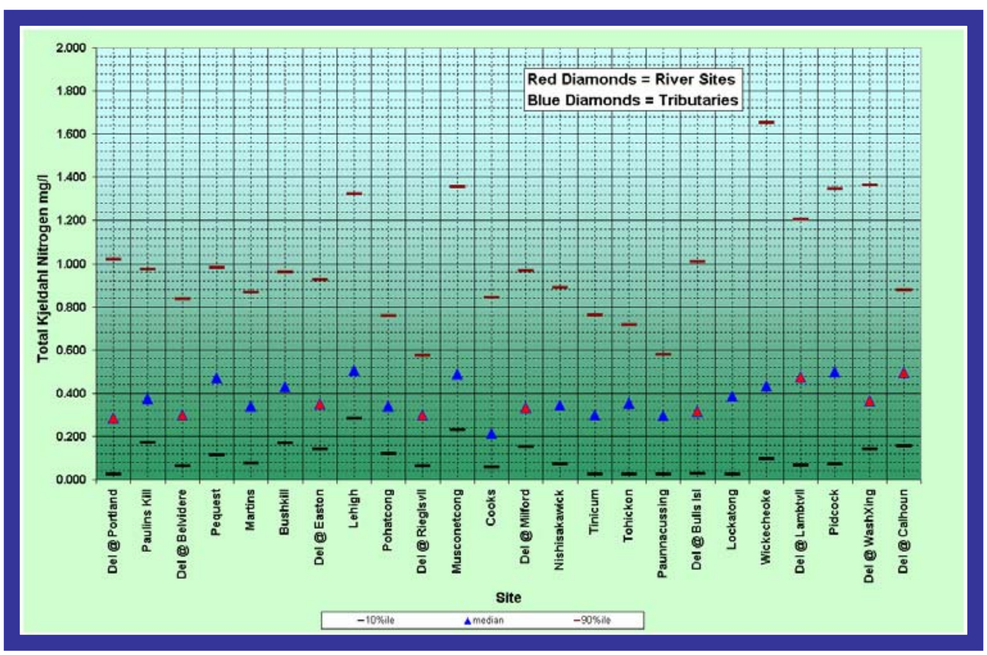
Specific Conductance in the Lower Delaware River and Tributaries



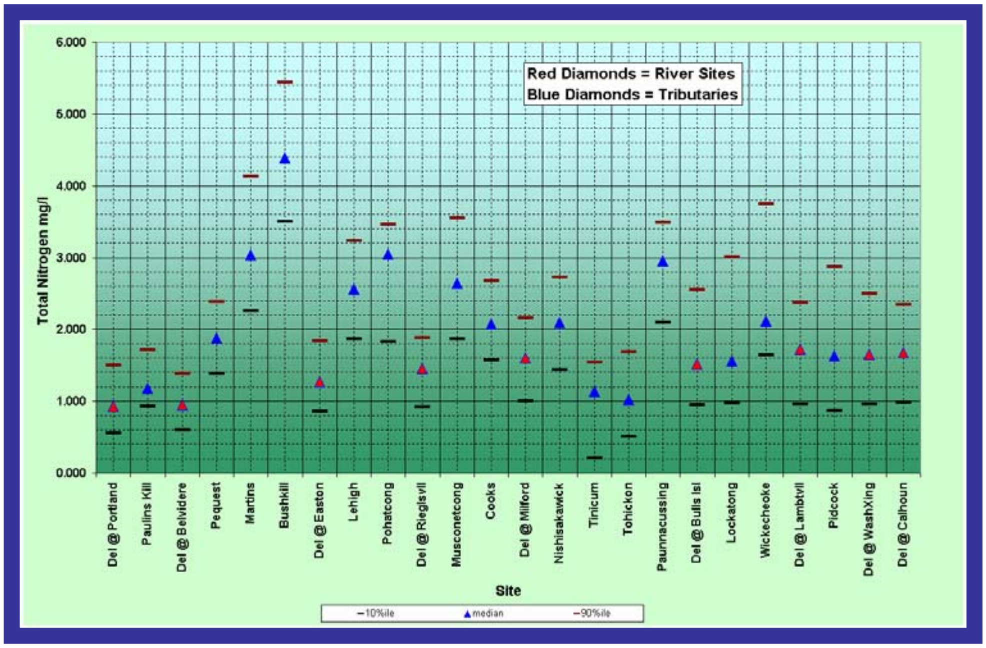
Total Nitrogen:Total Phosphorus Ratio in the Lower Delaware River & Tributaries



Total Kjeldahl Nitrogen in the Lower Delaware River and Tributaries



Total Nitrogen in the Lower Delaware River and Tributaries.



Appendix C: Longitudinal Water Quality Comparison of Median Concentrations from the Lower Delaware Monitoring Program, 2000-2003

Codes:

Trib vs River = Tributary BCP median concentrations statistically compared to upstream neighbor ICP
River vs River = Upstream ICP concentrations statistically compared to downstream neighbor ICP

BCP = Boundary Control Point (Tributary Sites near Delaware River confluence)
ICP = Interstate Control Point (Delaware River Sites)

BEL = Belvidere-Riverton Bridge ICP River Mile 197.84
BUL = Bulls Island Foot Bridge ICP; Lumberville-Raven Rock; River Mile 155.40
BUS = Bushkill Creek BCP; Northampton Co., PA; River Mile 184.10
CAL = Calhoun Street Bridge ICP, Trenton-Morrisville; River Mile 134.34
COO = Cooks Creek BCP; Bucks County, PA; River Mile 173.70
EAS = Northampton Street Bridge, Easton-Phillipsburg ICP; River Mile 183.82
LAM = Lambertville-New Hope Bridge ICP; River Mile 148.70
LEH = Lehigh River BCP; Northampton Co., PA; River Mile 183.66
LOC = Lockatong Creek BCP; Hunterdon Co., NJ; River Mile 154.00
MAR = Martins Creek BCP; Northampton Co., PA; River Mile 190.58
MIL = Milford-Upper Black Eddy Bridge ICP; River Mile 167.70
MUS = Musconetcong River BCP; Hunterdon/Warren Co., NJ; River Mile 174.60
NIS = Nishisakawick Creek BCP; Hunterdon Co., NJ; River Mile 164.10
PAN = Paunnacussing Creek BCP; Bucks Co., PA; River Mile 155.60
PAU = Paulins Kill River BCP, Warren Co., NJ; River Mile 207.0
PEQ = Pequest River BCP; Warren Co., NJ; River Mile 197.80
PID = Pidcock Creek BCP; Bucks Co., PA; River Mile 146.3
POH = Pohatcong Creek BCP; Warren Co., NJ; River Mile 177.40
POR = Columbia-Portland Footbridge ICP, River Mile 207.4
RIE = Riegelsville Bridge ICP; River Mile 174.80
TIN = Tinicum Creek BCP; Bucks Co., PA; River Mile 161.60
TOH = Tohickon Creek BCP; Bucks Co., PA; River Mile 157.00
WAX = Washington Crossing Bridge ICP; River Mile 141.8
WIC = Wickecheoke Creek BCP; Hunterdon Co., NJ; River Mile 152.50

No change or improves Delaware
Significantly higher than Delaware
Significant change in river

Longitudinal Water Quality Comparison of Sites in the Lower Delaware River
2000-2003 May to September Lower Delaware Monitoring Program Data

	TRIB VS. RIVER	RIVER VS. RIVER	TRIB VS. RIVER	TRIB VS. RIVER	RIVER VS. RIVER	TRIB VS. RIVER	TRIB VS. RIVER
	PAU vs POR	**BEL vs POR**	**PEQ vs BEL**	**BUS vs BEL**	**EAS vs BEL**	**LEH vs EAS**	**POH vs EAS**
Parameter	**Difference Medians**	**Difference Medians**	**Difference Medians**	**Difference Medians**	**Difference Medians**	**Difference Medians**	**Difference Medians**
PARAMETERS DESCRIBING DATA SET							
Discharge (cfs)	165.8	144.5	84.0	122.9	346.0	1,716.3	29.5
GENERAL WATER QUALITY PARAMETERS							
Discharge per Drainage Area (cfs/mi2)	-0.136	-0.019	-0.518	0.483	-0.002	0.210	-0.534
DO mg/l	-0.8	-0.3	1.56	1.71	-0.44	0.87	1.61
DO % Saturation	-9.3%	-3.3%	10.66%	9.1%	1.1%	2.7%	2.94%
Water Temperature F	-1.1	2.3	-7.8	-9.9	1.0	-4.0	-11.3
pH	0.30	0.00	0.69	0.50	0.09	0.07	0.31
TDS mg/l	189.0	12.0	230.0	307.0	20.0	70.0	100.0
TSS mg/l	4.5	0.5	3.0	2.0	1.0	0.0	1.0
Hardness mg/l	125.0	5.0	192.5	182.5	11.0	49.5	94.0
Alkalinity mg/l	102.0	6.0	161.0	113.5	8.00	21.5	75.5
Turbidity NTU	2.5	0.1	1.15	1.2	1.0	0.5	1.6
Chloride mg/l	27.0	1.5	22.0	11.5	1.5	5.0	5.0
NUTRIENTS AND PRIMARY PRODUCTION PARAMETERS							
Total Phosphorus mg/l	0.020	0.005	0.055	0.010	0.005	0.180	0.045
Orthophosphate mg/l	0.010	0.000	0.050	0.020	0.010	0.100	0.040
Nitrate NO3-N mg/l	0.080	-0.030	0.715	3.050	0.160	0.980	1.560
Total Kjeldahl Nitrogen mg/l	0.090	0.015	0.170	0.130	0.050	0.155	-0.010
Ammonia NH3-N mg/l	0.045	0.000	0.008	0.080	0.000	0.055	0.000
Total Nitrogen mg/l*	0.248	0.023	0.920	3.435	0.315	1.295	1.775
Chlorophyll A mg/m3	1.17	-0.23	0.24		-0.45	1.25	
Phytoplankton Biomass (mg/m3)**	78.39	-15.41	16.08		-30.15	83.75	
BACTERIA PARAMETERS							
Enterococcus col/100ml	68	24	194	354	106	-62	398
Fecal Coliform col/100ml	80	0	142	560	65	15	455
E. coli col/100ml	37	5	117	407	12	14	220

No change or improves Delaware
Significantly higher than Delaware
Significant change in river

Longitudinal Water Quality Comparison of Sites in the Lower Delaware River 2000-2003 May to September Lower Delaware Monitoring Program Data

	RIVER VS. RIVER	TRIB VS. RIVER	TRIB VS. RIVER	RIVER VS. RIVER	TRIB VS. RIVER	TRIB VS. RIVER	TRIB VS. RIVER	TRIB VS. RIVER
	RIE vs EAS	MUS vs RIE	COO vs RIE	MIL vs RIE	NIS vs MIL	TIN vs MIL	TOH vs MIL	PAN vs MIL
Parameter	Difference Medians	Difference Medians	Difference Medians	Difference Medians	Difference Medians	Difference Medians	Difference Medians	Difference Medians
PARAMETERS DESCRIBING DATA SET								
Discharge (cfs)	2,386.5	179.1	35.3	262.0	3	12	30	9
GENERAL WATER QUALITY PARAMETERS								
Discharge per Drainage Area (cfs/mi2)	0.110	-0.012	0.037	0.031	-0.950	-0.710	-0.923	-0.069
DO mg/l	0.70	0.60	1.30	0.00	0.85	1.00	0.30	0.62
DO % Saturation	2.68%	1.55%	6.19%	-1.59%	4.85%	7.46%	4.80%	2.34%
Water Temperature F	-0.87	-6.33	-8.6	-0.1	-5.1	-4.1	-0.5	-7.5
pH	0.03	0.28	0.38	-0.03	0.30	0.41	0.40	0.00
TDS mg/l	30.0	100.0	30.0	0.0	-20.0	30.0	19.0	-7.0
TSS mg/l	0.5	2.0	-2.0	0.5	-3.5	-3.0	-3.0	-4.0
Hardness mg/l	20.5	78.5	53.5	2.0	-8.5	22.0	-3.5	11.5
Alkalinity mg/l	10.5	55.5	51.5	0.0	0.0	16.0	1.0	2.0
Turbidity NTU	0.0	0.5	-1.1	0.4	-1.6	-1.8	-1.9	-2.1
Chloride mg/l	1.0	26.0	-7.1	0.0	-2.0	-3.0	11.0	8.0
NUTRIENTS AND PRIMARY PRODUCTION PARAMETERS								
Total Phosphorus mg/l	0.060	-0.040	-0.070	0.000	-0.050	-0.070	-0.070	-0.040
Orthophosphate mg/l	0.040	-0.040	-0.050	0.000	-0.020	-0.050	-0.045	-0.010
Nitrate NO3-N mg/l	0.355	0.875	0.610	0.035	0.370	-0.460	-0.560	1.330
Total Kjeldahl Nitrogen mg/l	-0.050	0.190	-0.085	0.035	0.010	-0.035	0.020	-0.040
Ammonia NH3-N mg/l	0.015	0.020	-0.015	-0.013	-0.003	-0.003	-0.003	-0.003
Total Nitrogen mg/l*	0.190	1.185	0.615	0.145	0.488	-0.465	-0.583	1.350
Chlorophyll A mg/m3	0.97	0.78		-0.62			0.34	
Phytoplankton Biomass (mg/m3)**	64.99	52.26		-41.54			22.78	
BACTERIA PARAMETERS								
Enterococcus col/100ml	-83	141	281	-19	180	140	530	260
Fecal Coliform col/100ml	-9	174	74	-26	35	105	28	30
E. coli col/100ml	6	69	62	-12	24	56	12	4

No change or improves Delaware
Significantly higher than Delaware
Significant change in river

Longitudinal Water Quality Comparison of Sites in the Lower Delaware River 2000-2003 May to September Lower Delaware Monitoring Program Data

	RIVER VS. RIVER	TRIB VS. RIVER	TRIB VS. RIVER	RIVER VS. RIVER	TRIB VS. RIVER	RIVER VS. RIVER	RIVER VS. RIVER
	BUL vs MIL	LOC vs BUL	WIC vs BUL	LAM vs BUL	PID vs LAM	WAX vs LAM	CAL vs WAX
Parameter	Difference Medians	Difference Medians	Difference Medians	Difference Medians	Difference Medians	Difference Medians	Difference Medians
PARAMETERS DESCRIBING DATA SET							
Discharge (cfs)	377	6	3	53.5	5	52	-326
GENERAL WATER QUALITY PARAMETERS							
Discharge per Drainage Area (cfs/mi2)	0.018	-0.963	-1.092	-0.007	-0.820	-0.002	-0.056
DO mg/l	0.19	-0.30	0.46	-0.55	-1.00	0.25	0.09
DO % Saturation	2.36%	-4.30%	2.17%	-4.97%	-12.62%	4.11%	-0.75%
Water Temperature F	-1.3	-3.3	-3.7	0.7	-3.9	-0.5	1.0
pH	0.00	-0.30	-0.07	-0.06	-0.15	0.16	0.10
TDS mg/l	0.0	-10.0	-20.0	-10.0	45.0	10.0	-10.0
TSS mg/l	-0.2	-3.8	-3.8	0.2	-2.0	1.0	0.0
Hardness mg/l	1.0	-9.5	-12.0	0.0	38.0	-2.5	3.5
Alkalinity mg/l	0.0	-2.5	-5.0	1.0	31.0	-1.0	0.0
Turbidity NTU	1.0	-2.8	-2.7	-1.9	1.7	1.8	-1.0
Chloride mg/l	0.0	-4.0	-1.0	3.7	-1.2	-2.7	0.0
NUTRIENTS AND PRIMARY PRODUCTION PARAMETERS							
Total Phosphorus mg/l	0.000	-0.060	-0.055	0.000	-0.015	-0.010	0.010
Orthophosphate mg/l	0.000	-0.030	-0.0300	-0.020	0.030	0.010	0.000
Nitrate NO3-N mg/l	-0.050	-0.070	0.630	0.000	-0.210	-0.030	0.030
Total Kjeldahl Nitrogen mg/l	-0.020	0.070	0.1200	0.160	0.025	-0.110	0.130
Ammonia NH3-N mg/l	-0.003	0.000	0.0000	0.010	0.015	-0.010	0.003
Total Nitrogen mg/l*	-0.083	0.033	0.598	0.203	-0.095	-0.070	0.020
Chlorophyll A mg/m3	0.90			0.25		-0.65	0.40
Phytoplankton Biomass (mg/m3)**	60.30			164.15		-43.55	26.80
BACTERIA PARAMETERS							
Enterococcus col/100ml	-16	216	126	8	433	-2	-6
Fecal Coliform col/100ml	10	-28	32	-8	143	8	28
E. coli col/100ml	18	-10	10	-18	67	9	9

Appendix D: Flow Measurement Results of the Lower Delaware Monitoring Program

Todd W. Kratzer, P.E.

Flow Measurement Results of the Lower Delaware Monitoring Program

Flow Monitoring

Associating water quality with flow is important for proper assessments of changes in water quality. A year with higher flows may have elevated pollutant loadings, presenting lower concentrations, thus showing a stable or better water quality when degradation may actually be occurring. The opposite may be true during lower flows. As pollution loadings increase beyond the receiving stream's dilution capacity, concentrations become elevated over a range of flows that would normally present lower concentrations. Flow data combined with water quality concentrations provides loading estimates over a range of flows. A loading estimate may reveal an increased pollution problem during higher flows that may have otherwise gone unnoticed if concentration was used as a sole indicator. Thus, loading provides an effective indicator for assessment and remediation of pollution impacts upon water quality.

River Flow Measurements

The Lower Delaware River, which extends from the southern terminus of the Middle Delaware National Scenic and Recreational River (Slateford, PA) to Trenton, NJ, has three calibrated U.S. Geological Survey (USGS) continuous flow monitoring stations: Belvidere bridge, Riegelsville bridge, and at the Calhoun Street Bridge at Trenton, NJ. Using these sites, and flow-measurement sites on the adjacent tributaries, flow was estimated for all of the water quality monitoring sites along the Lower Delaware River. **Table 1** shows the flow-estimation equations for the Lower Delaware River water quality monitoring sites. The equations use drainage-area weighting to interpolate or extrapolate flows for water quality monitoring sites that are not near the USGS flow-monitoring sites.

Table 1. Flow estimating equations for Delaware River monitoring sites, beginning at the most upstream site.

River Monitoring Site	River Mile	Drainage Area (mi^2)	Flow Estimating Equation[1]
Columbia/Portland Foot Bridge	207.40	4,165	Qport = Qbel – (Qbel * 0.048435)
Belvidere Bridge	197.84	4,377	Qbel = Qbel - (Qbel*0.034620)
Easton – Northampton St Bridge	183.82	4,717	Qnh = Qbel + [(Qrgl-Qbel)*0.110976]
Riegelsville Bridge	174.70	6,175	Qreg = Qreg
Milford – Upper Black Eddy Bridge	167.70	6,381	Qmil = Qtrent-[(Qtrent-Qrgl)*0.659504]
Frenchtown – Uhlerstown Bridge	164.30	6,408	Qfr = Qtrent-[(Qtrent-Qrgl)*0.614876]
Bulls Island – Lumberville foot bridge	155.40	6,598	Qbi = Qtrent-[(Qtrent-Qrgl)*0.300826]
Stockton Bridge	151.90	6,656	Qst = Qtrent-[(Qtrent-Qrgl)*0.204959]
Lambertville – New Hope Bridge	148.70	6,680	Qlam = Qtrent-[(Qtrent-Qrgl*0.165289]
Washington Crossing Bridge	141.80	6,735	Qwx = Qtrent-[(Qtrent-Qrgl)*0.074380]
Calhoun Street Bridge	134.34	6,780	Qtrent = Qtrent

[1] Delaware River flow estimate sites are represented as: Qport = flow at Portland; Qbel = flow at USGS gage at Belvidere; Qnh = flow at Northampton Street Bridge at Easton; Qrgl = flow at USGS gage at Riegelsville; Qmil = flow at Milford bridge; Qtrent = flow at USGS gage at Trenton (Calhoun Street Bridge); Qfr = flow at Frenchtown bridge; Qbi = flow at Bulls Island foot bridge; Qst = flow at Stockton bridge; Qlam = flow at Lambertville bridge; and Qwx = flow at Washington Crossing bridge.

Tributary Flow Measurements

Many of the tributaries to the Lower Delaware had not been monitored for flows prior to the initiation of the DRBC Lower Delaware Monitoring Program. There are several tributaries that are monitored for flow by the USGS, but these do not have continuous flow monitors near the confluence with the Delaware River where the DRBC water quality monitoring sites were located. The USGS gage on the Lehigh River was the exception since it had a flow-monitoring site very close to the mouth of the Lehigh River. Therefore, the DRBC implemented a flow-monitoring program for those tributaries that were being sampled for water quality. An association between flow and water surface elevation was calibrated for each tributary with several measurements over a range of flows. The measurement of the water surface elevation (stage measurement) was recorded to the nearest 0.01 feet and referenced to either a bridge datum or a staff gage. A flow versus stage association (calibration), known as a "rating" (created using linear regression), was established for each flow measurement site. The calibrated rating provided a direct relationship between stage and flow so that only stage measurements were needed each time a water quality sample was collected to associate the sample with the existing flow.

Some water quality monitoring sites were at or near a USGS flow and/or water quality monitoring site. Whenever possible, USGS flows were used to supplement the DRBC flow measurements, especially for the higher flows. Stage records (bridge or staff gages) were used to integrate DRBC and USGS flow-measurement data. Whenever available, the stage records presented a good relationship. The associated flows were then appended to both DRBC and USGS data sets to provide data for voids in the stage/flow rating curves. Continuous records for flow and stage data were available for Bushkill Creek from Lafayette College, thus allowing this same technique to be used to associate the Lafayette College flow estimates to the DRBC stage records.

Table 2 lists the streams that were monitored for water surface elevation and flow (cubic feet per second, cfs) at a reference datum (stage or gage reading, feet) that used either a marked in-stream staff gage (or rod) or a mark on a bridge deck (datum). Flow ratings should not be used for estimating stream flow beyond approximately 10 percent of the flow range used for the calibration.

Several tributaries in the Lower Delaware had unstable channels, requiring more flow measurements to maintain accuracy in the stage and discharge calibration. Tributaries exhibiting this characteristic were Martins Creek, Bush Kill, Nishisakawick Creek, Tohickon Creek, and Paunacussing Creek. Tohickon Creek flows that were measured by the DRBC near the mouth were compared to the USGS's flow measurement station at Pipersville, Pa. Bush Kill flows measured by the DRBC were referenced to both a bridge datum and a flow measurement station near the mouth that was maintained by Lafayette College. Due to changes in the channel cross-section at the DRBC gage site from higher flows that reposition the unstable substrate, the relationship between the stage and flow changed frequently. The continuous water depth monitor, operated by Lafayette College was located at a stable channel site and was therefore used as the water stage reference.

Two streams that did not present a safe cross-section for flow measurements were Paulins Kill and the Musconetcong River. The Musconetcong stage and flow calibration could utilize recent instantaneous flow measurements by the New Jersey District of the U.S. Geological Survey at the DRBC water quality site, or from a USGS continuous flow monitoring site approximately 10 miles upstream (Bloomsbury, NJ). The Paulins Kill required flow measurements near its confluence with the Delaware River, which was a difficult site to access. This site was characterized by a substrate of large boulders situated in a deep channel. The U.S. Geological Survey may be contracted for these measurements if a good relationship cannot be obtained between the DRBC gage readings and the closest upstream USGS gage. If a good relationship exists between the gages, then drainage-area-weighting should provide good flow estimates for the DRBC water quality site.

Table 2. Lower Delaware tributary flow measurement sites and stage-flow relationships.

Stream	Drainage Area (mi^2)	Calibration Flow Range[1] (cfs)	Stage-Flow Equations
Paulins Kill	177.00	Entire Range	1.405 x USGS flow at Blairstown
Pequest River	157.00	146 – 354	Q = (-371.84 x Gage Ht) + 5,562.3
Martins Creek	44.50	(2002) 7.8 – 40.3 (2003) 30.4 – 123.2	2002: DRBC Gage > 9.18’, Q = (-68.608 x Gage Ht) + 647.71 DRBC Gage ≤ 9.18’, Q = (-191.17 x Gage Ht) + 1,774.1 2003: All DRBC Gage Ht, Q = (-281.19 x Gage Ht) + 2,634.9
Bushkill Creek	80.00	(2001-2002) 30.2 – 215 (2003) 42.2 - 403	Continuous Lafayette flow monitor 2001-2002: Q = (-263.45 x Cemetery Road Gage Ht) + 4,621 2003: Q = (-309.56 x Cemetery Road Gage Ht) + 5,370.9
Lehigh River	1,361.00	Entire Range	1.004 x USGS flow at Glendon
Pohatcong Creek	57.10	5.40 – 116	Q = (-81.97 x Gage Ht) + 1,671.2
Musconetcong River	156.00	Entire Range	1.1064 x USGS flow at Bloomsbury
Cooks Creek	29.50	5.4 – 75.4	DRBC Gage > 16.83’, Q = (-11.091 x Gage Ht) + 196.24 DRBC Gage ≤ 16.83’, Q = (-76.392 x Gage Ht) + 1,297.3
Nishishakawick Creek	11.10	(2001-2002) 0.0 – 13.3 (2003) 3.0 – 32.5	2001–2002: DRBC Gage > 15.32’, Q = (-1.7218 x Gage Ht) + 27.925 DRBC Gage ≤ 15.32’, Q = (-34.838 x Gage Ht) + 535.38 2003: All DRBC Gage Ht, Q = (-32.604 x Gage Ht) + 523.89
Tinicum Creek	24.00	0.0 – 92.2	Q = (-34.458 x Rock Datum Gage) + 97.022
Tohickon Creek	112.00	3.8 – 59.2	DRBC Gage > 5.06’, Q = (-31.947 x Gage Ht) + 172.43 DRBC Gage ≤ 5.06’, Q = (-73.589 x Gage Ht) + 382.6
Paunacussing Creek	7.87	3.8 – 20.6	(-39.902 x Bridge Gage Ht) + 613.55
Lockatong Creek	23.20	0.0 – 28.3	DRBC Gage > 19.76’, Q = $(3 \times 10^{72}) \times e^{(-8.4058 \times \text{Gage Ht})}$ DRBC Gage ≤ 19.76’, Q = (-48.223 x Gage Ht) + 954.28
Wickecheoke Creek	26.60	0.4 – 53.8	DRBC Gage > 18.02’, Q = (-7.7843 x Gage Ht) + 142.85 DRBC Gage ≤ 18.02’, Q = (-38.331 x Gage Ht) + 693.43
Pidcock Creek	12.70	0.0 – 11.1	DRBC Gage > 15.86’, Q = (-12.349 x Gage Ht) + 198.12 DRBC Gage ≤ 15.86’, Q = (-39.247 x Gage Ht) + 624.77

[1] The measured flow range extended by ± 10 percent.

Figures 1-12 illustrate the stage and flow calibrations for several tributaries within the Lower Delaware River corridor, beginning at the most upstream site. Stage and flow calibrations (flow rating curve) should only be associated with the actual measured flow range. However, an extrapolation of the rating curve to ± ten percent of the measured flow range should maintain an acceptable accuracy. When two separate flow ranges were defined, then ± ten percent of each flow range was used for defining the maximum extent of each segment.

Most of the stage and discharge relationships indicated 2 distinct rating curves, one representing the higher flows and one representing the lower flows. **Figures 1c, 2, 5c, 6, 8, 10a, 11a, and 12** show dual stage and flow calibration curves for Pequest River, Martins Creek, Cooks Creek, Nishisakawick, Tohickon, Lockatong Creek, Wickecheoke Creek and Pidcock Creek, respectively. Dual rating curves are common for most streams in the Lower Delaware River. This effect may be due to the changes in cross-sectional area during low flows. Thalwegs present a modified cross-section, which usually is characterized by a minimal width-to-depth ratio than that of the normal channel. Therefore, changes in flow, conveyed in a thalweg, may represent greater changes in the associated water depth.

The following presents the stage and flow calibrations (ratings) that were established for selected tributaries within the Lower Delaware.

Pequest River

The Pequest River was monitored for flow at the Orchard Street Bridge by the DRBC. However, at the time of this report, only two flow measurements had been performed to calibrate the rating curve (**Figure 1a**). A USGS flow measurement site existed near the Market Street dam. However, these data could not be used to supplement the DRBC data since only two stage measurements were available to determine a relationship between the data sets (**Figure 1b**). If the USGS flow rating shows a good relationship to the DRBC rating then the USGS stage can be measured and directly associated with flows at the DRBC monitoring site. **Figure 1c** shows a good relationship between stage and flow for the USGS flow measurement site.

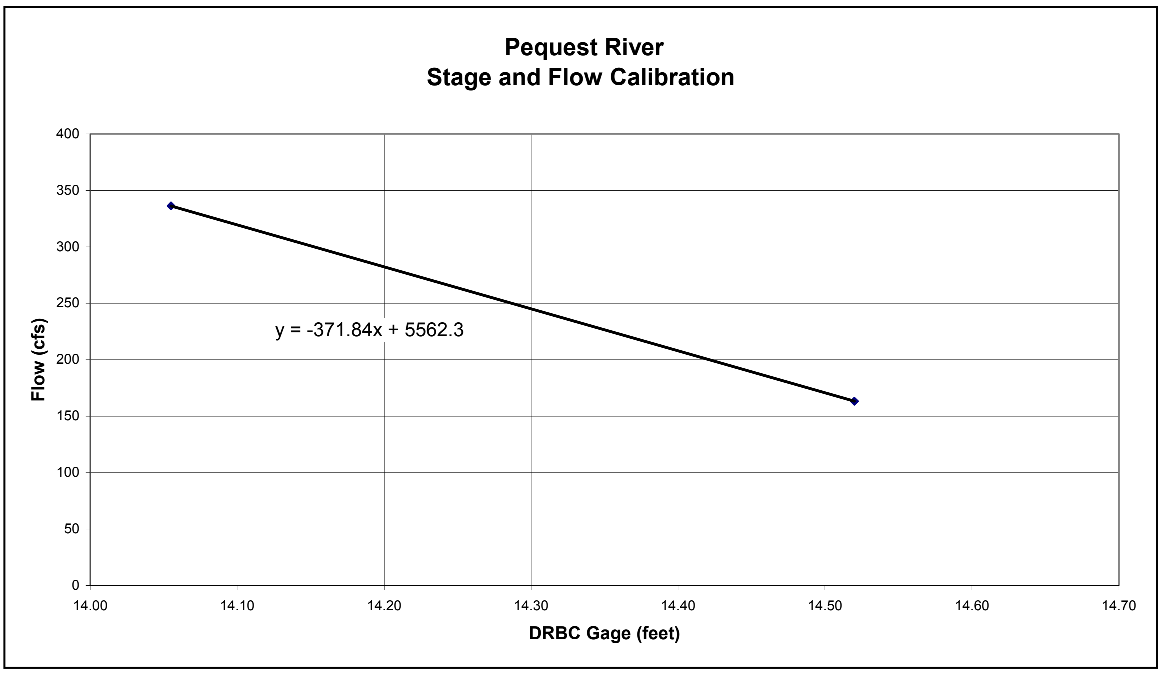


Figure 1a. DRBC stage and flow calibration for the Pequest River at river mile 197.8.

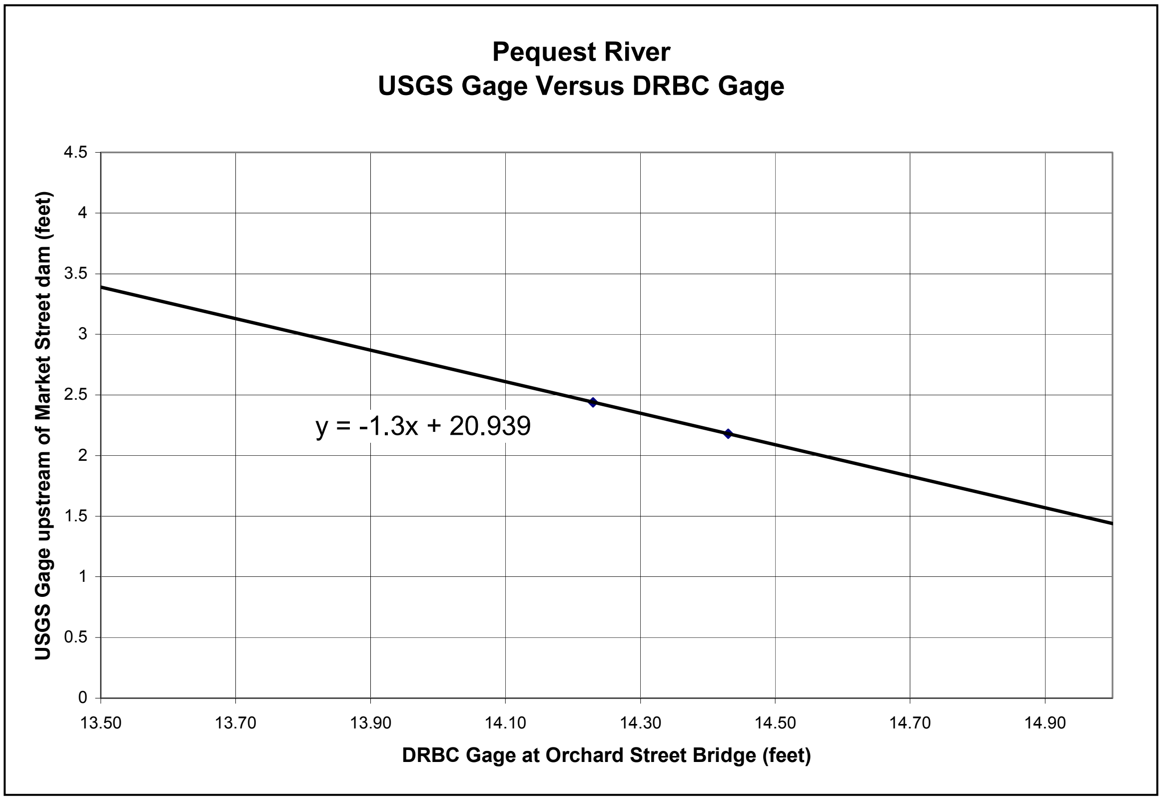


Figure 1b. USGS stage versus DRBC stage measurements for the Pequest River at river mile 197.8.

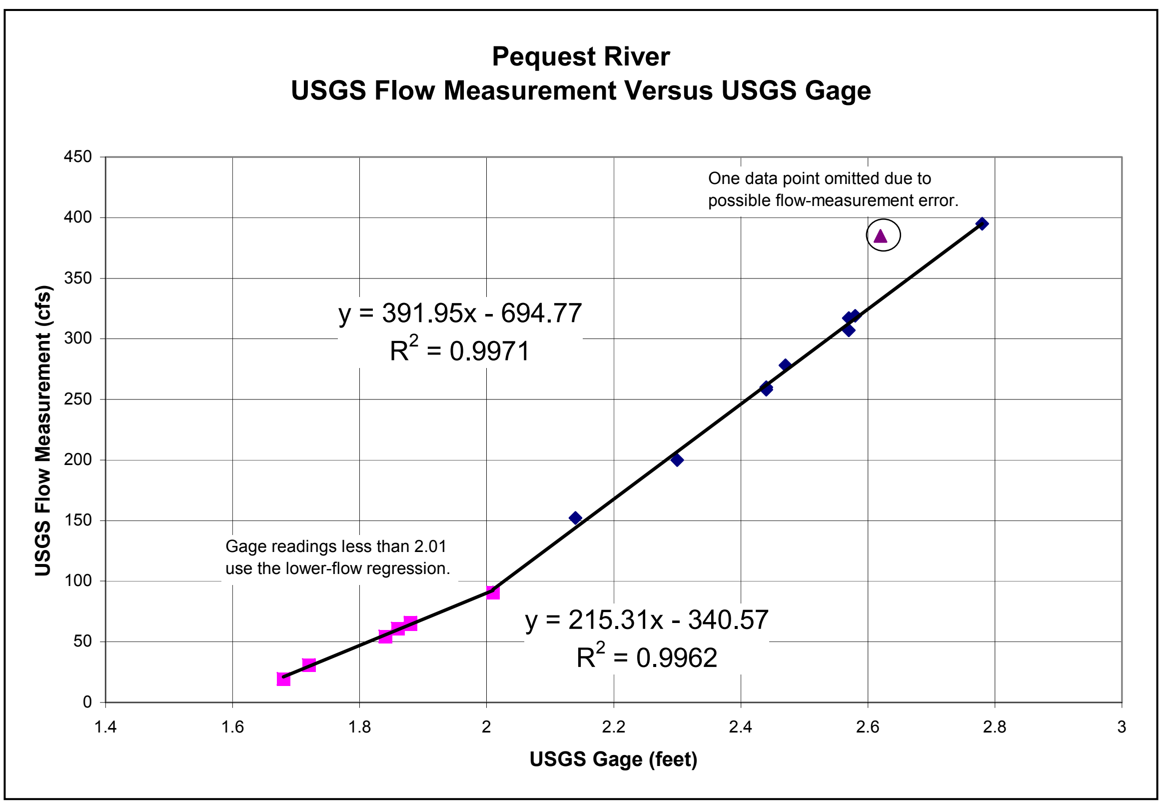


Figure 1c. USGS stage and flow calibration for Pequest River at river mile 197.8.

Martins Creek

Martins Creek presented two distinct rating curves: one for the 2002 and one for the 2003 data (**Figure 2**). The 2002 data showed a dual rating for higher and lower flows while the 2003 data showed a continuous relationship between higher and lower flows.

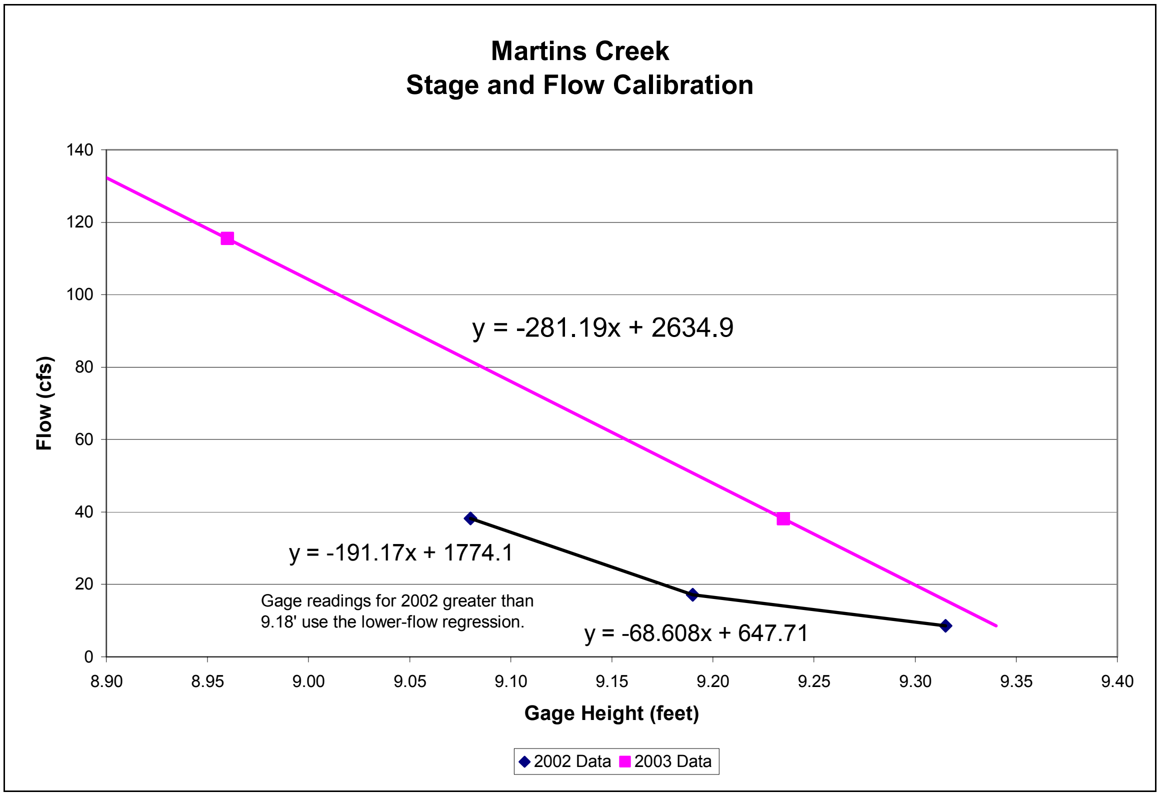


Figure 2. Stage and flow calibration for Martins Creek at river mile 190.58.

Bushkill Creek

Bushkill Creek flow measurements were performed at the Cemetery Road Bridge that is approximately 1.5 miles upstream from the mouth. **Figure 3a** shows the rating for the Cemetery Road bridge gage. This rating did not present a good relationship between the stage and flow. Continual scouring and deposition of unstable substrates at the bridge gage may have been the main cause of the shifting rating.

Concurrent with the DRBC Lower Delaware study, Lafayette College has conducted a water quality monitoring program. Lafayette College uses a continuous recording pressure transducer to measure the water depth (stage) at a site near the mouth of the Bush Kill. The stage had a good flow relationship and this flow was compared to the DRBC gage readings at the Cemetery Bridge that corresponded to the same date and time. This rating is presented in **Figure 3b**. The rating showed two distinct relationships between stage and flow for the combined data set of 2001 and 2002 and another rating for the 2003 data.

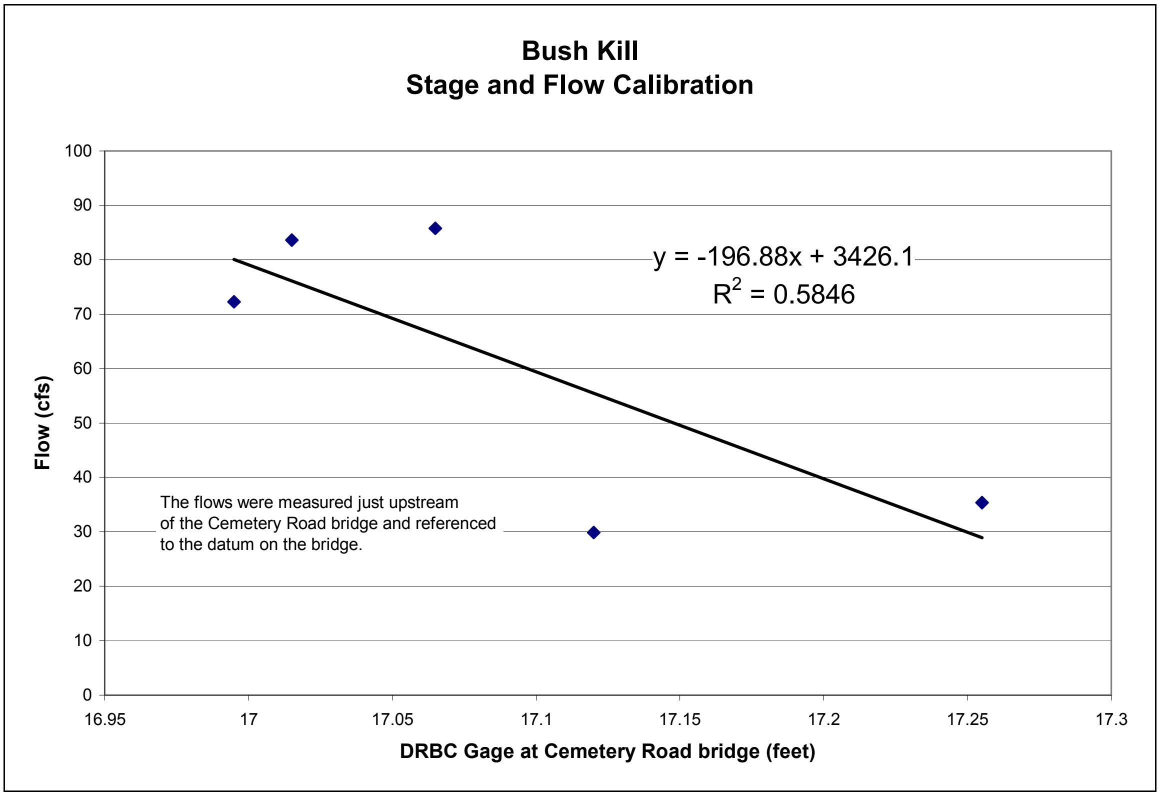


Figure 3a. DRBC stage and flow calibration for Bushkill Creek at the Cemetery Road Bridge, at river mile 184.1.

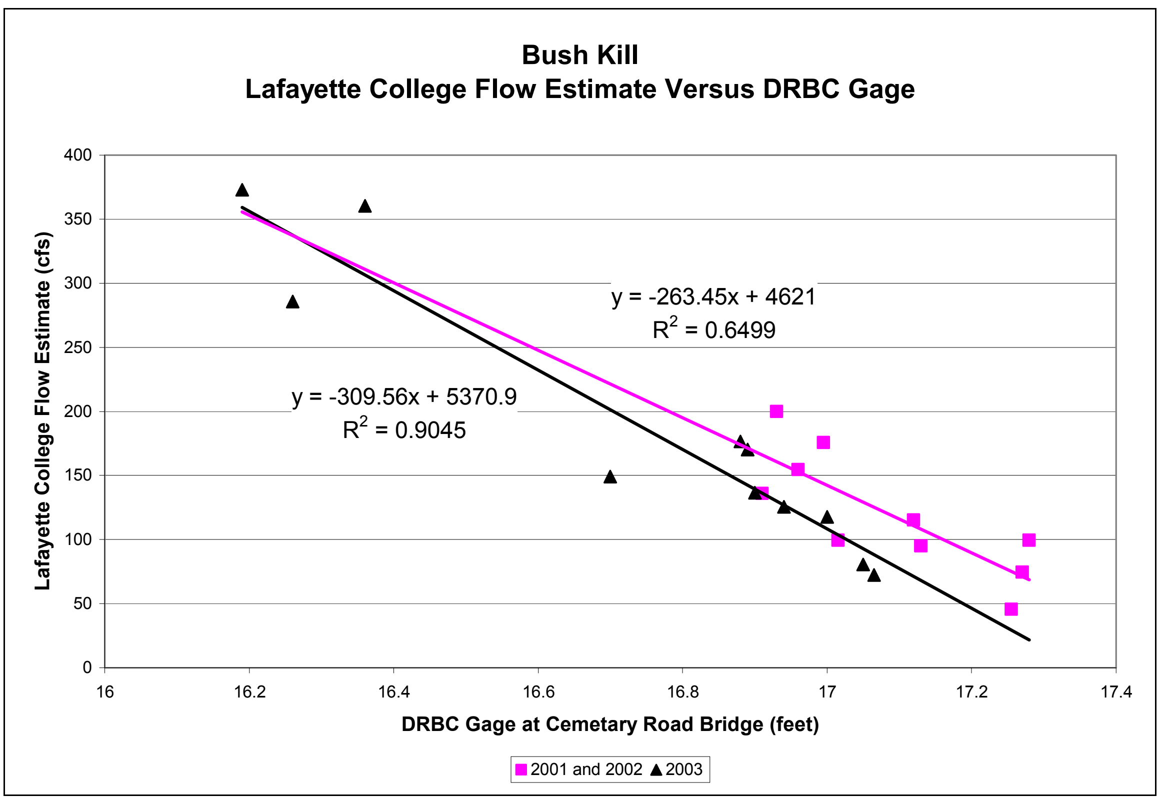


Figure 3b. Relationship between the Lafayette College flow estimates on the Bush Kill to the DRBC gage readings at the Cemetery Bridge.

Pohatcong Creek

A good relation was established at the Pohatcong Creek monitoring site for stage and flow as presented in **Figure 4**.

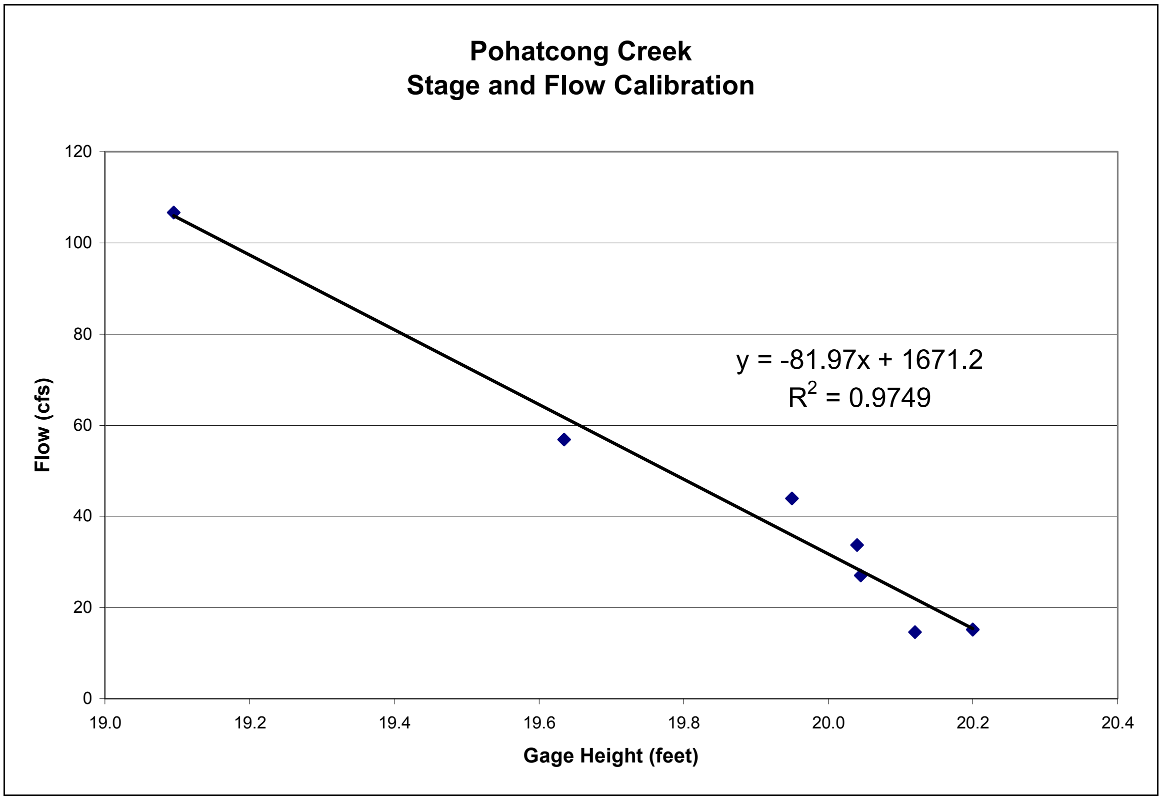


Figure 4. Stage and flow calibration for Pohatcong Creek at river mile 177.4.

Cooks Creek

Cooks Creek had a stable channel that provided a good stage and flow relationship. Since a USGS flow measurement station was located at this site, the USGS flow rating was transferred to the DRBC gage. This was accomplished by first developing the USGS flow rating (**Figure 5a**) and then determining the relationship between the USGS gage and the DRBC gage (**Figure 5b**). These both presented good associations that were then used to develop the flow rating between the DRBC gage and the USGS flows (**Figure 5c**).

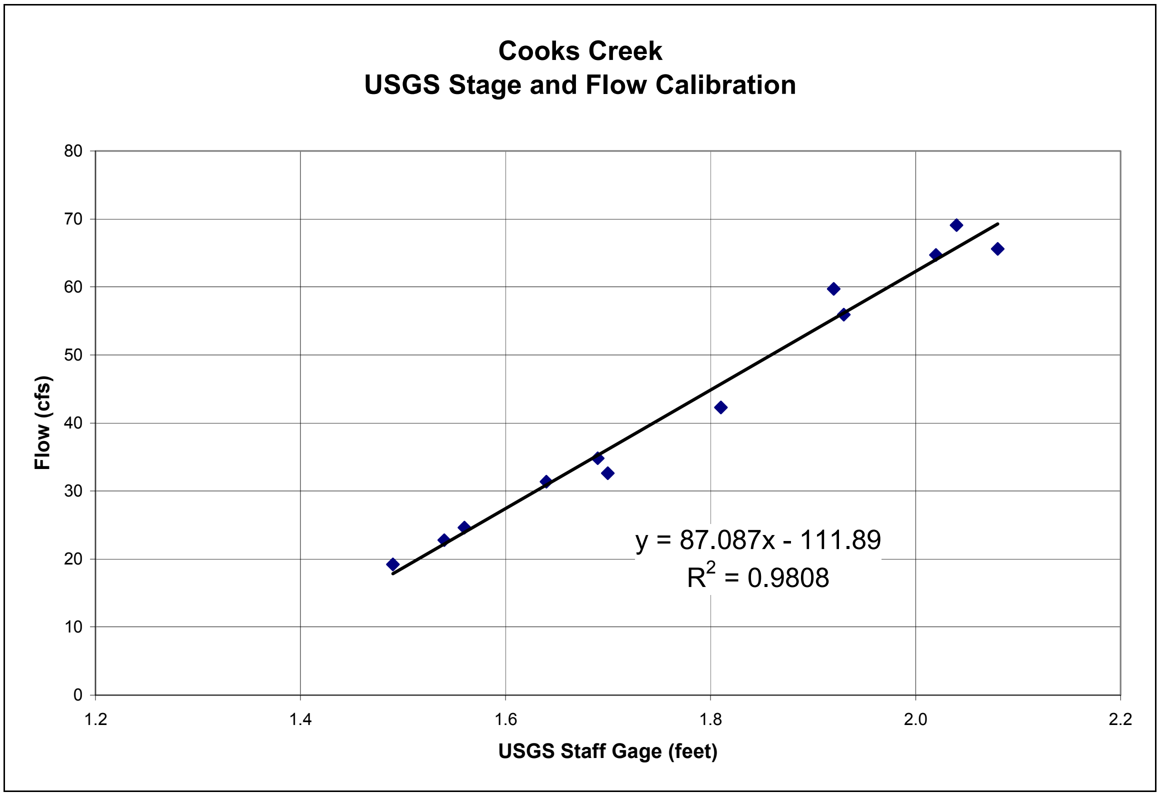


Figure 5a. USGS stage and flow calibration for Cooks Creek at river mile 173.7.

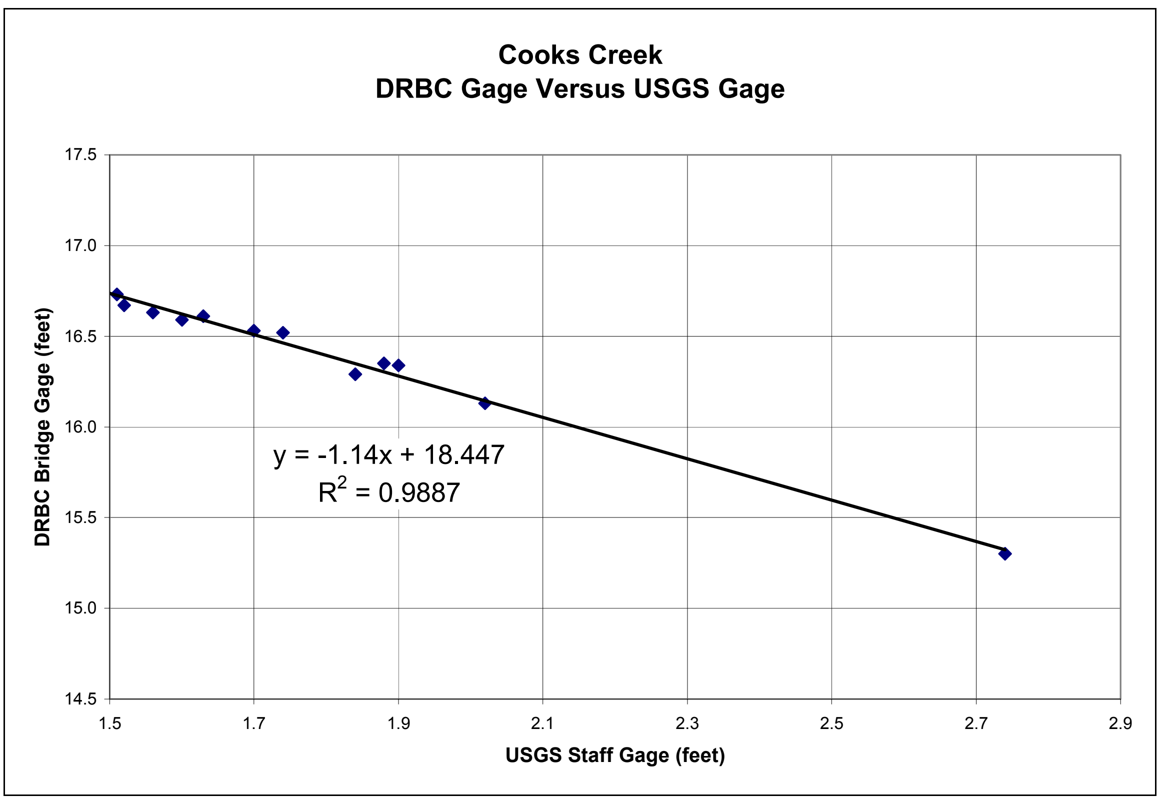


Figure 5b. DRBC bridge gage relationship to the USGS staff gage on Cooks Creek.

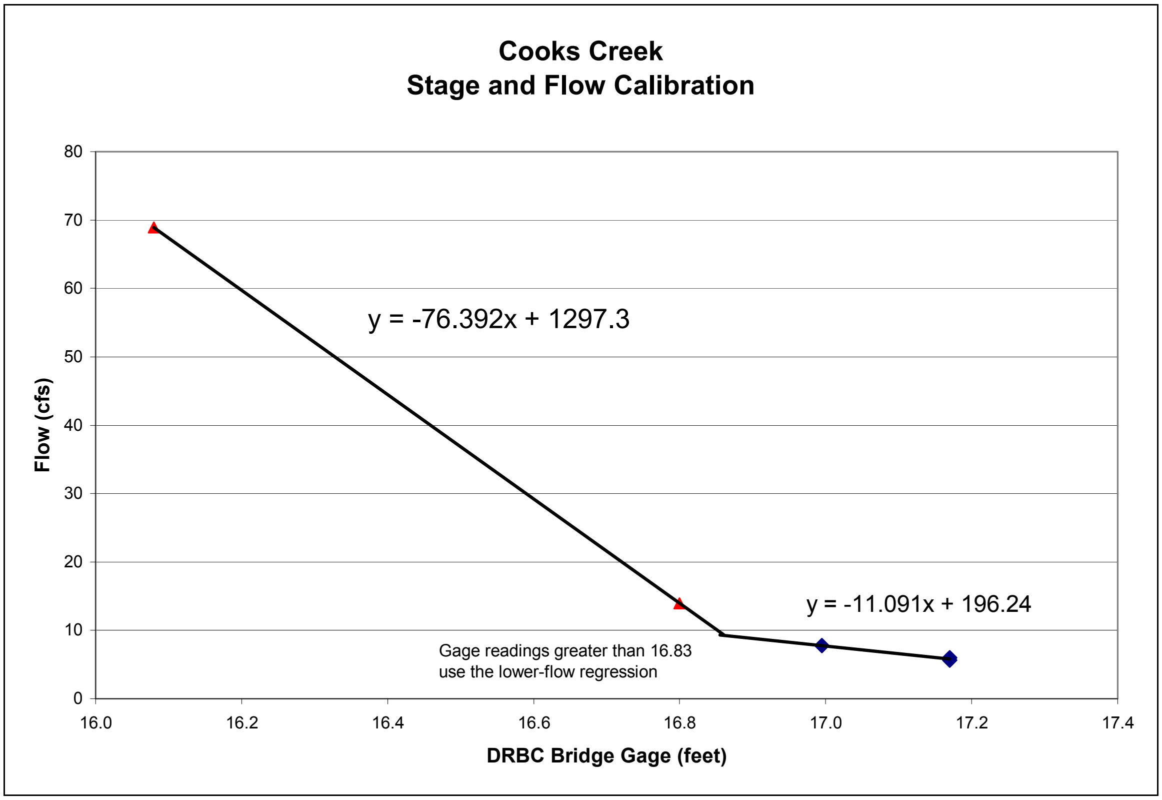


Figure 5c. DRBC stage and flow calibration for Cooks Creek at river mile 173.7.

Nishisakawick Creek

The flow measurement site for Nishisakawick Creek was located in a pooled area just upstream of the Route 12 Bridge. The stream channel was reconfigured by several large storm events. **Figure 6** shows a shift in the stage and discharge relationship for Nishisakawick Creek between the combined 2001 and 2002 data and the 2003 data. Additional stage and flow data were available from a USGS flow measurement station, located approximately 2 miles upstream from the mouth. However, only one comparison had been recorded of the USGS gage and the DRBC gage. Dual measurements need to be obtained between the USGS gage and the DRBC gage to determine if there exists a good relationship between the two stage references. If a good relationship exists, then the data sets can be combined to strengthen the stage-discharge relationship.

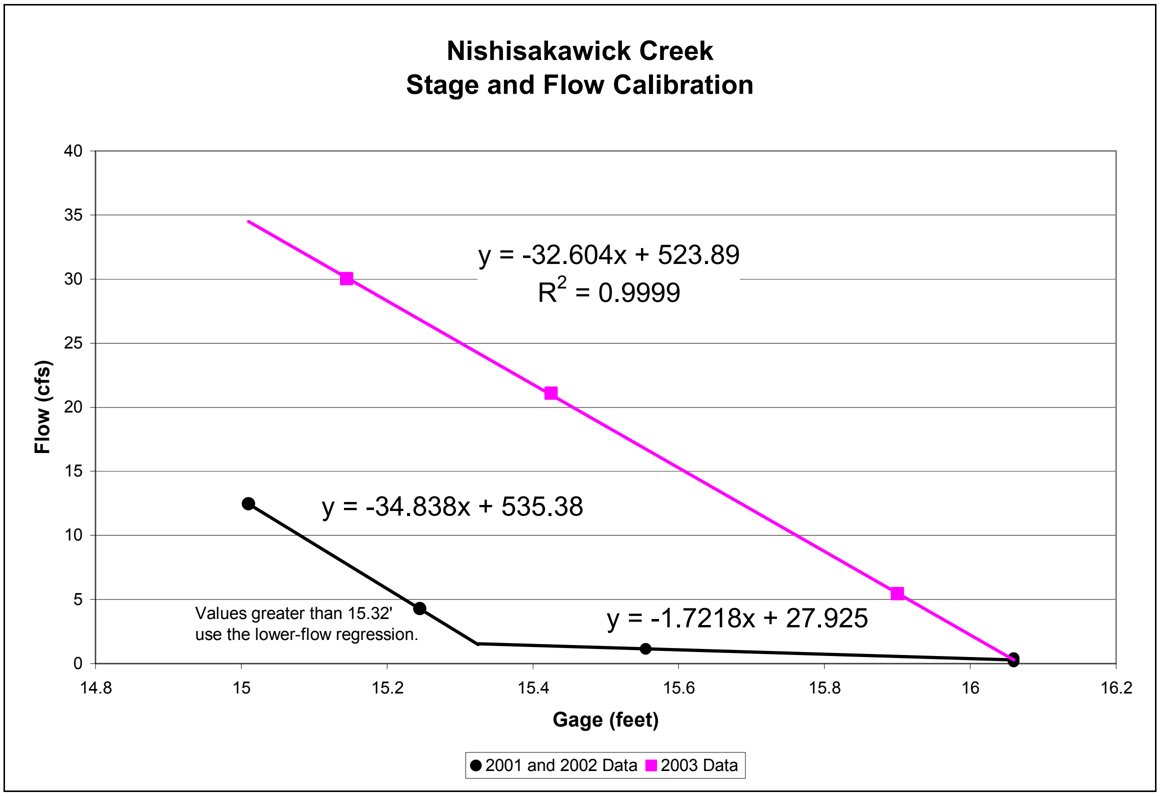


Figure 6. Stage and flow calibration for Nishisakawick Creek at river mile 164.1.

Tinicum Creek

A good relationship existed between the water stage and flow at the Tinicum Creek monitoring site (**Figure 7**). However, two of the flow measurements were approximately 15 to 20 cfs away from the linear regression line. The channel was very stable since it consisted primarily of bedrock. Therefore, the two flow measurements may have been offset from the data grouping due to backwater from the Delaware River during higher river flows.

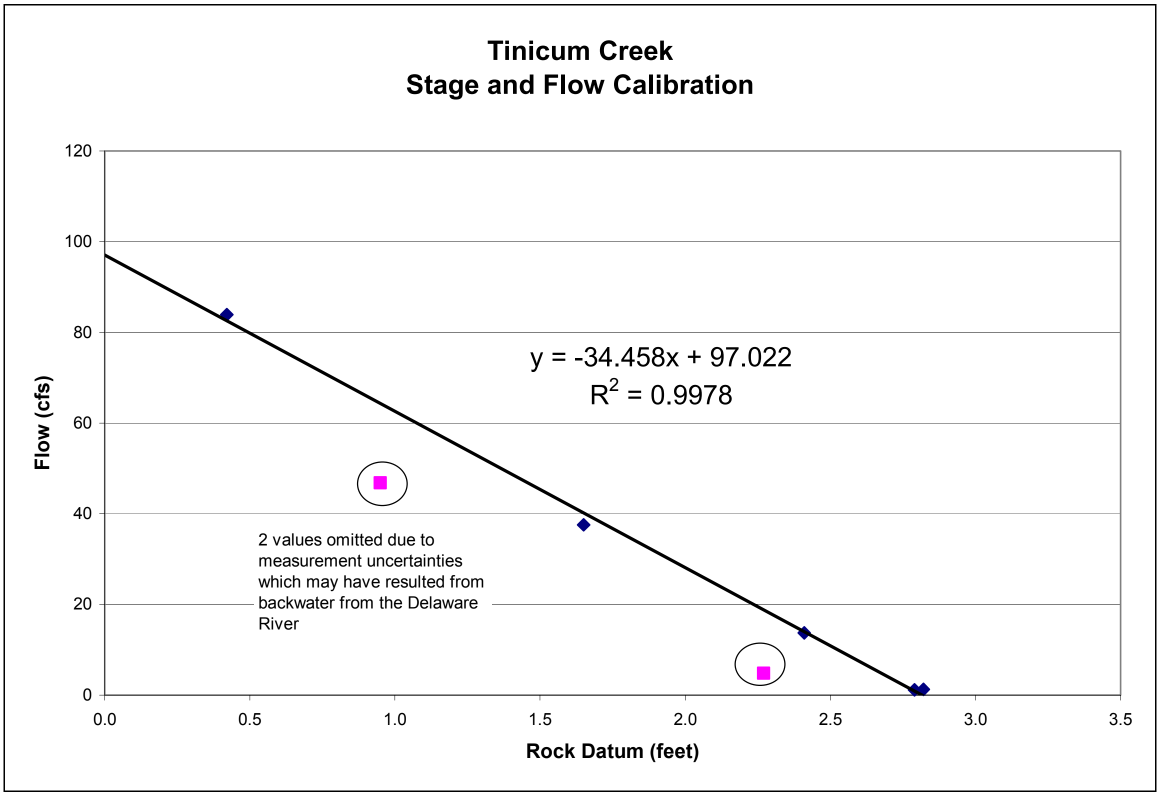


Figure 7. Stage and flow calibration for Tinicum Creek at river mile 161.6.

Tohickon Creek

Tohickon Creek exhibited a very unstable channel that required the gage to be relocated three times over three years. The most recent gage datum was located on the wing wall of the aqueduct over the Tohickon Creek. Although this site was not as accessible as the first two sites, the channel was more stable. A USGS flow measurement station was located approximately eight miles upstream from the DRBC site. There existed a good relationship between these two gages for flows up to approximately 45 cfs, after which the correlation became very weak. Therefore, the DRBC stage and flow rating was used independently of the USGS data. **Figure 8** shows the Tohickon Creek rating curve.

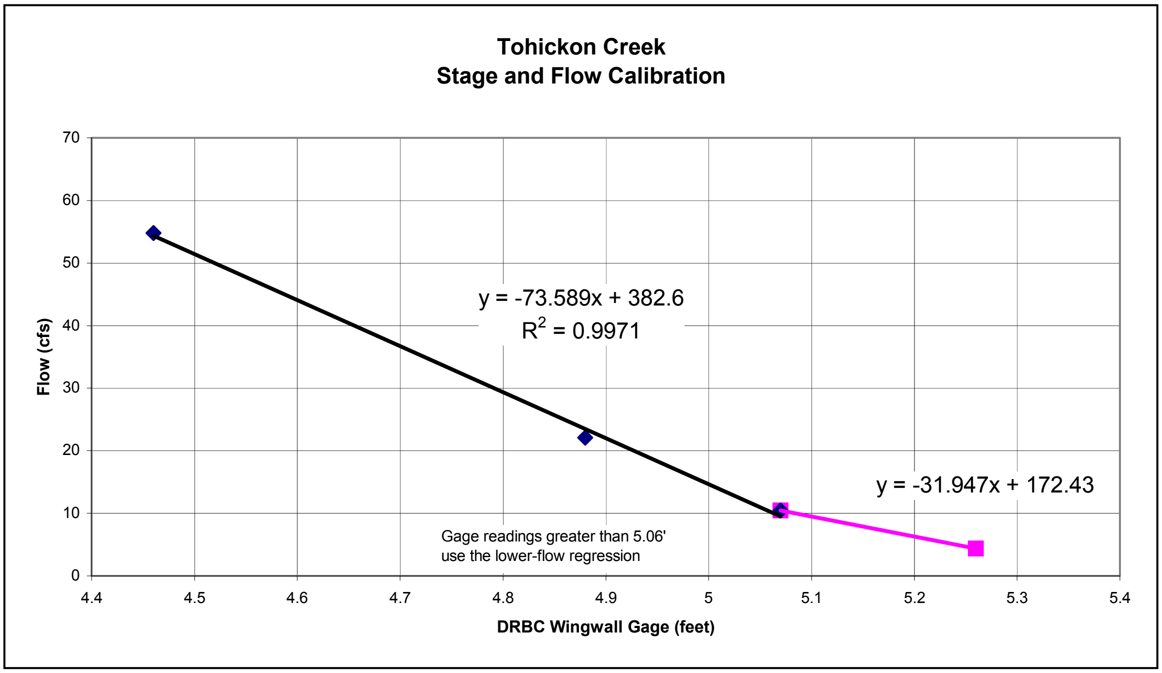


Figure 8. Stage and discharge calibration for Tohickon Creek at river mile 157.0.

Paunacussing Creek

The Paunacussing Creek channel at the Route 32 site has changed several times since the first flow measurement was performed in 2001. Scouring and deposition of the unstable sediments as well as the construction of a new bridge and abutments has required the recalibration of the flow rating many times. In 2003, the bridge datum was supplemented with a rod (staff) gage, located approximately 30 feet upstream of the bridge. This gage has shown to be stable except for an initial settling of the rod just after installation. **Figures 9a and 9b** present the stage and flow calibrations for the rod and bridge gages, respectively.

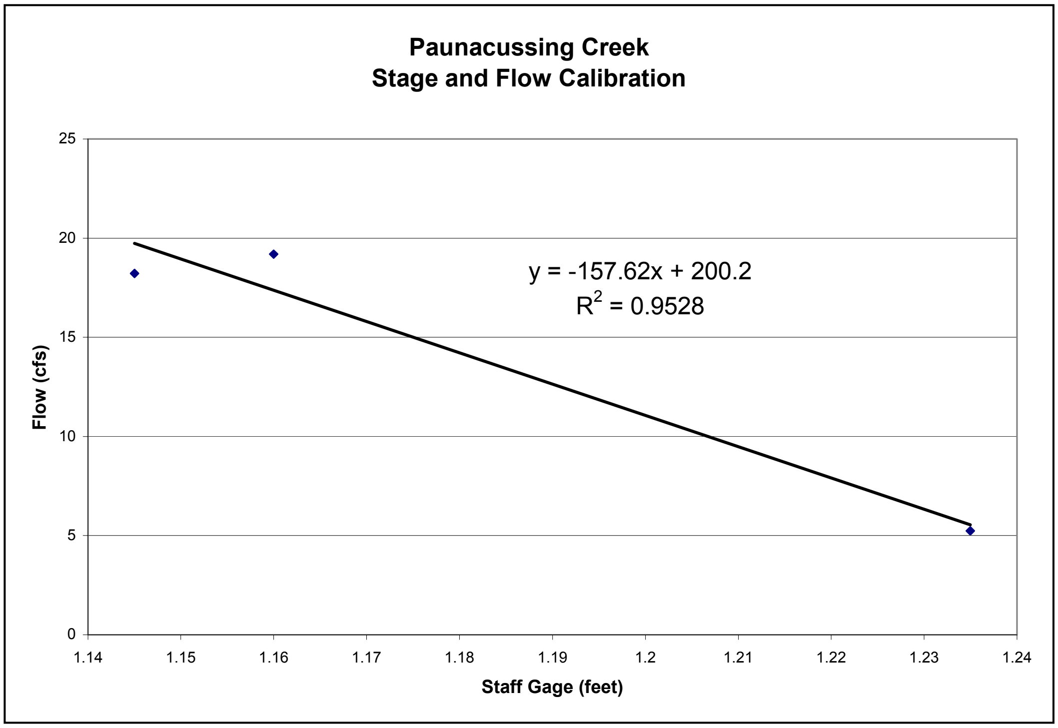


Figure 9a. Staff gage and flow calibration for Paunacussing Creek at river mile 155.6.

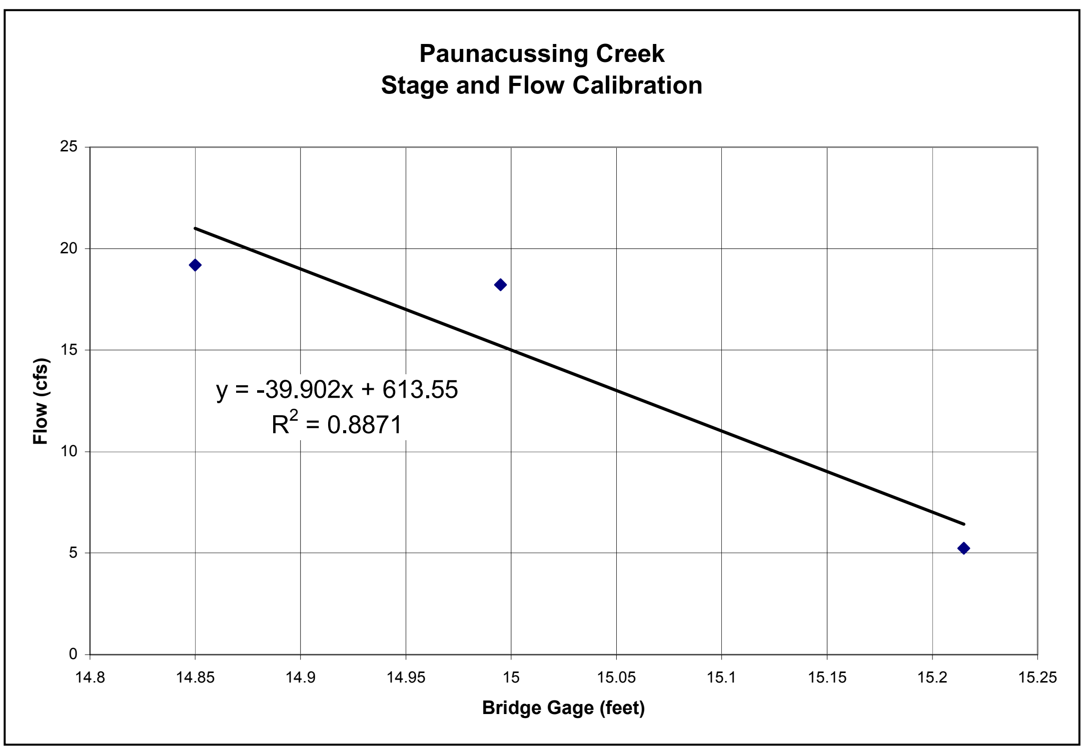


Figure 9b. Bridge gage and flow calibration for Paunacussing Creek at river mile 155.6.

Lockatong Creek

The Lockatong Creek gage has remained stable since it was first used in 2000. This site is approximately 1 mile upstream from the mouth of Lockatong Creek. The rating curve for this station is shown in **Figure 10a**. A USGS flow-monitoring site was located near the mouth. The USGS flow rating presented an unusual flow versus stage relationship. Therefore, in this case, the DRBC flow rating did not use the USGS data as a supplement. **Figure 10b** illustrates the USGS flow-rating curve for the Lockatong Creek at the route 29 bridge.

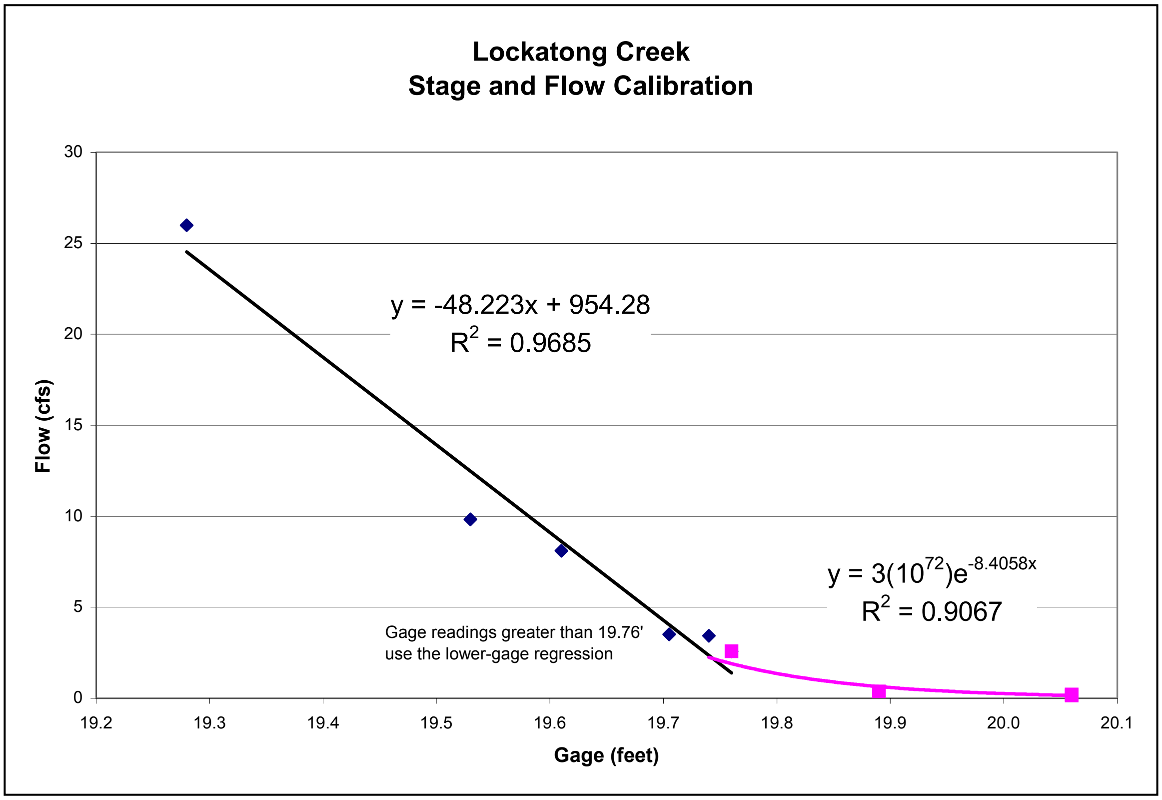


Figure 10a. Dual stage and flow calibrations for Lockatong Creek at river mile 154.0.

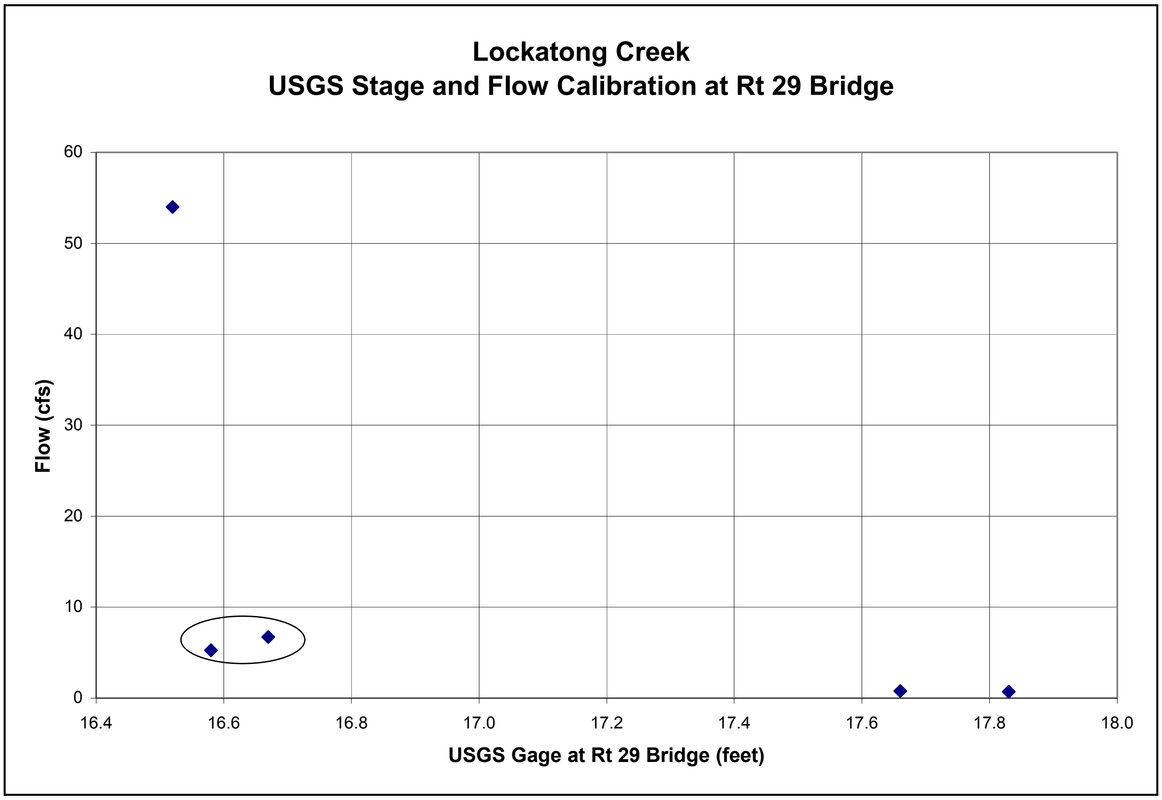


Figure 10b. USGS stage and flow calibration for Lockatong Creek at the route 29 bridge.

Wickecheoke Creek

The DRBC flow-monitoring site was located at the Route 29 Bridge, approximately a quarter mile upstream of the mouth. This site presented a stable relationship between stage and flow due to the bedrock substrate. The USGS also had a flow-monitoring site at a covered bridge that was approximately 2 miles upstream of this site. The stage and flow data from this site presented a good flow rating. Therefore, the USGS data were included in the DRBC flow rating as presented in **Figure 11a**. The USGS flow rating is presented in **Figure 11b** and the DRBC versus USGS stage measurement comparison is shown in **Figure 11c**. These relationships were used to develop the DRBC flow rating.

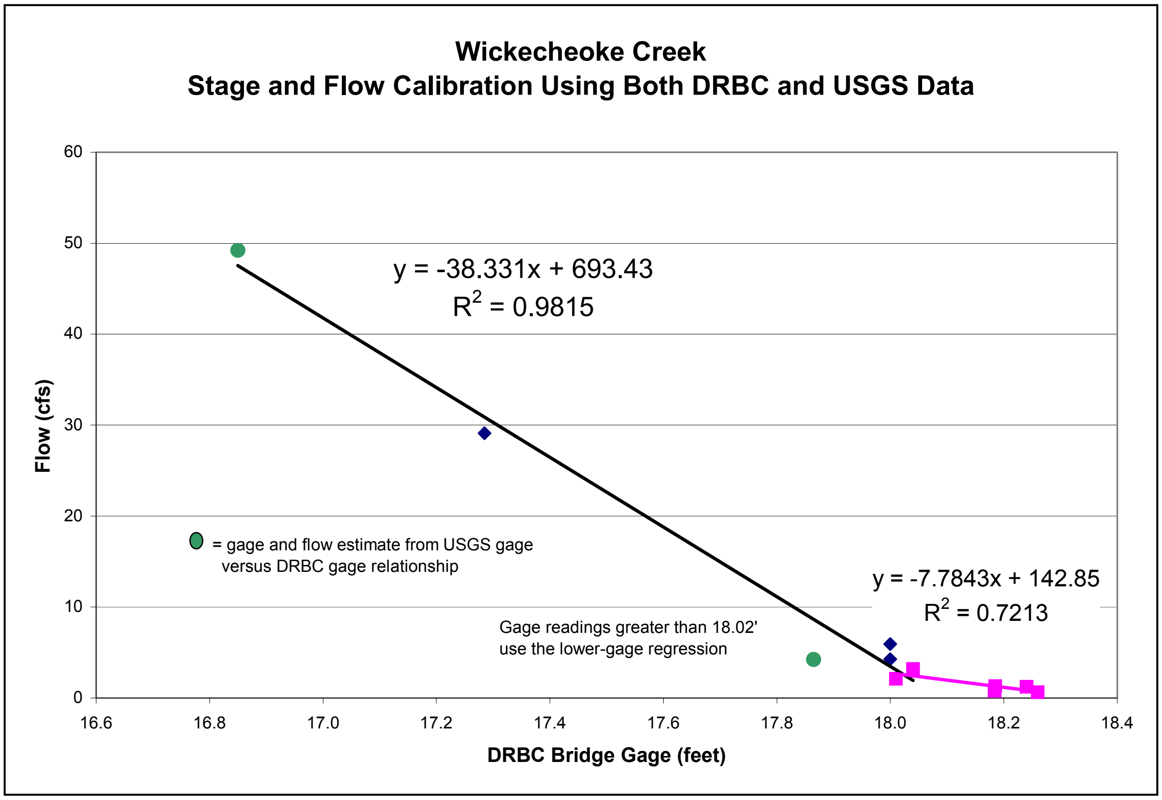


Figure 11a. Stage and flow calibrations for Wickecheoke Creek at river mile 152.5.

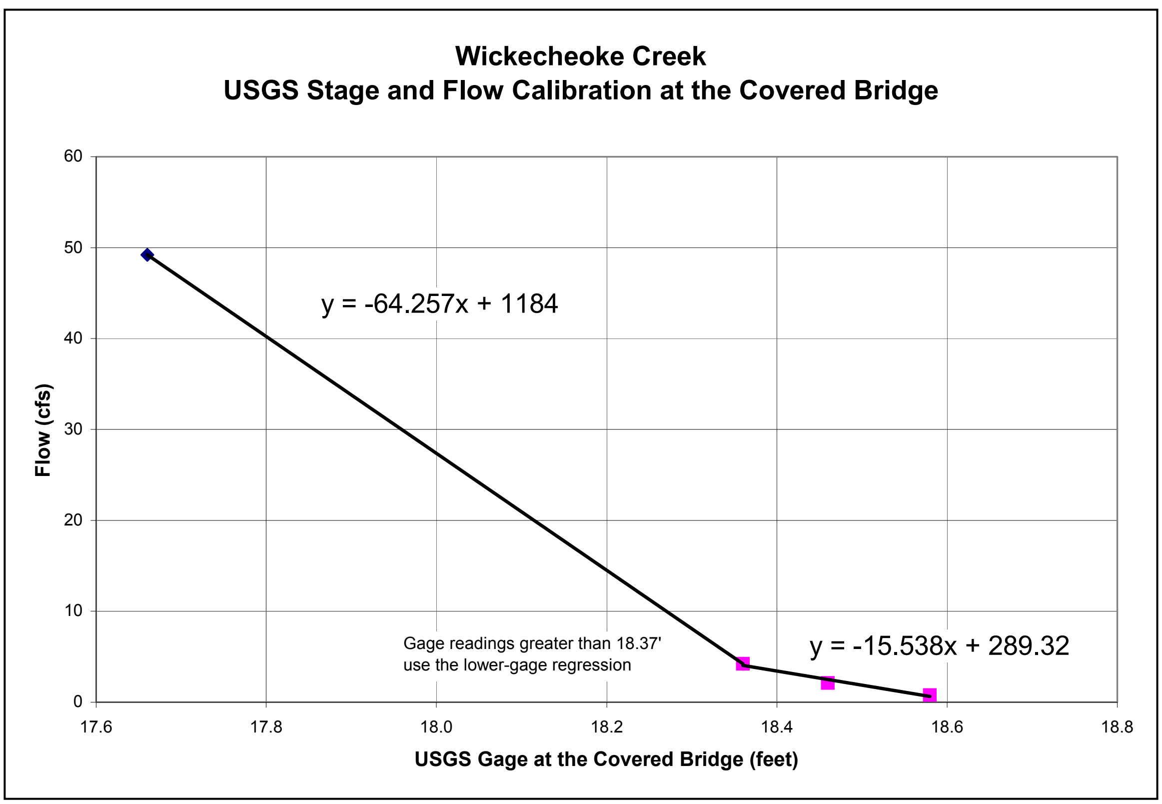


Figure 11b. USGS stage and flow calibration for Wickecheoke Creek at the covered bridge.

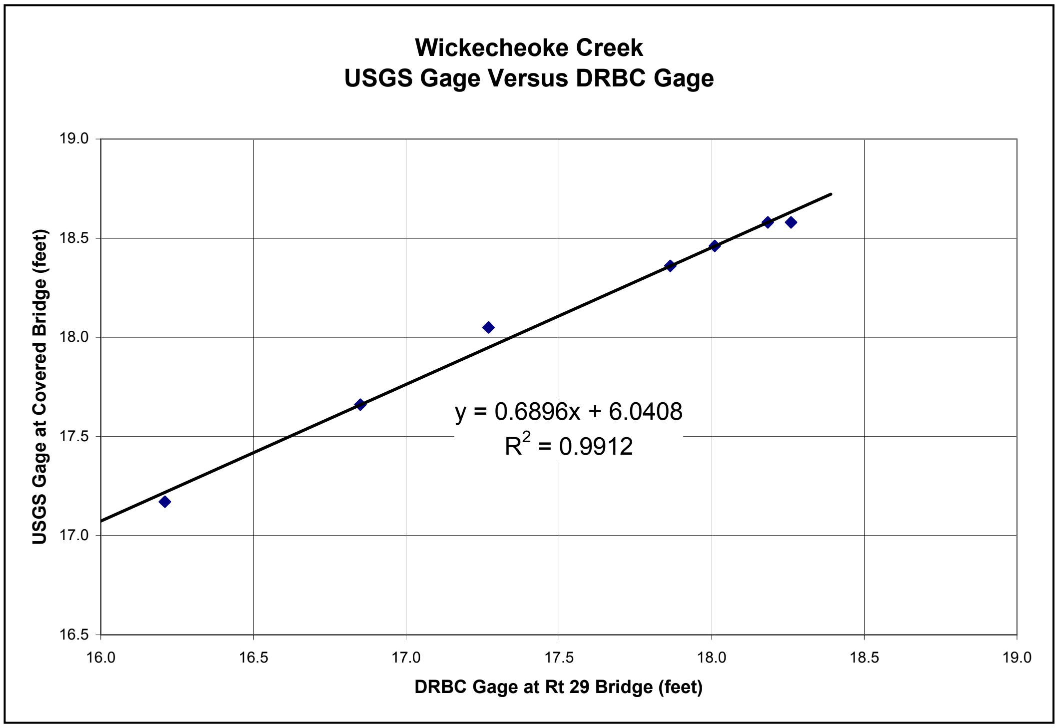


Figure 11c. USGS and DRBC stage relationship for Wickecheoke Creek.

Pidcock Creek

Pidcock Creek has shown a good stage and flow association since its initiation in 1998. This rating is presented in **Figure 12**.

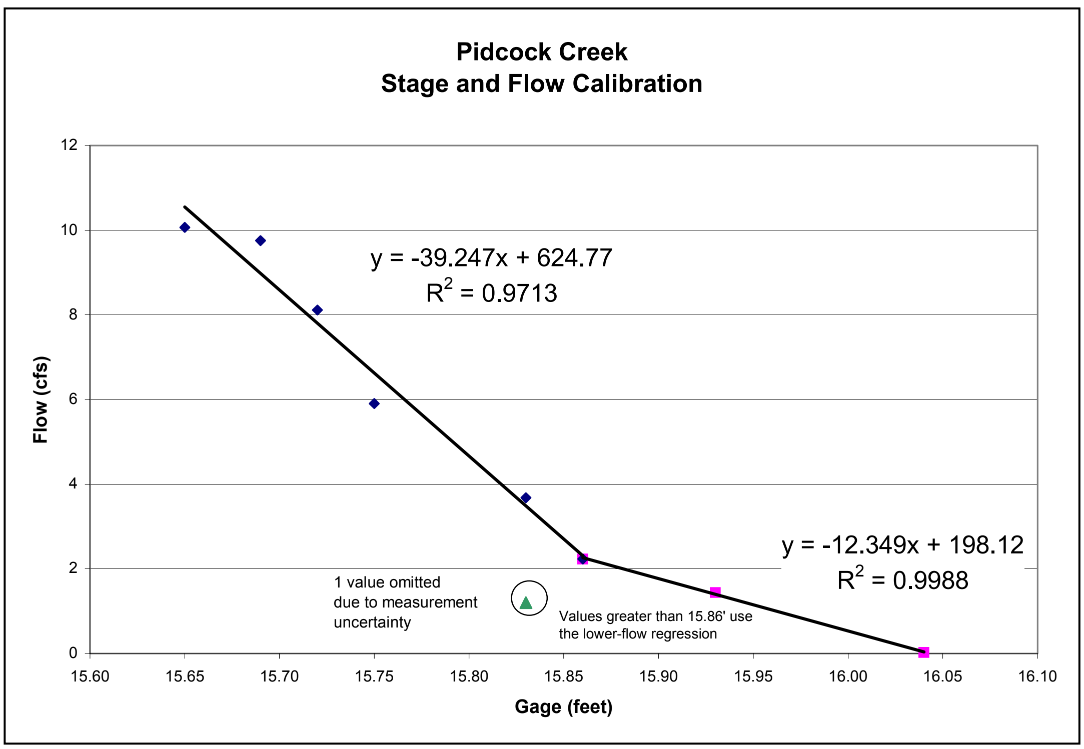


Figure 12. Stage and flow calibrations for Pidcock Creek at river mile 146.3.

Continuous Flow Monitoring as of March 25, 2004

USGS flow data were available as a continuous record for Tohickon Creek, Lehigh River, and the Musconetcong River. The records for the Lehigh River and Musconetcong River were transferred to the DRBC sampling site near the mouth of these streams by using the ratio of the drainage areas (drainage-area-weighting).

Continuous flow monitoring was used to determine: 1) hydrologic associations of streams without USGS flow gages to nearby USGS flow measurement stations; 2) areas (watersheds) with similar precipitation events; 3) flow-related fluctuations in water quality; and 4) estimates of temporal pollutant loading. Comparing the characteristics of hydrographs for the timing and duration of runoff events can identify areas exhibiting similar precipitation patterns. The timing and magnitude of runoff for peak flow and the trailing edge (base flow) may be associated with soil type and depth, karst conditions, and/or land use. Water quality samples that were collected near the flow monitors could be directly associated with the hydrograph (i.e., leading edge, peak, trailing edge, or base flow) to facilitate the assessment of unusual fluctuations in water quality.

Two pressure transducers were installed in neighboring watersheds during 2002 that drained to the Delaware River. One was placed near the mouth of Lockatong Creek and one was positioned near the mouth of Wickecheoke Creek. Both watersheds were located in Hunterdon County, New Jersey. Flow measurements were performed near the monitors and associated with the water depth as measured by the pressure transducers to calibrate flow with water depth. Using this association, continuous water stage measurements provided a continuous flow record.

The watersheds were similar in size: 23.2 and 26.6 square miles for the Lockatong and Wickecheoke Creeks, respectively, and had geological foundations of shallow soils with hard shale (argillite, Brunswick, “mud rock,” and some diabase) bedrock. Similar sized watersheds with similar geology should show similar runoff characteristics. **Figure 13** shows the relationship between the hydrographs from May through October 2002 and the timing of water quality sampling.

The peak flows near the mouth of each stream were constantly within 2 hours of each other, with a minimum lag time of 0.67 hour. However, when compared to the USGS flow data from the Tohickon Creek, peak flows were usually off by 4 or more hours. The Tohickon Creek gage is located nearby on the Pennsylvania side of the Delaware River.

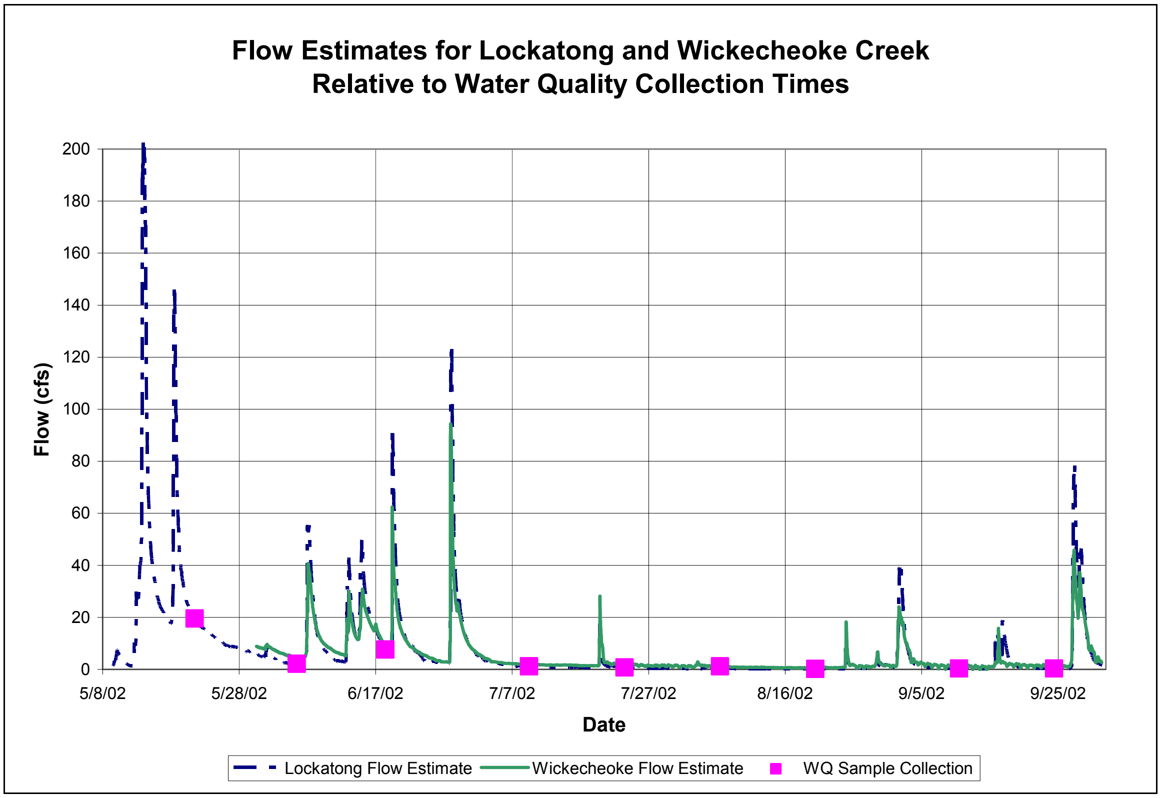


Figure 13. Comparison of runoff hydrographs for Lockatong and Wickecheoke Creeks and the associated flows during water quality sample collections.

Appendix E: Permitted Lower Delaware Dischargers of Over 100,000 gpd

Lower Delaware Major Discharger List - Dischargers of over 100,000 gpd

	St	State
	NPDESID	National Pollution Discharge Elimination System Permit Number
	Facility	Name of discharge facility
	Co	County
	AvgQ%	2000-2003 average monthly effluent flow, percent of permitted flow (PA) or capacity (NJ)
	AvgQRange%	2000-2003 Range of AvgQ%
	MaxQRange%	2000-2003 range of maximum monthly effluent flow, % of permitted flow (PA) or capacity (NJ)

St	NPDESID	Facility	Co	AvgQ%	AvgQRange%	MaxQRange%
PA	PA0020711	TOPTON BORO STP	BERKS			
PA	PA0020290	QUAKERTOWN SEWAGE TREATMENT PLANT (see DMR file)	BUCKS	89%	50-130%	58-298%
PA	PA0021741	DUBLIN BORO STP	BUCKS			
PA	PA0027634	PA AMER WATER YARDLEY DIST	BUCKS			
PA	PA0042641	DCNR-NOCKAMIXON STATE PARK	BUCKS			
PA	PA0050768	BEDMINSTER MA, STONEBRIDGE ESTATES	BUCKS			
PA	PA0052035	HERITAGE HILLS WWTP	BUCKS			
PA	PA0058343	BEDMINSTER WWTP	BUCKS			
PA	PA0012751	ZINC CORPORATION OF AMERICA (see DMR file)	CARBON			
PA	PA0020494	LEHIGHTON BORO	CARBON			
PA	PA0021199	BEAVER MEADOWS MUN AUTH	CARBON			
PA	PA0021555	WEATHERLY WTF	CARBON			
PA	PA0021873	JIM THORPE BORO	CARBON			
PA	PA0023051	PALMERTON BORO WWTF	CARBON			
PA	PA0032972	INTERNATIONAL RESORT PROPERTIE, Mountain Laurel Resort	CARBON			
PA	PA0060747	AMETEK WESTCHESTER PLASTICS DIVISION GREEN ACRES INDUSTRIAL PARK	CARBON			
PA	PA0061182	BIG BOULDER STP	CARBON			
PA	PA0061204	SPLIT ROCK WTP	CARBON			
PA	PA0062138	LAROCHE INDUSTRIES INCORPORATED	CARBON			
PA	PA0062243	NESQUEHONING REGIONAL STP (no DMR data online)	CARBON			
PA	PA0062626	CHAMPION AVIATION	CARBON			
PA	PA0062910	BOWMANSTOWN BORO STP	CARBON			
PA	PA0063487	NORTHSIDE HEIGHTS ESTATES	CARBON			
PA	PA0063711	CENTRAL CARBON MUN AUTH WWTF (no DMR data online)	CARBON			
PA	PA0063860	LEHIGHTON WATER AUTH	CARBON			
PA	PA0011134	AGERE SYSTEMS INC/ALLENTOWN	LEHIGH	29%	0-59%	0-90%
PA	PA0012203	ALLEN ORGAN MANUFACTURING	LEHIGH			
PA	PA0012505	LAFARGE CORPORATION WHITEHALL PLANT	LEHIGH			
PA	PA0014681	NESTLE PURINA PETCARE CO, FRISKIES PETCARE COMPANY INCORPORATED	LEHIGH			
PA	PA0020176	SLATINGTON MUNI WATERWORKS	LEHIGH	72%	69-78%	82-168%
PA	PA0021580	CATASAUQUA WWTF	LEHIGH	58%	38-73%	49-141%
PA	PA0026000	CITY OF ALLENTOWN WASTEWATER TREATMENT PLANT	LEHIGH	86%	75-101%	89-189%
PA	PA0053147	UPPER SAUCON TWP WATER	LEHIGH	55%	35-80%	61-174%
PA	PA0055174	BUCKEYE PIPELINE COMPANY LIMITED PARTNERSHIP MACUNGIE	LEHIGH			
PA	PA0062880	KIDSPEACE CORP, Orchard Hills Campus	LEHIGH			
PA	PA0063568	NORTHAMPTON BORO WTP	LEHIGH			
PA	PA0063983	ESSROC CEMENT CORP EGYPT PLT	LEHIGH			
PA	PA0070505	GEO SPECIALTY CHEMICALS TRIMET PRODUCTS GROUP	LEHIGH	73%	50-82%	62-90%
PA	PA0020435	WHITE HAVEN MUN AUTH STP	LUZERNE			
PA	PA0024716	FREELAND BORO MUN AUTH	LUZERNE			
PA	PA0036439	PA DPW/WHITE HAVEN CENTER	LUZERNE			
PA	PA0010987	DEPARTMENT OF THE ARMY TOBYHANNA	MONROE			

Lower Delaware Major Discharger List - Dischargers of over 100,000 gpd

St	State
NPDESID	National Pollution Discharge Elimination System Permit Number
Facility	Name of discharge facility
Co	County
AvgQ%	2000-2003 average monthly effluent flow, percent of permitted flow (PA) or capacity (NJ)
AvgQRange%	2000-2003 Range of AvgQ%
MaxQRange%	2000-2003 range of maximum monthly effluent flow, % of permitted flow (PA) or capacity (NJ)

St	NPDESID	Facility	Co	AvgQ%	AvgQRange%	MaxQRange%
PA	PA0060097	PAWC-POCONO CO PLACE WWTP	MONROE			
PA	PA0063533	TOBYHANNA TWP	MONROE			
PA	PA0011177	BETHLEHEM STRUCTURAL PRODUCTS CORPORATION	NORTHAMPTON			
PA	PA0011517	KEYSTONE CEMENT COMPANY	NORTHAMPTON			
PA	PA0012823	PPL MARTINS CREEK STEAM ELECTRIC STATION	NORTHAMPTON	109%	56-166%	66-268%
PA	PA0013064	ELEMENTS PIGMENTS INCORPORATED	NORTHAMPTON			
PA	PA0020206	BATH BOROUGH AUTHORITY STP	NORTHAMPTON			
PA	PA0026042	CITY OF BETHLEHEM WASTEWATER TREATMENT PLANT	NORTHAMPTON	68%	58-81%	70-244%
PA	PA0027235	EASTON AREA JOINT SEWER AUTHORITY WPCF	NORTHAMPTON	51%	40-62%	44-110%
PA	PA0028495	RHODIA INCORPORATED	NORTHAMPTON			
PA	PA0028568	BANGOR BOROUGH WASTEWATER TREATMENT	NORTHAMPTON	80%	56-133%	76-281%
PA	PA0031127	NORTHAMPTON BOROUGH	NORTHAMPTON	65%	43-94%	56-209%
PA	PA0037052	PEN ARGYL WASTEWATER TREATMENT PLANT	NORTHAMPTON			
PA	PA0041742	NAZARETH BORO MUNICIPAL AUTHORITY	NORTHAMPTON	88%	73-111%	69-254%
PA	PA0051691	PHARMACHEM CORPORATION	NORTHAMPTON			
PA	PA0052167	WIND GAP MUNICIPAL AUTHORITY	NORTHAMPTON	67%	28-106%	37-229%
PA	PA0053911	EAST BANGOR MUNI AUTH	NORTHAMPTON			
PA	PA0062791	JUST BORN MANUFACTURING	NORTHAMPTON			
PA	PA0063142	CHRINS	NORTHAMPTON			
PA	PA0063240	DANIELSVILLE WWTP	NORTHAMPTON			
PA	PA0063266	PONDEROSA FIBRES OF PA PARTNERSHIP, Newstech PA LP	NORTHAMPTON			
PA	PA0063606	RELIANT ENERGY MID-ATLANTIC	NORTHAMPTON			
PA	PA0064009	ESSROC CEMENT CORP	NORTHAMPTON			
PA	PA0064297	PORTLAND ULTRA-POLY, Portland Boro	NORTHAMPTON			
NJ	NJ0004421	FIBERMARK INCORPORATED HUGHESVILLE FACILITY	HUNTERDON			
NJ	NJ0004448	FIBERMARK INCORPORATED WARREN GLEN FACILITY	HUNTERDON			
NJ	NJ0004456	JAMES RIVER PAPER COMPANY INC, Curtis Spec Papers Milford	HUNTERDON			
NJ	NJ0005517	GILBERT GENERATING STATION	HUNTERDON			
NJ	NJ0020915	LAMBERTVILLE SEWAGE AUTHORITY	HUNTERDON	52%	41-81%	49-168%
NJ	NJ0021890	MILFORD SEWER UTILITY	HUNTERDON	66%	55-89%	60-223%
NJ	NJ0029831	FRENCHTOWN BOROUGH OF	HUNTERDON	114%	66-213%	79-434%
NJ	NJ0031208	ASBURY GRAPHITE MILLS INCORPORATED	HUNTERDON			
NJ	NJ0032271	TRAP ROCK INDUSTRIES INC - Lambertville Quarry	HUNTERDON			
NJ	NJ0027715	MERCER CO CORRECTION CTR STP	MERCER	101%	82-118%	97-186%
NJ	NJ0136581	Trap Rock Industries - MOORE'S STATION QUARRY	MERCER			
NJ	NJ0021369	HACKETTSTOWN TOWN MUA WATER PC PLANT @ IND PK	MORRIS	68%	55-87%	63-111%
NJ	NJ0027821	MUSCONETCONG SEWER AUTH WATER POLLUTION CONTROL FACILITY	MORRIS	92%	79-118%	91-179%
NJ	NJ0090051	Oakwood Village STP	MORRIS			
NJ	NJ0004791	SOUTHDOWN INC - Crest Aggregates	SUSSEX			
NJ	NJ0005711	SCHERING CORPORATION	SUSSEX			
NJ	NJ0020184	NEWTON WWTP	SUSSEX	70%	53-116%	58-262%
NJ	NJ0020419	LONG POND SCHOOL WWTP	SUSSEX	2%	0-3%	0-5%
NJ	NJ0004006	MALLINCKRODT BAKER INCORPORATED	WARREN			

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	St	State
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St	NPDESID	Facility	Co	AvgQ%	AvgQRange%	MaxQRange%
NJ	NJ0004049	FLOWSERVE CORP, Ingersoll Rand	WARREN			
NJ	NJ0004812	Amerace, THOMAS & BETTS ELASTIMOLD	WARREN			
NJ	NJ0004901	OXFORD TEXTILE INCORPORATED	WARREN			
NJ	NJ0004952	ROCHE VITAMINS INC - DSM Nutritional Products Inc	WARREN			
NJ	NJ0005118	BASF CORPORATION	WARREN			
NJ	NJ0020605	ALLAMUCHY STP, TOWNSHIP OF	WARREN	55%	41-79%	51-122%
NJ	NJ0021113	WASHINGTON BOROUGH WTF	WARREN	51%	42-62%	45-81%
NJ	NJ0024716	PHILLIPSBURG TOWN OF STP	WARREN	70%	63-75%	74-103%
NJ	NJ0028592	Hackettstown MUA - DIAMOND HILL ESTATES SEWAGE CO	WARREN	42%	29-70%	35-116%
NJ	NJ0028657	NOVAS BOREALIS COMPOUNDS INCORPORATED	WARREN			
NJ	NJ0033189	PEQUEST STATE FISH HATCHERY & EDUCATION CENTER	WARREN			
NJ	NJ0035114	BELVIDERE AREA WWTF	WARREN	61%	54-84%	61-127%
NJ	NJ0035483	OXFORD AREA WTF	WARREN	77%	62-100%	74-225%
NJ	NJ0074420	TILCON NY INCORPORATED OXFORD FACILITY, OXFORD QUARRY	WARREN			
NJ	NJ0077364	M&M Mars Inc	WARREN			
NJ	NJ0104060	ATLANTIC STATES CAST IRON PIPE COMPANY	WARREN			
NJ	NJ0104388	JCP&L - YARDS CREEK PUMPED STORAGE	WARREN			