2016

# ASSESSMENT OF MEASURABLE CHANGES TO EXISTING WATER QUALITY, ROUND 1: BASELINE EWQ (2000-2004) VS. POST-EWQ (2009-2011)

## DELAWARE RIVER BASIN COMMISSION, SCENIC RIVERS MONITORING PROGRAM

Delaware River Basin Commission
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# Delaware River Basin Commission

# Lower Delaware River
# Special Protection Waters

# Assessment of Measurable Changes to Existing Water Quality, Round 1: Baseline EWQ (2000-2004) vs. Post-EWQ (2009-2011)

Citation

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# Executive Summary

**Introduction:** The Lower Delaware is a 76-mile reach of the Delaware River extending from just below the Delaware Water Gap at Portland, PA (River Mile 209.5) to Calhoun Street Bridge at Trenton, NJ (River Mile 134.3). In 2000, federal legislation was enacted adding key segments of the Lower Delaware and selected tributaries to the National Wild and Scenic Rivers System. This designation was followed in April 2001 with a petition to DRBC from the Delaware Riverkeeper Network to classify the Lower Delaware as Special Protection Waters (SPW). In 2008, the DRBC by unanimous vote (DRBC 2008) added the Lower Delaware to Special Protection Waters as Significant Resource Waters, and adopted Existing Water Quality definitions for specific control points.

In partnership with the National Park Service (NPS), the Delaware River Basin Commission established the **Scenic Rivers Monitoring Program (SRMP)** to define the water quality for this reach of the river and assess any measurable changes to these high quality waters. The NPS administers a Lower Delaware Management Plan created for the Wild and Scenic designated reaches of the river. DRBC monitors the Lower Delaware, and is the lead agency for the first objective of the NPS management plan: to maintain existing water quality and to improve it where practical. The NPS management plan objective slightly differs from that of DRBC water quality regulations, which is to prevent degradation of water quality unless toward natural conditions.

Implementing the No Measurable Change management policy requires a periodic assessment of the water quality conditions of the Lower Delaware at specific control points in the main stem river and at the confluence of tributaries to the main stem. The existing water quality at the time of the SPW designation at these points was established as medians and upper and lower 95$^{th}$ confidence intervals for 20 parameters using a data set from 2000 through 2004. The current assessment utilizes data collected over three years from 2009 through 2011.

**Monitoring Design:** DRBC collected water quality samples for parameters in the DRBC water quality regulations from May through September at fixed sites called **Control Points** in the Lower Delaware River corridor from 2009 to 2011, with sampling targeted bi-weekly or monthly for a total of 5-10 samples per season at each location. This design resulted in a total of 15-30 samples during the study period. The control points were designated as **Interstate Control Points (ICP's)** if the point was located on the main stem of the interstate Delaware River, or as **Boundary Control Points (BCP's)** if they were located on tributaries in New Jersey or Pennsylvania near the confluence of each tributary watershed with the river. ICP's are monitored to document longitudinal water quality changes along segments of the Delaware River. BCP's are monitored to document watershed influences upon the Delaware River, and to measure water quality changes that occur in watersheds between the time periods.

**Assessment Methodology – generalized approach:** One of the important objectives of this study was to establish a replicable and dependable assessment methodology for identifying water quality changes that constitute "measurable change" as defined in DRBC water quality rules. The assessment methodology included in this report is graphical plots and statistical tests along with watershed characteristics to provide qualitative and quantitative assessments of measurable change. This report includes chapters for each of the ICPs and BCPs that describe in detail the information used in the assessment.

**Summary of Assessment Results**: A tabular summary of the assessment at each control point is presented in a matrix. No measurable change took place for 17 out of 20 parameters tested at almost all control points in the 2009-2011 assessment period. These include general water quality parameters such as alkalinity, hardness, pH, dissolved oxygen, temperature, turbidity, dissolved and suspended solids, all nutrient forms (ammonia, nitrate + nitrite, total nitrogen, total phosphorus, and orthophosphate), and 2 of 3 tested bacteria parameters (Enterococcus and Fecal coliforms). It should be noted that all seven of the parameters including all nutrient parameters that are evaluated for wastewater treatment facilities are included in this group.

Measurable change toward degraded water quality conditions was detected for three parameters: chlorides and specific conductance at almost all sites, and for *E. coli* at sites from Nishisakawick Creek in Frenchtown, NJ (River Mile 164.1) and downstream.

**Recommendations** are included in the report for future monitoring and policy considerations.

# Contents



## Download Individual Chapters:

# Abbreviations

| | |
|---|---|
| #/100 ml | Colonies per 100 milliliters, a unit of bacteria concentration |
| BaSE | Baseline Streamflow Estimator (USGS computer application) |
| BCP: | Boundary Control Point: A fixed monitoring location on a tributary to the Delaware River. |
| CDF: | Cumulative Distribution Function |
| CFS: | Cubic Feet per Second |
| DAW | Drainage Area Weighting |
| DO: | Dissolved Oxygen |
| DO%: | Dissolved Oxygen Percent Saturation |
| DEWA | Delaware Water Gap |
| DRBC: | Delaware River Basin Commission |
| DWGNRA | Delaware Water Gap National Recreation Area |
| EWQ: | Existing Water Quality (defined during 2000-2004), the baseline water quality data |
| ICP: | Interstate Control Point: A fixed monitoring location on the Delaware River |
| LDEL: | Lower Delaware (Delaware River mile 134.3 at Trenton to mile 209.5 at Portland) |
| MCP: | Monitoring Control Point – a site not meant for rules, but for modeling and diagnostic monitoring |
| mg/l | Milligrams per Liter, a unit of concentration |
| N+N | Nitrate plus Nitrite |
| NMC: | No Measurable Change, specifically defined in DRBC rules |
| NJDEP: | New Jersey Department of Environmental Protection |
| NJDOH-ECLS | New Jersey Department of Health, Environmental Chemistry and Laboratory Services |
| NPS | National Park Service |
| NWIS | National Water Information System (USGS water quality data repository) |
| OP: | Orthophosphate |
| PADEP: | Pennsylvania Department of Environmental Protection |
| Post-EWQ: | The 2009-2011 test water quality data used to assess water quality changes from baseline |
| QAPP | Quality Assurance Project Plan |
| QA/QC | Quality Assurance / Quality Control |
| SpC: | Specific Conductance |
| SPW: | Special Protection Waters |
| SRMP: | Scenic Rivers Monitoring Program |
| TDS: | Total Dissolved Solids |
| TKN: | Total Kjeldahl Nitrogen |
| TN: | Total Nitrogen |
| TP: | Total Phosphorus |
| TSS: | Total Suspended Solids |
| UDSRR | Upper Delaware Scenic and Recreational River |
| µmho/cm | Micro-mhos per centimeter, a unit of specific conductance (also µS/cm – micro-Siemens/cm) |
| UPDE | Upper Delaware |
| USEPA | United States Environmental Protection Agency |
| USGS: | United States Geological Survey |
| WQN: | Water Quality Network: PADEP's fixed water quality stations |

# Introduction

This document contains a discussion of water quality changes at each Special Protection Waters control point along the Lower Delaware River. At 24 sites located between the Delaware Water Gap and Trenton, NJ (see Chapters 1-24), water quality was compared between two time periods: the 2000-2004 Existing Water Quality (EWQ) baseline period and the 2009-2011 post-EWQ period, also referred to as the Lower Delaware Measurable Change Assessment Round 1. A matrix summarizing the assessment is also included.

Appendix A contains site-specific definition of Existing Water Quality at one new Monitoring Control Point location on the Delaware River (Sandts Eddy Fishing and Boating Access in Northampton County, PA), and at two new Boundary Control Point tributary watershed locations (Slateford Creek, PA and Lopatcong Creek, NJ). These EWQ definitions are provided as guidance for evaluation of new or expanding wastewater treatment plants and for consideration for future DRBC water quality rules.

Appendix B contains brief descriptions of the plots and statistical tests, with notes about interpretation of the plots. Additional information about the DRBC Special Protection Waters Program may be found here: http://www.state.nj.us/drbc/programs/quality/spw.html

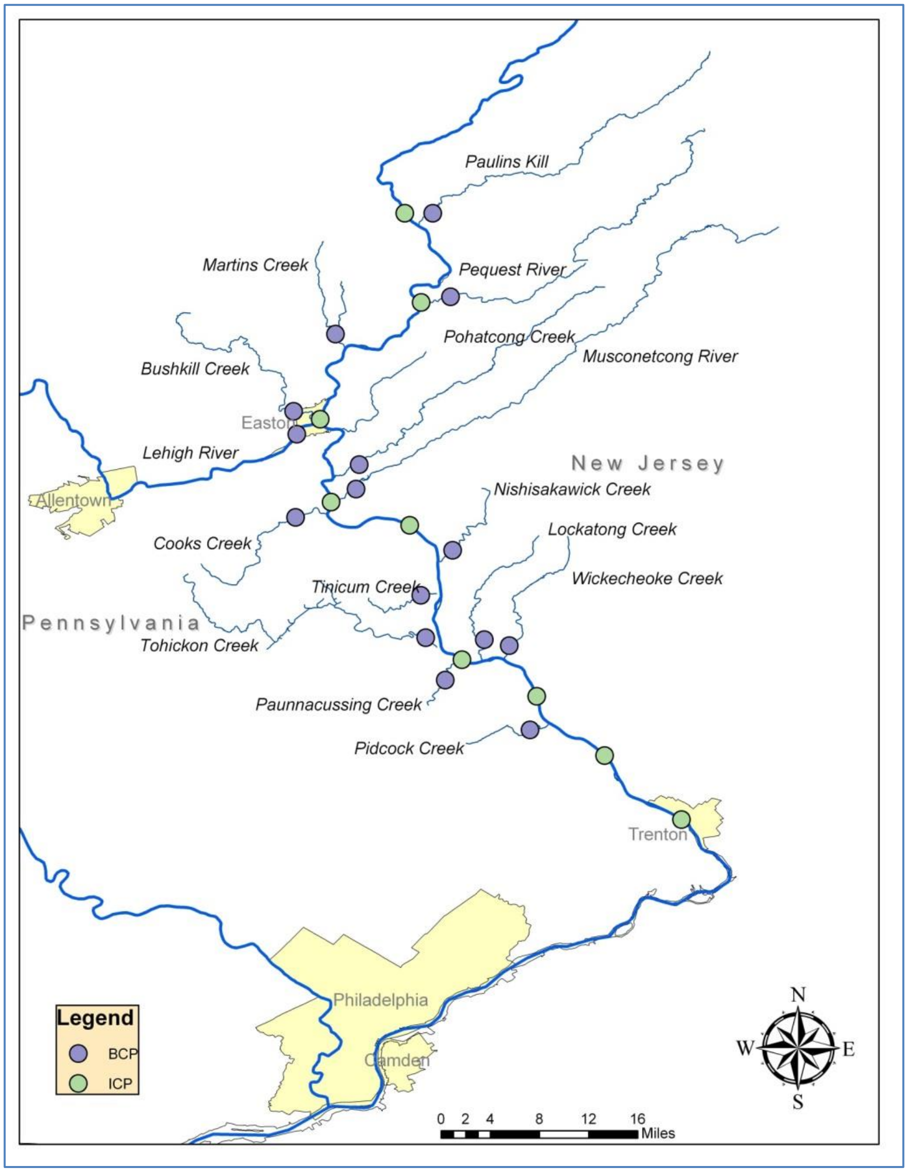
Appendix C contains a detailed description of our methods for estimating discharge at ungaged locations, and how those data are associated with the site-specific water quality data.

# Program Description

The Lower Delaware is a 76-mile reach of the Delaware River extending from just below the Delaware Water Gap at Portland, PA (River Mile 209.5) to Calhoun Street Bridge at Trenton, NJ (River Mile 134.3). In 2000, federal legislation was enacted adding key segments of the Lower Delaware and selected tributaries to the National Wild and Scenic Rivers System. This designation was followed in April 2001 with a petition to DRBC from the Delaware Riverkeeper Network to classify the Lower Delaware as Special Protection Waters (SPW). In 2008, the DRBC by unanimous vote (DRBC 2008) added the Lower Delaware to Special Protection Waters as Significant Resource Waters, and adopted Existing Water Quality definitions for specific control points. As part of this action, extensive revisions to Article 3 of the Commission's Water Quality Regulations were approved to incorporate 24 tables, one for each of the Control Point, defining the Existing Water Quality (EWQ) at each of the points.

In partnership with the National Park Service (NPS), the federal agency that administers Lower Delaware Wild and scenic River, the Delaware River Basin Commission established the **Scenic Rivers Monitoring Program (SRMP)** to define the water quality for this reach of the river and assess any measurable changes to these high quality waters. This program also includes components for the Middle Delaware River and Upper Delaware River. The NPS administers a Lower Delaware Management Plan created for the Wild and Scenic designated reaches of the river. DRBC monitors the Lower Delaware, and is the lead agency for the first objective of the NPS management plan: to maintain existing water quality and to improve it where practical. This objective slightly differs from that of DRBC water quality regulations, which is to prevent degradation of water quality unless toward natural conditions.

Figure 1: Lower Delaware Monitoring Locations for Special Protection Waters




## Monitoring Description

In the SRMP, monitoring sites are classified as **Control Points,** which are fixed sites along the Delaware River corridor: **Interstate Control Points (ICP's)** are locations on the interstate Delaware River, and **Boundary Control Points (BCP's)** are New Jersey or Pennsylvania sites located near the confluence of each tributary watershed entering the Delaware River. BCP's are monitored to document their influence upon the Delaware River, and to measure water quality changes that occur in the watershed between selected time periods. This report contains the first assessment of measurable changes to EWQ in the Lower Delaware (LDEL).

DRBC designed the SRMP to define and assess changes to site-specific water quality for as many tributaries as possible with the following objectives:

1. Covering as much watershed area as possible: the SRMP currently encompasses all watersheds of more than 20 square miles in size. This enables DRBC to evaluate approximately 85% of the watershed area of the Delaware River Basin above Trenton with as few sites as possible.
2. Monitor smaller watersheds that presently or in the future contain dischargers subject to Special Protection Waters regulations (e.g., Slateford Creek, PA);
3. Monitor smaller watersheds that have been designated as Wild and Scenic by the National Park Service (e.g., Paunnacussing Creek, PA);
4. Representatively monitor some small watersheds that possess general water quality characteristics of physiographic regions or ecoregions along the Delaware River (e.g., Pidcock Creek, PA represents the Piedmont physiographic region);
5. Within some large watersheds, conduct additional monitoring for construction and calibration of water quality models (e.g., Lehigh River, PA, Neversink River, NY, and Brodhead Creek, PA).

A complete description of the monitoring program is provided in the Scenic Rivers Monitoring Program Quality Assurance Project Plan (DRBC 2006, 2009, 2013). DRBC collects water quality samples from May through September in selected years, preferably sampling bi-weekly for a total of 10 samples per season at each location. This is conducted for 3 to 5-year periods, providing 30 to 50 samples per study period.

Monitoring Station numbering examples

- For ICPs, 'Delaware River at Trenton – 1344 ICP': River Mile 134.4, ICP = Interstate Control Point,
- For BCPs, 'Paulins Kill River, NJ – 2070 BCP: Delaware River Mile 207.0 at confluence, BCP = Boundary Control Point

## Assessment Approach

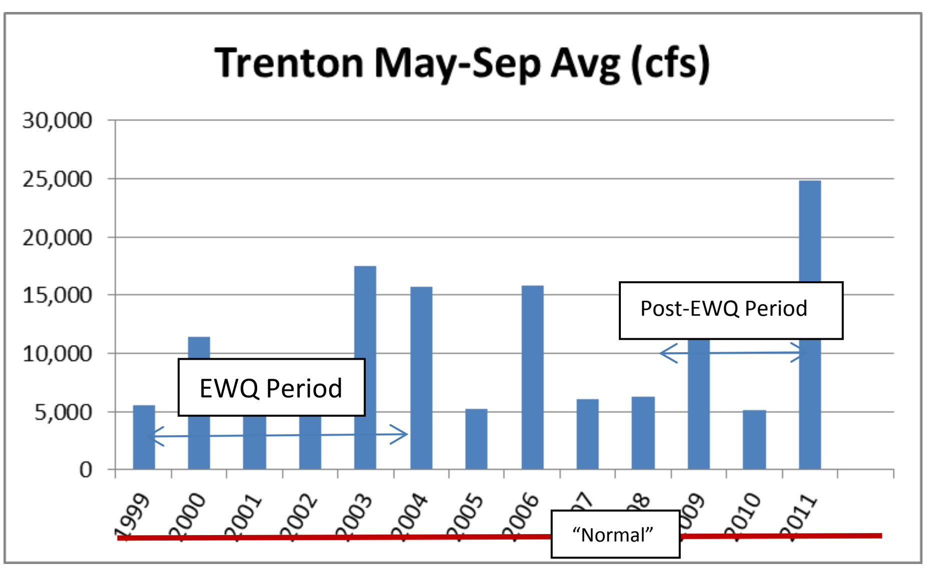
Each chapter of this report is organized by site and contains within-site water quality comparisons where Existing Water Quality (EWQ) was site-specifically defined in DRBC Special Protection Waters regulations. Each chapter starts with a short analysis of the flow conditions sampled during each study period and possible effects upon the water quality analyses. For each parameter listed in DRBC water quality regulations (Tables 2C to 2Z) the following plots are shown:

1. Scatter Plot of Concentration vs. Stream Flow (cfs), EWQ vs. Post-EWQ Monitoring Periods
2. Scatter Plot of Annual Concentration, 2000-2011
3. Box Plot Comparison of EWQ vs. Post-EWQ Concentrations
4. Cumulative Distribution Function (CDF) Comparison of EWQ vs. Post-EWQ Concentrations
5. Kruskal-Wallis Statistical Test of Difference between EWQ and Post-EWQ Concentrations
6. Short Discussion of Results

In this study, the plots are systematically used to qualitatively and quantitatively determine measurable change to existing water quality, an important concept in DRBC Special Protection Waters rules. The specific definition from DRBC water quality regulations follows:

> "Measurable Change to Existing Water Quality" is defined as an actual or estimated change in a seasonal or non-seasonal mean (for SPW waters upstream and including River Mile 209.5) or median (for SPW waters downstream of River Mile 209.5) in-stream pollutant concentration that is outside the range of the two-tailed upper and lower 95 percent confidence intervals that define Existing Water Quality.

The definition of measurable change is fairly simple, but some influential variables must be considered in order to make a fair and accurate assessment with an unbiased conclusion. An original objective of this program was to define EWQ to represent the full range of hydrologic conditions experienced at that location along the Delaware River or one of its tributaries. A five-year period (2000-2004) was used to define baseline EWQ. In the Lower Delaware, EWQ was defined "seasonally" by sampling 10 times within the annual May to September periods, and in fact represents very well almost the entire hydrograph.




The chart to the left indicates that comparison of the EWQ data set with the post-EWQ data set is not as simple as direct statistical comparison of medians and confidence intervals employed by the Kruskal-Wallis test. Many parameters are **flow related**, so comparing two time intervals means that flow must be accounted into the analysis.

That is why the scatter plots are included in this analysis, and why the decision that "measurable change" has occurred is more of a qualitative judgment rather than a direct quantitative test. Further information is supplied by the box plots and the cumulative distribution functions, which allow for comparison of the entire data distribution between the two periods rather than just the median and confidence intervals. All of the plots together, along with the statistical test, allow for a fairly accurate judgment of measurable change within a replicable decision process.

## Significant Findings

**No Measurable Change:**

Almost universally throughout the Lower Delaware there was no degradation, and possibly may have been improvement in concentrations of: ammonia, nitrate + nitrite, total nitrogen, Kjeldahl nitrogen, orthophosphate, and total phosphorus. All told there have been about 140 wastewater projects in Special Protection Waters reviewed and approved by DRBC since 1992. About 1/3 of the projects are located in the Lower Delaware and were implemented since the 2005 interim Lower Delaware SPW designation.

There are a few watersheds where bacteria levels apparently declined: Cooks Creek, PA; Musconetcong River, NJ; Pohatcong Creek, NJ; Lehigh River, PA; Martins Creek, PA; Pequest River, NJ; the Paulins Kill River, NJ; and the Delaware River near Riegelsville, Easton, and Belvidere. See individual chapters for discussion of each stream.

In Martins Creek, PA, improvements were apparent not only for the above-mentioned parameters but also dissolved oxygen, dissolved oxygen saturation, total suspended solids, and turbidity. A number of stream restoration and watershed protection projects were undertaken recently and may have shown tangible water quality benefits. Mr. John Mauser of the Martins-Jacoby Watershed Association presented a number of case studies, found here: http://www.dcnr.state.pa.us/cs/groups/public/documents/document/dcnr_002582.pdf

The **removal of dams on the Musconetcong River** may have provided water quality benefits. Although water quality of the Musconetcong is still poor relative to the Delaware River, slight improvements were observed in dissolved oxygen concentration and saturation values, and total suspended solids.

**Measurable Change:**

**Chlorides** and **specific conductance** rose in almost every watershed and at many Delaware River locations. Similar to other northern locations throughout the U.S. and Canada (Evans and Frick 2001; Kaushal et. al. 2005; Cunningham et. al. 2008; Kelly et. al. 2008; Daley et. al. 2009; Gardner and Royer 2010; Findlay and Kelly 2011; New Hampshire DES 2011; Hunt et. al. 2012; Cañedo-Argüelles 2013), the rise may be attributable to winter road salt applications. In a suburban watershed near the Lower Delaware, Skippack Creek concentrations are reaching levels that allow for growth of brackish-water algae instead of the expected freshwater species (USEPA and PADEP 2005). Concentrations in the Lower Delaware are presently well below such effect levels, and meet PA and NJ water quality criteria levels developed to protect human health. However, it appears that chloride concentrations and specific conductance are increasing.

Specific conductance is largely unregulated and understudied – there are no established ambient water quality criteria that are relevant to aquatic life, because there are many ions that can make up specific conductance. U.S. EPA published chloride criteria for aquatic life in 1986 that are applicable in the basin states: the acute criterion maximum concentration (CMC) is 860 mg/l, and the chronic criterion continuous concentration (CCC) is 230 mg/l (U.S. EPA 1986). The human health criterion throughout the basin states is 250 mg/l, but may only be applied at water supply intake locations, not for all ambient waters. Pennsylvania DEP has studied the issue of chloride impacts upon aquatic life, and recently made recommendations in their triennial review of water quality standards to improve chloride criteria for protection of aquatic life (PADEP 2015). Chlorides are naturally present in streams, mostly contributed by geological formations underlying the streams. So chloride concentrations up to approximately 30 mg/l are expected here. Winter road salting is proportionally the largest anthropogenic source, is also unregulated, and merits further investigation. Other man-made sources are smaller in their contributions, and include various industrial effluents, sewage, landfill leachate, agricultural runoff, and hydraulic fracturing products. Within the DRBC anti-degradation policy structure, these parameters have shown measurable changes to existing water quality, and not toward natural conditions.

We unexpectedly found that although chlorides and specific conductance increased, total dissolved solids appeared to decline or stay the same. Upon seeing this, our first response was to question our TDS laboratory methods, because specific conductance and TDS are expected to respond similarly – as one increases so does the other. We ultimately could not rule out inter-laboratory differences as the cause for these unexpected results. Although there were never any undetected TDS results, post-EWQ detection limits were lower than EWQ detection limits. All laboratories used the same EPA-approved method, but perhaps the overall testing range shifted lower along with the detection limits. This appeared to happen with several parameters – as detection limits declined, overall the data became less variable, slightly lower in concentration, and with fewer extreme high values.

**Escherichia coli** concentrations increased beyond EWQ targets in all watersheds downstream of Frenchtown, NJ except for the Paunnacussing Creek watershed in Bucks County. High levels of E. coli concentrations have sporadically been detected based on monitoring data at: Nishisakawick Creek (NJ), Tinicum Creek (PA), Lockatong Creek (NJ), Wickecheoke Creek (NJ), Pidcock Creek (PA), and at Bulls Island, Lambertville, Washington Crossing and Trenton on the Delaware River. E. coli concentrations increase with increasing flow conditions.

## Analytical Limitations and Sources of Uncertainty in this Assessment

There are several factors that contribute to uncertainty in the data. While these factors are not unique to this study, they are important to consider as part of the overall comparison between the EWQ and post-EWQ periods. Limitations and sources of uncertainty are described in more detail below.

**Dissimilar hydrological periods**: the EWQ period was composed of one “normal” flow year, two low-to-normal flow years, and two wet flow years. The post-EWQ period contained one normal flow year, one dry flow year, and one very wet flow year. This presented a problem at Trenton (see Chapter 1), where the Calhoun Street Bridge was closed for the entire dry 2010 monitoring season. So the Trenton post-EWQ data contain more high flow measurements and less low-flow measurements than the EWQ data, making direct comparison difficult at that location. There were a few other locations where wet or dry-weather samples were under-represented in the post-EWQ data, and those circumstances are noted in each chapter. This limitation is not deemed severe as long as flow is accounted into the analysis so that flow effects are recognized, if not fully controlled.

Future solution: for future assessment rounds, best attempts should be made to: 1) monitor for a minimum of three years at a rate of 10 samples per May to September season; and 2) classify samples on the flow duration curve for each site; then decide if additional monitoring (up to two additional years) might provide the most representative balance of low, normal and high-flow samples. This would ensure that variability attributable to flow is controlled to provide a clear and reliable judgment of water quality changes between the EWQ baseline (control) and subsequent assessment (test) periods.

Another challenge to direct comparison is the **number of data points** per period (N). Through this monitoring program we sought to balance collection of a statistically appropriate number of data points with the reality of competing resource demands. The first assessment round completed during 2009-2011 was designed to test measurable changes from the baseline but used a smaller data set. Some sites were sampled 10 times per season for three years (N=30), others only monthly within the May to September period for three years (N=15). Fewer observations result in higher variability, reduced ability to detect changes, and potential introduction of bias. In water quality analyses, a higher number of observations is preferable but not always obtainable. In future assessments, it may be preferable to drop sites in order to retain a higher number of observations at sites that are sampled.

Some water quality parameters are more **naturally variable** than others and thus less predictable without closely defining the conditions under which the samples were taken or vastly increasing the sampling rate. Examples of this include bacteria (Enterococcus, E. coli and Fecal Coliform) and Total Suspended Solids (TSS). Given that fewer data were collected from 2009-2011 than from 2000-2004, direct statistical comparison between the two data sets is confounded by influential factors that may not easily be quantified, such as land use changes or ecological processes. Other water quality parameters "behave" much more conservatively, and it takes fewer data to draw fairly accurate conclusions about changes. Examples of conservative parameters include specific conductance, total phosphorus, chloride and total dissolved solids (TDS).

**Time of day** is an influential factor for parameters that cycle up and down each day, such as dissolved oxygen, pH, water and air temperature, and nitrate. In this program, sampling is scheduled so that these parameters are at or near their daily maxima when sampled (roughly mid-day), and sites are visited in different order so that the sample time is varied within the daily time range when these parameters are near their daily maximum concentration. Note that in DRBC or state water quality regulations, many criteria are expressed as 24-hour averages, minima or maxima. These data do not represent daily lows or averages, which are better obtained from continuous monitoring stations such as those at Trenton, Frenchtown, Riegelsville and Belvidere. Comparison against criteria must take into account the difference in averaging period. DRBC recognizes the value of continuous monitoring stations for proper assessment of water quality standards, and has been supporting the addition of water quality meter installation at USGS gages located in all Zones of the Delaware River.

Another factor that may cause imbalance in data analyses is the water quality **test method** itself, as well as the **laboratory** performing the test. Since inception of this program, DRBC has changed contract laboratories several times. DRBC employed standard QA/QC safeguards to minimize the impact of using different labs including requiring that labs be state-certified for regulatory testing of the parameter list and use of EPA-approved methods for testing of ambient surface water. In addition, DRBC routinely performed blinded replicate samples and blinded rinsate blank samples to ensure the accuracy and precision of reported results. The fact remains however that method detection limit levels must be low enough to provide reliable information about high-quality streams and rivers. Many commercial laboratories typically test wastewater, not high-quality ambient surface water. Thus low-level analytical capability was uncommon in our earliest results through about 2002. As this low-level capability increases in the analytical community, we were better able to quantify low-concentration ambient surface waters. The early portion of the EWQ data set thus contains a fair amount of non-detect results and wide variability, whereas the latter portion of the baseline data and all of the post-EWQ data set contain virtually no non-detect results even in the best streams. This analytical difference hampers comparison. See Table 1 for detection limits from 2000-2011 for Scenic Rivers Monitoring Program parameters.

Table 1: Detection Limits for Selected Scenic Rivers Monitoring Program Parameters, 2000-2013

| Year | Ammonia mg/l | Nitrate + Nitrite mg/l** | Ortho-Phosphate mg/l | Total Phosphorus mg/l | TKN mg/l | TDS mg/l | TSS mg/l | Lab | Comment |
|---|---|---|---|---|---|---|---|---|---|
| 2000 | 0.10* | 0.50 | 0.01 | 0.01 | 0.10 | 20.0 | 2.0 | QC | |
| 2001 | 0.05 | 0.02 | 0.01 | 0.02 | 0.05 | 8.0 | 0.5 | NJAL | |
| 2002 | 0.05 | 0.02 | 0.01 | 0.02 | 0.05 | 8.0 | 0.5 | NJAL | |
| 2003 | 0.05 | 0.02 | 0.01 | 0.02 | 0.05 | 6.0 | 0.5 | NJAL | |
| 2004 | 0.02 | 0.02 | 0.01 | 0.01 | 0.05 | 6.0 | 2.0 | NJAL | |
| 2006 | 0.01 | No Tests | No Tests | No Tests | No Tests | 5.0 | 5.0 | ANSP | No Lower Del. sampling |
| 2007 | 0.005 | 0.007 | 0.002 | 0.002 | 0.038 | 3.1 | 0.43 | ANSP | No Lower Del. sampling |
| 2008 | 0.005 | 0.003 | 0.003 | 0.002 | 0.032 | 3.45 | 0.38 | ANSP | No Lower Del. sampling |
| 2009 | 0.004 | 0.007 | 0.002 | 0.002 | 0.044 | 3.71 | 0.75 | ANSP | |
| 2010 | 0.004 | 0.006 | 0.002 | 0.002 | 0.061 | 3.74 | 0.59 | ANSP | |
| 2011 | 0.004 | 0.006 | 0.002 | 0.002 | 0.050 | 1.57 | 0.75 | ANSP | |
| 2012 | 0.006 | 0.003 | 0.002 | 0.002 | 0.039 | 2.19 | 0.3 | ANSP | No Lower Del. sampling |
| 2013 | 0.006 | 0.004 | 0.002 | 0.008 | 0.028 | 1.0 | 1.0 | NJDOH | No Lower Del. sampling |

* In Table 1 above there are no data for ammonia samples taken in 2000. That year the detection limit was so high that almost all results were non-detects. Those data were discarded from this study.

**For the Lower Delaware EWQ definition period of 2000-2004, DRBC requested that the laboratories perform tests for Nitrate and for Nitrite individually, so the detection limits from 2000-2004 above are for Nitrate only. Nitrite sample results were almost exclusively non-detects, because Nitrite is converted relatively quickly to Nitrate in streams that Nitrite is rarely detected. Since 2004 Nitrate + Nitrite testing was requested to save on costs, and it is confident that Nitrate is proportionally so much greater than Nitrite that Nitrite is negligible.

# Recommendations:

## Monitoring Recommendations

1. **Sampling frequency** during selected years should always be twice monthly rather than once monthly. Once-monthly sampling does not represent the full range of flow conditions. Also, once-monthly sampling reduces the overall number of data which leads to a reduction in our ability to detect changes.
2. DRBC monitoring programs should continue to **use BaSE (USGS Baseline Streamflow Estimator model) to estimate stream flow** at ungaged water quality monitoring sites. Results from BaSE compared very favorably to our flow measurements made using benchmark gages and rating curves at considerably reduced effort.
3. When DRBC changes contract laboratories or makes use of multiple labs, we should **conduct more split sampling** analyses so that we can compare results among multiple laboratories conducting a selected USEPA-approved analytical method.
4. **Automate and add to this assessment procedure using R**. Creation of R scripts to automatically retrieve, process, and plot the latest water quality data would greatly enhance our assessment capability.
5. **Conduct bacterial track-down studies** for the Delaware River and its tributaries between Frenchtown-Uhlerstown and Trenton-Morrisville, NJ-PA. *E. coli* concentrations have risen within this reach and in most tributary watersheds. In addition there are several tributaries where recreational criteria are still exceeded, even though bacterial concentrations may have remained stable or dropped including Cooks Creek, PA; Musconetcong River, NJ; Pohatcong Creek, NJ; Bushkill Creek, PA (Northampton County).
6. **Continue to define site-specific water quality** for key tributaries within multiple objectives:
   a. Define EWQ for watersheds of more than 20 square miles in size. This enables DRBC to evaluate approximately 85% of the watershed area of the Delaware River Basin above Trenton with as few sites as possible.
   b. As necessary, monitor smaller watersheds that presently or in the future contain dischargers subject to Special Protection Waters regulations (e.g., Slateford Creek, PA);

c. As necessary, monitor smaller watersheds that have been designated as Wild and Scenic by the National Park Service (e.g., Paunnacussing Creek, PA);
d. Representatively monitor some smaller watersheds that possess general water quality characteristics of physiographic regions or ecoregions along the Delaware River (e.g., Pidcock Creek, PA represents small Delaware River tributaries within the Piedmont region);
e. Within some large watersheds, conduct additional monitoring for construction and calibration of water quality models to evaluate cumulative impacts of multiple dischargers and apportion capacity so that EWQ is not degraded.

## Policy and Water Quality Standards Recommendations

1. DRBC should adopt updated **recreational criteria** as recommended by U.S. EPA and implemented by our basin states.
2. **Provide support for stream gages** and **continuous water quality.** Monitoring installations operated by the U.S. Geological Survey are critically necessary for understanding and managing our water resources. DRBC currently provides support for numerous stream gages and continuous water quality monitors . DRBC specifically recommends new gaging as described below:
   - The **Paulins Kill River** is gaged at Blairstown, NJ, but there should be a stream gage placed below Columbia Lake's hydropower generating station near the Paulins Kill mouth. The hydropower facility alters the flow regime of the Paulins Kill, and the reservoir acts as a pollutant sink for the watershed area upstream. The Paulins Kill is a major tributary to the Delaware River. At this location, water from a 177 square mile watershed area enters the Delaware River and its impact must be considered. A similar situation existed with the Mongaup River, NY, where DRBC recently required re-installation of the stream gage below a hydropower facility so the Mongaup's influence upon the Delaware River could be measured.
3. Staff recommends that discussions with our basin states and advisory committees be initiated to identify and **implement ways to reduce chloride concentrations and stream conductivity**. Both water quality targets of DRBC anti-degradation rules and policies have been exceeded within a very short time period.
4. **Determine impact of non-seasonal water quality**: DRBC's dockets or permits allow higher effluent limitations especially for ammonia (2 to 3 times of summer limit) for October through April. The impact has not been evaluated sufficiently enough to determine non-seasonal effluent limitations that are protective of EWQ. Higher winter pollutant loads may harm aquatic life and may affect summer EWQ, and warrant further investigation.

## References

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## Lower Delaware River Special Protection Waters

### Measurable Change Matrix - Key to Symbols

**Site Key**

| | |
|---|---|
| Delaware River at Trenton | Delaware River Interstate Control Point (ICP) - dark blue |
| Pidcock Creek, PA | Pennsylvania Boundary Control Point (BCP) - dark red |
| Wickecheoke Creek, NJ | New Jersey Boundary Control Point (BCP) - dark green |

**Assessment Key (2000-2004 baseline vs. 2009-2011 assessment round 1)**

| | |
|---|---|
| | No indication of measurable change to EWQ |
| ** | Indication of measurable water quality change toward more degraded status |
| ~ | Weak indication of measurable water quality change toward more degraded status |

# Summary Matrix of Water Quality Changes at Lower Delaware Control Points: 2000-2004 Baseline vs. 2009-2011 Assessment Round 1

**Site Color Key:** Dark Blue =Interstate Control Point (ICP); Dark Red =Pennsylvania Tributary Boundary Control Point (BCP); Dark Green =New Jersey Tributary Boundary Control Point (BCP)

| | Parameter / Site---> | Del. River at Trenton | Del. River at Washngtn Crossing | Pidcock Creek, PA | Delaware River at Lambrtvlle | Wicke-cheoke Creek, NJ | Lockatong Creek, NJ | Delaware River at Bulls Island | Pauna-cussing Creek, PA | Tohickon Creek, PA | Tinicum Creek, PA | Nishi-sakawick Creek, NJ | Del. River at Milford | Cooks Creek, PA | Musco-netcong River, NJ | Del. River at Rieglsvll | Pohat-cong Creek, NJ | Lehigh River, PA | Del. River at Easton | Bushkill Creek, PA | Martins Creek, PA | Pequest River, NJ | Del. River at Belvidere | Paulins Kill River, NJ | Del. River at Portland |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Site Number---> | 1343 ICP | 1418 ICP | 1463 BCP | 1487 ICP | 1525 BCP | 1540 BCP | 1554 ICP | 1556 BCP | 1570 BCP | 1616 BCP | 1641 BCP | 1677 ICP | 1737 BCP | 1746 BCP | 1748 ICP | 1774 BCP | 1837 BCP | 1838 ICP | 1841 BCP | 1907 BCP | 1978 BCP | 1978 ICP | 2070 BCP | 2074 ICP |
| Field | Dissolved Oxygen (DO) mg/l | | | | | | | | | | | ~ | | | | | | | | | | | | | |
| Field | Dissolved Oxygen Saturation % | | | | | | | | | | | ~ | | | | | | | | | | | | | |
| Field | pH, units | | | | | | | | | | | | | | | | | | | | | | | | |
| Field | Water Temperature, degrees C | | | | | | | | | | | | | | | | | | | | | | | | |
| Nutrients | Ammonia Nitrogen as N, Total mg/l | | | | | | | | | | | | | | | | | | | | | | | | |
| Nutrients | Nitrate + Nitrite as N, Total mg/l | | | | | | | | | | | | | | | | ** | | | | | | | | |
| Nutrients | Nitrogen as N, Total (TN) mg/l | | | | | | | | | | | | | | | | ** | | | | | | | | |
| Nutrients | Nitrogen, Kjeldahl, Total (TKN) mg/l | | | | | | | | | | | | | | | | | | | | | | | | |
| Nutrients | Orthophosphate as P, Total mg/l | | | | | | | | | | | | | | | | | | | | | | | | |
| Nutrients | Phosphorus as P, Total (TP) mg/l | | | | | | | | | | | | | | | | | | | | | | | | |
| Bacteria | Enterococcus colonies/100 ml | ~ | | | ~ | | | | | | | | | | | | | | | | | | | | |
| Bacteria | Escherichia coli colonies/100 ml | ** | ** | ** | ** | ** | ** | | | ** | ** | ** | | | | | | | | | | | | | |
| Bacteria | Fecal coliform colonies/100 ml | | | | | | | | | | | | | | | | | | | | | | | | |
| Conventionals | Alkalinity as CaCO3, Total mg/l | | | | | | | | | | | | | | | | | | | | | | | | |
| Conventionals | Hardness as CaCO3, Total mg/l | | | | | | | | | | | ~ | | | | | | | | | | | | | |
| Conventionals | Chloride, Total mg/l | | | ** | | ** | ** | ** | ** | ** | | ** | ** | ** | ** | ** | ** | ** | ~ | ** | ** | ** | ** | | ** |
| Conventionals | Specific Conductance µmho/cm | | | ** | | ** | ** | ~ | ** | ** | ** | ** | ** | ** | ** | ~ | ** | ** | ~ | ~ | ~ | ** | ~ | | |
| Conventionals | Total Dissolved Solids (TDS) mg/l | | | | | | | | | | | | | | | | | | | | | | | | |
| Conventionals | Total Suspended Solids (TSS) mg/l | | | | | | | | | | | | | | | | | | | | | | | | |
| Conventionals | Turbidity NTU | | | | | | | | | | | | | | | | | | | | | | | | |

**KEY:** (blue) = No indication of measurable change to EWQ; ** = Indication of measurable water quality change toward more degraded status; ~ = Weak indication of measurable water quality change toward more degraded status